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Assessment Study of Groundwater Resources of the Ararat Valley

FINAL REPORT

MARCH 2014

ASSESSMENT STUDY OF GROUNDWATER RESOURCES OF THE ARARAT VALLEY

Subcontract Agreement HAYJRNAKHAGITS-23/01/13-1

FINAL REPORT

Client: Armenian Branch of Mendez England and Associates

Performer: Consortium of Hayjrnakhagits Institute CJSC (Leading Partner) and Mel-Hov LLC

March 2014

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BACKGROUND

This is the Final Report of the Assessment Study of Groundwater Resources of the Ararat Valley implemented by the Consortium of “Hayjrnakhagits Institute” Closed Joint Stock Company (CJSC) and “Mel-Hov” Limited Liability Company (LLC) from 01.02.2013 thru 15.03.2014. The Assessment Study was supported by the USAID-funded Clean Energy and Water Program (CEWP), which is implemented by Mendez England & Associates. The Final Report was prepared under the Subcontract Agreement signed between the Armenian branch of Mendez England & Associates, “Hayjrnakhagits Institute” CJSC and “Mel-Hov” LLC and based on the analysis, correlation and summary of observations of three interim reports. The Final Report includes the following:

- review of previously conducted assessments (1966 and 1984) of the Ararat Valley groundwater resources;
- observations and findings of the impacts of current and future water use under various proposed development scenarios based on the balance, depletion and recharge rates of groundwater resources of the Ararat Valley;
- proposals for future assessment of groundwater resources of the Ararat Valley;
- proposals for future measures aimed at sustainable management of groundwater resources of the Ararat Valley.

The findings and recommendations presented in the Interim and Final Reports are based on the review and analysis of archive materials and reports, as well as documents received from governmental agencies and other stakeholder institutions. These include:

- Results of hydrogeological exploration works conducted in the Ararat Artesian Basin (AAB) in 1966 and 1984 with estimation of resources;
- Results of groundwater sources inventory of the Ararat Artesian Basin conducted in 2006-2007;
- Results of groundwater monitoring data conducted within Ararat Artesian Basin in 2009-2012 by “Hydrogeological Monitoring Center” (HMC) State Non-Commercial Organization (SNCO) of the Ministry of Nature Protection of the Republic of Armenia (MNP);
- Results of measurements at the benchmark points of the drainage monitoring network Ararat Artesian Basin by conducted in 1997-2013 by “Amelioration/Melioratsia” CJSC of the State

Committee of Water Systems (SCWS) of the Ministry of Territorial Administration (MTA) of the RA from;

- Data on groundwater abstraction within the Ararat Artesian Basin from 1983-2013 according to archive materials and Water Use Permits (WUPs) issued by the MNP of to the various water users;
- Other archive materials (see list of literature).

In order to cross-check some of the existing data and supplement missing information, data was also used from visits made by the Consortium members to the regional authorities and communities of Armavir and Ararat Marzes, as well as from the results of continuous observations conducted in 64 randomly selected wells of Ararat Artesian Basin during the vegetation season: spring (May), summer (August) and autumn (November).

The present report does not include re-assessment of volumes of groundwater resources in the Ararat Artesian Basin as this was not required by the Statement of Work.

1. GENERAL CHARACTERISTICS OF THE ARARAT ARTESIAN BASIN

1.1. Hydrogeological conditions

The Ararat Artesian Basin (AAB) is located in the middle stream of Araks River within the Ararat Depression Valley and extends in the north-west and south-east direction for about 120.0 km with a width ranging from 10.0 to 30.0 km (Figure 1). The depression is located at the elevation ranging from 800 m to 1,000 m above the sea level and occupies an area of about 1,300 km^2. It is a natural groundwater storage area, and water enters into the storage area from the surrounding Ararat and Aragats mountains and from the Geghama and Armenia Par ridges.

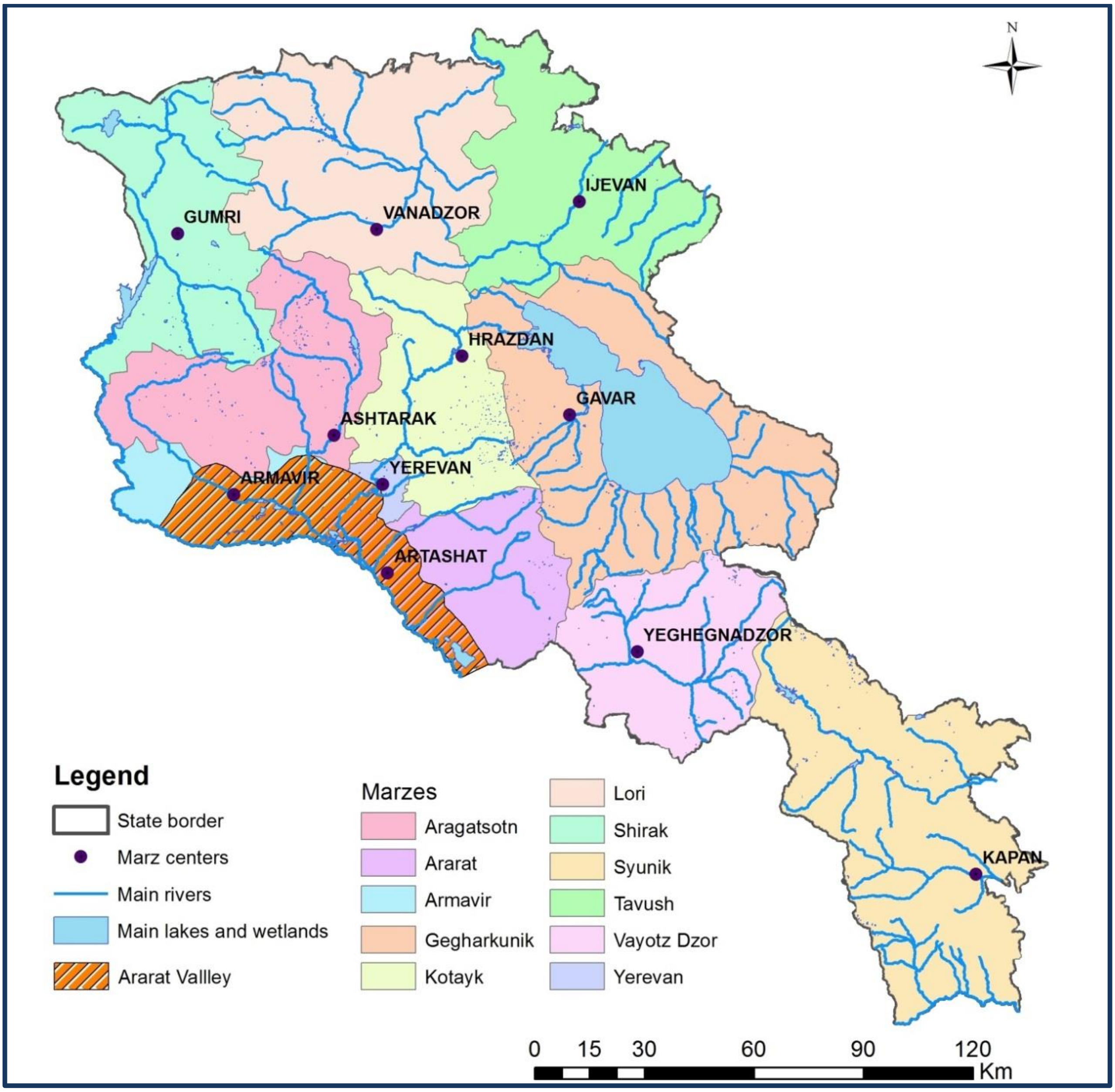


Figure 1. Location of Ararat Artesian Basin.

Geomorphologically, the Ararat Valley represents an inter-mountain depression associated with the valleys of the Araks River and its tributaries the Akhuryan, Sevjur, Kassakh, Hrazdan, Azat and Vedi. The ancient buried valleys of those rivers covered by the volcanic lava and sub-surface deposits of modern the drainage networks (rivers) serve as the routes through which water enters into Ararat groundwater basin. From a hydrogeological perspective, the Ararat Depression is a typical closed inter-mountain artesian basin with groundwater recharge, storage and discharge areas.

AAB has a complex tectonic and geological-hydrogeological structure. The depression represents a superimposed inter-mountain trough of the Araks River’s tectonic zone, divided by the subsequent folding process into the following five sub-structures (structures of second order) in west-to-east direction:

- Hoktemberyan depression;
- Sovetashen uplift;
- Artashat depression;
- Khor Virap uplift and
- Arazdayan depression.

The above mentioned tectonic structures differ in their geological composition, thickness of water bearing rocks, number of aquifers and impermeable layers and their hydraulic properties. The borders of the structures nearly coincide with administrative boundaries of Armavir and Ararat Marzes of Armenia (Figure 1).

The groundwater resources of AAB are developed from precipitation, condensation, discharge of deep artesian inflows, and partially from surface flows within the Araks catchment basin with an area of 31,500 km^2, including 14,900 km^2 of Armenian territory and 16,600 km^2 of Turkish territory.

Two groundwater layers (complexes) may be identified in the subsurface of AAB: unconfined aquifer and confined (artesian) water bearing complexes which may be conditionally divided into two aquifers (Annex 3).

The unconfined aquifer is found nearly everywhere within the AAB. It is located at a depth of 0.5-60.0 m. The flow direction coincides with the terrain inclination and is directed towards the Araks River. Groundwater is contained by sandy loam, loam sand and gravel-small pebble deposits.

Based on their origin, the confined aquifers of the intermountain depression of the Ararat Valley are conditionally divided into porous groundwater associated with lacustrine deposits and fissure-porous and fissure groundwater associated with lava rocks.

Based on the groundwater level, the confined aquifers of AAB are divided into:

a) artesian zone with water levels below the land surface (negative water level) – these are located within the outskirts of the Ararat Valley;

b) artesian zone with water levels above the land surface (positive water level) covering the central part of the Ararat Valley. The wells in this zone are flowing.

The following Table 1 presents the main hydrogeological characteristics of the aquifers of the Ararat Valley.

The two conditionally divided artesian aquifers are connected with successive complexes of folded systems made of permeable and semi-permeable rocks specified by unstable thicknesses and permeability, and they create a single water-bearing system. The recharge conditions and formation of usable (operational) water resources in these two artesian aquifers are also similar. The AAB is marked by a gradual increase of artesian pressure with depth, which is associated with upward discharge of groundwater in most parts of depression area.

The area of AAB is also marked by extreme instability of geological-lithological and hydrogeological parameters, in particular aquifers' spreading and thickness, variety of water bearing rocks and their hydraulic conductivity, transmissivity properties, water temperature and mineralization.

The description, analysis and summary of groundwater layers of AAB allows one to conclude that geological and hydrogeological conditions of the Ararat Valley are very complicated and they vary both between hydrogeological structures and within the same structure. This is clearly shown from the geological-hydrogeological and technical geological sections of boreholes drilled within the hydrogeological structures (Annexes 2 and 3).

1.2. Natural (recoverable) groundwater resources

According to V.T. Vehuni (1975), the deep groundwater discharge or recoverable (dynamic) natural resource in the AAB is 64.1 m^3/s or 2,021.5 Mm^3/year, of which 42.8 m^3/s or 1,349.7 Mm^3/year enters from the Turkish territory (Kars Plateau), and 21.3 m^3/s or 671.7 Mm^3/year - from the Armenian territory [13].

Table 1. Main hydrogeological characteristics of aquifers of the Ararat Valley.

Aquifer type	Depth to the top, m	Efficient thickness, m	Level, H - m	Yield, Q- l/s	Drawdown, S – m	Specific yield, q- l/s.m	Hydraulic conductivity, K-m/day	Transmissivity Km=qx130 m^2/day
Unconfined	1.7-33.2	7.5-59.2	-0.5 - -33.2	1.0-30.0	1.92-10.0	0.1-5.86	0.95-149.5	13.0-761.8
Hoktemberyan depression								
1st confined	2.0-71.0	13.4-59.5	-0.57 - -18.0 +0.85 - +12.8	7.2-80.5	2.4-12.0	0.87-21.3	2.53-115.37	113.1-1079.0
2nd confined	32.0-174.7	44.0-232.7	-7.2 - -90.0 +0.68 - +14.7	13.3-234.0 up to 600.0	1.2-14.3	3.7-24.39	3.97-21.93	481.0-3170.7
Sovetashen uplift								
1st confined	28.7-140.0	12.7-87.0	-0.8 - -20.0 +7.5 - +12.6	1.56-80.0	7.5-12.6	0.2-8.42	2.04-37.97	26.0-1094.6
2nd confined	40.5-176.0	28.5-141.4	-0.68 - -92.5 +4.7 - +15.4	2.3-252.0 up to 800.0	2.0-14.89	1.09-17.8	0.89-29.98	141.7-2158.0
Artashat depression								
1st confined	59.7-244.0	15.1-152.2	+0.2 - +8.5	7.6-40.0	3.65-9.62	2.14-5.48	2.81-30.56	408.0-712.4
Arazdayan depression								
1st confined	46.0-150.0	24.8-136.5	-3.2 - -33.8 up to +1.8	8.4-29.8	3.2-6.72	1.25-5.1	2.69-6.66	162.5-663.0
2nd confined	83.0-190.0	15.4-254.0	-2.1 - -12.0 +1.65 - +3.2	7.7-37.7	2.65-11.4	2.39-9.15	1.92-53.43	310.7-1189.5

According to H.A. Aghinyan, (1976) [14], the deep groundwater discharge or recoverable (dynamic) natural resource is 51.5 m^3/s or 1,624.1 Mm^3/year, of which 35.9 m^3/s or 1,132.1 Mm^3/year enters from the Turkish territory (Kars Plateau), and 15.6 m^3/s or 492.0 Mm^3/year - from the Armenian territory, including:

- South-western slopes of Mt. Aragats – 0.4 m^3/sec;
- Kassakh River Basin – 11.46 m^3/sec;
- Hrazdan River Basin – 2.61 m^3/sec;
- Azat River Basin – 0.13 m^3/sec;
- Vedi River Basin – 1.0 m^3/s.

The natural groundwater resources comprise 73.87 m^3/sec, including:

- Deep inflow – 51.5 m^3/sec,
- Drainage flow – 8.08 m^3/sec,
- Spring discharge – 14.29 m^3/sec.

The concentrated flows entering into AAB from Armenian territory were assessed in 1986-1989 by the Water Problems and Hydraulic Engineering Institute under the management of R.S. Minasyan, using a mathematical modeling method. The flow was estimated at 20.29 m^3/s or 639.9 Mm^3/year [19].

The deep groundwater discharge or natural groundwater resources of the AAB (the inflow into aquifers) were assessed by several researchers in various periods, in particular:

- 1954, A.O.Ohanyan – 71.7 m^3/s or 2,261.1 Mm^3/year;
- 1966, A.E.Amroyan – 107.32 m^3/s or 3,384.4 Mm^3/year;
- 1974, Z.V.Davletshina – 70.8 m^3/s or 2,232.7 Mm^3/year;
- 1974, M.S.Torgomyam – 30.12 m^3/s or 949.9 Mm^3/year;
- 1975, V.T.Vehuni – 64.1 m^3/s or 2,021.5 Mm^3/year;
- 1976, H.A.Aghinyan – 51.5 m^3/s or 1,624.1 Mm^3/year.

The Group of Experts conducting this assessment study has accepted the average arithmetical value (**57.8 m^3/s or 1,822.8 Mm^3/year**) of the deep groundwater discharge or recoverable (dynamic) natural resource of the AAB by the last two authors (Vehuni and Aghinyan) assessed using the balance method and based on the detailed data.

2. REVIEW OF PREVIOUS ASSESSMENTS OF GROUNDWATER RESOURCES

2.1. Assessment of groundwater resources and their use in 1966-1984

The operational resources of AAB were assessed by various authors within 1966-1984, and the results were approved by the State Commission of Reserves (SCR). The assessment results are summarized in Table 2 and Figure 2.

