EU4Environment in Eastern Partner Countries:
Water Resources and Environmental Data (ENI/2021/425-550)

DEVELOPMENT OF A QUANTITATIVE WATER RESOURCES MANAGEMENT PLAN FOR KASAKH SUB-BASIN IN ARMENIA

Executive summary

Yerevan, 2024

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EU4Environment
Water and Data in Eastern Partner Countries

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About EU4Environment – Water Resources and Environmental Data

This Programme aims at improving people's wellbeing in EU's Eastern Partner Countries and enabling their green transformation in line with the European Green Deal and the Sustainable Development Goals (SDGs). The programme's activities are clustered around two specific objectives: 1) support a more sustainable use of water resources and 2) improve the use of sound environmental data and their availability for policy-makers and citizens. It ensures continuity of the Shared Environmental Information System Phase II and the EU Water Initiative Plus for Eastern Partnership programmes.

The programme is implemented by five Partner organisations: Environment Agency Austria (UBA), Austrian Development Agency (ADA), International Office for Water (OiEau) (France), Organisation for Economic Co-operation and Development (OECD), United Nations Economic Commission for Europe (UNECE). The programme is principally funded by the European Union and co-funded by the Austrian Development Cooperation and the French Artois-Picardie Water Agency based on a budget of EUR 12,75 million (EUR 12 million EU contribution). The implementation period is 2021-2024.

https://eu4waterdata.eu

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Abbreviations

GHG	Greenhouse Gases
HMO	Hydrometeorological Organization
IPCC	Intergovernmental Panel on Climate Change
RA	Republic of Armenia
RB	River Basin
RBD	River Basin District
EBMP	River Basin Management Plan
SWB	surface water bodies
SNCO	State Non-Commercial Organization
WUA	Water User Association

b.

1. Introduction

The programme EU4Environment Water and Data support Eastern Partner countries for the implementation of RBMPs (River Basin Management Plans) to achieve good qualitative and quantitative status of water bodies in Armenia, Azerbaijan, Georgia, Republic of Moldova and Ukraine. A RBMP consists of several documents among which the programme of measures identifies various actions to be implemented in the basin to improve deteriorated water bodies.

Among the measures to be included in the programme of measures of a RBMP, quantitative water management is key. In order to concretely implement adaptive policies of the water sector, local mid-term water allocation plans at the sub-basin scale are the emerging tool in the European Union to prevent on-the-ground conflicts between users and limit environmental impact and economic losses. Relevant implementation of local water allocation plans with reinforced and transparent mechanisms of water resources monitoring will allow as well connecting with emergency plans through the determination threshold at key monitoring point.

In this Quantitative Water Resources Management Plan for Kasakh Sub-basin of Armenia, the main tools for assessment of water deficit and water saving objectives are ensuring the preservation of environmental flows. The way it is determined is a key factor, which vary from countries and their data and knowledge availability context.

Monthly environmental flow is being approached in Armenia using a standardized hydrological calculation presented in the provisions of RA Gov't Decision 57-N from January 25, 2018, (non-official translation below):

When estimating the value of the environmental flow in the areas of the currently operating hydrological observation points of the studied rivers, the average discharge of 10 consecutive days with the multi-year lowest discharge in the winter period is taken as a basis.

Taking into account the fact that there are no hydrobiological, hydrogeological and hydrochemical monitoring data in the rivers of the Republic of Armenia, the monthly values of the environmental flow at the hydrological observation point are determined by adding to the average discharge value of the 10 consecutive days with the lowest discharges in the winter period, the multi-year natural minimum average monthly of the given month 1/3 of the output value, 33%, which is a "safety factor", ensures the hydromorphological, oxygen and thermal conditions of the river, which ensure the survival and reproduction of aquatic organisms. If the monthly calculated value of the environmental flow is greater than the value of the natural minimum flow of the given month, then the value of the natural minimum flow of the given month is selected as the environmental flow. In the case of reservoirs with a volume of 20 million sq. m and more, when determining the environmental discharge, the average discharge of 10 consecutive days with the lowest discharge during the multi-year winter period is taken as a basis.

To better reflect the historical situation of water availability measured in each river, an additional low flow reference indicator, QMNA5, was considered in this study based on the recommendation of the

International Office for Water (France). QMNA5 corresponds to a “minimum discharge with a probability of not reoccurring more than once every 5 years” or a “flow with a probability of exceeding 4 out of 5 years”. The longer the discharge data series is, the more the result is precise. More importantly it gives a picture of low waters in dry weather conditions, so it is bound to be broken only if an exceptional drought occurs as climatic risk.

Also, a proposal for operative management of surface flow per nodal point is proposed. The idea is to set the target minimum flows for taking certain actions by the management body.

2. Description of Kasakh River Basin

2.1 Location of the Basin

The Kasakh basin is generally located in the Aragatsotn, Armavir, and Kotayk regions, and very partially in the Lori and Shirak regions of the Republic of Armenia. The length of the Kasakh River is 89 km, and the catchment area is 1,480 km^2. Kasakh River basin extends within the northern latitude 40°10′- 40°76′ and the eastern longitude 44°10′- 44°54′. The maximum extent of the area is 36 km from the east to the west, and 73 km from the north to the south.

Kasakh basin includes territories from three Armenian Marzes - Aragatsotn, Armavir, and Kotayk The location of the Kasakh river basin is given in Figure 1.

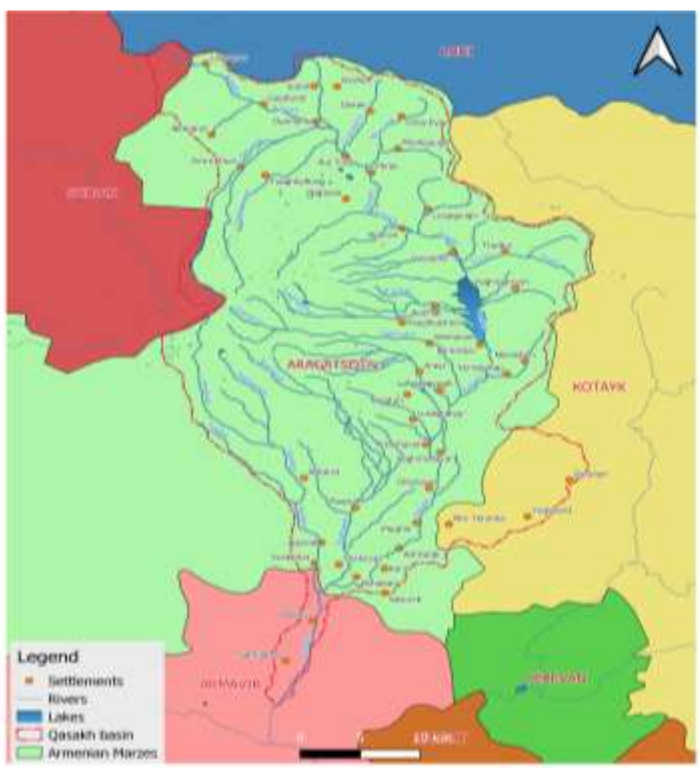


Figure 1. Location of Kasakh River basin

2.2 Hydrography

Kasakh River originates from the southern slopes of the western part of the Pambak Range, at 2200 m altitude and flows into the Metsamor River. It has a length of 89 km, the area of the basin is 1480 km^2. The river flow is formed by the waters of the tributaries flowing from the eastern slopes of Mount Aragats and the southern slopes of the Pambak Range. The basin is surrounded by the Tsaghkunyats Range in the east. In the upper streams, the river flows through the wide plateau covered with the Aparan alluvial sediments. In the mid-streams, near the town of Ashtarak, the valley becomes a gorge, after which the valley extends at 2-3 km and again enters the narrow gorge. Downstream the Oshakan village, the river flows into the Ararat Valley.

The relatively large tributaries of Kasakh, which originate from the slopes of Mount Aragats, are Gegharot (length is 25,0 km, the catchment area is 66,0 km^2), Shahverd (35,6 km and 162 km^2) and Amberd (36,0 km and 141 km^2). Kasakh is a typical mountain river. It has a great drop and a great average inclination. As it is shown in Figure 2, approximately half of flow feeding comes from underground sources, which means that seasonal fluctuations in some regions of Kasakh River basin can be not so severe.

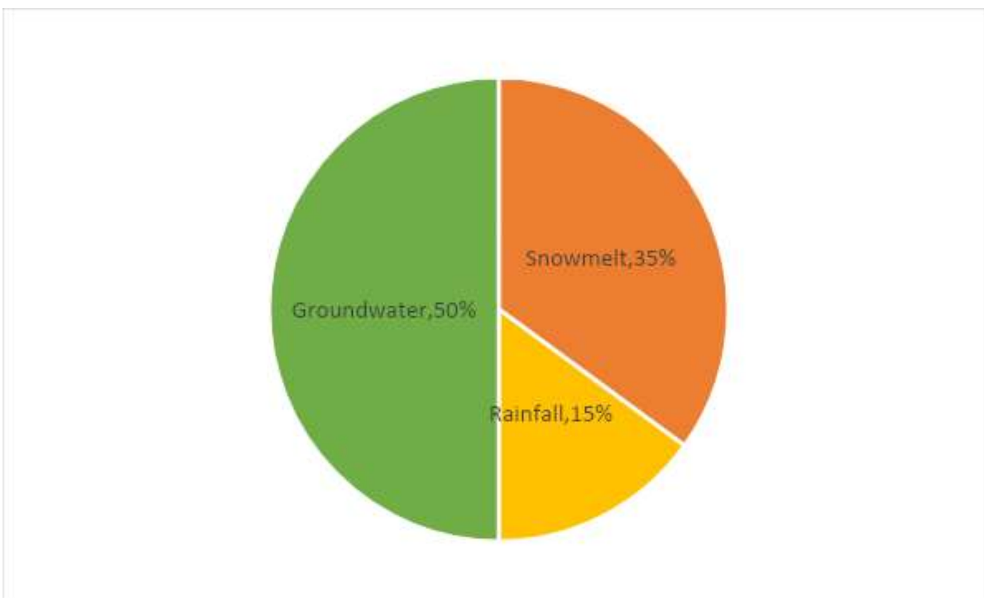


Figure 2. Share of river flow feeding source in Kasakh River basin

Source: Ministry of Environment, Armenia (2023)

There are two reservoirs in the Kasakh River basin - Aparan and Halavar.

Table 1. Some characteristics of reservoirs in the Kasakh River basin

Name	Surface Area, ha	Volume (mln.m^3)	Dam height (m)	Year of construction	Water Use Purpose
Aparan	740	91.0	52.6	1966	irrigation
Halavar	59.0	5.50	31.40	1982-1983	irrigation

Source: Water Committee of RA MTAI.

There are no large natural lakes in the Kasakh River basin. As one of the major natural lakes, Lake Kari (Kasakh River Basin) could be noted. The lakes of the Kasakh River basin are of glacial origin.

2.3 Hydrometeorological Monitoring Network

There are 4 hydrological monitoring posts (Kasakh-Vardenis, Kasakh-Ashtarak, Gegharot-Aragats, and Shahverd-Parpi) and 5 meteo stations (Tsaghkahovit, Aparan, Aragats, Hamberd, and Ashtarak) operating in Kasakh basin (Fig. 3).

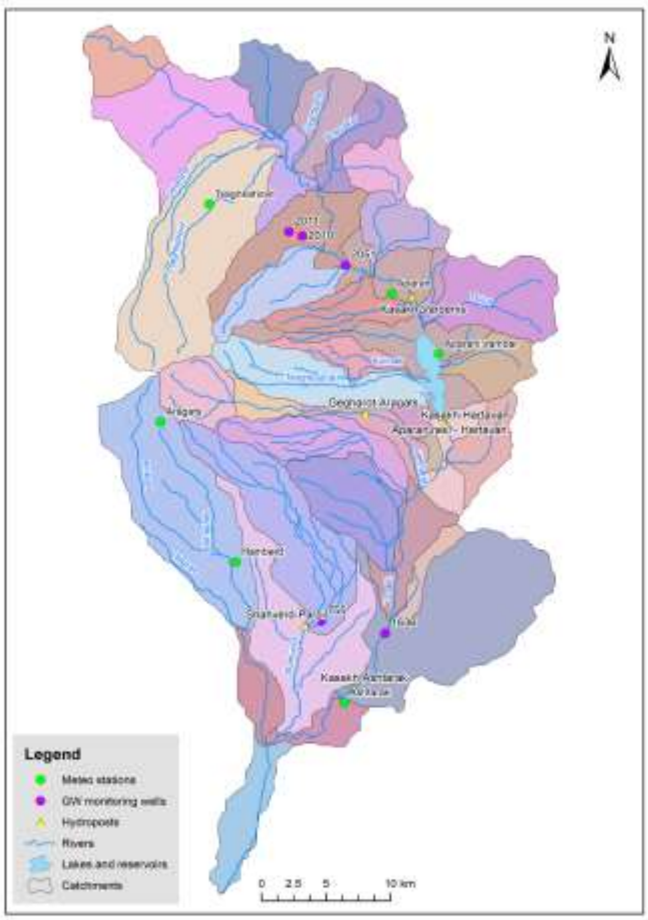


Figure 3. Hydrometeorological Monitoring Network in Kasakh River Basin

Source: Hydrometeorology and Monitoring Center SNCO (Armhydromet)

2.4 Hydrogeological Monitoring Network

There are 10 hydrogeological monitoring observation stations in Kasakh basin: 5 springs, 2 shallow groundwater wells - non-pressure, 3 non-fountaining wells - pressure.

Table 2. Hydrogeological Monitoring Network in Kasakh River Basin

Number of Monitoring Site	Type of the Monitoring Site	Location	Discharge (Q)l/sec or level (below the Earth surface) (S), m		Total Mineralization, mg/l		Total Hardness, mEq/l	
			Nov.	May	Nov.	Nov.	May	Nov.
755	spring	Aragatsotn Marz, Ghazaravan village	Q=2.9	Q= 2.9				
1636	spring	Aragatsotn Marz, Karbi village	Q= 6.56	Q= 6.52	197	222	2.0	2.065
2010	Shallow groundwater well - non-pressure	Aragatsotn Marz, Nigavan village	S= 4.97	S= 7.39	100.4	206	1.0	2.0
2011	Shallow groundwater well - non-pressure	Aragatsotn Marz, Nigavan village	S= 6.04	S= 8.50				
2051	spring	Aragatsotn Marz, Aparan	Q=6.77	Q= 4.73				
2086	Non-fountaining well-pressure	Armavir Marz, Doghs villagw	S= 49.6	S= 49.92				
2089	Non-fountaining well-pressure	Aragatsotn Marz, Karbi village	S= 46.55	S= 46.97	184.6	209	2.0	2.18
2107	spring	Aragatsotn Marz, Aparan	Q=4.9	Q= 3.9	132.3	124.5	2.0	1.5
2108	spring	Aragatsotn Marz, Byurakan village	Q=2.39	Q= 2.48				
2119	Non-fountaining well-pressure	Aragatsotn Marz, Parpi village	S=105.23	S= 103.31				

Source: Hydrometeorology and Monitoring Center SNCO (Armhydromet)

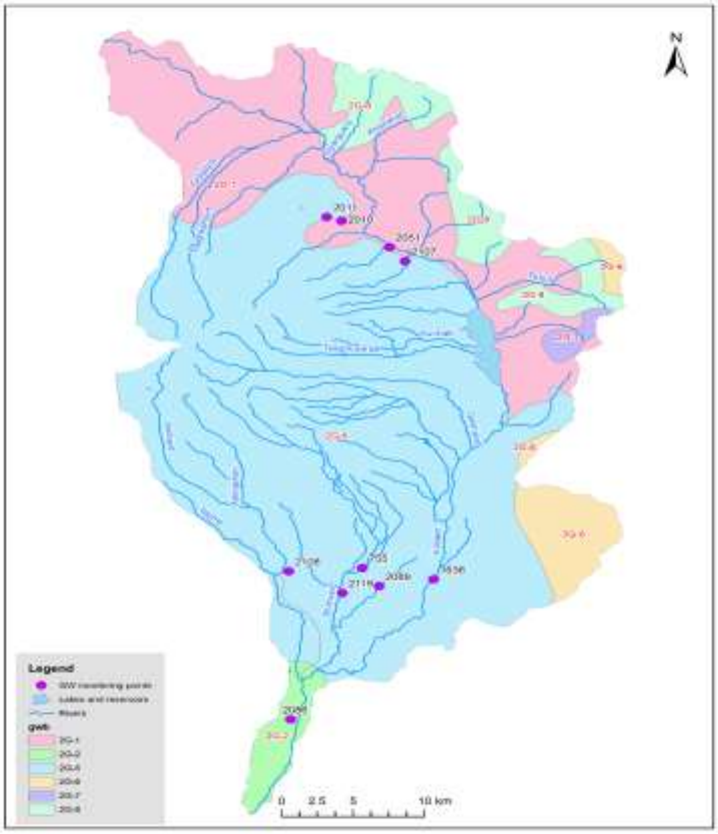


Figure 4. Hydrogeological Monitoring Network in Kasakh River Basin

Source: Hydrometeorology and Monitoring Center SNCO (Armhydromet)

2.4 Identified water demand and main deficit areas

In general, water deficit refers to water quality, so water quantity, both to surface water and groundwater as well. According to the Water Framework Directive, water quality of water bodies must achieve at least the “Good” status. In this regard, in compliance with the Government Decree No75-N of 2011, the chemical status of the 9 monitoring observation points does not refer to the Good status. Thus, only in 2 points (Aparan reservoir and 0,5 km above Aparan town) partially refer to the Good status.