Table 2. Operational groundwater resources of AAB approved in 1966-1984 by categories.

Approval year	Approved operational resources, m^3/s	SCR protocol No.	Including				
			Category A+B*		Category C_1* wells, m^3/s	Category C_2* wells, m^3/s	Usable resource, m^3/s
			Springs, m^3/s	Wells, m^3/s			
1966	25.0	4901	19.1	0	5.9	0	25.0
1966	38.4	4949	19.5	4.9	6.0	8.0	30.4
1974	61.8	7252	19.5	8.8	11.6	21.9	39.9
1984	95.3	9475	21.9	Maximal 51.7 Average annual 34.7	0	21.7	Maximal 73.6 Average annual 56.6

* Category A - Minimal water discharge based on continuous hydrogeological monitoring during three and more years (reliable /usable resource).
Category B - Minimal water discharge based on continuous hydrogeological monitoring during at least one year (reliable /usable resource).
Categories C_1 and C_2 - The difference between the natural resources and resources of categories A+B, the suitability of which is determined as a result of additional investigations. The category C_1 is accepted by SCR as usable resource.

The approved operational resources of AAB were estimated based on springs and well clusters.

There are several spring groups associated with the groundwater of the Ararat inter-mountain depression. Their resources make up 21,921.2 l/s or 690.6 Mm^3/year including:

1) Metsamor-Aknalich – 17,765.3 l/s or 560.2 Mm^3/year;
2) Arevik– 671.0 l/s21.2 Mm^3/year;
3) Blue Lake – 2,604.2 l/s or 82.1 Mm^3/year;
4) Sarvanlar – 165.5 l/s or 5.2 Mm^3/year;
5) Uchkerpi – 490.7 l/s or 15.5 Mm^3/year;
6) Novruzlu – 224.5 l/s or 7.1 Mm^3/year.

1,593 wells were drilled as of 1984, of which 878 were artesian wells, and the remaining 715 were operated by pumps.

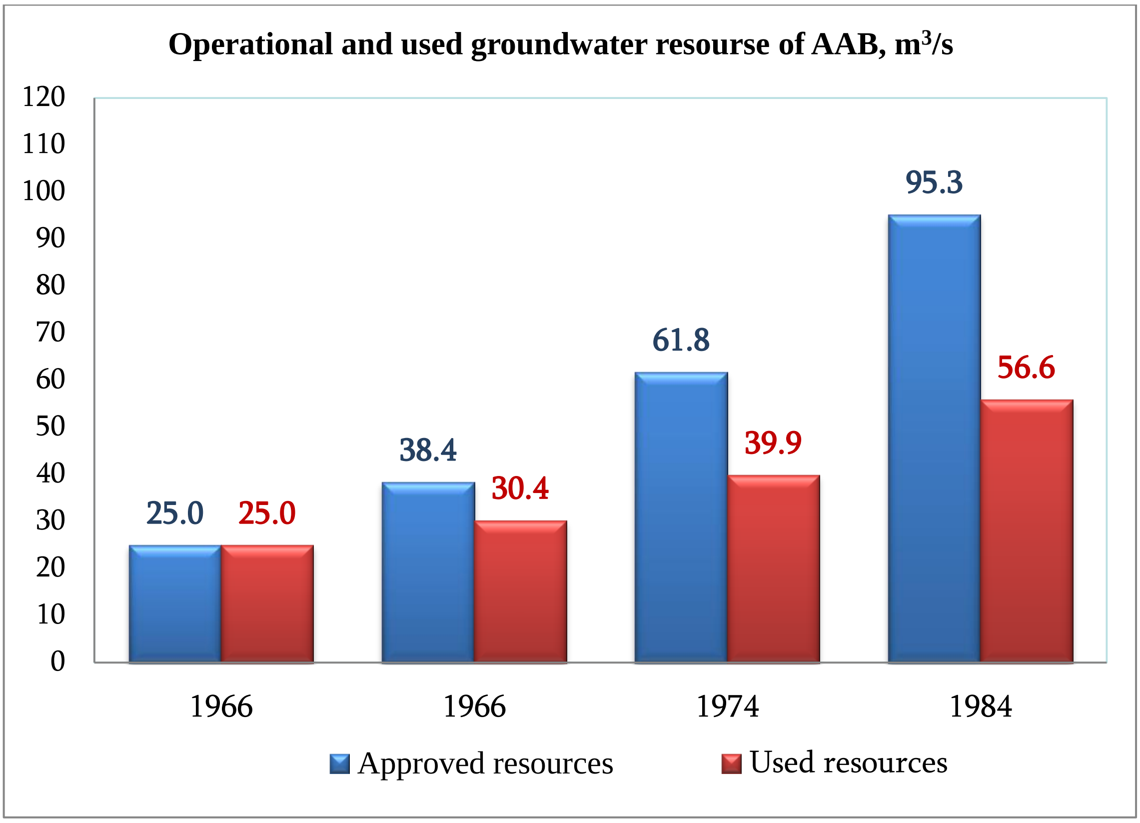


Figure 2. Operational and used groundwater resources of AAB approved in1966-1984.

The following Table 3 and Table 4 present the discharge of springs and major wells of AAB and information on their purpose of use.

Table 3. Discharges of springs of AAB as of 1984 and their purpose of use.

Name of spring groups	**Discharge of spring, l/s, 1984**		**Is used, l/s**		**Purpose of use**		**Approved resources category A+B, l/s**
	maximal / minimal	**average**	**maximal / minimal**	**average**	**potable and household**	**irrigation**	
Hoktemberyan depression							
Metsamor-Aknalich group	28300.0 / 24370.0	26100	22200.0 / 420	10500	420.0 Armavir, Metsamor NPS	21780	17765.3
Arevik group	712.0 / 674.0	700	500.0 / 250.0	375.0	-	500	671.0
Sub-total	**29012 / 25404**	**26800**	**22700 / 670**	**10875**	**420.0**	**222280**	**18436.3**
Sovetashen uplift							
Kapuyt Lake group	-	2700	2740 / 2615	2675	2700.0 Technical water supply of Yerevan	-	2604.2
Yerakamurj (Uch Kerpi) group	542.0 / 490.0	520	500.0 / 300.0	400.0	-	500.0	490.7
Sis (Sarvankar) group	221 / 172	200	200.0 / 180.0	190.0	-	190.0	165.5

Name of spring groups	Discharge of spring, l/s, 1984		Is used, l/s		Purpose of use		Approved resources category A+B, l/s
	maximal / minimal	average	maximal / minimal	average	potable and household	irrigation	
Sub-total		**3420**	**3440.0 / 3095.0**	**3265**	**2700.0**	**690**	**3260.4**
Artashat depression							
Novruz group	250.0 / 220.0	235	250.0 / 180.0	215.0	-	215	224.5
TOTAL		**30455**	**26390.0 / 4115.0**	**14355**	**3120.0**	**23185.0**	**21921.2**

Table 4. Yield of major well groups of AAB.

Number of wells Maximal / Minimal	Operational yield as of 1984, l/s		Number of wells and purpose of use		Approved resources Category A+B
	maximal / minimal	average	Drinking – household and irrigation of private lands	irrigation	
1	**2**	**3**	**4**	**5**	**6**
1. Hoktemberyan depression					
a) Western site – 39 communities					
488 / 157	17898.0 / 3470.0	10117.0	153	335	
b) Eastern site – 26 communities					
610 / 422	19059.0 / 4931.0	12364.0	188	422	
Total in Hoktemberyan depression, in Gai-Haykashen deposit					31880.8 5063.6
with Gai-Haykashen deposit					**36944.4**
2. Sovetashen uplift - 18 communities					
285 / 266	9613.0 / 7208.0	8455.0	88	197	9601.8
3. Artashat depression - 7 communities					
131 / 118	3057 / 640	2220.0	33	98	3056.7
4. Arazdayan depression - 5 communities					
79 / 24	2140 / 436	1505.0	22	57	2138.9
Total in Ararat Depression	**51757 / 16393**	**34661.0**	**484**	**1109**	**51741.8**

The recoverable/usable resource of 51,741.8 l/s or 51.7 m^3/s, or 1,630.4 Mm^3/year verified by wells corresponds to the maximal abstraction during vegetation season (mid-April – October). The minimal abstraction is observed from November to mid-April and makes up 16,393.0 l/s or 16.4 m^3/s, or 517.2 Mm^3/year. Thus, the actual average abstraction by wells from AAB made up

34,661.0 l/s or 34.7 m^3/s, or 1,094.3 Mm^3/year on average as of 1984, and that value was set by the SCR as the average annual permitted usable abstraction for an unlimited period. This is because water abstraction in such volumes does not distort the AAB groundwater balance, and abstraction of groundwater resources is within the approved recoverable/usable resources (category A+B) without violating the stipulated groundwater operation regime. Hence, the stipulated usable resources for AAB shall be:

- by wells: 34.7 m^3/s or 1,094.3 Mm^3/year;
- from springs: 21.9 m^3/s or 690.6 Mm^3/year;

total: 56.6 m^3/s or 1,784.9 Mm^3/year.

Regime observations conducted within 1978-1983 showed that the groundwater level is lowered by up to 3.0 m in the case of maximal abstraction of 51.7 m^3/s or 1,630.4 Mm^3/year during the vegetation season. The water level is restored during the minimal abstraction of 16.4 m^3/s or 517.2 Mm^3/year. Based on these findings, the SCR approved the average annual abstraction of 34.7 m^3/s, or 1,094.3 Mm^3/year.

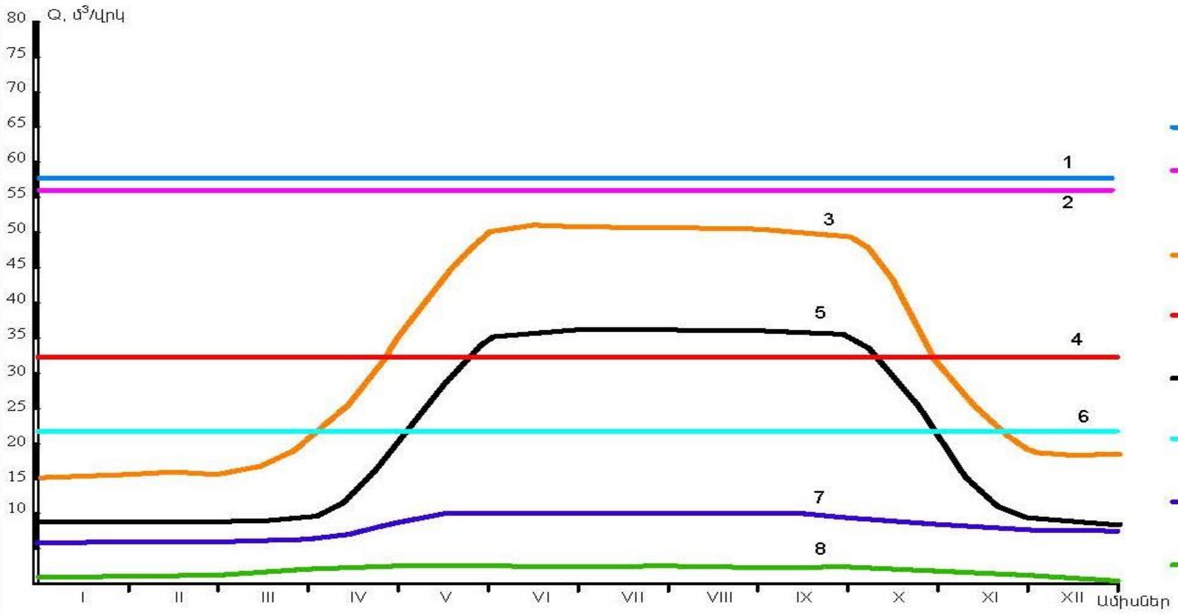
The following Table 5 summarizes the operational resources of AAB by Marzes estimated by springs and wells.

Table 5. Operational resources of AAB by Marzes as of 1984 estimated by springs and wells.

Marz name	Approved operational resources by categories, l/s				
	A	B	C_2	A+B	A+B+C_2
Springs					
Armavir	14676.0	3760.3	-	18436.3	18436.3
Ararat	3484.9	-	-	3484.9	3484.9
Sub-total by springs	**18160.9**	**3760.3**	**-**	**21921.2**	**21921.2**
Wells					
Armavir	21410.8	15533.6	4551.0	36944.4	41495.4
Ararat	11701.3	3096.1	17124.0	14797.4	31921.4
Sub-total by well	**33112.1**	**18629.7**	**21675.0**	**51741.8**	**73416.8**
Total AAB	**51273.0**	**22390.0**	**21675.0**	**73663.0**	**95338.0**
	Approved operational resources by categories, m^3/s				
Total AAB	**51.3**	**22.4**	**21.7**	**73.7**	**95.3**

The following Figure 3 presents the diagram of groundwater resources of AAB and permitted usable resources as of 1984 by hydrogeological structures of the second order.

Figure 3. Diagram of AAB groundwater resources approved as of 1984 and approved /permitted usable resources.



LEGEND

1. Groundwater resources of AAB 57.8 m^3/s.
2. Actually estimated groundwater resources approved by wells and springs of AAB - 56.6 m^3/s (34.7+21.9 m^3/s).
3. Total groundwater abstraction from entire basin by wells.
4. Average annual groundwater abstraction by wells 34.7 m^3/s.
5. Average annual groundwater abstraction from Hokteberyan depression (22.5 m^3/s).
6. Approved resources of existing springs of AAB (21.9 m^3/s).
7. Average annual groundwater abstraction from Sovetashen uplift by wells (8.5 m^3/s).
8. Average annual groundwater abstraction from Artashat and Arazdayan depressions (3.7 m^3/s).

By its chemical composition, the AAB groundwater in 1983 referred mainly to hydro-carbonate, sodium-calcium, sometimes magnesium, sulphate, and sodium types of water. It should be noted that various hydrogeological structures are specified by different types of water. This is due to the variable lithological and petrographical composition of both groundwater recharge and transport areas.

Table 6 presents quality characteristics of AAB groundwater as of 1983.

Table 6. Quality characteristics of AAB groundwater as of 1983.

Name of hydrogeological structure	Catchment area, chemical type, mineralization and use purpose
Mineralization up to 1.0 g/l	
1. Hoktemberyan depression	Akhuryan catchment area Hydrocarbonate-sodium, 0.35-0.7 g/l PHWS*
2. Sovetashen uplift	Sevan-Hrazdan catchment area Sulfate-sodium, 0.7-1.0 g/l PHWS*
3. Artashat depression	Ararat catchment area Hydrocarbonate, sodium-calcium, 0.5-0.8 g/l PHWS*
4. Arazdayan depression	Ararat catchment area Hydrocarbonate, sodium-calcium, 0.4-1.0 g/l PHWS*
Mineralization 1.0-3.0 g/l	
Hoktemberyan depression	Akhuryan catchment area, hydrocarbonate-sodium, ITWS* and I*
Sovetashen uplift	Sevan-Hrazdan catchment area, sulfate-sodium, ITWS* and I*
Arazdayan depression	Ararat catchment area, hydrocarbonate-sulfate-sodium-calcium, ITWS* and I*
5. Gai-Haykashen deposit	Sevan-Hrazdan catchment area, Hydrocarbonate- calcium, 0.2-0.6 g/l PHWS*

*PHWS – potable and household water supply; ITWS – industrial-technical water supply; I – irrigation

2.2. Analysis of groundwater springs and wells inventoried in 2006-2007

In May-December 2006-2007 the “Institute of Water Problems and Hydraulic Engineering” CJSC after Academician I.V. Yeghiazarov conducted an inventory of wells and springs in Ararat and Armavir Marzes of ABB, investigated their technical state, and prepared a cadastre of wells and springs.

81 springs and 1,993 wells were surveyed in Armavir Marz, cards were prepared for 1,794 wells and they were included into the inventory cadastre. 199 wells drilled within the area of 12 communities were surveyed.

74 springs and 1,471 wells were surveyed in Ararat Marz, cards were prepared for 1,156 wells and they were included into the inventory cadastre. 315 wells drilled within the area of 15 communities were surveyed.

All the surveyed wells were drilled manually or by drilling rigs to a depth of 8.0-22.0 m with a diameter of 132-151 m. The wells were equipped with d=127-146 mm steel casings. The capacity of those wells varied between 0.17-3.0 l/s. The wells were drilled within homestead plots and were used for household purposes. They abstracted water from the unconfined aquifer.

Results of the inventory of wells in 2006-2007 and analysis of the inventory data conducted by the Team of Experts are presented in Table 7.

Table 7. Analysis of inventory results conducted in 2006-2007

Name	**Inventory of springs and wells**			**Analysis of inventory data**		
	AAB	**including**		**AAB**	**including**	
		Ararat Marz	**Armavir Marz**		**Ararat Marz**	**Armavir Marz**
Total number of counted wells, including:	3464	1471	1993	3466	1473	1993
- surveyed unconfined water wells	514	315	199	514	315	199
- wells accounted in cadastre	2950	1156	1794	2952	1158	1794
- artesian wells	1280	712	568	1286	682	604
Number of wells with negative level	1670	444	1226	1666	476	1190
Number of operational wells	1952	800	1152	1986	792	1194
Number of non-operational wells	998	356	642	966	366	600
Number of wells drilled: - until 1966	794	302	492	796	304	492
- within 1966–1984	1507	634	873	1507	634	873
- within 1984–2008	649	220	429	649	220	429
Purpose of use: - irrigation	1874	803	1071	1874	803	1071
- fishery	276	102	174	299	102	197
- technical	354	135	219	358	135	223
- potable-household	438	116	322	421	118	303
Intake by operational wells, l/s, including:	58519.9	21130.2	37389.7	55826.0*	20787.0*	35039.0*
- irrigation	24846.1	8606.5	16239.6	-	-	-
- irrigation and potable	9482.8	1604.2	7878.6	-	-	-
- fishery	11781.7	4627.1	7154.6	12702.2	4952.8	7749.4
- technical	2640.8	953.5	1687.3	-	-	-
- potable-household	9768.5	5338.9	4429.6	-	-	-

Name	Inventory of springs and wells			Analysis of inventory data		
	AAB	including		AAB	including	
		Ararat Marz	Armavir Marz		Ararat Marz	Armavir Marz
Number of liquidated wells	105	105	-	114	105	9
Number of wells subject to liquidation	234	127	107	348	141	207
Number of temporarily shut down (conserved) wells	452	27	425	301	27	274
Number of wells subject to rehabilitation	207	97	110	203	93	110

As it can be seen from the table, there are some discrepancies between inventory results and analyzed data. In opinion of the Team of Experts, this is due to inaccurate analysis of well inventory cadastre cards. Furthermore, the inventory did not account for 514 surveyed unconfined water wells.

The Table 8 presents the inventory of AAB groundwater abstraction conducted in 2006-2007.

It should be noted that as a result of detailed analysis of well inventory cards conducted by the Team of Experts, it was identified that total discharge of the artesian wells makes up 30,028.0 l/s (Table 8), and the discharge of wells operated with pumps is 6,449.0 l/s rather than 25,798.0 l/s, (i.e. one fourth), as the pumps operate only three months a year. Thus, the actual intake in 2006-2007 was 30,028.0+6,449.0=36,477.0 l/s or 36.5 m^3/s, or 1,151.1 m^3/year instead of 55,826.0 l/s or 55.8 m^3/s or 1,759.7 m^3/year (Tables 7 and 8).

According to inventory results, 649 new wells were drilled between 1984 and 2008 for irrigation, potable-household, technical and fishery purposes. Out of the existing 2,952 wells, 1,986 wells with an abstraction of 36,477.0 l/s or 36.5 m^3/s, or 1,151.1 Mm^3/year were operated as of 2007, which exceeded the permitted level of 1984 (34.7 m^3/s, or 1,094.3 Mm^3/year).

2.3. Analysis of groundwater level fluctuations based on historical and recent monitoring data

Observations of groundwater level in AAB were conducted by various researchers in various periods.

According to observations conducted by A.E. Amroyan for assessment of groundwater resources of ABB as of 01.01.1966 [6], variation of static groundwater levels in the boreholes changed from -36.0 m to +6.4 from ground surface.

Table 8. Inventory of AAB groundwater abstraction conducted in 2006-2007.

No.	Name	Number of well			Operation		Operation purpose				Drilling year			Abstraction, l/s		Number of wells to be liquidated/liquidated
		Accounted	including		still operational	do not operate	irrigation	fishery	technical	Potable household	until 1966	1966- 1984	1984- 2008	total	including fishery	
			flowing	with negative level												
Armavir Marz																
1	Baghramyan area	64	-	64	27	37	31	-	18	15	1	36	27	797.4	-	-/9
2	Armavir area	766	93	673	392	374	510	3	85	168	264	407	95	10243.6	14.0	9/119
3	Echmiadzin area	964	511	453	775	189	530	194	120	120	227	430	307	23998.0	7735.4	-/79
Sub-total Armavir Marz		1794	604	1190	1194	600	1071	197	223	303	492	873	429	35039.0	7749.4	9/207
Ararat Marz																
1	Masis area	689	614	75	571	118	445	82	52	110	220	340	129	15210.7	4507.6	-/89
2	Artashat area	215	47	168	113	102	150	4	58	3	45	132	38	2481.2	238.0	45/22
3	Ararat area	254	21	233	108	146	208	16	25	5	39	162	53	3095.1	207.2	60/30
Sub-total Ararat Marz			682	476	792	366	803	102	135	118	304	634	220	20787.0	4952.8	105/141
Total			1286	1666	1986	966	1874	299	358	421	796	1507	649	55826.0*	12702.2	114/348

According to Y.I. Zaytsev and B.G. Loginov [8], the piezometric levels in the boreholes of the Arevabuyr and Marmarashen sites have stabilized at the levels from +8.5 m to +21.8 m above ground.

Afterwards, in 1970-73, Z.V. Davletshina and Y.I. Zaytsev conducted hydrogeological investigations aimed at substantiation of the Master Water Use Plan [7]. According to these investigations the piezometric levels within the eastern part of Hoktemberyan depression stabilized at + 20.0 m above ground level.

Investigations conducted in 1978-1983 (S. B. Panosyan, V. Kh. Ghazaryan [12]), showed that the piezometric level of the confined aquifer was from +12.7 m to +16.63 m above ground level under the distorted regime.

On assignment from Yerevan Water Supply and Sanitation CJSC, specialized investigations were conducted in 2005 (V. P. Prazyan, V. A. Meltonyan [15]) for efficient utilization of Gai-Haykashen drinking groundwater deposit. Control yield and level were measured in 38 wells under these investigations.

The following Table 9 shows comparative results of these measurements in 1981 and 2005.

Table 9. Comparison of well yield and level measurements in Gai-Haykashen deposit of drinking groundwater deposits in 1981 and 2005

No.	Well number	Yield, l/s		Water level below ground surface, m		Difference: + increase - reduction	
		Initial 1981	Actual 2005	Initial 1981	Actual 2005	Discharge	Water level
1	1/3	256	250	16.54	12.2	-6	-4.34
2	2/3	190	162	15.48	10.64	-28	-4.84
3	3/3	170	132	15.43	9.7	-38	-5.73
4	4/3	137	78	15.31	8.85	-59	-6.73
5	5/3	130	94	13.63	9.5	-36	-4.13
6	6/3	225	143	13.31	7.8	-82	-5.51
7	7/3	187	180	13.03	10.2	-7	-2.85
8	8/3	130	70	13.5	8.49	-60	-5.04
9	9/3	178	150	13.85	8.96	-28	-4.89
10	10/3	200	175	13.96	10.15	-25	-3.81
11	11/3	200	172	14.36	9.11	-28	-5.85
12	12/3	192	172	14.88	8.72	-20	-6.16
13	13/3	210	180	15.93	9.68	-30	-6.25

No.	Well number	Yield, l/s		Water level below ground surface, m		Difference: + increase - reduction	
		Initial 1981	Actual 2005	Initial 1981	Actual 2005	Discharge	Water level
14	14/3	187	175	16.30	13.82	-12	-2.48
15	15/3	155	136	16.7	13.61	-19	-3.09
16	16/3	80	59	16.51	9.77	-21	-6.74
17	17/3	164	140	12.98	9.76	-24	-3.22
18	18/3	231	160	12.7	7.8	-71	-4.9
19	19/3	132	95	13.98	9.36	-37	-4.62
20	1/4	185	141	15.62	9.2	-44	-6.42
21	2/4	160	115	14.91	8.45	-45	-6.46
22	3/4	180	140	15.02	9.72	-40	-5.3
23	4/4	180	142	15.59	9.2	-38	-6.39
24	5/4	142	122	15.41	11.2	-20	-4.21
25	6/4	163	129	15.24	10.53	-34	-4.71
26	7/4	116	100	15.6	11.6	-16	-4.0
27	8/4	83	67	15.6	10.7	-16	-4.9
28	9/4	108	66	16.53	9.13	-42	-7.4
29	10/4	136	68	14.14	7.96	-68	-6.18
30	11/4	120	102	14.07	9.85	-18	-4.22
31	12/4	124	95	13.01	7.71	-29	-5.39
32	13/4	69	58	14.86	9.4	-11	-5.46
33	14/4	104	90	15.16	10.25	-14	-4.91
34	15/4	244	233	15.3	10.2	-11	-5.1
35	16/4	120	84	15.39	8.6	-36	-6.79
36	17/4	125	90	16.4	10.4	-35	-6.0
37	18/4	185	170	16.42	12.0	-15	-4.42
38	19/4	142	135	16.63	12.16	-7	-4.47
		6040	4870			-1170	

The table shows that the groundwater piezometric level has reduced from 2.5 m to 6.8 m within the period of 1981-2005, which was accompanied by a yield reduction from 6.0 l/s to 82.0 l/s.

In addition to the Gai-Haykashen area, the same has been observed in recent years in the communities of Taronik, Zartonk, Griboyedov, Apaga, Aknashen, Lusagyug, Jrarat, Metsamor, Haykashen, Araks, Ranchpar and Noramarg located within the Metsamor River Basin. Fisheries are concentrated mainly in the low hypsometric levels of the central parts of AAB, and the piezometric levels and the yields of 303 artesian wells have decreased due to a sharp increase in abstraction (12,702.2 l/s or 12.7 m^3/s, or 400.5 Mm^3/year in 2007 and 36,477.0 l/s or 36.5 m^3/s, or 1,151.1 Mm^3/year in 2013). The discharge of those artesian wells was only 604.0 l/s in 2011-2012, while in 1990 it was 6,118.6 l/s.

Depletion of the confined water layer in AAB is accompanied by a gradual reduction of capacities in all wells, which provides evidence that in the central part of the basin the outflow of the groundwater balance exceeds the inflow.

Groundwater regime observations in AAB were resumed in 2009 by HMC SNCO after a 15-year interruption. There were 17 artesian wells, 2 unconfined water wells and 2 springs in the monitoring network of HMC SNCO in 2009 (21 observation stations in total). Two springs with a total discharge of 37.7 l/s were removed from the network in 2010. Measurements of water discharge, level, pressure and temperature at observation stations were conducted six times a month.

The review of monitoring data for 2009-2012 provided by HMC SNCO demonstrated that a considerable reduction of both groundwater discharge and level was observed in AAB. For example, the average annual discharge of 17 artesian wells in 2012 (10.5 l/s) decreased more than five times compared to 2009 values (59.4 l/s), which is due to a sharp increase in intake corresponding with the development of fishery industry.

Within the same period, HMC SNCO took samples from 9 specific observation stations for testing the quality characteristics of ABB groundwater. In 2009-2010 the sampling was carried out four times a year, and in 2011-2012 – once a year. Data on groundwater chemical composition from 1981 and 2012 was compared. The chemical analyses do not indicate essential changes in groundwater composition except for in the Sovetashen uplift (Masis region) where some increase in mineralization up to 0.3 g/l is observed in the sulfate type of groundwater (Table 10).

Table 10. Data on groundwater chemical analysis for the period of 1981-2012.

Location and Number of the Well	**Date of the chemical analysis**	**Parameters, mg/l**						**Mineralization, mg/l**
		Na+K	**Ca**	**Mg**	**HCO_3**	**SO_4**	**Cl**	
Masis region, Arevabuyr community, N: 195	10.1981	175.0	146.3	81.5	292.8	556.8	184.6	1490.4
	09.2009	356.9	120.2	58.1	274.6	687.5	215.2	1731.0
	10.2012	358.2	132.3	46.5	284.4	699.4	239.7	1799.5
Masis Region, Sis community, N: 78	06.1989	38.1	36.0	29.2	219.6	41.1	49.7	435.0
	06.2009	177.2	48.1	14.6	213.6	210.4	88.3	763.1

Location and Number of the Well	Date of the chemical analysis	Parameters, mg/l						Mineralization, mg/l
		Na+K	Ca	Mg	HCO_3	SO_4	Cl	
Echmiadzin region, Aknalich community, N: 108	10.1983	85.3	36.1	26.2	183.0	187.4	35.5	567.0
	10.2012	93.6	36.1	28.8	238.0	83.8	70.5	552.7
Armavir region, Vardanashen community, N: 192	11.1984	63.4	32.1	29.2	305.0	30.0	42.6	507.0

Since 2011, the HMC SNCO has carried out monitoring of water abstraction and temperature in the fisheries of ABB. The following Table 11 presents summarized monitoring data for 2011-2012.

Table 11. Monitoring data conducted in 2011-2012 in selected fisheries of AAB.

No.	Community name	Number of wells	Average annual abstraction, l/s	Number of wells	Average annual abstraction, l/s
		2011		2012	
Armavir Marz					
1	Gai	40	1886.0	44	2393.3
2	Apaga	16	278.7	16	243.0
3	Araks	9	430.5	12	523.8
4	Jrarat	29	1226.2	33	1121.1
5	Griboyedov	3	61.0	-	-
6	Aknashen	2	61.9	3	79.2
7	Jrarbi	1	19.0	1	19.0
8	Lusagyug	15	587.2	14	440.1
9	Metsamor	15	963.2	13	655.7
Subtotal in marzes		**130**	**5513.7**	**136**	**5475.2**
Ararat Marz					
1	Sis	23	1884.0	27	1334.5
2	Ranchpar	22	1580.5	15	1313.0
3	Armash	5	314.5	5	292.0
4	Arevabuyr	2	60.0	2	29.5
5	Hovtashat	25	1599.2	39	2942.3
6	Sipanik	8	966.0	12	1300.7
7	Dzorak	9	936.0	9	1199.9
8	Noramarg	20	970.5	20	1222.1
9	Sayat-Nova	22	3097.3	20	3007.8
10	Hayanist	1	108.0	1	99.0
11	Marmarashen	2	546.0	6	791.3
12	Masis	2	262.5	2	241.1
13	Darbnik	2	149.5	3	157.4
14	Dashtavan	-	-	2	184.7
Subtotal in marz		**143**	**12474.0**	**163**	**14115.3**
Total in AAB		**273**	**17987.7**	**299**	**19590.5**

The table shows that in 2012 monitoring was conducted for only 299 wells with a total abstraction of 19,590.5 l/s or 19.6 m^3/s, or 618.1 Mm^3/year, which already exceeded the average annual consumption of 12,919.0 l/s or 12.9 m^3/s, or 406.8 Mm^3/year by 878 wells approved in 1984.

470 wells were actually used in AAB as of 2013 for fishery purposes with a total discharge of 35,497.3 l/s or 35.5 m^3/s, or 1,119.4 Mm^3/year, which exceeded the annual abstraction of 34.7 m^3/s or 1,094.3 Mm^3/year (see Table 4) permitted for wells in 1984. This quantity does not include the total discharge of 20,052.7 l/s by 1,311 wells operating in AAB for various other purposes.