Table 3. Chemical Status of the monitoring observation points

Water Body	Observation Point	Water Quality (Status)	Key Pressure Indicators	Main Cause of Pressure
Kasakh River	0.5km above Aparan town (43)	Good-moderate (II-III)	____	Negligible pressure
	0.5km down Aparan town (44)	Poor (V)	NO_2^-, Fe, NH_4^+, PO_4^{3-}	Untreated communal wastewater and agricultural drain water
	1km above Ashtarak town (45)	Moderate (III)	PO_{43-}, V (III)	
	3.5km down Ashtarak town (46)	Moderate (III)	PO_{43-}, V (III)	
	River mouth (47)	Insufficient (IV)	PO_{43-}, NO_3^-, V (III)	

Gegharot River	0.5km down Aragats settl. (48)	Poor (V)	Zn, Ni, Fe, Al, Mn, Co	Geological and geochemical features, influence of natural acidic waters
	River mouth (49)	Moderate-Insufficient (III-IV)	Fe, NH_4^-, Mn, PO_4^{3-}, NO_3^- , NO_2^-	
Shaghvar River	0.5km down Parpi settl. (50)	Moderate-Insufficient (III-IV)	PO_4^{3-}, P, V	Should be additionally studied
Aparan Reservoir	At the dam (111)	Good-moderate (II-III)	_____	Negligible pressure

Source: Hrazdan RBMP, 2020

3. Human activities on the basin including socio-economic information

3.1 Administrative Areas of Kasakh River Basin

Kasakh RB comprises administrative areas of Aragatsotn (Ashtarak, Aparan and Alagyaz communities) and Armavir (Ejmiatsin community) Marzes.

Aragatsotn Marz (Province)

Aragatsotn marz is located in the northwest of the territory of the Republic of Armenia. The marz is bordered by Shirak and Lori Marzes in the North, Kotayk Marz in the East, Armavir Marz and Yerevan city in the South, and borders Turkey on the state border. The 3 motor highways of republican importance – Yerevan – Ashtarak – Talin - Gyumri, Yerevan – Ashtarak - Spitak and Yerevan – Armavir – Qarakert - Gyumri run through the territory of the Aragatsotn Marz. The territory of the marz intersects with the principal railway of the Republic of Armenia as well.

The famous Observatory of Byurakan, the Institutes of Radiophysics and Electronics, and Physical researches of the National Academy of Sciences are located in the marz.

In 2021 the share of economy main branches of Aragatsotn Marz in the total volume of correspondent branches of the republic comprised:

➢ industry 2.1 %,

➢ agriculture 9.3 %,

➢ construction 4.0 %,

➢ retail trade 1.9 %,

➢ services 0.7 %.

The main economic branches of the marz are industry and agriculture. Industry is specialized in manufacture of food products and of drinks, precious articles and exploiting of mines of building materials. The geographical position and climatic conditions of the marz are favorable for the development of both plant growing (grain, potatoes, perennial grass, and forage crops) and cattle breeding. Agriculture is mainly specialized in plant growing (especially, crop-production) and cattle breeding. Freight and passenger transportation in the marz are implemented by road transport.

Marz center Ashtarak town (as of the beginning of the year, 2022 comprised 16.6 ths. people) is situated on the bank of Kasakh river, at a distance of 19 km to the North-West from Yerevan. The town is the junction of Yerevan-Gyumri and Yerevan-Spitak roads. Ashtarak town developed as a satellite town of Yerevan. It is the administrative and political, economic, scientific, educational and cultural centre of the marz. The main branch of the economy is food and beverage production.

Aparan town (as of the beginning of the year, 2022 comprised 5.9 ths. people) is the second town in the marz by its largeness and importance. It is situated on the bank of the Kasakh river (in the distance of 60 km from Yerevan). The main branch of the economy is food production.

Talin town (as of the beginning of the year, 2022 comprised 4.0 ths. people) is located on the south-western slope of Aragats mountain (at a distance of 65 km from Yerevan). The base of the economy is precious articles production.

The main statistical indicators of Aragatsotn Marz are presented in Table 4.

Table 4. Main statistical indicators of the Aragatsotn marz, 2017-2021

	2017	**2018**	**2019**	**2020**	**2021**
Number of de jure population of marz, as of January, 1 000 persons	127.1	125.4	124.7	124.5	124.6
of which ● urban	27.6	27.0	26.8	26.6	26.5
● rural	99.5	98.4	97.9	97.9	98.1
Natural growth rate, per 1 000 inhabitants	3.6	2.7	2.2	-1.6	1.5
Gross domestic product (at market prices), mln. drams	…	190 498.2	165 502.0	150 875.1	…
Volume of industrial production, mln. drams	53 521.5	51 407.4	45 690.4	44 182.2	51 433.8
Gross agricultural output, at current prices, bln. Drams	88.4	91.3	79.7	82.5	87.2
Volume of construction, mln. drams	21 326.5	20 752.2	13 298.4	14 243.9	20 466.3

https://www.armstat.am/file/Map/Aragats.pdf

3.2 Stakeholder Communities in Aragatsotn Marz

a. Ashtarak community

Ashtarak extended community includes Ashtarak town and 29 villages: Agarak, Aghdzq, Antarut, Avan, Aragatsotn, Aruch, Artashavan, Bazmaghbyur, Byurakan, Dprevank, Lernarot, Karbi, Kosh, Ghazaravan, Nor Amanos, Nor Yedesia, Nor Yerznka, Voskehat, Voskevaz, Saghmosavan, Sasunik, Tegher, Ushi, Ujan, Parpi, Ohanavan, Oshakan and Orgov. The total number of population of the extended community is 78,208 as of 2019[1]:

Industry occupies an important place in the economy of the community. There are enterprises of various branches here. The food industry is developed. There are grape processing and raw wine receiving points here. Ashtarak is famous for making aromatic wines and dried fruits for ages.

Agriculture is also developed, especially fruit growing and viticulture. The lands are mainly irrigated by Qasakh waters. In reserve lands, perennial plants occupy 58 ha, pastures - 433 ha. Cereal and vegetable crops are also cultivated. Cattle breeding, poultry breeding, poultry meat and egg production are developed in the region.

b. Aparan community

Aparan extended community includes Aparan town and 21 villages: Aragats, Ara, Apnagyugh, Yeghipatrush, Yernjapat, Ttujur, lusagyugh, Tsaghkashen, Kayq, Hartavan, Dzoraglukh, Nigavan, Shenavan, Shoghakn, Chqnagh, Jrambar, Saralanj, Vardenis, Vardenut, Quchak and Meliqgyugh. The total number of population of the extended community is 24,872 as of 2019[2].

Industry occupies an important place in the economy. There are a number of businesses in Aparan. The food industry is also developed here, there is a dairy processing and cheese production factory.

The lands of the community are mainly used as arable lands, grasslands and pastures. About 35 percent of the community's surface is privatized. The community is also engaged in the cultivation of grain, fodder and vegetable crops. There are also perennial plantations, but they do not occupy a large area. Livestock breeding is also practiced in Aparan. The dairy sector is developed, and raw materials are processed in the local cheese factory.

c. Alagyaz community

Alagyaz extended community includes 10 villages Alagyaz, Kaniashir, Charchakis, Mijnatun, Mirak, Shenkani, Jamshlu, Ria Taza, Sadunts and Sipan. The total number of population of the extended community is 4,896 as of 2019[3].

The community is located on the southern slopes of the Pambak mountain range, at an altitude of 2050 m above sea level, on the right bank of the Qasakh River. The specialization branch of the community's

[1] http://aragatsotn.mtad.am/about-communities/801/
[2] http://aragatsotn.mtad.am/about-communities/802/
[3] http://aragatsotn.mtad.am/about-communities/806/

economy is livestock breeding, for which there are favorable conditions: rich alpine meadows. They are engaged in large and small cattle breeding, and agriculture. They grow grain, fodder, and vegetable crops.

d. Armavir Marz (Province)

Armavir marz is situated in the Western part of the RA. In the North it borders Aragatsotn marz, in the East – the capital Yerevan, in the South-East –Ararat marz and in the West it borders the state border of Turkey. Yerevan-Armavir, Yerevan-Karakert, Yerevan-Gyumri highways and Yerevan-Tbilisi railway of republican importance run through the territory of the marz. Armavir marz is notable for its developed agriculture and industry in the republic. The geographical position and climatic conditions of the marz are favorable for the development of both plants growing (perennial grass and vegetables) and cattle breeding. In the sphere of animal husbandry, farming of cattle sheep and goats, pigs and poultry is mainly developed and in crop production - fruit-growing, grape-growing, horticulture and plant-growing. Cereal grains and vegetables are mainly processed. Industry is specialized in producing electricity, food products, beverages and building materials. Freight and passenger transportation in the marz are implemented by road transport. In 2021 the share of economy main branches of Armavir marz in the total volume of correspondent branches of the republic comprised.

➢ industry 5.0 %,

➢ agriculture 22.6 %,

➢ construction 7.3 %,

➢ retail trade 4.5 %,

➢ services 1.5 %.

Armavir town (as of the beginning of 2022 comprised 27.7 ths. people) is in the distance of 44 km to the North-West of Yerevan. There are factories in the city (wine industry) (brandy) (since 1966), canneries, milk և dairy products, bread, gas appliances, molybdenum enrichment, machine-building, fittings և other construction materials, furniture factories, the only factory in Armenia, production and service companies engaged in small and medium business.

The territory of Metsamor town (as of the beginning of 2022 8.4 ths. people) is popular for the atomic station in the Republic of Armenia at the distance of 38 km from Yerevan, which occupies 300 ha of the territory and by its size and power is the only one in the South Caucasus.

Vagharshapat town (as of the beginning of the 2022 comprised 46.4 ths. people) is situated in the distance of 20 km from Yerevan. It is the first town in the marz by its size and importance. There are 5 churches in Vagharshapat. Among them stands out the main church of Armenia, the Mother Cathedral located in the complex of Saint Etchmiadzin, the spiritual and administrative center of the Armenian Apostolic Church, the Mother Cathedral.

The main statistical indicators of Armavir Marz are presented in Table 5.

Table 5. Main statistical indicators of the Armavir marz, 2017-2021

	2017	2018	2019	2020	2021
Number of de jure population of marz, as of January, 1 000 persons	264.6	263.9	263.8	264.0	264.4
of which ● urban	83.2	82.6	82.4	82.5	82.5
● rural	181.4	181.3	181.4	181.5	181.9
Natural growth rate, per 1 000 inhabitants	2.9	3.5	3.4	-2.2	1.8
Gross domestic product (at market prices), mln. drams	…	380 625.7	384 781.2	343 646.5	…
Volume of industrial production, mln. drams	78 421.5	83 574.8	108 408.0	122 516.0	121 311.9
Gross agricultural output, at current prices, bln. Drams	184.2	177.5	178.7	181.0	211.1
Volume of construction, mln. drams	25 865.7	37 276.7	37 120.9	23 228.1	37 419.8

www.armstat.am/file/Map/Armavir.pdf

3.3 Stakeholder Communities in Armavir Marz

a. Araks community

Araks extended community includes 13 villages: Gay, Jrarat, Aknashen, Apaga, Aratashen, Araks, Artimet, Griboedov, Lusagyugh, Khoronq, Haykashen, Metsamor and Jrarbi. The total number of population of the extended community is 27491[4].

The population of the villages is engaged in fruit growing, vegetable growing, horticulture, poultry breeding, and cattle breeding.

b. Khoy community

Khoy extended community includes 17 villages: Geghakert, Aghavnatun, Amberd, Aygeshat, Aragats, Arshaluys, Dasht, Doghs, Lernamerdz, Tsaghkalanj, Tsaghkunq, Tsiatsan, Haytagh, Hovtamej, Monteavan, Mrgastan and Shahumyan. The total number of population of the extended community is 32775[5].

The population of the villages is engaged in fruit growing, vegetable growing, horticulture, poultry breeding, and cattle breeding.

[4] http://armavir.mtad.am/about-communities/250/

[5] http://armavir.mtad.am/about-communities/200/

3.4 Population and Demography

This chapter was prepared based on data RA Statistical Committee and Development strategies for 2017-2025 for the Aragatsotn and Armavir Marzes.

Aragatsotn Marz occupies 2,756^2 km which is 9.3% of the entire territory of the Republic of Armenia. The population of the marz as of January 1, 2022 was 124,646 persons – 63,963 women and 60,683 men. The share of the marz population in the total population of the RA in 2021 was 4.2%. National minorities are Yezidis, Assyrians, Russians and Kurds.

Armavir Marz occupies 1,231 km^2 which is 4.1% of the entire territory of the Republic of Armenia. The population of the marz as of January 1, 2022 was 264,483 persons – 136 278 women and 128 105 men. The share of the marz population in the total population of the RA in 2021 was 8.9%. National minorities are Yezidis and Assyrians.

The average density of population in the water basin in 2011 was 397 people / km^2. Most of the population is concentrated in economically and industrially active zones, especially in Yerevan.

The average density of population in Armavir Marz was about 5 times higher than in Aragatsotn Marz in 2022 although the territory of Aragatsotn Marz is twice as large. In Aragatsotn Marz the average density of population in 2022 was 45 people/km^2, in Armavir Marz 215 people/km^2. Most of the population is concentrated in economically and industrially active zones - in the towns Armavir, Ashtarak, Aparan.

3.5 Migration Dynamics

The dynamics of migration is presented in Table 6 according to the recorded cases of migration: the flows of departures, returns and new arrivals during 2016-2017[6].

Table 6. Volume and Place of Migration Flows, 2016-2017

Marz	**Migration from RA**	**Migration to RA**	**New migrant to RA**	**Migration from RA**	**Migration to RA**	**New migrant to RA**
	Absolute Figures			**Percent**		
Aragatsotn	950	169	1370	0.7	0.2	26.4
Armavir	712	106	0	0.5	0.1	0

The RBD is rich in numerous historical and architectural monuments, which gives it great recreational and tourism development potential. Tourism is beginning to develop rapidly in the Kasakh RB, especially

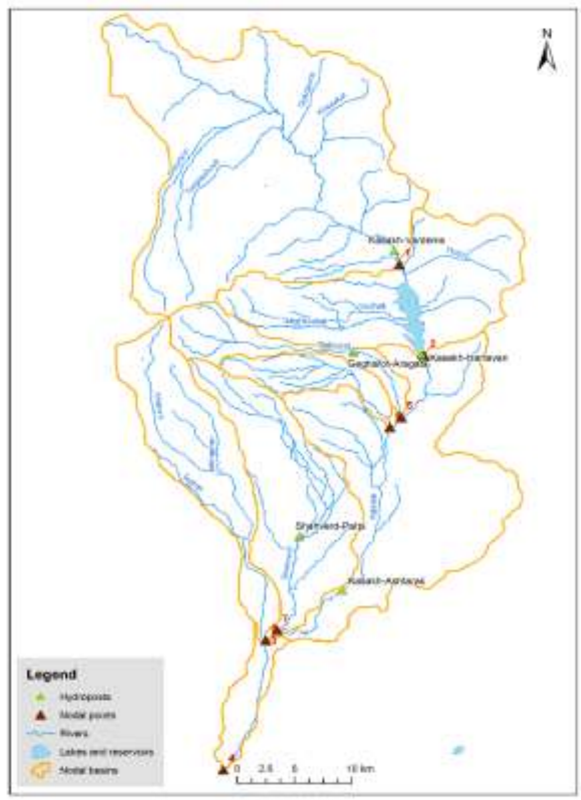
[6] armstat.am/file/article/migration_profile_arm_2017.pdf

in Ashtarak, Aparan, Byurakan and Amberd. There are several hotels and cottages in the gorge of the river Kasakh.

The number population within the Kasakh river basin increases seasonally up to 7 times, which leads to increase of sewage discharge into the river.

c. 4. Estimation of Water Balance, Environmental Flow, Water Use, and Deficit in Kasakh River Basin

The objective of the analysis presented below is to estimate the human quantitative impact on the water resources in Kasakh River basin and come up with the methodology for better quantitative water management in the basin. To achieve this objective, Kasakh basin was delineated into 8 sections (nodal basins) based on the hydrographic network structure, and for each section, the natural water balance, actual hydrological regime, and water use has been studied. Environmental flow is the key instrument in assessing the deficit, water scarcity, and drought risks in the basin. Trends in groundwater levels/discharges have been also reviewed to identify if there are areas in Kasakh basin with overexploitation of groundwater resources.



4.1 Setting the Nodal Points for the Calculations

Based on hydrographic network structure and water use peculiarities, 8 nodal points have been selected for the estimation of water balance, water use, and deficit in different parts of the Kasakh River basin:

1. Upper flow of Kasakh River, from source to Kasakh-Vardenis hydropost,
2. Aparan Reservoir area, from source to Aparan dam,
3. Middle flow of Kasakh River, from source to the point of influence of Amberd River,
4. Lower flow of Kasakh River, from source to the mouth,
5. Gegharot River basin,
6. Apnagyugh River basin,
7. Shahverd River basin,
8. Amberd River basin.

Figure 5. Identification of Nodal Points for Water Balance Calculation

4.2 Estimation of Natural (non-influenced by uses) Water Balance per Nodal Point

To understand the natural hydrology of Kasakh basin, water balance was calculated for each nodal point based on the raster models for precipitation, evaporation, and surface natural flow. The basis for these rasters is the hydrometeorological observation data received from the Hydrometeorology and Monitoring Center SNCO of the Ministry of Environment.

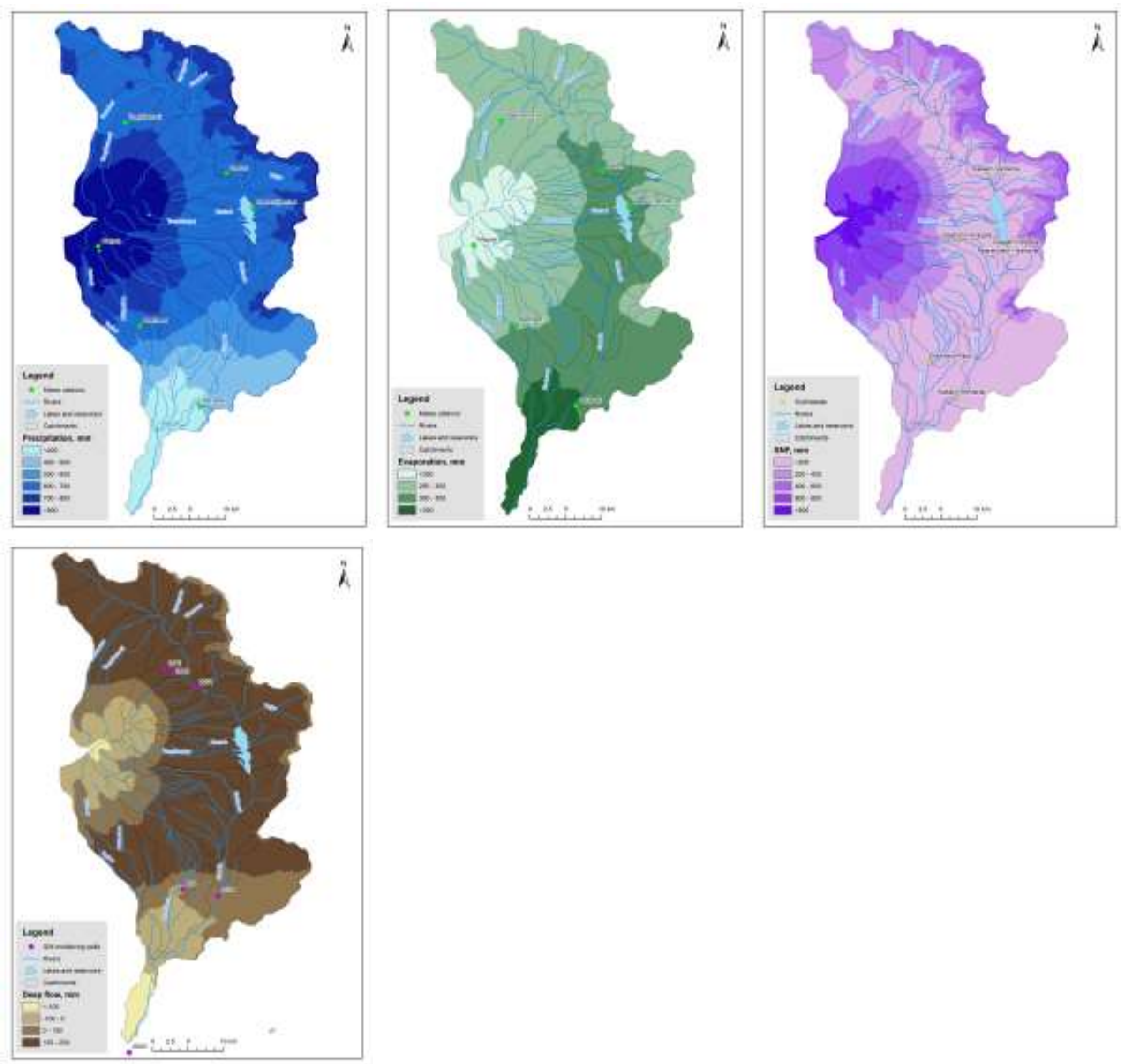


Figure 6. Simple natural water balance equation: Precipitation - Evaporation - Surface Natural Flow = Deep Flow

Below in the tables multi-year monthly average values of the natural water balance elements presented separately for each of 8 nodal basins. Natural wet seasons (3 consecutive months in the year with the highest values of the surface natural flow and precipitation) highlighted with green, and natural dry seasons (another 9 months of the year) – with orange.

This information helps to understand the natural hydrological conditions in Kasakh River basin.

Nodal basin N 1

Name Kasakh, upper flow

Area, km^2 493.93

Table 7. Water balance in Kasakh upper flow nodal basin

million m^3/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	7.1	6.7	13.7	47.7	40.0	21.4	14.5	10.6	8.7	7.6	7.3	7.1	192.2
Precipitation	20.3	23.8	29.4	39.0	43.1	42.0	36.9	27.7	19.1	23.6	23.5	21.8	350.2
Evaporation	0.0	0.0	0.0	7.6	16.3	22.8	28.8	28.9	21.7	11.7	0.8	0.0	138.6
Deep flow	13.2	17.1	15.7	-16.3	-13.2	-2.2	-6.4	-11.8	-11.3	4.4	15.3	14.8	19.4

In the upper part of the Kasakh basin, around 57% of annual surface flow is and 35% of precipitation accounts for April, May, and June.

Nodal basin N 2

Name Kasakh, Apar Reservoir are

Area, km^2 197.3

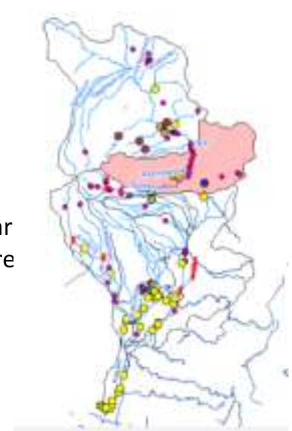


Table 8. Water balance in Kasakh Aparan Reservoir nodal basin

million m^3/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	1.2	1.1	2.3	8.1	6.8	3.6	2.5	1.8	1.5	1.3	1.2	1.2	32.7
Precipitation	7.2	8.5	10.5	13.9	15.4	15.0	13.2	9.9	6.8	8.4	8.4	7.8	125.2
Evaporation	0.0	0.0	0.0	3.1	6.7	9.3	11.8	11.8	8.9	4.8	0.3	0.0	56.8
Deep flow	6.0	7.4	8.2	2.7	1.9	2.0	-1.1	-3.7	-3.6	2.4	6.8	6.6	35.7

In the Aparan reservoir area of the Kasakh basin, there is a same distribution of surface natural flow and precipitation between wet and dry seasons.

Nodal basin N 1+2
Name Kasakh
Area, km² 691.22

Table 9. Total water balance in Kasakh first and second nodal basins

million m³/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	8.3	7.8	16.0	55.8	46.8	25.0	17.0	12.4	10.1	8.8	8.6	8.3	224.9
Precipitation	27.5	32.3	39.9	52.9	58.5	57.0	50.1	37.7	25.9	32.0	31.9	29.6	475.4
Evaporation	0	0	0	10.7	23.0	32.1	40.6	40.7	30.7	16.4	1.2	0	195.4
Deep flow	19.2	24.5	23.9	-13.6	-11.3	-0.1	-7.5	-15.5	-14.8	6.7	22.2	21.3	55.1

In the Aparan reservoir area of the Kasakh basin, there is the same distribution of surface natural flow and precipitation between wet and dry seasons.

Nodal basin N 3
Name Kasakh, middle flow
Area, km² 275.6

Table 10. Water balance in Kasakh Middle Flow nodal basin

million m³/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	5.9	5.6	7.4	12.7	10.2	16.4	15.7	11.3	8.3	7.5	6.3	6.1	113.5
Precipitation	26.5	26.6	36.5	72.7	64.9	10.4	-3.3	-11.0	3.7	43.0	32.4	29.7	332.1
Evaporation	0.0	0.0	12.3	17.8	17.6	20.8	21.5	22.0	20.3	17.8	15.1	0.0	165.2
Deep flow	20.6	21.1	16.8	42.2	37.2	-26.8	-40.5	-44.3	-25.0	17.7	11.0	23.6	53.5

In the basin of the middle flow of Kasakh river, around 35% of annual surface flow is and 44% of precipitation accounts for April, May, and June.

Nodal basin N 1+2+3
Name Kasakh
Area, km² 1225.1

Table 11. Total water balance in first three nodal basins, totally

million m³/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	14.2	13.4	23.3	68.5	56.9	41.4	32.7	23.8	18.5	16.3	14.9	14.4	338.4
Precipitation	54.0	59.0	76.4	125.6	123.4	67.4	46.8	26.6	29.6	75.0	64.3	59.3	807.5
Evaporation	0.0	0.0	12.3	28.5	40.5	52.9	62.1	62.7	51.0	34.2	16.3	0.0	360.5
Deep flow	39.8	45.6	40.7	28.6	25.9	-26.9	-48.0	-59.8	-39.8	24.4	33.1	44.9	108.5

Nodal basin N 4
Name Kasakh, lower flow
Area, km² 29.4

Table 12. Water balance in Kasakh lower flow nodal basin

million m³/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	1.2	2.7	2.9	14.9	10.9	6.3	1.7	-0.4	0.9	1.2	1.5	1.1	45.0
Precipitation	6.8	7.4	9.6	15.8	15.5	8.5	5.9	3.4	3.7	9.4	8.1	7.5	101.6
Evaporation	0.0	0.0	1.6	3.8	5.4	7.0	8.2	8.3	6.7	4.5	2.1	0.0	47.6
Deep flow	5.6	4.8	5.0	-2.9	-0.7	-4.8	-4.0	-4.5	-3.9	3.7	4.4	6.4	9.1

In the basin of the lower flow of Kasakh river, around 71% of annual surface flow is and 39% of precipitation is coming in April, May, and June.

Nodal basin N 1+2+3+4
Name Kasakh
Area, km² 1386.2

Table 13. Total water balance for first four nodal basins

million m³/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	15.4	16.1	26.3	83.4	67.9	47.7	34.4	23.4	19.4	17.5	16.4	15.5	383.4
Precipitation	60.8	66.4	86.0	141.4	138.9	75.9	52.7	30.0	33.4	84.4	72.4	66.8	909.1
Evaporation	0.0	0.0	13.9	32.3	45.9	59.9	70.3	71.0	57.7	38.7	18.4	0.0	408.1
Deep flow	45.4	50.3	45.7	25.7	25.2	- 31.7	-51.9	-64.4	-43.8	28.1	37.5	51.3	117.6

Nodal basin N 5
Name Gegharot River
Area, km² 52.74

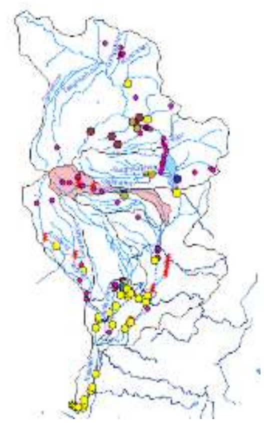


Table 14. Water balance for Kasakh Gegharot River nodal basin

million m³/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	0.7	0.6	0.7	1.6	4.8	7.1	5.9	2.9	1.6	1.1	0.9	0.7	28.5
Precipitation	3.8	4.2	4.9	5.2	5.3	3.9	3.4	2.3	1.9	3.4	3.9	3.8	46.1
Evaporation	0.0	0.0	0.0	0.0	0.0	2.1	4.5	4.7	2.7	0.0	0.0	0.0	14.0
Deep flow	3.1	3.5	4.2	3.7	0.5	-5.3	-7.1	-5.2	-2.4	2.3	3.0	3.0	3.5

There is another picture in Gegharot River basin: 62% of annual surface flow accounts for May-July and 33% of precipitation is in March-May.