The use of groundwater under distorted regime (exceeding the average annual permitted abstraction specified for wells in 1984) negatively affects both the capacity and piezometric level of water in wells.

Considering that the main water source of the unconfined water layer is the upward flow from the artesian aquifer of AAB, continuous abstraction by artesian wells drilled for fishery purposes in the artesian aquifer under distorted groundwater balance causes depletion of confined aquifer levels and unconfined water levels in the Ararat Valley resulting in a reduction of the capacity of wells.

The following Table 12 presents data of groundwater level dynamics based on 30 wells out of 455 observation wells monitored by “Amelioration/Melioratsia” CJSC in 2010-2013, which are considered to be the most specific for each region.

Table 12. Groundwater level monitoring data 2010-2013.

Well number	**Groundwater level during vegetation season**				**Difference of levels**
	2010	**2011**	**2012**	**2013**	**2010-2013**
Armavir region					
98	1,93	2,42	2,59	2,74	-0,81
114	2,43	2,34	2,70	2,95	-0,52
162	2,52	2,79	3,03	3,17	-0,65
173	2,30	2,82	3,10	3,03	-0,74
175	1,36	1,79	1,81	1,92	-0,57
Echmiadzin region					
209	1,91	2,74	2,93	3,22	-1,32
214	2,03	3,19	3,61	3,71	-1,69
224	3,20	3,31	4,11	4,67	-1,47
225	2,81	3,14	3,58	4,25	-1,44
266	1,11	1,58	1,64	2,18	-1,07
269	2,02	2,28	2,58	3,18	-1,16
279	1,71	2,32	2,65	2,80	-1,09
Masis region					
362	5,55	6,05	6,63	7,31	-1,77

Well number	Groundwater level during vegetation season				Difference of levels
	2010	2011	2012	2013	2010-2013
366	2,88	3,09	2,92	4,50	-1,62
368	3,95	4,46	4,90	5,21	-1,26
369	4,02	4,36	4,86	5,06	-1,04
375	4,19	4,99	5,10	5,20	-1,02
436	1,81	2,50	2,83	2,99	-1,18
481	1,68	2,33	2,80	3,20	-1,52
483	1,15	1,51	1,80	2,36	-1,21
Artashat region					
555	0,94	0,86	1,54	2,14	-1,2
584	1,49	2,28	2,51	2,87	-1,38
608	1,77	2,15	2,30	2,44	-0,67
621	1,64	2,09	2,07	2,48	-0,84
654	1,60	1,65	2,17	2,20	-0,60
Ararat region					
685	3,75	4,12	4,40	4,43	-0,68
730	3,94	4,72	4,74	4,96	-1,01
732	2,99	3,71	3,55	3,65	-0,66
762	4,74	5,42	5,52	5,7	-0,96
765	2,36	2,74	2,89	3,06	-0,69

The table shows that groundwater levels in 2013 have dropped by 0.5-1.8 m from 2010 levels. Under the given conditions, a lack of water is observed in the drainage network within the AAB regions (to the north and north-west from fisheries at comparatively high hypsometric elevations).

The consortium of local firms "Hayjrnakhagits Institute" CJSC and "Mel-Hov" LLC has conducted continuous observations of a randomly selected 64 wells of AAB under the contract with the USAID Clean Energy and Water Program covering the entire vegetation season: spring (May); summer (August) and autumn (November). Observations were conducted with a frequency of three observations per month. Results are presented in Annex 4 of this Report.

The results of continuous observations were compared with similar results of 1981, based on which the SCR approved operational resources of AAB. The comparison of 1981 and 2013 results is presented further in this Report. According to these results, the groundwater's piezometric level in the wells of the Echmiadzin area has decreased by 2.5-11.7 m (Haykashen vil.), which was accompanied by a 34.0-169.0 l/s reduction of yield (Haykashen vil.). The level in Masis area decreased by 3.9-15.0 m (Sipanik vil.), accompanied by a 44.0-199.0 l/s reduction of yield (Sipanik vil.). The level and capacity have decreased in wells located mainly within the central part of AAB covering the Echmiadzin and Masis areas.

3. DESCRIPTION OF PAST AND CURRENT TRENDS OF GROUNDWATER USE

3.1. Trends of groundwater abstraction in 1978-2013

Based on the data of hydrogeological investigations conducted in 1978-1983 in ABB, it was identified that there were 2,003 wells as of 1983, of which 1,593 were operational. Out of those 1,593 wells, 878 were flowing artesian wells, and the remaining 715 were operated by pumps. The abstraction made up 12,919.0 l/s or 12.9 m^3/s, or 406.8 Mm^3/year and 2,1742.0 l/s or 21.7 m^3/s, or 685.7 Mm^3/year, correspondingly.

According to regime observations conducted within the period of 1978-1983, the maximal consumption in those years was in the vegetation season (mid-April – October) and reached 51.7 m^3/s or 1,630.4 Mm^3/year, and the minimal (November – mid-April) made up 16.4 m^3/s or 517.2 Mm^3/year. The average annual abstraction reached 34.7 m^3/s or 1,094.3 Mm^3/year. In 1983 this value was set by the SCR instruction as the groundwater use limit not to be exceeded.

According to groundwater sources inventory data conducted during 2006-2007 in AAB, 1,986 wells were used in 2007 with an average discharge of 36,477.0 l/s or 36.5 m^3/s, or 1,151.1 Mm^3/year. Out of these 1,986 wells, 1,145 were artesian wells with an average discharge of 30,028.0 l/s or 30.0 m^3/s, or 946.1 Mm^3/year, and 841 wells with an average abstraction of 6,449.0 l/s, or 6.4 m^3/s, or 201.8 Mm^3/year were operated by pumps.

Out of the 3,318 wells existing in AAB as of 01.07.2013, 1,781 wells were actually operational with a total abstraction of 55,550.0 l/s or 55.6 m^3/s, or 1,753.4 Mm^3/year. 440 wells with a consumption of 35,497.3 l/s or 35.5 m^3/s, or 1,119.5 Mm^3/year were used for fishery purposes, and 1,311 wells with an abstraction of 20,052.7 l/s or 20.1 m^3/s, or 633.9 Mm^3/year were used for irrigation, industrial and potable-household purposes. There were 895 artesian wells with a discharge of 47,149.3 l/s or 47.1 m^3/s, or 1,485.3 Mm^3/year. 886 wells were operated by pumps with an abstraction of 8,400.7 l/s or 8.4 m^3/s, or 264.9 Mm^3/year. The abstraction of water by fisheries is implemented from the high quality lava and under-lava water-bearing rocks, i.e. from aquifers having strategic importance for potable and household water supply.

The following Table 13 summarizes the past use of groundwater in AAB before development of fisheries (1983) and recent trends (2006-2013).

As may be seen from Table 13, the average total abstraction of wells in 2006-2007 already exceeded by 1,816.0 l/s or 1.8 m^3/s, or 56.8 Mm^3/year the permitted annual abstraction of 34,661.0

l/s or 34,7 l/s, or 1,094.3 Mm^3/year approved in 1984. The increase of abstraction took place mainly within the most water rich places of artesian zone – in the Echmiadzin and Masis areas.

The abstraction in AAB as of 01.07.2013 made up 55,550.0 l/s, which exceeded the permitted average annual abstraction of 34,661.0 l/s approved in 1984 by 20,889.0 l/s or 20.9 m^3/s, or 659.1 Mm^3/year. Thus, there was a 1.6-fold excess, and a factor of 4.5 excess in the Masis area alone.

The abstraction in AAB as of 01.07.2013 has increased by 19,073.0 l/s or 19.1 m^3/s, or 601.5 Mm^3/year compared with the 2007 inventory results (36,477.0 l/s), although the number of operating wells has decreased by 205. This is mainly due to large abstractions from the newly drilled artesian wells (100.0-250.0 l/s).

Due to intensive development of fish farms in the last 7-8 years, abstraction of water for fishery purposes only made up 35,497.3 l/s or 35.5 m^3/s, or 1,119.4 Mm^3/year out of 55,550.0 l/s abstracted from AAB, which is 22,795.1 l/s or 22.8 m^3/s, or 719.0 Mm^3/year greater than was used for the same purpose in 2007 (12,702.2 l/s or 12.7 m^3/s, or 400.5 Mm^3/year).

This situation caused a sharp depletion of levels and capacities of the artesian wells of AAB, including a decrease in the discharge of the Sevjur-Aknalich springs. According the Armenian Hydrometeorological Monitoring Service [4], the flow of the Sevjur River (which comes from the average discharge of Sevjur-Aknalich springs) dropped down to the following levels by year:

- 1983 – 26.1 m^3/s or 823.1 Mm^3/year,
- 1990 - 11.7 m^3/s or 369.0 Mm^3/year,
- 2003 – 9.8 m^3/s or 309.1Mm^3/year,
- 2005 – 10.9 m^3/s or 343.7 Mm^3/year,
- 2007 – 9.8 m^3/s or 309.1 Mm^3/year,
- 2008 – 8.1 m^3/s or 255.4 Mm^3/year,
- 2009 – 8.7 m^3/s or 374.4 Mm^3/year,
- 2013 – 3.0 m^3/s or 94.6 Mm^3/year.

The Armenian Nuclear Power Plant is cooled by water from groundwater sources: main and stand-by pumps installed on Metsamor / Sevjur River. Due to the sharp reduction of the Sevjur–Aknalich springs discharge, currently the nuclear plant can take only 500.0 l/s (water requirement - 998.0 l/s), which endangers normal operation of the plant. The sharp reduction of water discharge in springs raises serious concerns as it endangers the safety of Metsamor nuclear power plant’s operation.

Table 13. Analysis of past and current groundwater use in AAB.

Area name	Number of wells / abstraction (l/s) operated in 1983	Number of operating wells 2006-2007, included in inventory l/s		Difference between 2007 and 1983 (- decrease + increase) total	Wells actually used as of 01.07.2013 and yields, l/s		Difference between 2013 and 1983 (- decrease + increase)	Difference between 01.07.2013 and 2007 (- decrease + increase)	Difference between 2013 and 2007 for fisheries (- decrease + increase)	Number / yield (l/s) of artesian wells as of 01.07.2013
		Total	including fishery		total	including fishery				
Baghramyan and Armavir	488 10117.0	419 2900.0	3 14.0	-69 -7217.0	280 2747.0	3 48.0	-208 -7370.0	-139 -153.0	0 +34.0	0
Echmiadzin	610 12364.0	775 16990.0	194 7735.4	+165 +4626.0	584 12571.0	173 6163.3	-26 +207.0	-191 -4419.0	-21 -1572.1	282 9901.0
Sub-total Armavir Marz	**1098 22481.0**	**1194 19890.0**	**197 7749.4**	**+96 -2591.0**	**864 15318.0**	**176 6211.3**	**-234 -7163.0**	**-330 -4572.0**	**-21 -1538.1**	**282 9901.0**
Masis	285 8455.0	571 14680.0	82 4507.6	+286 +6225.0	651 37969.0	281 28959.7	+366 +29514.0	+80 +23289.0	+199 +24452.1	564 36700.0
Artashat	131 2220.0	113 952.0	4 238.0	-18 -1268.0	124 979.0	0	-7 -1241.0	+11 +27.0	-4 -238.0	33 205.0
Ararat	79 1505.0	108 955.0	16 207.2	+29 -550.0	142 1284.0	13 326.3	+63 -221.0	+34 +329.0	-3 +119.1	16 343.3
Sub-total Ararat Marz	**495 12180.0**	**792 16587.0**	**102 4952.8**	**+297 +4407.0**	**917 40232.0**	**294 29286.0**	**+422 +28052.0**	**+125 +23645.0**	**+192 +24333.2**	**613 37248.3**
Total AAB	**1593 34661.0**	**1986.0 36477.0**	**299 12702.2**	**+393 +1816.0**	**1781 55550.0**	**470 35497.3**	**+188 +20889.0**	**-205 +19073.0**	**+171 +22795,1**	**895 47149.3**

The remaining 1,800.0 l/s of discharge from the Sevjur-Aknalich springs is distributed between the Armavir (1,400.0 l/s) and Echmiadzin (400.0 l/s) areas for irrigation purposes.

Meanwhile, it should be stated that the number of wells with negative level in 2013 has reduced by 152 compared to 1983, and the water use has reduced by 8,832.0 l/s or 8.8 m^3/s, or 277.5 Mm^3/year. Lower water use is due to higher electricity tariffs for pump operation, abandonment of some lands, and a sharp reduction of the areas with flowing wells (the area with positive groundwater pressure has reduced from 32,760 ha (1983) to 10,706 ha (2013), i.e. there was a 3-fold decrease.

3.2. Analysis of groundwater use in AAB fixed by Water Use Permits

The Ministry of Nature Protection of the RA has issued 1,571 Water Use Permits (WUPs) as of 2013 for groundwater abstraction in AAB for various purposes, including:

- for irrigation purposes - 890 wells for intake of 5,896.8 l/s or 5.9 m^3/s, or 186.1 Mm^3/year;
- for fishery purposes - 576 wells for intake of 43,154.1 l/s or 43.2 m^3/s, or 1,362.3 Mm^3/year;
- for industrial purposes - 45 wells for intake of 135.6 l/s or 0.14 m^3/s, or 4.4 Mm^3/year;
- for potable water supply purposes - 60 wells for intake of 646.8 l/s or 0.65 m^3/s, or 20.5 Mm^3/year.

The total abstraction by 1,571 wells fixed by WUPs was 49,833.3 l/s or 49.8 m^3/s, or 1,570.5 Mm^3/year.

The following Table 14 presents data on water abstraction volumes in AAB according to issued WUPs and the actual abstraction in 1983-2013. The next Table 15 presents data on WUPs issued by the MNP of the RA to various sectors in 2008-2013.

As may be seen from Table 14, out of the 3,318 wells existing in the AAB as of 01.07.2013, 1,781 were actually used with a total yield of 55,550.0 l/s or 55.6 m^3/s, or 1,753.4 Mm^3/year, including:

- 1,250 wells with WUPs, with total yield of 42,381 l/s or 42.4 m^3/s, or 1,337.1 Mm^3/year;
- 531 wells without WUPs, with total yield of 13,169.0 l/s or 13.2 m^3/s, or 416.3 Mm^3/year.

There were 895 artesian wells with total yield of 47,149.3 l/s or 47.1 m^3/s, or 1,485.3 Mm^3/year. Table 14 shows that in 2013 the abstraction increased by 17,121.3 l/s or 17.1 m^3/s, or 539.3 Mm^3/year compared to 01.01.2008 (1,145 wells with total yields of 30,028.0 l/s or 30.0 m^3/s, or 946.1 Mm^3/year), even though the number of wells decreased by 250. The yields of 886 wells with negative level operated by pumps was 8,400.7 l/s or 8.4 m^3/s, or 264.9 Mm^3/year, and 1,537 wells were not operated.

Table 14. Number of wells operated with WUPs and total actual abstraction in 1983-2013.

Year	Number of wells total/ operated	Number of wells with issued WUPs / abstraction (l/s)	Number of actually operated wells / abstraction (l/s)	Including		Number of operating with WUPs / abstraction (l/s)	Number of operating without WUPs / abstraction (l/s)	Number of WUPs issued for fishery purposes/ abstraction (l/s)	Number of wells actually used for fishery purposes/ abstraction (l/s)
				flowing	by pumps				
1983	2003 410	NA	1593 34661.0	878 12919.0	715 21742.0	NA	NA	NA	NA
2007	2952 966	531 19620.0	1986 36477.0	1145 30028.0	841 6449.0	531 19620.0	1455 16857.0	109 6280.2	299 12702.2
2013	3318 1537	1571 49833.3	1781 55550.0	895 47149.3	886 8400.7	1250 42381,0	531 13169.0	576 43154.1	470 35497.3

Table 15. Number of wells and yields permitted by the WUPs to various sectors by the Ministry of Nature protection of the RA in 2008-2013.