Nodal basin N 6
Name Apnagyugh river
Area, km² 43.0

Table 15. Water balance in Kasakh Aphc basin

million m³/month	1	2	3				7	8	9	10	11	12	Annual
Surface natural flow	0.2	0.2	0.3	0.6	1.8	2.7	2.2	1.1	0.6	0.4	0.3	0.3	10.7
Precipitation	2.5	2.7	3.2	3.4	3.5	2.6	2.2	1.5	1.2	2.2	2.6	2.5	30.2
Evaporation	0.0	0.0	0.0	0.0	0.0	1.9	4.0	4.1	2.4	0.0	0.0	0.0	12.3
Deep flow	2.2	2.5	3.0	2.9	1.7	-1.9	-4.0	-3.6	-1.7	1.8	2.2	2.2	7.1

Apnagyugh River basin is quite similar to Gegharot: 63% of annual surface flow is in May-July and 33% of precipitation is in March-May. The difference between precipitation and surface flow high periods is because of low temperatures in these basins and snowmelt-runoff is starting with high intensity only in May.

Nodal basin N	7
Name	Shahverd river
Area, km^2	162.52

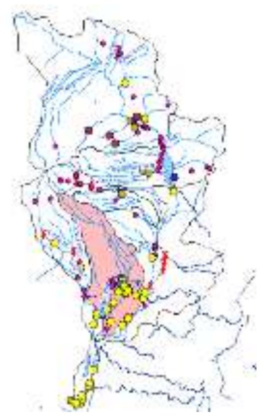


Table 16. Water balance in Kasakh Shahverd river nodal basin

million m^3/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	1.7	1.7	2.0	2.3	2.3	1.9	1.6	1.7	1.5	1.6	1.7	1.7	21.8
Precipitation	8.6	8.5	9.1	11.3	13.7	7.7	4.8	2.9	3.2	7.6	7.1	8.0	92.5
Evaporation	0.0	0.0	0.0	2.6	5.6	8.2	10.6	10.7	8.2	4.5	0.7	0.0	51.1
Deep flow	6.8	6.7	7.1	6.4	5.7	-2.4	-7.3	-9.5	-6.6	1.6	4.8	6.3	19.6

In Shahverd River basin, surface flow is distributed quite evenly within the year with a slight peak in March-May – 30%.

Nodal basin N	8
Name	Amberd river
Area, km^2	131.7

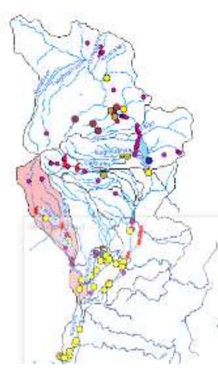


Table 17. Water balance in Kasakh Amberd river nodal basin

million m^3/month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Surface natural flow	3.5	3.5	4.1	4.8	4.8	3.9	3.4	3.5	3.1	3.2	3.4	3.5	44.8
Precipitation	8.6	8.5	9.1	11.3	13.7	7.7	4.9	3.0	3.2	7.7	7.1	8.0	92.7
Evaporation	0.0	0.0	0.0	1.9	4.1	5.9	7.6	7.8	6.0	3.3	0.5	0.0	37.0
Deep flow	5.0	4.9	5.1	4.7	4.8	-2.2	-6.1	-8.3	-5.9	1.2	3.2	4.5	10.9

The same picture as in Shahverd is also in Amberd River basin: a slight peak in surface flow is in March-May – 31%. This picture is explained with the prevailing groundwater feeding in these two basins

4.3 Assessment of vulnerability of the surface flow to climate change

Vulnerability of surface natural flow to climate change in 8 sections of Kasakh basin was also assessed based on IPCC RCP6.0 and RCP8.5 scenarios. The results are presented in the table below:

Table 18. Projected Surface Natural Flow in Kasakh Basin, million m³

Nodal Basin N	Nodal Basin Name	Average SNF	SNF, RCP6.0, 2040	SNF, RCP6.0, 2070	SNF, RCP6.0, 2100	SNF, RCP8.5, 2040	SNF, RCP8.5, 2070	SNF, RCP8.5, 2100
1	Kasakh, upper flow	192.2	169.5	160.1	149.3	168.2	146.3	122.4
2	Kasakh, Aparan Res. area	32.7	28.8	27.2	25.4	28.6	24.9	20.8
3	Kasakh, middle flow	113.5	101.0	96.1	90.4	100.9	89.1	77.1
4	Kasakh, lower flow	45	40.0	38.1	35.8	40.0	35.3	30.6
5	Gegharot River	28.5	25.5	24.6	23.2	26.0	23.5	21.4
6	Apnagyugh River	10.7	9.5	9.2	8.7	9.7	8.8	8.0
7	Shahverd River	21.8	20.2	19.5	18.7	20.1	18.5	16.8
8	Amberd River	44.8	41.4	40.0	38.4	41.2	37.9	34.4

4.4 Estimation of Environmental Flow

The next step of the assessment of water balance is estimation of the monthly environmental flow in order to understand the limits of water available for consumption in different parts of Kasakh basin. Monthly environmental flow was calculated using the provisions of RA Gov't Decision 57-N from January 25, 2018 non-official translation below). Calculated environmental flow values have been compared with the multi-year average minimum, 2021 and 2022 minimum flow values to identify the sections of the basin where and months when the environmental flow has been violated and based on that, design water saving objectives for those sections.

Table 19. Environmental flow, Kasakh-Vardenis

Discharge, m³/s	**Month**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Multi-year average	0.51	0.56	1.30	3.81	3.38	1.74	0.73	0.52	0.55	0.56	0.58	0.56
Multi-year average minimum	0.073	0.06	0.2	0.66	0.37	0.12	0.016	0.01	0.012	0.013	0.011	0.11
2021 minimum	0.33	0.33	0.44	0.78	0.60	0.18	0.26	0.17	0.32	0.20	0.21	0.26
2022 minimum	0.29	0.30	0.35	0.71	0.83	0.33	0.29	0.29	0.29	0.29	0.29	0.29
Environmental flow	**0.073**	**0.060**	**0.126**	**0.278**	**0.182**	**0.100**	**0.016**	**0.010**	**0.012**	**0.013**	**0.011**	**0.096**
env flow compared to multi-year average minimum	0.000	0.000	0.074	0.382	0.188	0.020	0.000	0.000	0.000	0.000	0.000	0.014
env flow compared to 2021 minimum	0.257	0.257	0.367	0.707	0.527	0.107	0.187	0.097	0.247	0.127	0.137	0.187
env flow compared to 2022 minimum	0.217	0.227	0.277	0.637	0.757	0.257	0.217	0.217	0.217	0.217	0.217	0.217

Table 20. Environmental flow, Kasakh-Ashtarak

Discharge, m³/s	Month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Multi-year average	2.55	2.59	3.97	7.04	3.83	3.44	3.49	3.44	2.68	2.78	2.95	2.65
Multi-year average minimum	1.44	1.4	2.02	1.7	1.3	1.07	1.1	1.16	1.42	1.39	1.63	1.88
2021 minimum	2.20	2.40	2.20	3.94	1.37	1.30	1.80	1.80	1.47	2.44	2.10	1.88
2022 minimum	1.80	2.10	2.10	2.25	2.25	1.45	1.50	1.45	1.50	1.65	2.10	2.31
Environmental flow	**1.440**	**1.400**	**1.947**	**1.700**	**1.300**	**1.070**	**1.100**	**1.160**	**1.420**	**1.390**	**1.630**	**1.880**
env flow compared to multi-year average minimum	0.000	0.000	0.073	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
env flow compared to 2021 minimum	0.760	1.000	0.253	2.240	0.070	0.230	0.700	0.640	0.050	1.050	0.470	0.000
env flow compared to 2022 minimum	0.360	0.700	0.153	0.550	0.950	0.380	0.400	0.290	0.080	0.260	0.470	0.430

Table 21. Environmental flow, Gegharot-Aragats

Discharge, m³/s	Month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Multi-year average	0.23	0.22	0.33	0.76	1.72	2.45	1.89	0.87	0.50	0.37	0.31	0.31
Multi-year average minimum	0.035	0.042	0.083	0.17	0.14	0.15	0.11	0.032	0.024	0.027	0.031	0.036
2021 minimum	0.02	0.02	0.06	1.15	0.91	0.15	0.03	0.03	0.00	0.02	0.02	0.02
2022 minimum	0.02	0.02	0.03	0.10	0.94	0.78	0.03	0.03	0.02	0.02	0.00	0.04
Environmental flow	**0.035**	**0.042**	**0.083**	**0.166**	**0.140**	**0.150**	**0.110**	**0.032**	**0.024**	**0.027**	**0.031**	**0.036**
env flow compared to multi-year average minimum	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
env flow compared to 2021 minimum	-0.013	-0.020	-0.024	0.984	0.770	0.000	-0.083	-0.005	-0.024	-0.005	-0.009	-0.014
env flow compared to 2022 minimum	-0.015	-0.022	-0.053	-0.068	0.800	0.630	-0.076	-0.002	-0.003	-0.010	-0.031	0.004

Table 22. Environmental flow, Shahverd-Parpi

Discharge, m³/s	Month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Multi-year average	0.60	0.60	0.68	0.80	0.82	0.65	0.56	0.58	0.53	0.54	0.57	0.59
Multi-year average minimum	0.3	0.3	0.3	0.32	0.33	0.23	0.23	0.22	0.23	0.21	0.21	0.21

2021 minimum	0.39	0.39	0.55	0.34	0.34	0.39	0.34	0.34	0.39	0.45	0.39	0.33
2022 minimum	0.32	0.37	0.42	0.42	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.20
Environmental flow	**0.300**	**0.300**	**0.300**	**0.320**	**0.330**	**0.230**	**0.230**	**0.220**	**0.230**	**0.210**	**0.210**	**0.210**
env flow compared to multi-year average minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
env flow compared to 2021 minimum	0.090	0.090	0.250	0.020	0.010	0.160	0.110	0.120	0.160	0.240	0.180	0.120
env flow compared to 2022 minimum	0.020	0.070	0.120	0.100	-0.120	-0.020	-0.020	-0.010	-0.020	0.000	0.000	-0.010

As we can see from the tables above, in the last two years, environmental flow was violated in Gegharot (nodal basin 5) and Shahverd (nodal basin 7) river basins.

Environmental flow values were estimated also for other nodal basins where we don’t have hydroposts (Table 23).

Table 23. Environmental flow per nodal points

Nodal Basin N	**Nodal Basin Name**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	Kasakh, upper flow	0.073	0.06	0.12	0.27	0.182	0.099	0.016	0.01	0.012	0.013	0.011	0.0963
2	Kasakh, Aparan Res. Area	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
3	Kasakh, middle flow	2.30	2.24	3.11	2.72	2.08	1.71	1.76	1.86	2.27	2.22	2.61	3.01
4	Kasakh, lower flow	2.45	2.91	3.43	3.35	2.42	1.99	1.81	1.78	2.41	2.34	2.91	3.16
5	Gegharot River	0.04	0.04	0.08	0.17	0.14	0.15	0.11	0.03	0.02	0.03	0.03	0.04
6	Apnagyugh River	0.01	0.02	0.03	0.06	0.05	0.06	0.04	0.01	0.01	0.01	0.01	0.01
7	Shahverd River	0.31	0.31	0.31	0.34	0.35	0.24	0.24	0.23	0.24	0.22	0.22	0.22
8	Amberd River	0.68	0.68	0.68	0.72	0.74	0.52	0.52	0.50	0.52	0.47	0.47	0.47

4.5 Introducing a French approach in assessing the water scarcity: QMNA5

To better understand the situation with water availability, with the recommendation of the International Office for Water (France), an additional water scarcity assessment indicator, QMNA5, was considered in this study. In our case, QMNA5 which corresponds to a "minimum discharge with a probability of not reoccurring more than once every 5 years" or a "flow with a probability of being exceeded 4 out of 5 years"). In other words, it's a minimum flow with 80% probability of occurrence.

In the tables below, comparison of QMNA5 calculated for 4 hydroposts in Kasakh basin with monthly minimum discharges for 2018-2022 is presented:

Table 24. QMNA5, Kasakh - Vardenis

Discharge, m³/s	**Month**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
QMNA5	0.19	0.21	0.26	0.59	0.77	0.25	0.050	0.050	0.090	0.13	0.19	0.22
2018	0.51	0.57	0.58	0.52	0.74	0.73	0.46	0.47	0.42	0.42	0.42	0.42
2019	0.42	0.41	0.52	2.38	2.25	0.47	0.41	0.17	0.22	0.27	0.27	0.25
2020	0.23	0.29	0.31	0.85	1.33	0.25	0.25	0.25	0.25	0.53	0.24	0.27
2021	0.33	0.33	0.44	0.78	0.60	0.18	0.26	0.17	0.32	0.20	0.21	0.26
2022	0.29	0.30	0.35	0.71	0.83	0.33	0.30	0.32	0.33	0.33	0.31	0.30

Table 25. QMNA5, Kasakh - Ashtarak

Discharge, m³/s	**Month**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
QMNA5	1.95	2.08	2.2	1.98	1.7	1.6	1.78	1.55	1.59	1.68	2.00	2.05
2018	2.62	2.62	2.75	2.35	2.35	2.91	2.62	2.35	2.35	2.35	2.35	2.35
2019	2.25	2.55	2.55	3.89	3.55	3.89	2.25	2.25	2.25	2.95	2.70	2.55
2020	2.28	2.28	2.65	3.45	1.25	1.25	1.25	1.40	1.65	2.88	2.86	2.64
2021	2.20	2.40	2.20	3.94	1.37	1.30	1.80	1.80	1.47	2.44	2.10	1.88
2022	1.91	2.47	2.56	4.31	3.90	1.66	1.78	1.52	1.50	1.52	2.29	2.31

Table 26. QMNA5, Gegharot - Aragats

Discharge, m³/s	**Month**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
QMNA5	0.080	0.080	0.081	0.20	0.45	0.30	0.14	0.076	0.070	0.070	0.070	0.072
2018	0.10	0.095	0.10	0.23	0.28	1.15	0.25	0.19	0.14	0.12	0.13	0.43
2019	0.13	0.047	0.028	0.14	0.78	1.43	0.32	0.04	0.05	0.028	0.038	0.048
2020	0.046	0.036	0.081	0.45	-	-	-	-	0.025	0.025	0.036	0.023
2021	0.022	0.022	0.059	1.15	0.91	0.15	0.027	0.027	0	0.022	0.022	0.022
2022	0.036	0.040	0.044	0.31	1.30	0.93	0.034	0.030	0.021	0.017	0	0.040

Table 27. QMNA5, Shahverd - Parpi

Discharge, m³/s	Month											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
QMNA5	0.43	0.47	0.45	0.46	0.35	0.35	0.36	0.35	0.35	0.40	0.50	0.42
2018	0.32	0.39	0.39	0.39	0.43	0.68	0.72	0.48	0.48	0.47	0.48	0.53
2019	0.69	0.71	0.63	0.58	0.53	0.53	0.44	0.44	0.52	0.53	0.53	0.58
2020	0.54	0.59	0.54	0.54	0.59	0.59	0.54	0.54	0.54	0.54	0.54	0.56
2021	0.39	0.39	0.55	0.34	0.34	0.39	0.34	0.34	0.39	0.45	0.39	0.33
2022	0.32	0.37	0.42	0.42	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.20

In the tables above, values marked with red show the months in the period of 2018-2022 when the observed minimum flow was lower than 80% probability flow. QMNA5 can be considered as a threshold complementing environmental flow in assessing the water scarcity situation in sub-basins.

4.6 Water Use in Kasakh River Basin

In this chapter, the analysis of water use per nodal basin is presented based on the water use permit data received from the Ministry of Environment and irrigation water abstraction data received from the Water Committee of the Ministry of Territorial Administration and Infrastructure. Thus, in Table 28 and Figures 7 and 8, water use for different economy purposes is presented.

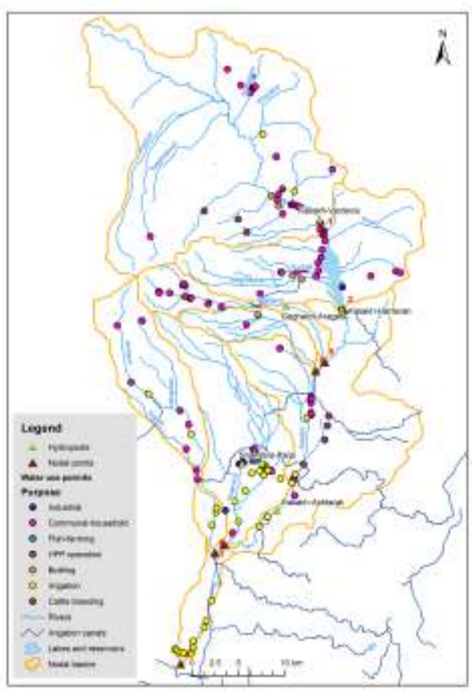
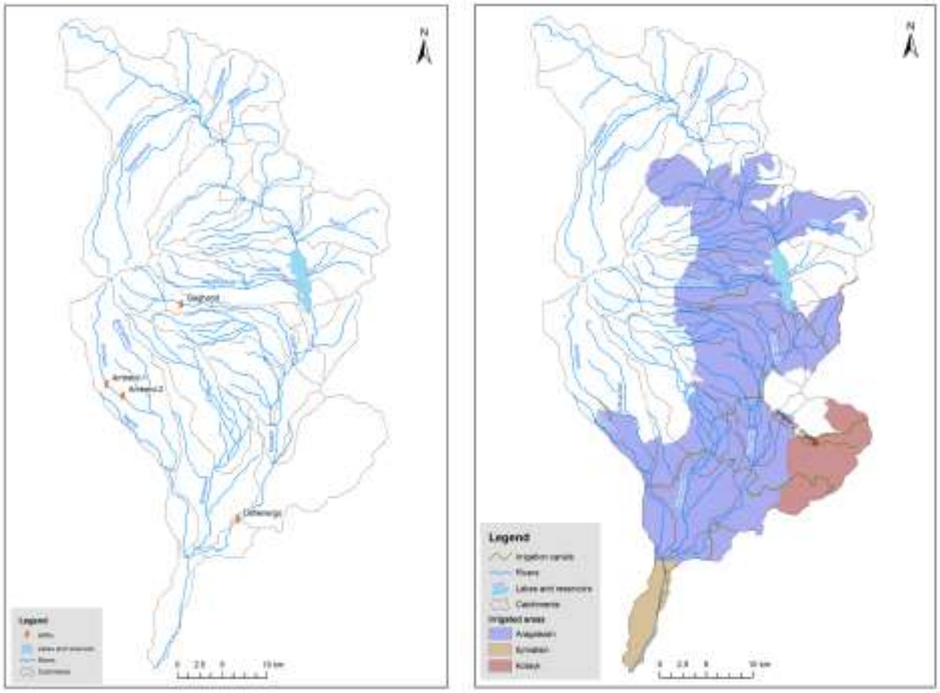


Figure 7. Water Use in Kasakh River Basin

Source: Ministry of Environment, Armenia (2023)



a) b)

Figure 8. HPPs (a) and WUA Irrigated Areas (b) in the Kasakh River Basin

Source: ArmStat; MTAI Water Committee

Table 28. Water abstraction for irrigation in Kasakh River basin

N	Source name	System name	Water abstraction, 1000m^3		
			2020	2021	2022
1	Aparan Reservoir	Kasakh irrigation system	23367.6	23661.4	24908.7
		Yernjatap, Hartavan pumping stations	371.7	765.6	667.5
2	Halavar Reservoir	Aparan inter-farm canal	0	79.13	228.8
3	Gegharot River	Kuchak pumping stations N1,2	38.3	33.1	65.1
4	Kasakh River	Ashtarak main canal	3155	3288	4641
		Kasakh-Ejmiatsin canal	7487.4	5421.6	7666.4
		Oshakan main canal	3435.1	3365.2	4311.4

Source: MTAI Water Committee, 2023

In general, total water use in Kasakh RB among all 8 nodal basins, is presented in tables 29-38. In fact, the most overloaded by water uses are middle, lower flows and Shahverd river. The main water use purpose for all this area is irrigation.

Table 29. Water use in nodal basin 1: Kasakh, upper flow

Water use, million m³	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0	0	0.00	0.00	0.00	0.00
Drinking-household	0	47.54	0.00	38.03	0.00	9.51
Fishery	0	0	0.00	0.00	0.00	0.00
HPP operation	0	0	0.00	0.00	0.00	0.00
Bottling	0	0.040	0.00	0.00	0.00	0.04
Irrigation	4.95	0.131	0.99	0.03	3.96	0.11
Cattle breeding	0	0.017	0.00	0.00	0.00	0.01

Source: Ministry of Environment, Armenia (2023)

Table 30. Water use in nodal basin 2: Kasakh, Aparan Reservoir area

Water use, million m³	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0.20	0	0.2	0.0	0.04	0.00
Drinking-household	0	48.01	0.0	38.4	0.00	9.60
Fishery	0	0	0.0	0.0	0.00	0.00
HPP operation	0	0	0.0	0.0	0.00	0.00
Bottling	0	0.36	0.0	0.0	0.00	0.36
Irrigation	4.95	0.131	1.0	0.0	3.96	0.11
Cattle breeding	0	0.017	0.0	0.0	0.00	0.01

Source: Ministry of Environment, Armenia (2023)

Table 31. Water use in nodal basin 3: Kasakh, middle flow

Water use, million m³	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0.20	0.26	0.2	0.2	0.04	0.05
Drinking-household	0.00	114.45	0.0	91.6	0.00	22.89
Fishery	0.00	2.33	0.0	1.9	0.00	0.47
HPP operation	109.04	0.00	109.0	0.0	0.00	0.00
Bottling	0.00	0.53	0.0	0.0	0.00	0.53
Irrigation	51.08	1.55	10.2	0.3	40.86	1.24
Cattle breeding	0.00	0.02	0.0	0.0	0.00	0.01

Source: Ministry of Environment, Armenia (2023)

Table 32. Water use in nodal basin 4: Kasakh, lower flow

Water use, million m³	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0.20	0.26	0.2	0.2	0.04	0.05
Drinking-household	0.00	114.45	0.0	91.6	0.00	22.89

Fishery	0.00	2.33	0.0	1.9	0.00	0.47
HPP operation	109.04	0.00	109.0	0.0	0.00	0.00
Bottling	0.00	0.53	0.0	0.0	0.00	0.53
Irrigation	51.08	2.94	10.2	0.6	40.86	2.35
Cattle breeding	0.00	0.02	0.0	0.0	0.00	0.01

Source: Ministry of Environment, Armenia (2023)

Table 33. Water use in nodal basin 5: Gegharot River

Water use, million m^3	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0.00	0.00	0.0	0.0	0.00	0.00
Drinking-household	0.00	0.43	0.0	0.4	0.00	0.09
Fishery	0.00	0.00	0.0	0.0	0.00	0.00
HPP operation	68.74	0.00	68.7	0.0	0.00	0.00
Bottling	0.00	0.00	0.0	0.0	0.00	0.00
Irrigation	0.00	0.00	0.0	0.0	0.00	0.00
Cattle breeding	0.00	0.00	0.0	0.0	0.00	0.00

Source: Ministry of Environment, Armenia (2023)

Table 34. Water use in nodal basin 6: Apnagyugh River

Water use, million m^3	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0	0	0	0	0	0
Drinking-household	0	0.1	0	0.08	0	0.02
Fishery	0	0	0	0	0	0
HPP operation	0	0	0	0	0	0
Bottling	0	0.17	0	0	0	0.17
Irrigation	0	0	0	0	0	0
Cattle breeding	0	0	0	0	0	0

Source: Ministry of Environment, Armenia (2023)

Table 35. Water use in nodal basin 7: Shahverd River

Water use, million m^3	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0	0.26	0	0.21	0	0.05
Drinking-household	0	214.3	0	171.44	0	42.86
Fishery	0	2.32	0	1.86	0	0.46
HPP operation	0	0	0	0	0	0
Bottling	0	0	0	0	0	0
Irrigation	4.67	1.4	0.93	0.28	3.73	1.12
Cattle breeding	0	0	0	0	0	0

Source: Ministry of Environment, Armenia (2023)

Table 36. Water use in nodal basin 8: Amberd River

Water use, million m³	SW abstraction	GW abstraction	SW return	GW return	SW water loss	GW water loss
Industrial	0	0	0	0	0	0
Drinking-household	0	1.12	0	0.9	0	0.22
Fishery	0	0	0	0	0	0
HPP operation	49.5	0	49.5	0	0	0
Bottling	0	0	0	0	0	0
Irrigation	21.02	0.53	4.2	0.11	16.81	0.43
Cattle breading	0	0	0	0	0	0

Source: Ministry of Environment, Armenia (2023)

Table 37. Monthly water uses (surface) in the nodal basins of Kasakh River basin

Water use, million m³	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
NB1	0.00	0.00	0.00	0.00	0.00	0.79	1.19	1.19	0.59	0.20	0.00	0.00
NB2	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
NB3	0.00	0.00	0.00	0.00	0.00	7.38	11.07	11.07	5.54	1.85	0.00	0.00
NB4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB7	0.00	0.00	0.00	0.00	0.00	0.75	1.12	1.12	0.56	0.19	0.00	0.00
NB8	0.00	0.00	0.00	0.00	0.00	3.36	5.04	5.04	2.52	0.84	0.00	0.00

Source: Ministry of Environment, Armenia (2023)

Table 38. Monthly water uses (groundwater) in the nodal basins of Kasakh River basin

Water use, million m³	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
NB1	0.80	0.80	0.80	0.80	0.80	0.82	0.83	0.83	0.81	0.80	0.80	0.80
NB2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
NB3	1.16	1.16	1.16	1.16	1.16	1.39	1.51	1.51	1.34	1.22	1.16	1.16
NB4	0.00	0.00	0.00	0.00	0.00	0.22	0.33	0.33	0.17	0.06	0.00	0.00
NB5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NB6	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NB7	3.61	3.61	3.61	3.61	3.61	3.84	3.95	3.95	3.78	3.67	3.61	3.61
NB8	0.02	0.02	0.02	0.02	0.02	0.10	0.15	0.15	0.08	0.04	0.02	0.02

Source: Ministry of Environment, Armenia (2023)

d. 5. Irrigation Water Demand Calculation

The geographical location and climate of the Kasakh River Basin is favorable for both crop cultivation (grain, potatoes, perennial plantations, fodder crops) and livestock breeding. The agriculture in this area is specialized mainly in crop production, particularly cereals, and cattle farming.

The irrigation infrastructure of the Kasakh River Basin consists of a system of reservoirs, pumping stations and canals. The total volume of the reservoirs built in Kasakh River Basin amounts to 97.7 million m^3.

The main irrigation beneficiaries of Kasakh River Basin are “Jrar” CJSC (bulk irrigation water supply agency), Aragatsotn WUA, Echmiadzin WUA and Kotayk WUA. Below, in Tables 39-41, are presented the main canals, existing and planned reservoirs of the Kasakh RB. Thus, as it shown in these tables, the main water consumer of this river basin area is agriculture.

Table 39. Hydraulic structures of the basin

N	Kasakh River Basin				
	Canal name	Water source	Length (km)	Capacity (m3/s)	Service area (ha)
1	Arzni-Shamiram canal	Hrazdan River	92.0	18.0	12,000.0
2	Lower Hrazdan canal	Hrazdan River	53.4	11.0	6,450.0
3	Kasakh irrigation system	Aparan reservoir	14.0	12.0	2,600.0
4	Yernjatap	Kasakh River	10.1	0.9	1,497.0
5	Kuchak	Gegharot River	2.0	0.2	170.0
6	Yeghvard	Kasakh River	16.5	0.6	150.0
7	Kasakh-Echmiadzinl	Kasakh River	18,1	5.0	1,188.0
8	Ashtarak canal	Kasakh River	9,4	1,5	280.0
9	Oshakan canal	Kasakh River	4,5	1,0	160.0

Table 40. Existing reservoirs

N	Kasakh River Basin				
	Reservoir name	Water source	Dam height (m)	Total volume (mln m^3)	Useful volume (mln m^3)
1	Aparan	Kasakh River	52.6	91.0	81.0
2	Halavar	Halavar River	31.4	5.5	5.3
3	Tsilkar		13.0	1.2	1.2

Source: MTAI Water Committee

Table 41. Planned reservoirs

N	Kasakh River Basin				
	Reservoir name	Water source	Dam height (m)	Total volume (mln m^3)	Useful volume (mln m^3)
1	Yeghvard Reservoir	Hrazdan River	25/14	94.0	90.0
2	Kasakh Reservoir	Kasakh River	32.0	11.5	11.5

Source: MTAI Water Committee

5.1 Description of the current status of irrigation in Kasakh River basin

a. "Jrar" CJSC

"Jrar" CJSC operates Aparan Reservoir and Halavar Reservoir and carries out water intake from Kasakh River. The following tables (Table 42 and Table 43) were prepared based on the information provided by "Jrar" CJSC.

Table 42. Volumes of water taken from intake points of Kasakh River and supplied to WUAs in various years (2018-2022)

N	**WUA name**	**2018 mln m^3**	**2019 mln m^3**	**2020 mln m^3**	**2021 mln m^3**	**2022 mln m^3**
1	Aragatsotn	45.47	42.01	41.58	42.05	48.73
2	Echmiadzin	40.55	36.08	29.52	18.37	38.23
3	Total	86.02	78.09	71.10	60.42	86.96

Source: MTAI Water Committee

Table 43. Releases for irrigation purposes

N	**Reservoir name**	**2018 mln m^3**	**2019 mln m^3**	**2020 mln m^3**	**2021 mln m^3**	**2022 mln m^3**
1	Aparan	31.830	68.063	48.225	40.155	48.524
2	Halavar	0.177	0.125	0.000	0.082	0.229
3	Total	32.007	68.188	48.225	40.237	48.753

Source: MTAI Water Committee

b. *“Aragatsotn” WUA*

The total irrigated area located under command of Kasakh River Basin within the service area of Kasakh WUA makes up 10,175.8 ha, including 6,411.3 ha of currently not cultivated lands (which are potentially irrigable). The following tables (Table 44 and Table 45) were prepared based on the information provided by WUA.

It should be stated that WUA did not provide information on crop patterns. It was selected approximately based on the specific pattern of each area.

Table 44. The intake volumes by the WUA in various years (2020-2022).

N	Water source	2020 mln m3	2021 mln m3	2022 mln m3
1	Aparan Reservoir	23.739	24.427	25.576
2	Halavar Reservoir	0.000	0.079	0.229
3	Gegharot River	0.038	0.033	0.065
4	Kasakh River	14.077	12.074	16.618
5	Total	37.854	36.613	42.488

Source: MTAI Water Committee

Table 45. The water delivery by the WUA in various years (2020-2022).