Marz name	Number of wells and abstractions allowed by WUPs in 2008-2013, l/s	Including			
		irrigation	fishery	industrial	potable
Armavir	78 4088.1	21 480.6	47 3543.0	2 7.3	8 57.2
Ararat	196 19180.1	35 529.7	155 18634.0	2 0.6	4 15.8
Total in AAB	**274** **23268.0**	**56** **1010.3**	**202** **22177.0**	**4** **7.9**	**12** **73.0**

The Law of the RA on National Water Program adopted in 2006 specifies the following base values for Armenian groundwater resources:

- Total groundwater resource - 3,611 Mm^3/year or 114.5 m^3/s;
- Recoverable (usable) groundwater resources – 1,000 Mm^3/year or 31.7 m^3/s;
- Strategic groundwater resources – 1,100 Mm^3/year or 34.9 m^3/s;
- National water reserve – 1,200 Mm^3/year or 38.0 m^3/s.

Team of Experts believes that the base values specified by the Law have to be revised. But, in any case, the requirements set by legislation should have been implemented after its enactment.

The fish production was included in the list of priority development programs of the country in 2008. 274 new WUPs with a total yield of 23,268.2 l/s or 23.3 m^3/s, or 734.8 Mm^3/year were issued during 2008-2013 (Table 15). The results of the 2006-2007 inventory were not taken into account during issuance of WUPs, according to which the use of AAB groundwater in 2008 (36,477.0 l/s or 36.5 m^3/s, or 1,151.1 Mm^3/year) had already exceeded the average annual use permitted by SCR in 1984 (34,661.0 l/s or 34.7 m^3/s, or 1,094.3 Mm^3/year).

The analysis of materials presented by stakholder agencies shows that the actual abstraction values do no match with those provided by WUPs. The actual operational parameters of wells do not comply with parameters of issued WUPs (Table 16). The actually-used volume of water is up to 5.8 m^3/s or 182.9 Mm^3/year higher than provided by WUPs.

As may be seen from Tables 15 and 16, the actual abstraction for fishery purposes alone made up 35,497.3 l/s or 35.5 m^3/s, or 1,119.5 Mm^3/year. It exceeded by 22,795.1 l/s or 22.8 m^3/s, or 719.0 Mm^3/year the abstraction of 2007 for the same purpose, or exceeded by 34,661.0 l/s or 34.7 m^3/s, or 1,094.3 Mm^3/year the permitted use approved by SCR for wells in 1984.

Table 16. Analysis of water use in AAB in accordance with WUPs issued for fisheries and of actual water use as of 01.07.2013.

Marz	Number of fish farms / Operational farms	Number of wells with WUPs / Operational	Wells that operate without WUPs	Abstraction, l/s					*Additional Information*
				Abstraction allowed by WUPs, l/s	Actual abstraction as of 01.07.2013, l/s	Including:		The difference between permitted and actual abstraction l/s	
						With WUPs	Without WUPs		
Armavir	142 / 81	263 / 176	20	13559.6	6211.3	6019.3	192.0	-7540.3	61 fisheries and 107 wells do not operate, including 3 not drilled yet. 38 wells are operated by pumps.
Ararat	125 / 109	313 / 294	15	29594.5	29286.0	27984.0	1302.0	-1610.5	16 fisheries and 6 wells do not operate, including 11 wells that are not drilled yet. 6 wells are operated by pumps.
Total in AAB	**267 / 190**	**576 / 470**	**35**	**43154.1**	**35497.3**	**34003.3**	**1494.0**	**-9150.8**	**77 fisheries and 141wells do not operate, including 14 wells that are not drilled yet. 44 wells are operated by pumps.**

The following Figure 4 presents the diagram of average annual abstraction by wells in AAB in 1984 (approved by SCR), in 2008 (according to results of inventory in 2006-2007) and in 2013.

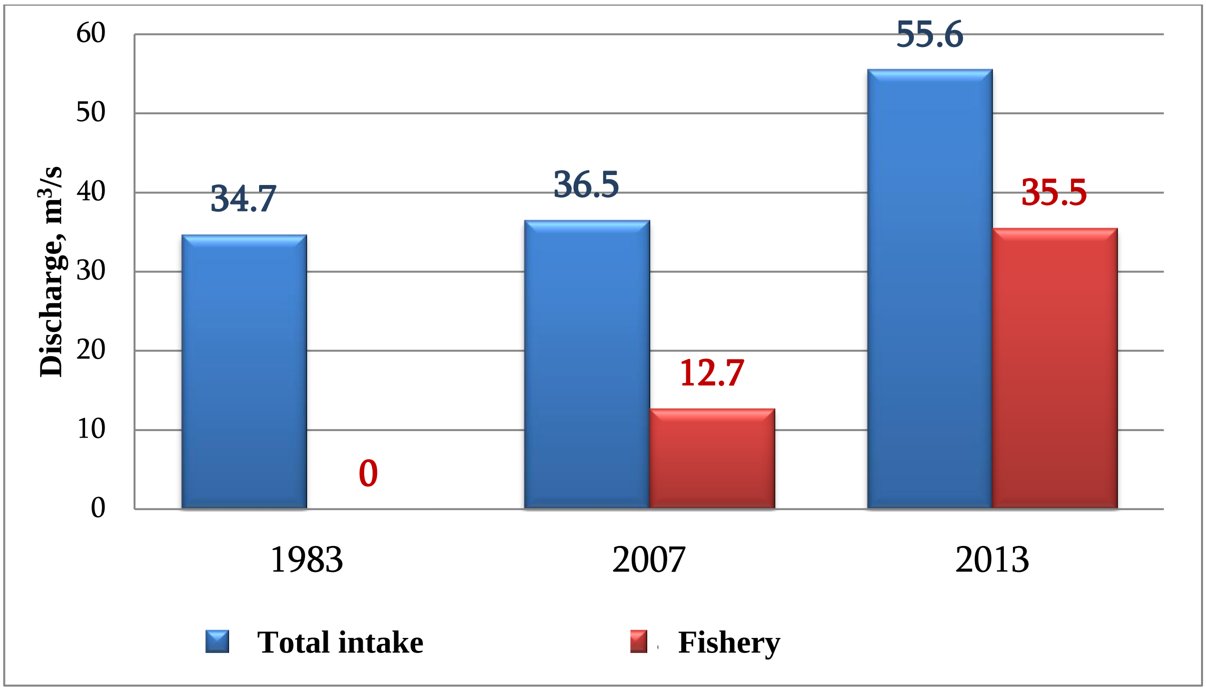


Figure 4. Actual abstraction in AAB in 1984, 2008 and 2013 by wells including for fishery purposes.

Out of the 611 wells drilled for fishery purposes (both with and without WUPs), 141 were not operational as of 2013. 14 wells with WUPs were not drilled, and the actually-operating 190 fisheries used 470 wells with a discharge of 35,497.3 l/s or 35.5 m^3/s, or 1,119.5 Mm^3/year (Table 15), including:

- 435 wells with WUPs with a discharge of 34,000.3 l/s or 34.0 m^3/s, or 1,072.2 Mm^3/year;
- 35 wells without WUPs with a discharge of 1,494.0 l/s or 1.5 m^3/s, or 47.3 Mm^3/year.

127 fishery wells were not used in 2013 as they were not flowing anymore due to a reduction of groundwater level in AAB. As a result, 77 fisheries were closed, and abstraction in 44 wells is implemented by centrifuge pumps.

Depletion of piezometric levels of artesian wells of AAB also caused irrigation and potable-household water supply problems in dozens of communities of AAB.

The observations and analyses conducted under this assessment study identified that the area of groundwater with positive pressure in AAB has decreased from 32,760 ha (1983) to 10,706 ha (2013), i.e. has reduced by a factor of three (Annex 1). The area with positive pressure included 44 communities in 1983. Currently, the three-fold decreased area includes only 13 communities, i.e. 44 communities are deprived of irrigation and potable-household water abstracted by artesian wells.

3.3. Changes in operation of the drainage network

The above presented trends of groundwater use in AAB affect the operation of the drainage network of the Ararat Valley. There were 1,534.66 km of operational drainage networks in AAB as of 2013 including 905.16 open drainage and 629.5 km closed drainage. They covered the area of 25,025.0 ha and 7,729.0 ha, respectively.

Until 2002, the drainage network of AAB was an efficiently operating system, ensuring diversion of about 36.3 m^3/s or 1,144.8 Mm^3/year water to the Araks, Hrazdan and Metsamor rivers.

Since 2003, the volumes drained by the drainage network have begun to increase first gradually, and then sharply, reaching 58.11 m^3/s or 1,832.6 Mm^3/year in 2013, exceeding the design capacity of the network by 60% (Figure 5).

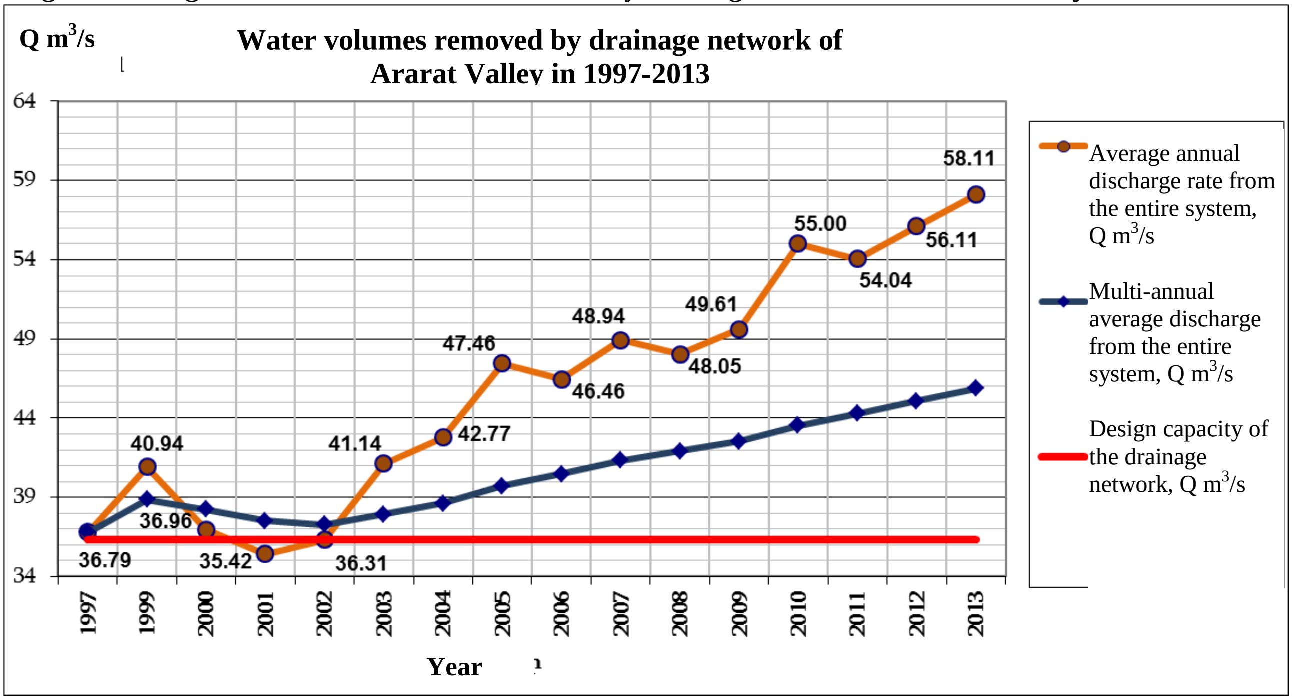
The results of investigation of water use and diversion conditions by fisheries showed that they release about 27.8 m^3/s or 876.7 Mm^3/year of water into the drainage network, violating the conditions set by WUPs. This has caused increasing water level in the network and groundwater level in the surrounding areas, water logging of soil and settlements, salinization and alkalinisation of soil, reduction of drainage network capacity and ultimately a reduction of crop productivity.

In particular, the average volume of water drained by the drainage network of the Ararat Valley makes up 58.11 m^3/s or 1,832.6 Mm^3/year, out of which 27.8 m^3/s or 876.7 Mm^3/year flows into the drainage network from fisheries, and 30.31 m^3/s or 955.9 Mm^3/year is the drainage water (Table 17). Meanwhile, there is a lack of water in the border areas of the Ararat Valley, especially north and north-west of the fisheries of Armavir Marz due to widespread depletion of the groundwater table at relatively high hypsometric levels.

Table 17 Discharges in drainage network of Ararat Valley by sites in 2012-2013.

Name of collector, catchment area	2012					2013				
	Discharge by quarters, m^3/s				Mean annual discharge, m^3/s	Discharge by quarters, m^3/s				Mean annual discharge, m^3/s
	I	II	III	IV		I	II	III	IV	
Sevjur-Kassakh site	7.55	8.23	6.71	7.19	7.42	7.23	5.37	3.07	4.64	5.08
Hrazdan right-bank collector	23.7	20.27	20.81	22.72	21.88	24.52	22.43	20.98	23.11	22.78
Hrazdan left-bank collector	8.20	7.50	8.10	7.30	7.77	9.60	8.80	8.30	8.00	8.68
Hrazdan-Araks collector	12.18	20.6	25.97	17.5	19.04	18.09	22.62	20.26	25.55	21.57
TOTAL	**51.63**	**56.6**	**61.59**	**54.71**	**56.11**	**59.44**	**59.22**	**52.61**	**61.3**	**58.11**

Figure 5. Diagram of water volumes removed by drainage network of Ararat Valley in 1997-2013.



4. IMPACT OF WATER USE ON GROUNDWATER BALANCE AND RECHARGE OF AQUIFERS

4.1. Assessment of groundwater inflow and outflow components in Ararat artesian basin

In order to assess the recharge rate of AAB aquifers, the groundwater inflow and outflow components of the basin have been analyzed.

The inflow component of the natural groundwater resource flowing into AAB was assessed by various authors in various periods. As it was stated in Chapter 1, the Team of Experts conducting this study has accepted the average arithmetical value of the deep groundwater discharge or recoverable natural groundwater resources of the AAB estimated by V. Vehuni (1975) and H.A. Aghinyan (1976) using the balance method. Recoverable natural groundwater resources (inflow) of the AAB are **57.8 m^3/s or 1,822.8 Mm^3/year**. The outflow component of the AAB was estimated as the sum of natural discharge through springs - 21.9 m^3/s or 690.6 Mm^3/year and average annual abstraction by wells - 34.7 m^3/s or 1,094.3 Mm^3/year approved in 1984, which makes up 56.6 m^3/s or 1,784.9 Mm^3/year. Groundwater discharge into rivers was not measured and discharge numbers remain unknown. It is clear, however, that the groundwater discharge component is an important part of groundwater balance as the Metsamor River, for example, is recharged (fed) exclusively by groundwater.

Table 18 below shows the average annual abstraction by wells approved in 1984 based on regime observations at fixed points conducted in 1978-1983 by AAB regions (hydrogeological structures of second order). Such abstraction will not distort the ratio of the inflow and outflow components and water-bearing capacity of AAB aquifers.

Table 18. The values of average annual abstraction from hydrogeological structures of second order established in 1984.

Name of hydrogeological structure	The established permissible abstraction, m^3/s		
	Maximal (vegetation season, from mid-April to October)	Minimal (off-vegetation season, from November to mid-April)	Average annual
Hoktemberyan depression`	36.9	8.2	22.5
- western part (Baghramyan and Armavir area)	*17.9*	*3.3*	*10.1*
- eastern part (Echmiadzin area)	*19.0*	*4.9*	*12.4*
Sovetashen uplift (Masis area)	9.6	7.2	8.5
Artashat depression (Artashat area)	3.1	0.6	2.2
Arazdayan depression (Ararat area)	2.1	0.4	1.5
Total in AAB	**51.7**	**16.4**	**34.7**

Table 19 presents the inflow and outflow components of AAB aquifers by hydrogeological structures of second order based on the observation results of 1978-1983.

Table 19. Inflow and outflow components of AAB aquifers by hydrogeological structures of second order as of 1984.