N	Name of the system	2020 mln m3	2021 mln m3	2022 mln m3
1	Kasakh irrigation system, Yernjatap and Hartavan pumping stations	14.907	15.325	16.032
2	Aparan secondary canal	0.000	0.048	0.310
3	Kuchak pumping station	0.021	0.018	0.029
4	Kasakh River	6.815	6.100	8.371
5	Total	21.743	21.491	24.742

Source: MTAI Water Committee

Thus, Aragatsotn WUA has taken 42.5 mln m^3 of water and delivered 24.7 mln m^3 for the irrigation of 3,764.51 ha. The actual efficiency was 58%, and the average water norm was 6,572.4 m^3/ha.

c. "Echmiadzin" WUA

The total irrigated area located under the command of Kasakh River Basin within the service area of Echmiadzin WUA makes up 11,812.0 ha, including 6,215.0 ha of currently not cultivated areas (which are potentially irrigable).

According to information provided by Echmiadzin WUA, it took 115.7 mln m^3 of water and delivered 46.7 mln m^3 for the irrigation of 5,597.0 ha. Thus, the actual efficiency was about 40%, and the average water norm was 8,353.0 m^3/ha.

It should be stated that WUA did not provide information on crop patterns. It was selected approximately based on the specific pattern of each area.

The volume of water delivery to each settlement was calculated based on the irrigation regimes of the settlement area, corresponding irrigation norms, and crop mix.

d. "Kotayk" WUA

Currently, Kotayk WUA does not take water for irrigation purposes from the Kasakh River basin, however, such intake is planned in mid-term and long-term perspective. In particular, it is planned to increase the intake from the Kasakh River Basin through Kasakh irrigation system up to 1 mln m^3 in the next 5 years for the irrigation of 200 ha of agricultural lands (according to Kotayk WUA).

5.2 Scenarios for the irrigation water demand

Detailed calculations were conducted for the estimation of the water intake in Kasakh River basin required for covering the irrigation water demand of the lands/settlements located within the service areas of WUAs, using irrigation norms and regimes of agricultural crops.

As WUA did not provided information on the crop pattern/mix, it was selected approximately based on the data of previous years (the error is estimated 5%).

Three scenarios were considered for estimating the coverage of irrigation water demand through the intake from Kasakh River Basin.

a) "Aragatsotn" WUA

a-1. Scenario 1

Under this scenario, the actual volume of water taken for the irrigation of 1 ha was calculated, and the same approach was used for the estimation of the water demand/intake of the perspective lands (Table 46).

Table 46. The calculated actual volume of water taken for a 1ha irrigated area

Irrigated lands		**Perspective lands**		**Total lands**	
ha	Water intake (m^3)	ha	Water intake (m^3)	ha	Water intake (m^3)
3,764.51	50,030,485.52	6,411.30	85,206,428.41	10,175.81	135,236,913.93

a-2. Scenario 2

Under this scenario, the intake for the actual irrigated lands was calculated based on WUA data, while the intake for the perspective areas was estimated based on the irrigation norms and regimes of corresponding agricultural plots, applying the data of losses provided by WUAs (Table 47).

Table 47. The data on actual and perspective irrigated lands, applying the data of losses provided by WUAs

Irrigated lands		**Perspective lands**		**Total lands**	
ha	Water intake (m^3)	ha	Water intake (m^3)	ha	Water intake (m^3)
3,764.51	50,030,485.52	6,411.30	56,988,122.43	10,175.81	107,018,607.95

a-3. Scenario 3

Under this scenario, the intake for the actual and perspective irrigated lands was estimated based on the irrigation norms and regimes of corresponding agricultural crops, applying the design loss factor (30%) (Table 48).

Table 48. The data on actual and perspective irrigated lands, applying the design losses factor (30%)

Irrigated lands		**Perspective lands**		**Total lands**	
ha	Water intake (m^3)	ha	Water intake (m^3)	ha	Water intake (m^3)
3,764.51	33,900,016.61	6,411.30	44,089,073.38	10,175.81	77,989,089.99

Under this scenario, the water intake and delivery were estimated without taking into account the losses on field and climate changes.

b) *“Echmiazdin" WUA*

b-1. Scenario 1

Under this scenario, the actual volume of water taken for irrigation of 1 ha was calculated, and the same approach was used for the estimation of the water demand/intake of the perspective lands (Table 49).

Table 49. The calculated actual volume of water taken for a 1ha irrigated area

Irrigated lands		**Perspective lands**		**Total lands**	
ha	Water intake (m^3)	ha	Water intake (m^3)	ha	Water intake (m^3)
5,597.00	115,693,916.24	6,215.00	128,528,327.12	11,812.00	244,222,243.36

b-2. Scenario 2

Under this scenario, the intake for the actual irrigated lands was calculated based on WUA data, while the intake for the perspective areas was estimated based on the irrigation norms and regimes of corresponding agricultural crops, applying the data of losses provided by WUAs (Table 50).

Table 50. The data on actual and perspective irrigated lands, applying the data of losses provided by WUAs

Irrigated lands		**Perspective lands**		**Total lands**	
ha	Water intake (m^3)	ha	Water intake (m^3)	ha	Water intake (m^3)
5,597.00	115,693,916.24	6,215.00	129,987,232.14	11,812.00	245,968,019.64

b-3. Scenario 3

Under this scenario, the intake for the actual and perspective irrigated lands was estimated based on the irrigation norms and regimes of corresponding agricultural crops, applying the design loss factor (30%) (Table 51).

Table 51. The data on actual and perspective irrigated lands, applying the design losses factor (30%)

Irrigated lands		**Perspective lands**		**Total lands**	
ha	Water intake (m^3)	ha	Water intake (m^3)	ha	Water intake (m^3)
5,597.00	66,274,735.71	6,215.00	73,518,157.14	11,812.00	139,792,892.86

Under this scenario, the water intake and delivery were estimated without taking into account the losses on field and climate changes.

c) «Kotayk» WUA

c-1. Scenario 3

Under this scenario, the intake for the perspective irrigated lands was estimated based on the irrigation norms and regimes of corresponding agricultural crops, applying the design loss factor (30%) (Table 52).

Table 52. The data on actual and perspective irrigated lands, applying the design losses factor (30%)

Irrigated lands*		Perspective lands		Total lands	
ha	Water intake (m^3)	ha	Water intake (m^3)	ha	Water intake (m^3)
		200.00	1,258,909.09	200.00	1,258,909.09

*Note: there are no irrigated areas.

Source: MTAI Water Committee

Under this scenario, the water intake and delivery were estimated without taking into account the losses on field and climate changes.

5.3 Analysis

The water intake from Kasakh River basin for irrigation purposes was estimated for three scenarios (see Table 53).

The losses on field and climate changes were not estimated in any of the scenarios.

Furthermore, the crop pattern/mix was estimated by regions, which may not comply with the actual data. However, the error is low (up to 5%).

- ✔ The 30% loss applied in 3rd scenario is unrealistic within the current irrigation system. Under that scenario, 219.0 mln m^3 of water must be taken for the irrigation of 22,287 hectares.
- ✔ The loss assumed for the 2nd scenario complies with the loss within the existing irrigation systems, and the water demand for the crop pattern/mix was calculated in accordance with the irrigation norms and regimes. In this case, 354.2 mln m^3 of water must be taken for the irrigation of 22,287 ha.
- ✔ Calculations of the 1st scenario comply with the actual water intake/delivery data of WUAs. In that case, 379.5 mln m^3 of water must be taken for the irrigation of 22,287 ha.

Table 53. Water intake for irrigation purposes from Kasakh River basin estimated for three scenarios

WUA name	Service area (ha)	Water demand for all lands (m^3)		
		Scenario 1	Scenario 2	Scenario 3
Aragatsotn	10,175.81	135,236,913.93	107,018,607.95	77,989,089.99
Echmiadzin	11,812.00	244,222,243.36	245,968,019.64	139,792,892.86
Kotayk	300.00		1,258,909.09	1,258,909.09
Total	**22,287.81**	**379,459,157.29**	**354,245,536.68**	**219,040,891.94**

5.4 Conclusion

In the case of best scenarios (Scenario 3), for the medium-term perspective it would be difficult to cover the irrigation water demand by the intake from Kasakh River basin.

However, for the long-term perspective, it is appropriate to estimate the water demand for irrigation from the Kasakh River Basin considered based on the results of Scenario 3 – 219.7 million m^3.

Kasakh water reservoir

With the support of the European Union (EU) to the Government of RA through"Recovery, Resilience and Reform" Programme, it is planned to build 17 reservoirs within the framework of the "Additional "B" initiative of the Eastern Partnership Priorities after 2020 initiative.

Construction of Kasakh water reservoir is included in these plans, which is planned to be built in the administrative area of Amberd community of Armavir marz, RA, at the junction of the Kasakh and Amberd rivers, in order to accumulate flood discharges. The water source for the reservoir is the floodwaters of the Kasakh and Amberd rivers. As a result of preliminary studies, the volume of the reservoir is 11.5 million m^3 and it is planned to subsidize the 2nd stage of Lower Hrazdan.

At the time of this project, the government of RA initiated technical environmental and social impact assessment works for the Kasakh water reservoir. More details will be clarified after the end of these studies.

e. 6. Water Accounts – physical water supply and use tables

The System of Environmental Economic Accounting (SEEA) water accounting approach (SEEA Water) is a statistical approach to inform policymakers on stocks, use, and quantity of water, comprising a set of connected physical and monetary indicators. The SEEA water has been developed under the auspices of the United Nations Statistical Committee and is an internationally agreed statistical framework (The Framework for the Development of Environment Statistics (FDES 2013)).

SEEA water covers the stocks and flows of water between environment and economy, the environmental pressures of the economy in terms of water abstraction and discharge, the supply of water and its use as input in different economic activities, the reuse of water within the economy. Physical flows comprise surface water, groundwater, soil water, which are provided by the environment and withdrawn by different economic agents.

The statistics of water abstraction, water use, wastewater discharge and wastewater treatment disaggregated by NACE (Classification of economic activities) or ISIC (no difference in two digit level) are available at the marz level for the years 2011- 2022 (ArmStatBank.am). The database contains data collected from those economic units which have permissions on abstraction of freshwater, discharge of wastewater and pollution. In order to convert the marz scale data to a river basin scale data, those water bodies are taken into consideration which serve as sources of withdrawal and/or discharge within the river basin.

Along with all that, there was also a need to make a seasonal distribution of annual volumes. However, since the above-mentioned database is formed on the basis of annual reports, it became necessary to use another information source, more specifically, the database of quarterly reports on natural use taxes paid by reporting organizations to the tax service, where water volumes are also recorded. Here too, problems arose, particularly with regard to organizations that are exempt from taxes. Regarding these, statistical assessments were made, which were discussed with specialists from the relevant field. Based on the quarterly payments, coefficients were obtained by which the entire annual volume was distributed in the corresponding 4 quarterly tables. The main three activities have been considered – hydropower plants, irrigation and drinking water supply services.

Table. 54. Quarter coefficients

Type	Quarter	2020	2021	2022
HPP	I-quarter	5.2	8.7	5.2
	II-quarter	78.1	75.6	78.1
	III-quarter	11.2	8.2	11.2
	IV-quarter	5.5	7.5	5.4
surface water - irrigation	I-quarter	0	0	0
	II-quarter	24.5	33.2	21.1
	III-quarter	75.5	66.8	78.9
	IV-quarter	0	0	0
ground water - drinking	I-quarter	24.7	25.6	24.9
	II-quarter	24.9	25.9	25
	III-quarter	25.2	24.3	25
	IV-quarter	25.2	24.3	25.1

These coefficients were used for quarterly distribution of water by the main NACE or ISIC activities - agriculture (surface - irrigation), manufacturing (ground - drinking water), electricity supply (surface HPP), water supply services (ground - drinking water) and households (ground - drinking water),

The annual volumes of abstracted water for irrigation are based on the dataset from Table 54. Water abstraction for irrigation in Kasakh RB. The losses and supply volumes are derived from the above-mentioned Database. Consumption in this field comprises appox. 30% of the total abstraction for irrigation.

The return water mainly refers to losses, flows from sewage (80% of drinking water from household) and the part of (15%, depending on the type of soil) irrigation which goes back to the soil.

Table 55. The annual volumes of abstracted water

	2020 mln.cub.m	2021 mln.cub.m	2022 mln.cub.m
Water Use	198.1	225.4	212.5
Water Supply	176.5	206.4	184.4
Consumption	21.6	19.0	28.1

Compiled Water Accounts quarterly distributed for 2020, 2021 and 2022 are shown in separate Water Account report.

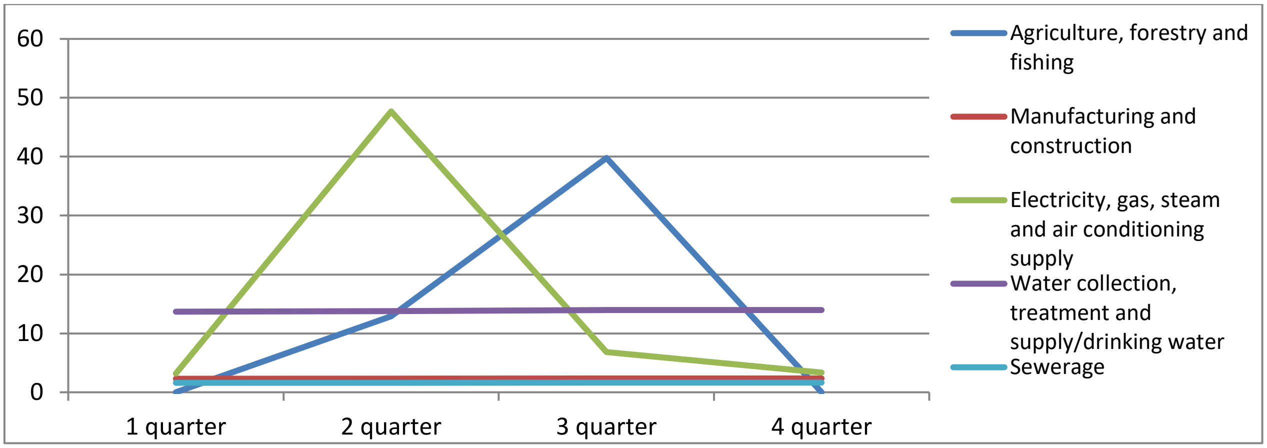


Figure 9. Water Use by NACE and quarters, 2020

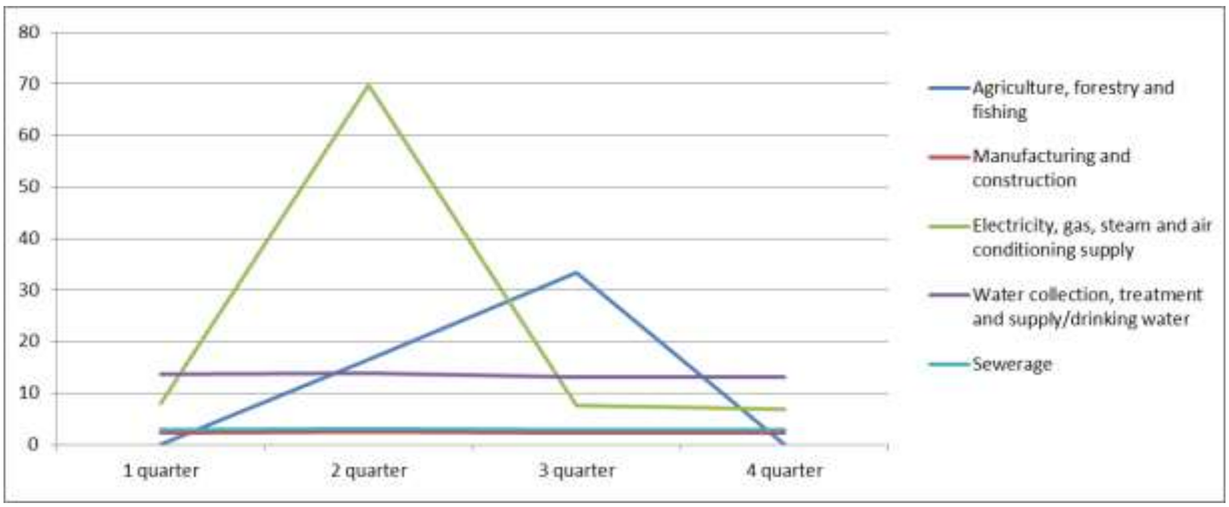


Figure 10. Water Use by NACE and quarters, 2021

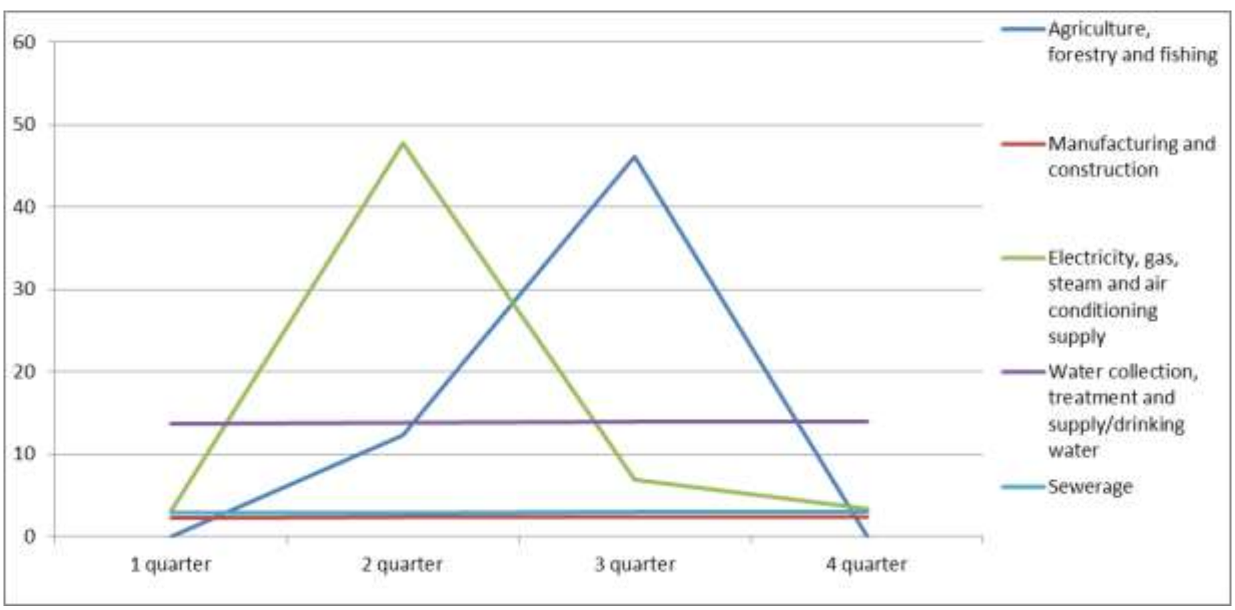


Figure 11. Water Use by NACE and quarters, 2022

According to the figures 9, 10, 11 the significant increase in Quarter indicate sates seasonal irrigation needs in Agriculture sector.

Water usage remains relatively stable across quarters, with minor fluctuations in Manufacturing and Construction. This sector shows consistent water demand throughout the year.

There is a substantial increase in water use in Quarter 2 in Electricity, Gas, Steam and Air Conditioning Supply sector, due to increased surface water flows. Water usage decreases in Quarter 3 but remains relatively high compared to Quarters 1 and 4.

The Supply and Use data are very similar.

Thus, for the seasonal variations - sectors like Agriculture and Electricity, Gas, Steam and Air Conditioning Supply show notable changes between quarters, likely influenced by seasonal factors such as agricultural cycles or temperature variations.

And as a stable demand, sectors involved in water supply (both drinking water and sewerage) exhibit stable water consumption patterns, indicating consistent operational needs.

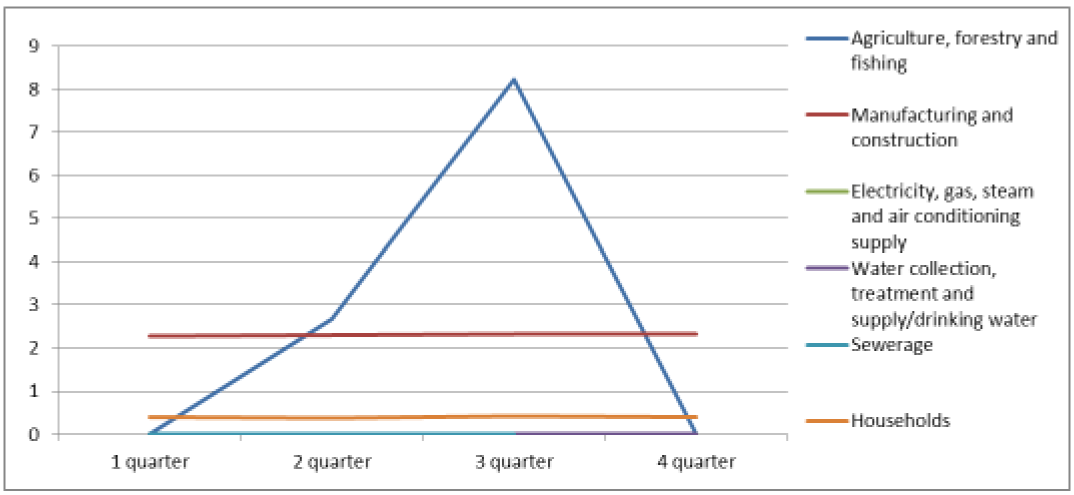


Figure 12. Water Consumption by NACE and quarters, 2020

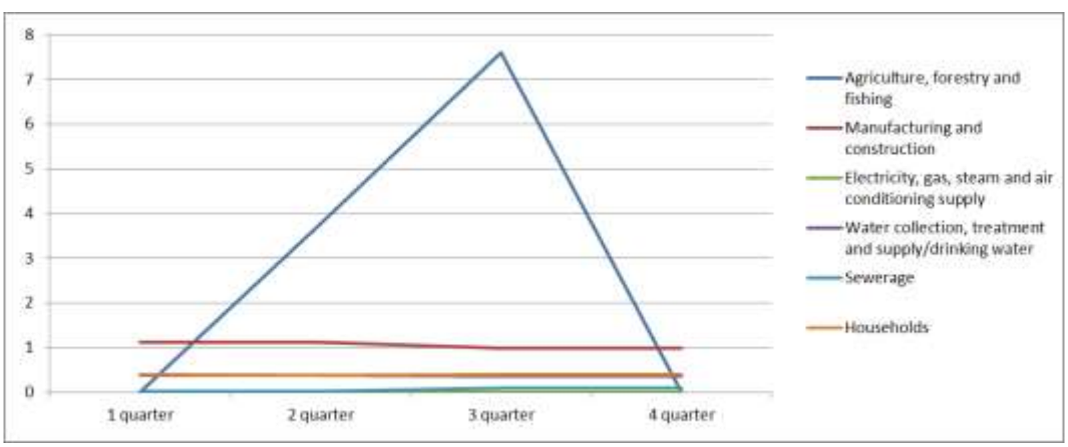


Figure 13. Water Consumption by NACE and quarters, 2021

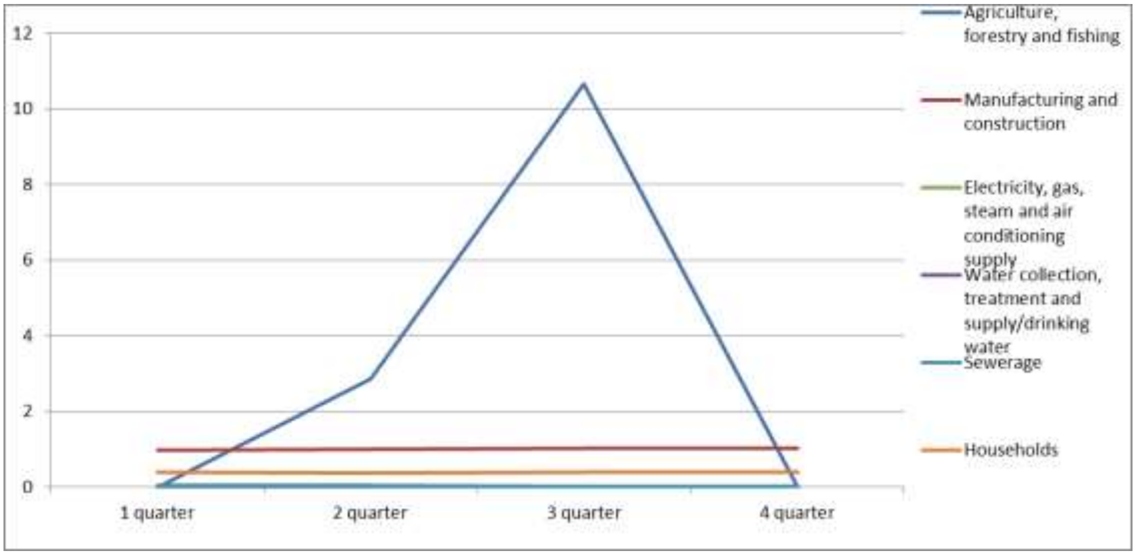


Figure 14. Water Consumption by NACE and quarters, 2022

For Water consumption indicator we can assume that in the Agriculture, Forestry, and Fishing sector the increase in Quarter 3 reflects irrigation needs during the growing season, while the absence of water uses in Quarters 1 and 4 may indicate seasonal fluctuations or non-irrigation periods. In the Manufacturing and Construction sector water consumption remains relatively stable across all quarters. This indicates consistent water demand in this sector throughout the year, possibly for industrial processes and construction activities. The consumption by households shows minor fluctuations between 2020 – 2022, across the quarters, indicating stable usage typical for residential water consumption patterns. The absence of reported water usage or discharge for some sectors like mining or other service providers suggests either minimal water usage in these sectors or a lack of available data.

7. Recommendations for quantitative water management in Kasakh River basin, including a crisis management and low water cases during the periods of drought and water scarcity

7.1 Surface water management

The main outcome of this exercise is to propose a methodology for operative decision-making on water restriction on a basin or nodal basin in crisis management situation. It is based on direct reading in quasi real time of river flow monitoring versus precalculated threshold values. The threshold values has been selected in order to monitor both the respect of the Armenian legislation on environmental flow and to discriminate the periods of drought and water scarcity.

The main objective of the proposed system is to avoid reaching the Armenian environmental flow in accordance with the regulations, by gradually implementing restrictions to limit abstractions.

The tandem with QMNA5 and Armenian Environmental thresholds makes up a key parameter for assessing the surface water deficit and scarcity in the river basin, and building a water scarcity and drought risk management tool. Below in the scheme (Fig. 6), a proposal for operative management of surface flow per point of interest is presented. The idea is to set the target minimum flows for taking certain actions by the management body. According to our proposal, once the discharge reach the threshold of environmental flow + 50% ("Vigilance flow"), all responsible authorities receive an information about the possible water deficit if nothing is done. Regarding the information received, the procedure is defined by the executive body, namely, Ministry of Environment. Potentially, it may be through a phone call, SMS, or through e-mail, depending on the receiver preferences and technical arrangements. The main managing bodies and stakeholders (Ministry of Environment, Water Committee, Armhydromet) must have access to the Armhydromet database through an API with an interface for visualizing river flow data and potentially key water users). Ideally, the interface needs to be integrated to the Water Cadastre Information System of the Ministry of Environment, which is also needs to be interoperable with Armhydromet (river discharge monitoring data) and Water Committee (water use data) information systems. The system can be operational for both traditional hydropost with 2 water flow measurements per day or automatic hydropost. The main effort for that is to accelerate data input in close to real time after its reading by the observer and allow distant access to the reference data base with API technology.

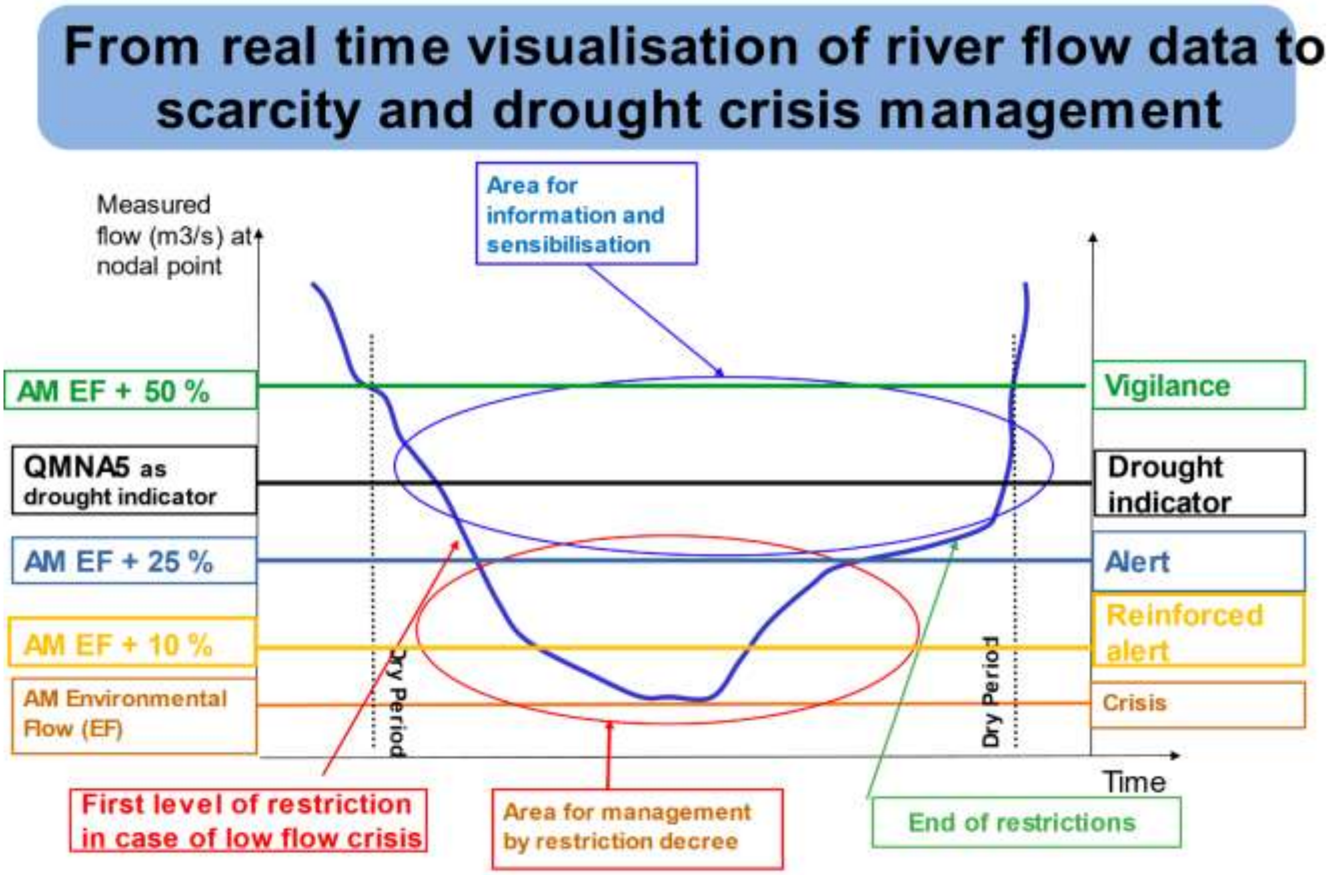


Figure 15. Proposed methodology for managing water uses in water deficit periods

Table 56 below illustrates comparison of environmental flow and QMNA5 with the monthly minimum discharges in Kasakh-Ashtarak hydropost, as an example for crisis flow management methodology application. However, for the operative management, it advised to make decision on the thresholds values based on the arithmetic indication and possible adjustment to the specific context and historical observation.