Name of hydrogeological structure	**Inflow component (natural recoverable resources) m^3/s***	**Established outflow component, m^3/s**		
		Total	**including**	
			Average abstraction by springs	**Average annual yield set for wells**
Hoktemberyan depression`	-	40.9	18.4	22.5
- western part (Baghramyan and Armavir area)	-	*10.1*	*0*	*10.1*
- eastern part (Echmiadzin area)	-	*30.8*	*18.4*	*12.4*
Sovetashen uplift (Masis area)	-	11.8	3.3	8.5
Artashat depression (Artashat area)	-	2.4	0.2	2.2
Arazdayan depression (Ararat area)	-	1.5	0	1.5
Total in AAB	**57.8**	**56.6**	**21.9**	**34.7**

* As there were no data in the first column (inflow component by hydrogeological structures), only the total inflow was used.

Table 20 presents actual average annual abstraction volumes in AAB by wells in 1983, 2007 and 2013 by regions to show the trends of groundwater use from AAB.

Table 20. Current and past average annual abstraction from AAB.

Region name	**Actual average abstraction, l/s**			**Difference between 2007 and 1983, - reduction + increase**	**Difference between 2013 and 1983, - reduction + increase**
	1983	**2007**	**2013**		
Baghramyan and Armavir	10117.0	2900.0	2747.0	-7217.0	-7370.0
Echmiadzin	12364.0	16990.0	12571.0	+4626.0	+207.0
Masis	8455.0	14680.0	37969.0	+6225.0	+29514.0
Artashat	2220.0	952.0	979.0	-1268.0	-1241.0
Ararat	1505.0	955.0	1284.0	-550.0	-221.0
Total AAB	**34661.0**	**36477.0**	**55550.0**	**+1816.0**	**+20889.0**

According to the inventory data of 2007, the actual abstraction in the Echmiadzin and Masis areas within the positive pressure zone made up 31.7 m^3/s or 999.7 $Mm^3/year$, which was by 10.9 m^3/s or 343.8 $Mm^3/year$ higher than the average norm of 20.8 m^3/s or 656.0 $Mm^3/year$ established under operational regime for this region in 1984.

As may be seen from Table 20, since 2007 the actual abstraction by wells from AAB was distributed unevenly and concentrated mainly in the Echmiadzin and Masis areas within the zone of positive pressure and exceeded the average annual abstraction permitted for wells in 1984. Furthermore, starting from the same period, the well impact radius (200-500 m, established in 1966-1984 based on hydrogeological investigations) was not taken into consideration during drilling of wells.

There were 3,318 wells drilled within AAB as of 2013. 1,781 of them with a total intake of 55.6 m^3/s or 1,753.4 Mm^3/year were actually used, including 50.5 m^3/s or 1,592.6 Mm^3/year in Masis and Echmiadzin areas. 1,235 wells with a discharge of 50.5 m^3/s or 1,592.6 Mm^3/year have been operating in this zone with positive pressure, thus violating the average annual discharge of 20.8 m^3/s or 656.0 Mm^3/year set for wells of this area.

470 wells with an abstraction of 35.5 m^3/s were actually used for fish production alone, which by itself exceeded the average annual yield set for wells (34.7 m^3/s). The over-abstraction of the resources in the Masis and Echmiadzin areas made up 29.7 m^3/s or 936.7 Mm^3/year in 2013. The over-abstraction in AAB within the same period made up 20.9 m^3/s or 659.0 Mm^3/year.

Investigations conducted by the Team of Experts have identified that the technical characteristics of wells (diameter and depth) drilled for fishery purposes have been amplified, and as a result the abstraction was significantly higher than was allowed by WUPs. In the past, abstraction from the second aquifer was implemented by pipes with a diameter of 168 mm and 219 mm. Currently 324 mm pipes ae used for groundwater abstraction, which increases the abstraction volume by 50%.

Given the higher than permitted abstraction in the Masis and Echmiadzin areas, the 200-500 m impact radius specified for wells has undoubtedly been exceeded.

Investigations conducted in 1966 have shown that in the case of a 3.5 m^3/s abstraction, the impact radius is 0.8 km and depression cone surface is about 2.0 km^2. Meanwhile, in case of well clusters, the discharge of wells is reduced by 15.0-20.0%. The impact radius of the Metsamor-Aknalich springs is 4.5 km, and the depression cone surface is 60.0-65.0 km^2 [7, 8].

In the case of the 50.5 m^3/s of current actual abstraction in Masis and Echmiadzin districts, the impact radius made up 13 km, and the depression cone area became 530 km^2, expanding to the discharge area of the Sevjur-Aknalich springs. As a result, the discharge of the Sevjur-Aknalich springs has decreased sharply from 17.8 m^3/s (1983) to 3.0 m^3/s (2013).

Due to inadequate technical design of wells drilled in AAB in the past 6-7 years and non-compliance with the established 500 m distance between wells, natural hydraulic connections between layers were distorted. In particular, because of the drilling of wells in too dense of a network, the number of hydrogeological "windows" between various aquifers has increased, causing depletion of piezometric level, mixing of water from various aquifers, and changes in chemical content of groundwater (increasing mineralization up to 0.3 g/l). The outflow component of aquifers also was impacted; the discharge of natural springs has decreased sharply. Meanwhile, abstraction by wells has increased by 20.9 m^3/s, which disturbs the natural conditions of AAB aquifer recharge.

A considerable reduction in groundwater pressure and in the capacity of wells is observed in the central part of the pressure zone of AAB. The piezometric levels of groundwater have decreased by 6.0-9.0 m, sometimes by 15.0 m (e.g. well 13/3, Sipanik vil.) in 1983-2013, which is accompanied by reduction of the yield by 6.0–200.0 l/s.

The investigations conducted by the Team of Experts under this study showed that in the Artashat and Arazdayan depressions, where water is abstracted mainly by submersible pumps without exceeding the volumes of operational regime set in 1984, no essential changes of groundwater level were observed, and they were only of seasonal nature.

4.2. Impact of development scenarios on groundwater balance and recharge rates

Abstraction of groundwater by wells in Ararat Valley, mainly in the water rich artesian zones of Masis and Echmiadzin areas has increased significantly in past 10 years due to the rapid growth of the fish industry and exceeded the average abstraction of 34,661.0 l/s or 34.7 m^3/s, or 1,094.3 Mm^3/year permitted by SCR in 1984. Such operation of groundwater resources has disturbed the inflow and outflow components ratio in the groundwater balance and the natural conditions of groundwater recharge. As a result, the water levels of unconfined and artesian aquifers have depleted, and the discharges of groundwater springs and well yields have decreased.

According to estimates of the Experts, if the current water use scenario in the Ararat Valley continues, and the operational regime with average annual abstraction by wells established for AAB in 1984 (34.7m^3/s) is not maintained, the groundwater level and the capacity will continue to decrease by 5-10% in coming 1-2 years from central part of the basin towards the west and north-west.

The artesian zone will continue to shrink, resulting in more communities deprived of irrigation and potable-household water. It is expected that reduction of positive hydrostatic pressure will actually altogether eliminate the flow of the Sevjur-Aknalich group of springs currently used for cooling the Armenian Nuclear Power Plant and for water supply to already reduced irrigation areas. This will entail even more serious social-economic problems in the Ararat Valley.

Future development of the fish industry in the AAB is not clear.

In 2013, following the requirements of the Government Decisions N: 800-N, July 18 2013 on establishing the Program of Measures and Priority Issues of the Government of Armenia[1], the Ministry of Agriculture presented a Draft Concept for Development of Fish Farms in Armenia in late 2013.

According to the Government, fish production has a great potential in Armenia. However, the technology that has been used in the existing fish farms is not efficient and requires large amounts of fresh water resources, which leads to over-abstraction of drinking water resources, particularly in the Ararat Valley. It is proposed to continue the development of the fish farms with application of modern technologies, which will reduce water use in coming years by 25-30% and increase production two-fold. The fish farms are proposed to be developed on the saline lands of the Ararat Valley.

At the time of this report's preparation, the aforementioned Concept was not officially approved or adopted. However, the Team of Experts would like to emphasize that fish production should be based only on volumes of recoverable (usable) groundwater resources available in the Ararat Valley and follow water use priorities defined by Armenian legislation. According to this Assessment Study, in order to maintain groundwater balance in the Ararat Valley, use of groundwater resources for fish production shall be reduced not by the 25-30% proposed in the Concept, but a factor of three. The average annual abstraction by wells from the artesian zone of the AAB for fish production purposes shall not exceed *12.0* m^3*/s or 378.4* Mm^3*/year, compared to the 35.5* m^3*/s or* 1,119.4 Mm^3/year which was used for fish production purposes in 2013.

In past years large amounts (about one billion AMD) from the state budget were allocated in accordance with corresponding governmental resolutions to solve the existing problems and ensure irrigation water supply (where possible without the use of water from Lake Sevan). To this end, dozens of wells were drilled, pump equipment was installed, canals were constructed, an intake basin and a pumping station were reconstructed and constructed, and about 43 illegal wells were conserved or dismantled. However these measures were not sufficient to provide a comprehensive solution to the problem. Additional 7000 million AMD is required for implementation of additional

[1] Decision N: 800-N, dated July 18, 2013 on Establishing the Program of Measures and Priority Issues of the Government of Armenia, http://www.arlis.am/documentview.aspx?docid=87656

measures to cope with lack of water in the Metsamor River and AAB, taking alos into consideration the reserve capacities of the existing infrastructure[2].

Although adequate activities are implemented with state financial assistance, problems still exist in those areas where there are no other alternative resources or possibilities except for the water of Lake Sevan. In order to ensure water requirements of these areas, an additional 77.2 Mm^3 would have to be released from the Lake Sevan to increase water supply to the endangered 8,180.0 ha. However, the Team of Experts of this study disagrees with such a decision.

In addition to the negative impacts stated above and additional electricity costs due to pumping of water from the wells, the continuous depletion of groundwater level entails higher irrigation water demand on the lands of the Masis and Echmiadzin regions, and land degradation.

That is evidenced by the results of "Investigation of Issues Associated with Degradation of Cultivated Lands of Masis and Echmiadzin Regions of the Ararat Valley, Reduction of Groundwater Level" [18] conducted in 2013 by the branch of "Pedology, Agrochemistry, and Amelioration Scientific Center after H. Petrosyan" under the assignment of the State Committee of Water Management of the Ministry of Territorial Administration of the RA. Specifically:

- As the groundwater ensures some humidity in the upper layers of the soil, lowering of the groundwater table has caused humidity reduction, hence higher irrigation water demand. As a result of groundwater level depletion, there is no humidity inflow from the soil, hence irrigation standards and the number of water applications has increased by 20-25%, causing considerable change of irrigation standards and regimes specified for crops.
- Changes in water-temperature regimes of soil have distorted the balance of formation and decomposition of organic matter in the Ararat Valley which was stable for centuries. These resulted in reduction of humus content in soil. It was reduced by 0.5-1% in the 0-50 cm layer of the soil, causing decomposition of structural micro aggregates and aggregates of soil, conversion of soil into dust, deterioration of hydrophysical properties of soil, and ultimately reduction of soil fertility.

Masis municipality received warnings from 11 inhabitants in December 2013, who complained that cracks and fissures have appeared in the structural walls of their houses, endangering the stability of their facilities. Having analyzed the groundwater monitoring data (Table 21), it may be assumed that the main reason is the depletion of the groundwater table by 0.4-1.41 m.

[2] Draft Կ-440-07.02.2014-ԳԲ-010/0 on Making Amendment in the RA Law on Establishing the Annual and Complex Program of Measures for Restoration, Protection and Reproduction of the Lake Sevan Ecosystem. http://www.parliament.am/drafts.php?sel=showdraft&DraftID=32781

Table 21. Data of groundwater level monitoring carried out in observation wells of Masis settlement in 2009-2013.

Well number	**Groundwater level during vegetation season**					**Difference of levels**
	2009	**2010**	**2011**	**2012**	**2013**	**2009-2013**
483	-0.92	-1.10	-1.46	-1.77	-2.33	-1.41
531	-3.25	-3.25	-3.88	-3.96	-4.01	-0.76
530	-2.91	-3.05	-3.35	-3.58	-3.82	-0.91
553	-3.89	-4.16	-4.55	-4.63	-4.62	-0.74
1*	-2.40	-2.48	-2.52	-2.88	-3.0	-0.6
2*	-2.0	-2.45	-2.69	-3.01	-3.35	-1.35
4*	-2.5	-2.61	-2.71	-2.84	-3.0	-0.5
5*	-2.4	-2.56	-2.84	-3.42	-3.7	-1.3
8*	-1.2	-1.28	-1.39	-1.48	-1.6	-0.4
9*	-2.7	-2.84	-2.95	-3.31	-3.42	-0.72

* Wells were drilled within the area of Masis in 2009 for irrigation with water abstracted from shallow groundwater aquifers.

At the same time, there are fisheries in the Ararat Valley with no insulation on the bottom, and large volumes of water infiltrate into adjacent areas. This creates a dangerous situation both for the stability of houses and land fund. According to estimates, currently about 21,000 ha has high humidity content and faces the danger of secondary salinization.

5. CONCLUSIONS

Used information sources

Results of the Assessment Study of Groundwater Resources of Ararat Valley conducted by the consortium of "Hayjrnakhagits Institute" CJSC and "Mel-Hov" LLC with the assistance USAID funded Clean Energy and Water Program during February 2013-March are presented in this report.

The findings and recommendations presented in this Report are based on the review and analysis of archive materials and reports, documents received from concerned governmental agencies:

- Results of hydrogeological exploration works conducted in the Ararat Artesian Basin (AAB) in 1966 and 1984 with estimation of resources;
- Results of groundwater sources inventory of the Ararat Artesian Basin conducted in 2006-2007;
- Results of groundwater monitoring data conducted within Ararat Artesian Basin in 2009-2012 by "Hydrogeological Monitoring Center" (HMC) State Non-Commercial Organization (SNCO) of the Ministry of Nature Protection of the Republic of Armenia (MNP);
- Results of measurements at the benchmark points of the drainage monitoring network Ararat Artesian Basin by conducted in 1997-2013 by "Amelioration/Melioratsia" CJSC of the State Committee of Water Systems (SCWS) of the Ministry of Territorial Administration (MTA) of the RA from;
- Data on groundwater abstraction within the Ararat Artesian Basin from 1983-2013 according to archive materials and Water Use Permits (WUPs) issued by the MNP of to the various water users;
- Other archive materials (see list of literature).

Geological-hydrogeological conditions and recoverable groundwater resources

The Ararat Artesian Basin is located in the middle stream of the Araks River within the Ararat Depression Valley and extends in a NW-SE direction for about 120.0 km with a width of 10.0-30.0 km.) and occupies an area of about 1,300 km^2.

AAB has a complex tectonic and geological-hydrogeological structure, represented by three depressions (Hoktemberyan, Artashat and Arazdayan) and two uplifts (Sovetashen and Khor Virap).

Groundwater resources of AAB are developed from precipitation, condensation and discharge of deep artesian inflows within the Araks catchment basin on an area of 31,500 km^2, including 14,900 km^2 of Armenian territory and 16,600 km^2 of Turkish territory.

Two groundwater complexes have been identified in the subsurface of AAB: an unconfined aquifer and confined (artesian) water bearing complex which is conditionally divided into two aquifers. Artesian aquifers are connected with successive complexes of folded systems made of permeable and weakly permeable rocks, specified by extreme instability of geological-lithological and hydrogeological parameters, in particular spreading and thickness, variety of water bearing rocks and their hydraulic conductivity, transmissivity properties, water temperature and mineralization.

The operational groundwater resources of AAB were assessed by various authors within 1966-1984, and the results were approved by the State Commission of Reserves (SCR) in 1984.
The Team of Experts conducting this study has accepted the average arithmetical value of recoverable (dynamic) natural resources of the AAB calculated by V. Vehuni in 1975 and H. Aghinyan in 1976 using balance method. Recoverable groundwater resources which could be abstracted without damage to the environment of the Ararat Artesian Basin (safe yield) make up **57.8 m^3/s or 1,822.8 Mm^3/year**.