Table 56. Environmental flow, Kasakh-Ashtarak

Discharge, m^3/s	**Month**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Multi-year average	2.55	2.59	3.97	7.04	3.83	3.44	3.49	3.44	2.68	2.78	2.95	2.65
Multi-year average minimum	1.44	1.4	2.02	1.7	1.3	1.07	1.1	1.16	1.42	1.39	1.63	1.88
2021 minimum	2.20	2.40	2.20	3.94	1.37	1.30	1.80	1.80	1.47	2.44	2.10	1.88
2022 minimum	1.80	2.10	2.10	2.25	2.25	1.45	1.50	1.45	1.50	1.65	2.10	2.31
Armenian Environmental flow	**1.440**	**1.400**	**1.947**	**1.700**	**1.300**	**1.070**	**1.100**	**1.160**	**1.420**	**1.390**	**1.630**	**1.880**

QMNA5	**1.95**	**2.08**	**2.2**	**1.98**	**1.7**	**1.6**	**1.78**	**1.55**	**1.59**	**1.68**	**2.00**	**2.05**
Armenian Environmental flow + 10 % =	1.584	1.54	2.142	1.870	1.43	1.177	1.21	1.276	1.562	1.529	1.793	2.068
Armenian Environmental flow + 25 %	1.8	1.75	2.434	2.125	1.625	1.338	1.375	1.45	1.775	1.738	2.038	2.35
Armenian Environmental flow + 50 %	2.16	2.1	2.921	2.55	1.95	1.605	1.65	1.74	2.13	2.085	2.445	2.82

Restrictions that shall be made after the violations of the allowable threshold of flows are presented below, in Table 57. Descriptions of these restrictions are presented for guiding purposes. The volume of temporary restricted water use can vary in different cases and must be regulated by the water resources management body.

Based on Table 57, in the case of ***"Vigilance flow"***, it is recommended to raise awareness on the need of water saving without changing the maximum abstraction volume mentioned in water use permits. If surface water body flows through specially protected natural areas (SPNAs), then volume of abstraction regulated by water use permits could be temporarily reduced by 5%. The water abstraction points that are situated before the boundaries of the SPNAs shall be regulated accordingly. In the case of no tributary or other underground inflow in the river section from the abstraction points and the boundary, the regimes of the most downstream two water users can be revised by their priority, according to the law "On National Water Policy".

Table 57. Water Balance Crisis Management

Type of target flow (TF)	**Type of notification**	**Actions**		**Next actions**
		Approaching the TF	The TF is crossed for 3 – 4 – 7 days	Actions that shall be done after the rehabilitation of the sections' flow
Vigilance flow = about AM EF + 50 %	phone call, or SMS, or e-mail	Water users are notified about the situation		
Alert Flow = about AM EF + 25 %	phone call, or SMS, or e-mail	Water users are notified about the situation	Temporary decrease of water abstraction at the top water users. The calculation of the volume of restrictions depends on the extent of environmental flowing level crossing. The first water use purpose, which abstraction level shall be revised is *Fisheries* from surface water. Decreasing of water abstraction among that water users shall be calculated and implemented evenly, considering the principle of parity. If such an approach significantly worsens the activity and performance of the fishing companies, then the decrease shall be done for the *Industry* purpose. The decreasing parity of abstraction in this case shall be 60:40 as fisheries and industry, accordingly. The action on temporary decreasing of water abstraction should be calculated in the manner that deficiency of water resources will cover the environmental flow level plus 5-	Stepwise rehabilitation of the water abstraction shall be implemented on 5th day of the flow recovery. "Stepwise" definition in this case means the same proportion for the purposes. First end of restriction shall be done for the *water use categories with the higher priorities.*

			10%, which will be considered as a “security belt”. In the case of no available fish farms at the top section, abstraction decrease by the above-mentioned principle shall be implemented for the priorities, mentioned in the law “On the basis of water national policy”. This means, that first restricted abstraction shall be done for *Industry, and then for Energy, and then for Irrigation.* Water abstraction for drinking and household water supply must be the same, without restrictions. If within 3 days flow is not recovered (at the same weather and hydrometeorological conditions), then temporary abstraction of the above-mentioned purposes shall be decreased by additional 10% for all the above-mentioned water users.	
Reinforced alert flow = about AM EF + 10 %	phone call, or SMS, or e-mail		Decreasing proportions of water abstraction within 40% for different purpose of the water uses shall be decreased by the following proportion: Fisheries – 40%, Industry – 33%, Energy – 33%, Agriculture – 33%. In the case of non-availability, every next water use purpose with a higher priority decreases abstraction by 10%.	Stepwise rehabilitation of the water abstraction shall be implemented on 7th day of the flow recovery. “Stepwise” definition in this case means the same proportion for the purposes.

			If within 5 days flow is not recovered (at the same weather and hydrometeorological conditions), then temporary abstraction of the above-mentioned purposes shall be decreased by an additional 5% for all the above mentioned water users. Water use on international agreements purposes should be stopped, informing the other sides of the agreements.	
Crisis flow: Armenian Environmental flow	phone call, or SMS, or e-mail		Temporary cessation of water uses for the following purposes: Fisheries, Industry, Energy, and Agriculture Water use on international agreements purposes should be stopped, informing the other sides of the agreements. If within 5 days flow is not recovered (at the same weather and hydrometeorological conditions), then temporary abstraction of the above-mentioned purposes shall be decreased by additional 20% for all the above mentioned water users.	Stepwise rehabilitation of the water abstraction shall be implemented on 7th – 10th - 14th day of the flow recovery. "Stepwise" definition in this case means the same proportion for the same purposes.

The next level of restrictions is the “Reinforced alert” with Environmental flow -10%. And the last one is Crisis flow: Environmental flow, when the strictest restrictions are being imposed.

Once the discharge comes back to the environmental flow value, the restrictions will be progressively lifted.

As mentioned above, to make this process work smoothly, near real-time data on river discharges and water abstractions is needed that must be transferred to the Armydromet water information system to be accessible directly by decision-makers through API. Therefore, establishing inter-institutional cooperation on water-related data management, a clear data-sharing framework, and water information system development strategy is crucial for timely and operational quantitative water management. The main data providers should be Armhydromet SNCO of the Ministry of Environment (hydrometeorological data) and the Water Committee of the Ministry of Territorial Administration and Infrastructure (water use data). Water resources management, jointly with basin management organizations, must undertake appropriate measures based on this information.

On the long run it is advised to develop continuous measurement systems at nodal points with the installation of new hydropost in the following order of priority:

1. Upstream Nodal basin 4: Kasakh, lower flow, that will be an indicator of surface water use pressures in the whole basin.
2. Downstream Nodal basin 3: Kasakh, middle flow, that have the advantage to discriminate the water use pressures from the 2 Marz and the 2 different main WUAs and thus send specific restriction order to one of them more specifically if needed.
3. Downstream Nodal basin 8: Amberd river. That will give a picture of the water balance in this basin and send specific restriction order to the water user of this sub-basin in case of crisis.

This investment would allow to manage the entire Kazakh watershed with modest cost. It makes sense economically only if the data from these hydroposts are managed efficiently in quasi real time so that the management water actors can make better decision faster.

Note that this type of analysis could be up-scale for the different river basins districts of Armenia with the objective to identify the most pertinent existing hydropost for crisis management and calculate the most adapted thresholds and spot the new priority hydropost to equip the nodal point of basin importance. The latter shall be mentioned as such in the RBMP.

7.2 Groundwater management

To assess the good quantitative status of groundwater resources i.e. its vulnerability to human overuse, we propose to consider trends in interannual groundwater level from monitoring points analyzed at the same season throughout last decade. We shall also take into account the fact that impacts on groundwater are becoming visible in a longer time range compared to the surface water. This can be done through the development of conceptual model of main aquifers by consultant companies specialized in hydrogeology.

The current monitoring strategy for groundwater resources quantitative status assessment done by Armhydromet **would deserve to be optimized to more precisely fulfil this objective and make a clear link with groundwater bodies and related groundwater use data (water use permits from Ministry of Environment, factual water use data from the Water Committee)**. Unfortunately, in Kasakh basin groundwater monitoring doesn't have a long history. In the table and figure below, groundwater level/discharge observations (annual average) in monitoring points of Kasakh basin for the period of 2015 – 2023 are presented.

Table 58. Groundwater quantity trends in Kasakh River basin

Monitoring point N / location / type	GWB N	2015	2016	2017	2018	2019	2020	2021	2022	2023
N2010, Nigavan shallow GW well, m	2G-1	-5.45	-6.9	-8.43	-8.72	-6.36	-6.67	-7.06	-6.69	-6.4
N2011, Nigavan shallow GW well, m	2G-5	-8.48	-7.97	-8.65	-9.07	-8.54	-7.97	-8.18	-8.37	-8.12
N2051, Aparan, spring, l/s	2G-1	6.52	6.11	5.37	5.54	5.10	4.80	5.70	5.20	4.60
N755, Ghazaravan, spring, l/s	2G-5	3.61	3.55	3.09	3.17	2.96	2.72	3.00	2.92	2.90
N1636, Karbi, spring, l/s	2G-5	6.29	5.66	5.40	6.04	6.65	6.16	7.52	6.42	5.95
2086, Doghs, GW well, m	2G-2	-	-	-	-	-	-	-50.10	-50.03	-49.96

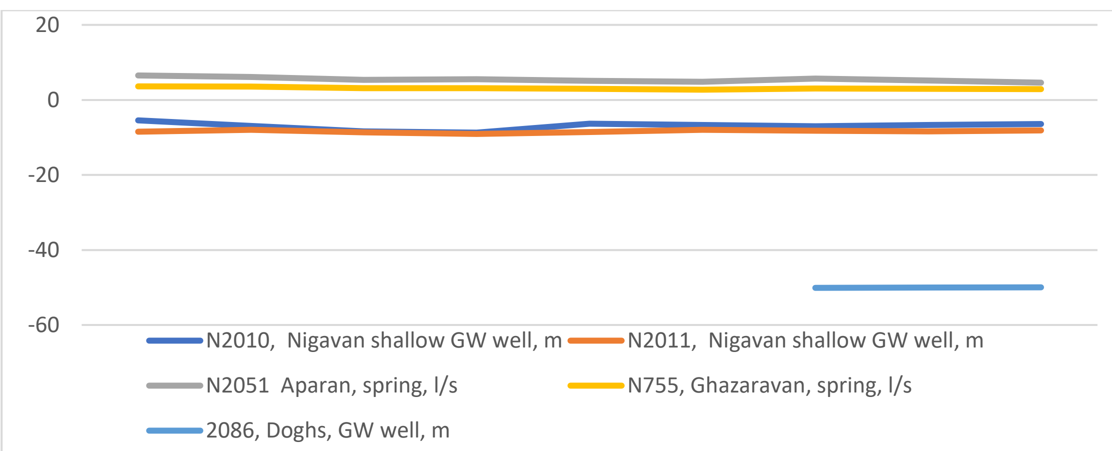


Figure 16. Groundwater quantity trends in Kasakh River basin

As we can see from this data, there is a quite stable situation with groundwater in Kasakh basin, some slight decrease in the discharge of springs is observed nevertheless that can be a first sign for overuse.

In case of a clear decline trend in groundwater level/discharge, the groundwater uses must be reviewed by the water management body.

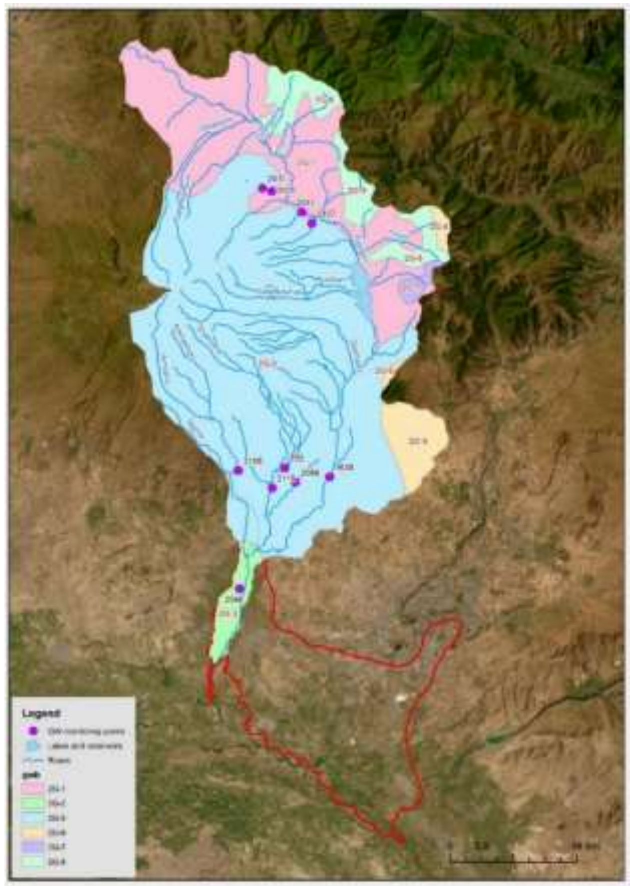


Figure 17. Groundwater bodies and observation points in Kasakh basin

The figure illustrates the need to further adapt the monitoring strategy to the assessment of the quantitative status of the ground water bodies.

7.3 Conclusions and Recommendations

Summarizing the data management and issues situation presented above, the following key points on data availability and better management are proposed:

1. Water Cadastre Information System must be complemented by the operative water deficit management tool/interface. For this, data from hydroposts at selected key points best reflecting the situation in upstream nodal basin and water use meters of the related nodal basin must be inputted to the Water Cadastre system in quasi real-time. The information shall be made available

to the water managers community through API including through the proposed operative water deficit management interface, which automatize data treatment.

2. The water-related data management framework must be designed and institutionalized to make the Water Cadaster Information System, including the operative management component, sustainable and mandatory to use.
3. Opportunities of remote sensing data integration into the operative management workflow need to be studied: 1- for potential snowmelt-runoff and reservoir level forecasts and 2- for water level measurement through the new satellite program run by CNES and NASA and supported by OiEau for use development. The latter is working for large rivers (around 50 m), lakes and reservoirs with a frequency of measurement of around 15 days which is very efficient to extent the monitoring network and revise the monitoring strategy to reserve hydropost with higher frequency measurement to real time water balance observation and crisis management.
4. There is a need to identify in RBMP of each river basin district at least one or two nodal point of basin importance that deserve to be equipped an hydropost ideally with automated data collection and transfer system. This measure seems particularly reasonable considering that all large water users must be equipped with automated and real-time water measurement devices, according to the Armenian government decision.
5. Each groundwater body (GWB) at risk regarding its quantitative status should have at least one groundwater monitoring point monitored each year at the same season to verify its trend.
6. Opportunities for QMNA5 integration into the crisis flow management workflow needs to be further studied and agreed with the water management authority. At a first stage the proposal is to use it as drought indicator checking that the threshold is not broken more than 2 times out of 10 years.
7. On the long run, the way to fix the threshold and the environmental flow in particular could be presented as an evolutive method based on the data and information level including using QMNA5 which is from construction more in relation with the statistical reality of the river and biological monitoring. The current arithmetic formula to calculate the Armenian environmental flow has the advantage of the simplicity but as well some limitation to best reflect the impact on biodiversity of man-made influence on river flow.