In 1984 the State Commission of Reserves approved a safe annual average yield of groundwater resources in the amount of 56.6 m^3/s, of which safe abstraction by wells is 34,7 m^3/s and by springs is 21,9 m^3/s. If groundwater abstraction will not exceed the approved safe yield, natural hydrodynamic and hydrochemical balance of interconnected subsurface system will not be distorted.

Analysis of groundwater use in the AAB has revealed that the actual consumption already in 2007 has exceeded volumes permitted by the SCR.

Assessment of groundwater use

Analysis of groundwater consumption in 1978-1983 in ABB led to the identification of 2,003 wells as of 1983, of which 1,593 were operational. Out of 1,593 wells, 878 were flowing artesian wells and the remaining 715 were operated by pumps. The abstraction made up 12.9 m^3/s, or 406.8 Mm^3/year from flowing wells and 21.7 m^3/s, or 685.7 Mm^3/year from the pump operated wells. These volumes did not exceed the safe yield approved by the SCR in 1984.

According to groundwater source inventory data conducted during 2006-2007 in AAB, 1,986 wells were used in 2007 with an average abstraction of 36.5 m^3/s, or 1,151.1 Mm^3/year. Thus average total abstraction from the wells already in 2006-2007 had exceeded the permitted annual abstraction (34,7 m^3/s) by 1.8 m^3/s. The increase of abstraction was concentrated mainly within the most water rich places of artesian zone – in the Echmiadzin and Masis areas.

Due to intensive development of fish farms in the last 7-8 years, abstraction of groundwater solely for fishery purposes increased up to 35.5 m^3/s, or 1,119.4 Mm^3/year and total abstraction in the AAB (including drinking, agricultural and industrial water supply) increased to 55,6 m^3/s.

This situation caused the development of groundwater level drawdowns and depletion of the capacities of artesian wells in AAB, including reduction of discharge of the Sevjur-Aknalich Springs.

Due to the inadequate technical design of numerous wells drilled in AAB in the past 6-7 years and non-compliance with the established 400-1,000 m distance between wells, natural hydraulic connections between layers were distorted. Due to the overly-dense network of newly-drilled wells, the number of hydrogeological "windows" between various aquifers has increased causing depletion of the piezometric level, mixing of water from various aquifers, and changes in chemical content of groundwater (increasing mineralization of waters to up to 0.3 g/l, see table 10). The outflow component of aquifers by regions was also distorted. The discharges of natural springs and yield of wells have reduced sharply under the conditions of increased abstraction by wells.

<u>Impacts of groundwater abstraction</u>

Groundwater abstraction in the AAB area and its impacts, including environmental have been thoroughly analysed in the Interim and Final reports. Main conclusions are presented below.

- Out of 3,318 wells existing in AAB, 1,781 wells were actually operated in 2013 with a total abstraction of 55.6 m^3/s, or 1,753.4 Mm^3/year, including 895 artesian wells with a discharge of 47.1 m^3/s or 1,485.3 Mm^3/year. 1,250 wells with an abstraction of 42,381 l/s or 42.4 m^3/s, or 1,337.1 Mm^3/year were operated with Water Use Permits and 531 wells with an abstraction of 13,169.0 l/s or 13.2 m^3/s, or 416.3 Mm^3/year were operated without Water Use Permits. However, according observations of the Team of Experts conducting this study, the above data are not full and complete, and the resulting findings do not reflect the actual abstraction. In the opinion of the Team of Experts, the actual abstraction is about 20% higher.
- Out of 55,550.0 l/s or 55.6 m^3/s, or 1,753.4 Mm^3/year used in AAB as of 2013, the abstraction only for fish production purposes made up 35,497.3 l/s or 35.5 m^3/s, or 1,119.5 Mm^3/year, which exceeded the volume of 22,795.1 l/s or 22.8 m^3/s, or 719.0 Mm^3/year used in 2007 for the same purpose and exceeded the volume of 34,661.0 l/s or 34,7m^3/s permitted by SCR for wells in 1984. Meanwhile, the total water use (55.6 m^3/s or 1,753.4 Mm^3/year) exceeded 1.6 times the average annual permitted abstraction of 34.7 m^3/s or 1,094.3 Mm^3/year set in 1984.
- 1,235 wells with discharge of 50.5 m^3/s or 1,592.6 Mm^3/year have been operated within the positive pressure zone in the Masis and Echmiadzin areas as of 2013, which is 2.4 times (for

the Echmiadzin area) and 4.5 times (for the Masis area) higher than the permitted average annual abstraction. The over-abstraction of groundwater in the Masis and Echmiadzin areas made up 29.7 m^3/s or 936.7 Mm^3/year in 2013. The over-abstraction in AAB within the same period made up 20.9 m^3/s or 659.0 Mm^3/year.

- The MNP of the RA has issued 1,571 WUPs as of 2013 for groundwater abstraction in AAB for irrigation, fishery, industrial and drinking purposes. The total abstraction by 1,571 wells fixed by WUPs was 49,833.3 l/s or 49.8 m^3/s, or 1,570.5 Mm^3/year.
- Water use permits were issued in 2008-2013 for 274 new wells with a total discharge of 23,268.2 l/s or 23.3 m^3/s, or 734.8 Mm^3/year. While issuing WUPs, data from the 2006-2007 inventory was not taken into account. According to the inventory data, the groundwater abstraction in AAB yet in 2007 exceeded by 36,477.0 l/s or 36.5 m^3/s, or 1,151.1 Mm^3/year the permitted annual abstraction by wells specified by SCR in (1984 34,661.0 l/s or 34.7 m^3/s, or 1,094.3 Mm^3/year).
- The analysis of materials presented by concerned agencies shows that the actual abstraction values do no match with those provided by WUPs. As of 2013, the actual abstraction was 55.6 m^3/s or 1,753.4 Mm^3/year, which is by 5.8 m^3/s or 182.9 Mm^3/year higher than the 49.8 m^3/s or 1,570.5 Mm^3/year accounted for by WUPs.
- 470 wells with a total discharge of 35.5 m^3/s or 1,119.4 Mm^3/year were used solely for fish production purposes, which exceeded the permitted operational regime for wells (34.7 m^3/s or 1,094.3 Mm^3/year) ;
- Due to the inadequate technical design of numerous wells drilled in AAB in the past 6-7 years and non-compliance with the established 400-1,000 m distance between wells, natural hydraulic connections between layers were distorted. In particular, because of the drilling of wells in too dense of a network, the number of hydrogeological “windows” between various aquifers has increased, causing depletion of the piezometric level, mixing of water from various aquifers, and changes in the chemical content of groundwater (increasing of mineralization of waters to up to 0.3 g/l). The outflow component of aquifers also was impacted; the discharge of natural springs has decreased sharply.
- The water levels of confined aquifers of AAB in wells with positive pressure have reduced by 2.5-6.5 m and the capacity of wells has gone down to 82.0 l/s within the period of 1983-2005.
- The piezometric levels of groundwater in the central artesian part of AAB – north and north-west from the Masis and Echmiadzin areas, have decreased considerably within the perioed of 1983-2013. The piezometric levels of groundwater have decreased by 6.0-9.0 m, sometimes by 15.0 m, which is accompanied by a reduction in well capacity by 6.0–200.0 l/s. This provides

evidence that the groundwater abstraction is implemented in an unbalanced manner and disturbs the operational regime set for wells.

- The piezometric levels and discharges have decreased in 303 artesian wells observed in the Echmiadzin area of Armavir Marz, which are used for the supply of potable-household and irrigation water. The total yield of those wells made up 6,118.6 l/s in 1990, while it was only 604.0 l/s in 2011. Out of those 303 artesian wells, 122 do not flow anymore. Out of 611 wells of the artesian zone used for fish production purposes, 141 wells do not operate, and 127 do not flow anymore.
- Most of the wells investigated (2303 wells or 80%) were drilled before 1984. Being operated over the long period, most of the wells are deteriorated and in poor technical state. Their casing pipes are deteriorated, corroded and punched and do not serve their purpose. As a result the water of various aquifers is mixed up, causing deterioration of groundwater quality, which may harm population health and water supply conditions, and cause other negative impacts. In addition, the wells are filled with sand, leading to reduced groundwater levels in these wells.
- Most of the wells were drilled without technical expertise provided for the design. The depth and structure of the wells were selected without taking into consideration hydrogeological conditions.
- Valves of the most of the wells are out of order, which does not allow regulating or closing the flowing wells.
- Due to the current actual abstraction in the Masis and Echmiadzin regions, the depression cone area in the artesian aquifers became 530 km^2, expanding to the discharge area of the Sevjur-Aknalich springs. As a result, the discharge of the Sevjur-Aknalich springs has decreased sharply from 17.8 m^3/s (1983) to 3.0 m^3/s (2013).
- In the western parts of the Artashat, Ararat, and Armavir areas, where water is abstracted mainly by submersible pumps, no essential changes of groundwater levels were observed, as the abstraction on this area does not exceed the operational regime set by SCR in 1984.
- The area of groundwater with positive pressure in AAB made up 10,706 ha in 2013, which was three times less than in 1983 (32,760 ha). The area with positive pressure included 44 communities in 1983, and currently includes only 13. At present, 31 communities are partially or completely deprived of irrigation and potable-household water abstracted by artesian wells.
- The discharges of springs of AAB supplied by groundwater have reduced considerably. In particular, the discharge of the Metsamor-Aknalich group of springs has decreased. Yet this group of springs is the water source of Metsamor (Sevjur) river, which in its turn is the water source for many irrigation canals and pump stations. Due to the continuous reduction of water

flow in the Metsamor-Aknalich springs, the flow of the Metsamor River has reduced from 17.8 m^3/s (1983) to 3.0 m^3/s (2013).

- The Armenia's Metsamor Nuclear Power Plant is cooled by water from groundwater sources. Due to the sharp reduction of the Metsamor–Aknalich springs discharge, currently the nuclear plant can take in only 500.0 l/s (the water requirement, however, is 998.0 l/s), which endangers normal operation of the plant. The sharp reduction of water discharge in these springs raises serious concerns as it endangers the safety of nuclear power plant's operation.
- Lack of water creates a deficit in irrigation systems as well. The largest among them are the Arevshat stage-1, Aknalich and Metsamor pumping stations. Arevshat is a subsidiary pumping station which pumps water from Metsamor River to the Lower Hrazdan canal ensuring irrigation of 6,229 ha belonging to 21 communities. Currently the pump station does not operate due to lack of water in the Metsamor–Aknalich springs. The Aknalich pumping station ensures irrigation of 1,201 ha belonging to 5 communities located under via the Upper and Lower Aknalich canals. The Metsamor pumping stations ensure irrigation of 750 ha of 3 communities through a diversion canal. Overall, the irrigation of 8,180 ha of 29 communities is endangered.

Urgent measures for the improvement of management of groundwater resources in AAB should be taken before more serious social-economic problems arise not only in the Ararat Valley but in the entire country.

6. RECOMMENDATIONS

Based on the above presented conclusions, the Team of Experts developed the following proposals and recommendations for improvement of the groundwater situation.

Proposals on future assessment of groundwater resources of the Ararat Valley

The Team of Experts considers the recoverable/usable groundwater resources of AAB approved in 1984 for use within an indefinite period to be reliable and realistic and they do not need to be re-assessed. If the operational regime (average annual abstraction of 34.7 m^3/s or 1,094.3 Mm^3/year) specified by SCR in 1984 was maintained during the last 10 years, there would be no problems with depletion of groundwater resources of AAB.

The re-assessment of groundwater resources in the AAB would be needed in the case of no positive results being observed in the AAB after implementation of the measures proposed by the Team of Experts. The re-assessment of groundwater resources can be conducted without extensive hydrogeological surveys (exploratory drilling and pumping tests), but rather with the application of modern technologies and mathematical modelling using available groundwater data.

Considering that there were some shortcomings in the inventory conducted in 2006-2007, and the borehole drilling in AAB has continued in 2008-2013, including the drilling of un-accounted-for and/or not-permitted boreholes, the Team of Experts recommends carrying out a new inventory in 2014 within the artesian zone of the Ararat Valley prior to any activities aimed at regulation of groundwater levels and discharges and restoration of resources. The inventory will clarify the following:

- the number and total abstraction of the existing and operating wells;
- purpose and ownership of wells;
- availability of wells certificates (passports) and their legitimacy;
- technical and sanitary state of wells;
- location of wells (coordinates and distance between them).

Qualified hydrogeologists shall be involved in inventory activities.

Based on inventory results, adequate proposals will be selected for liquidation, temporary closure of wells and limitation of abstraction (converting wells to valve regime operation). Proposals will also be recommended to ensure and improve drinking-household and irrigation water supply.

Recommendations for the measures aimed at sustainable groundwater management in Ararat Valley

In order to achieve sustainable management of groundwater resources in the Ararat Valley, the Team of Experts conducting this study recommends limiting the current total abstraction by wells in AAB and bringing it to the permitted 34.7 m^3/s or 1,094.3 $Mm^3/year$ set by the SCR in 1984. The average annual discharge by hydrogeological structures and regions set for wells shall not exceed the following values

- Hoktemberyan depression: 22.5 m^3/s or 709.6 $Mm^3/year$, including:
  - western part, Baghramyan and Armavir areas: 10.1 m^3/s or 318.6 $Mm^3/year$;
  - eastern part, Echmiadzin area: 12.4 m^3/s or 391.0 $Mm^3/year$;
- Sovetashen uplift, Masis area: 8.5 m^3/s or 268.0 $Mm^3/year$;
- Artashat depression: 2.2 m^3/s or 69.4 $Mm^3/year$;
- Arazdayan depression: 1.5 m^3/s or 47.3 $Mm^3/year$.

At the same time, the average annual groundwater abstraction from the artesian zone of the AAB by wells shall not exceed 15.0 m^3/s or 473.0 $Mm^3/year$, including 12.0 m^3/s or 378.4 $Mm^3/year$ for fish production. To this end, it is recommended to implement the following measures:

Technical measures.

1. In order to maintain the current level of fish production, introduce water-saving closed and semi-closed systems in all fisheries in 1-2 years, which will reduce groundwater consumption by 70.0%. It should be noted that while this Report was in preparation, two German companies made proposals on introduction of semi-closed water saving systems in the selected pilot fisheries of AAB. At the same time a Danish company carried out a 4-day workshop on introduction of similar technologies in fisheries. However, implementation of pilot projects has not started yet, and the results will be available in the coming months.
2. After completion of the recommended inventory, close down temporarily or liquidate the required number of wells to reduce abstraction by artesian wells taking into account the wells' impact radius and technical state; convert other wells into valve operation regime.
3. Simultaneously with regulation of the abstraction regime in the AAB as it is specified by the regions, carry out mandatory monitoring of all fisheries with introduction of remote control system as a pilot project.
4. In order to get complete data on the quantity and quality of AAB groundwater, expand the existing benchmark monitoring network by at least 15 observation points covering all five hydrogeological structures.
5. Simultaneously with regulation of water abstraction within the artesian zone, liquidate existing 348 emergency, unsanitary and abandoned ownerless wells (according to inventory data of (2006-2007).

6. In order to restore the artesian zone of ABB to its 1984 state, strictly prohibit drilling of new wells in the depression cone area, including drilling of wells for which WUPs were issued, but were not drilled yet.

Legal and institutional measures

7. Based on the results of new inventory and provided recommendations, re-formulate WUPs issued for fishery and other purposes, taking into account the average annual abstraction by wells in accordance with hydrogeological structures and areas specified in this chapter.
8. Strengthen the control and supervision over water abstraction quotas and limitations by wells with and without WUPs.
9. Govern by approved recoverable/usable groundwater resources and by water use priorities established by legislation while elaborating sectoral development conceptual programs.
10. Ensure conjunctive management and protection of Armenia's surface and groundwater (including fresh, mineral, thermal) resources.
11. Improve regular data and communication exchange between state agencies involved in investigation, management and protection of groundwater resources, ensure maintenance of State Water Cadastre and provision of data and information from the Cadastre.
12. Establish regulations for providing borehole drilling permits for groundwater resource use. According to that regulation, the borehole drilling permission should be obtained before getting a water use permit.
13. Make amendments to the Water Code of the RA and Land Code of the RA to fill the gap in the area of investigation, management and protection of groundwater resources (fresh, mineral and thermal) and to eliminate the discrepancies.
14. Establish the values of recoverable (natural) groundwater resources, national water resources, usable water resources and strategic resources according to Chapter 2, Article 4, Cl. 2 of the RA Law on "National Water Program" (implementation of long term (2015-2020) activities program).

The Team of Experts thinks that duly implementation of the above presented measures will support recovery of the hydrogeological characteristics of groundwater aquifers and restoration of the artesian zone area of Ararat Valley. As a result, the water supply of communities now deprived of water will be restored by artesian wells. In particular, we think that after completion of the recommended inventory and limiting the abstraction by wells within 1-2 years as recommended, the natural flow of Sevjur-Aknalich springs will start to recover and within 3-4 years the flow of the Metsamor River will gradually be restored.

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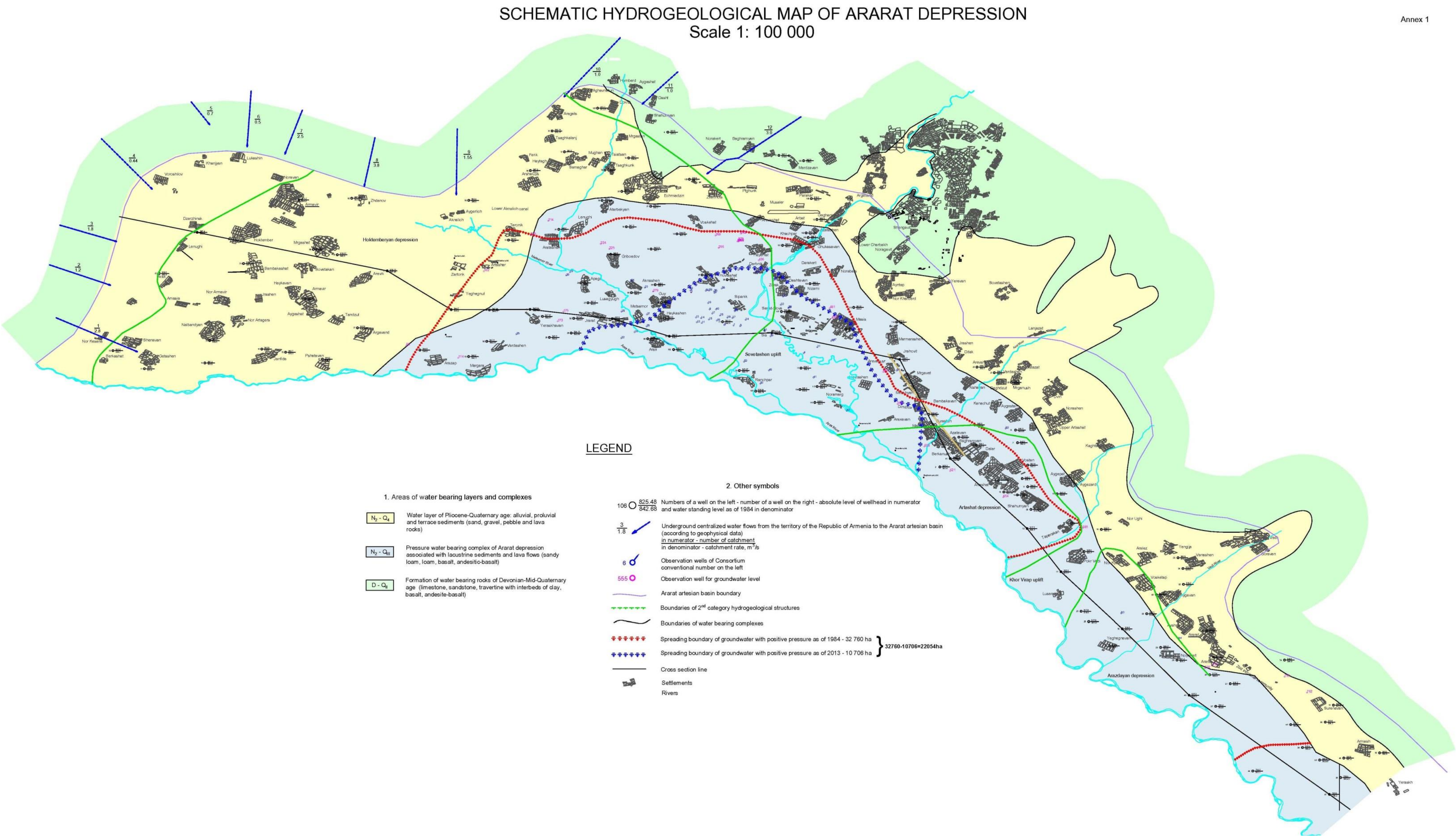
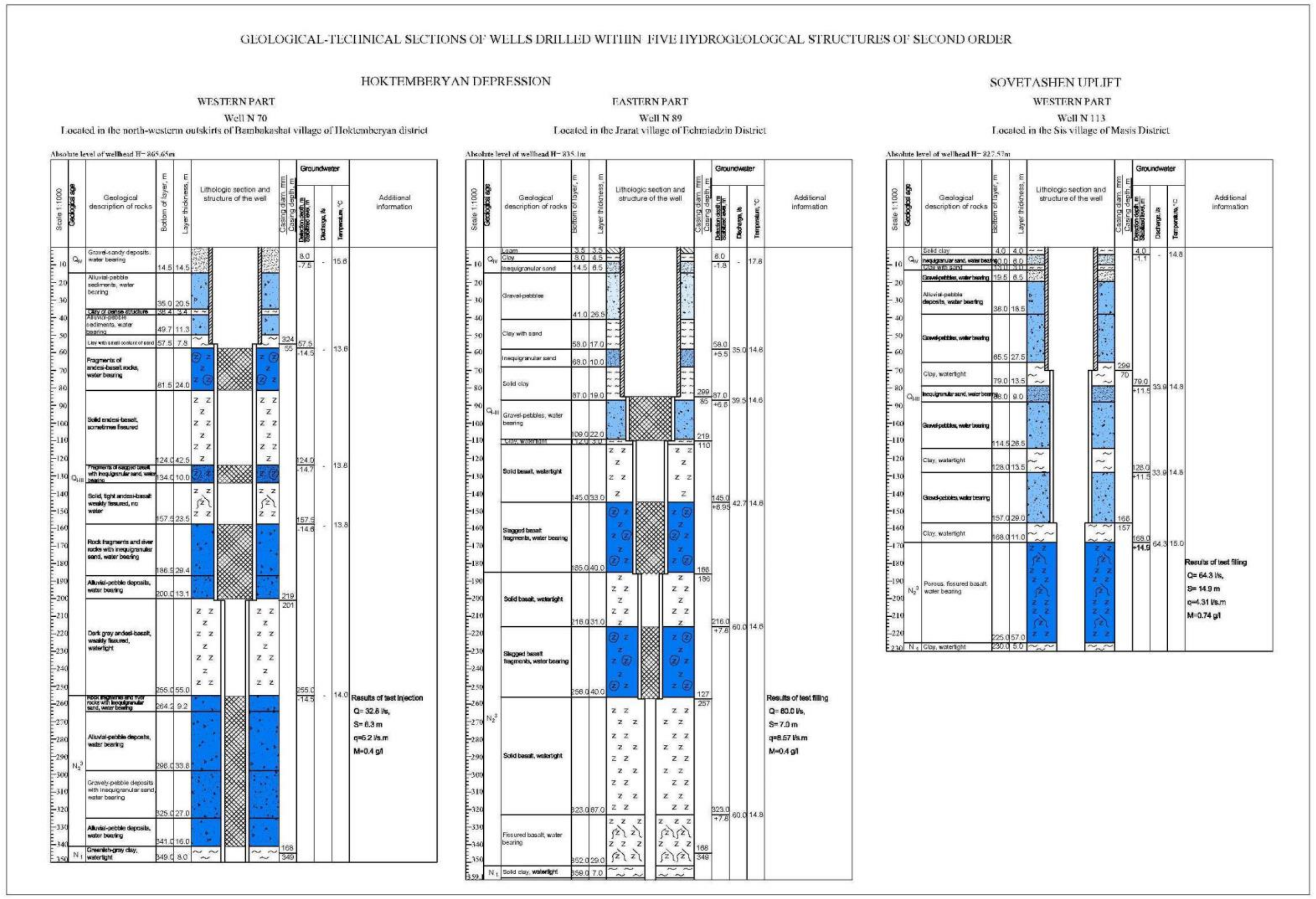
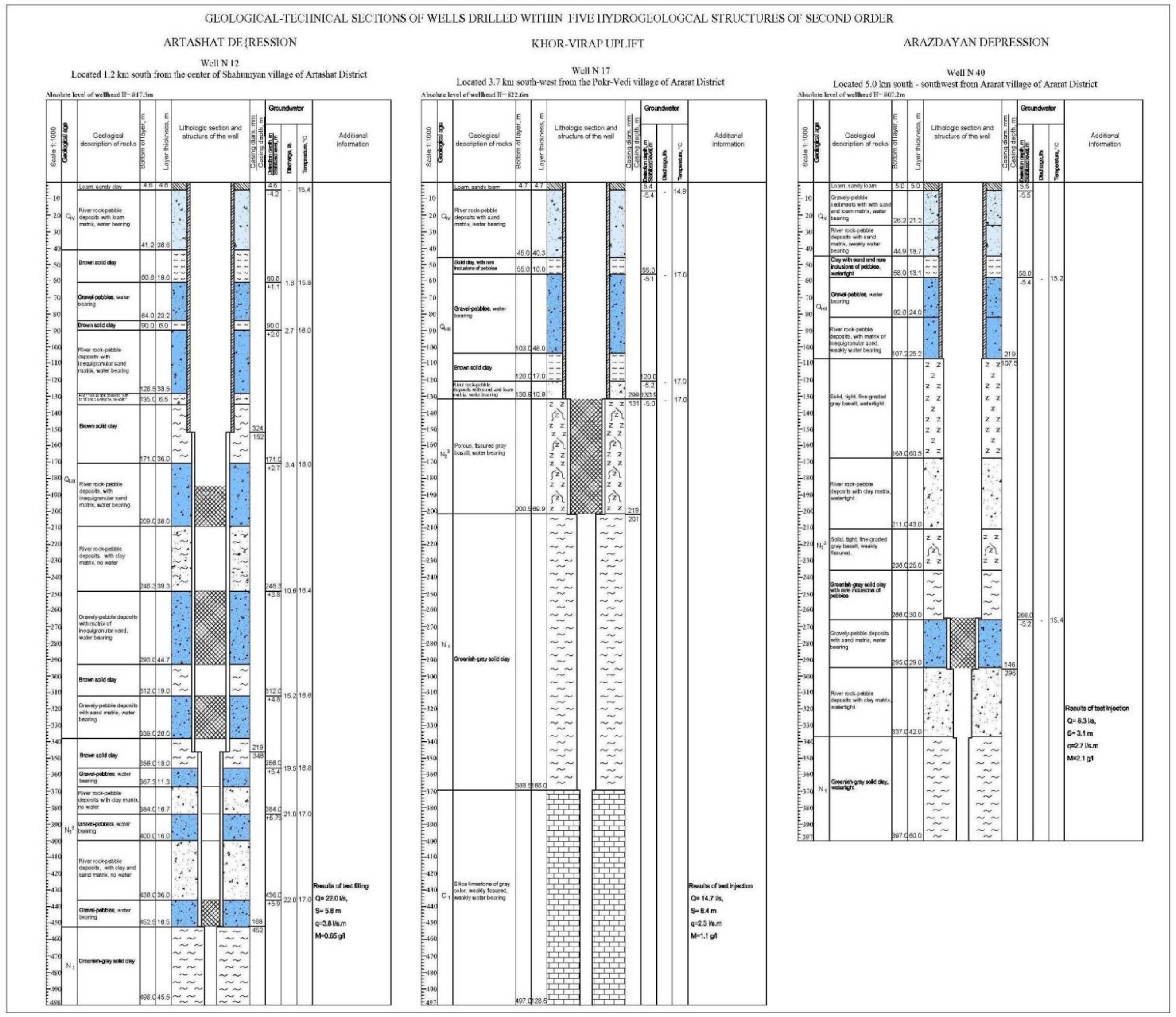
ANNEX 1. SCHEMATIC HYDROGEOLOGICAL MAP OF ARARAT DEPRESSION

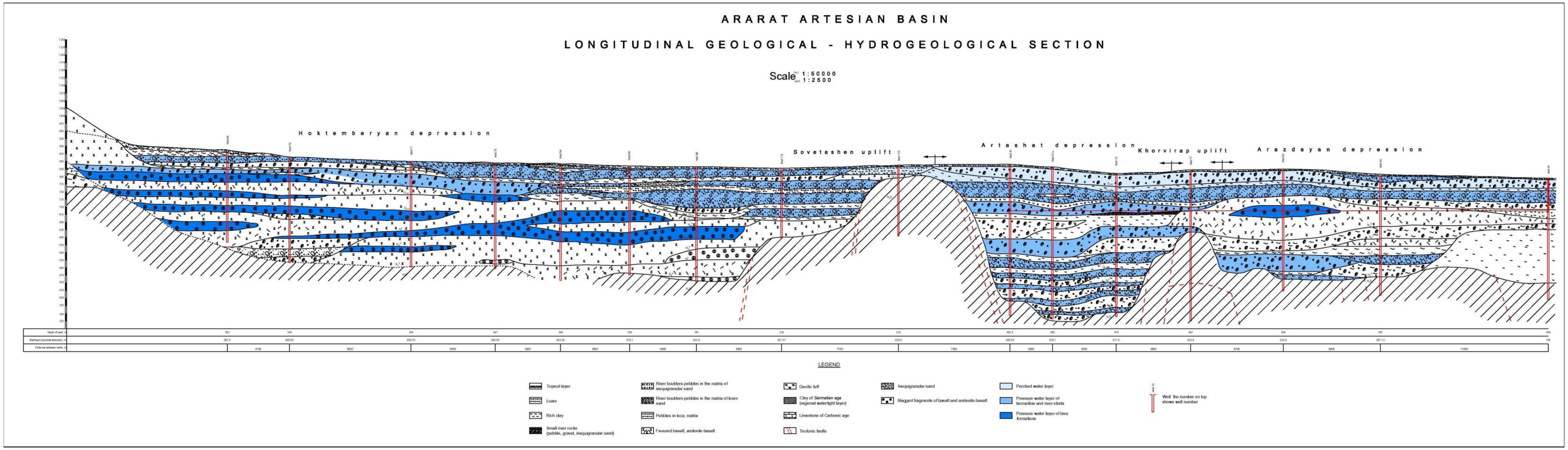


ANNEX 2. GEOLOGICAL-TECHNICAL SECTIONS OF WELLS DRILLED IN FIVE HYDROGEOLOGICAL STRUCTURES OF SECOND ORDER





ANNEX 3. LONGITUDINAL GEOLOGICAL-LITHOLOGICAL SECTION OF ARARAT ARTESIAN BASIN



ANNEX 4. WATER DISCHARGE AND WATER LEVEL MEASUREMENT RESULTS IN RANDOMLY SELECTED WELLS OF AAB

No	Community and water user name	Well number (conditional/field) and hypsometric elevation, m	Well coordinates Northern latitude-X, Eastern Longitude -Y	Well yield (Q, l/d) and level (H-m) or pressure (H+m)									Average Q - l/s H - m	Year/Q Year/H	Difference - decrease + increase
				Month, day											
				V			VIII			XI					
				2	12	22	2	12	22	2	12	22			
Armavir Marz															
1	Gai Vahan Azatyan	1 0 835.6	X=40^{O} 05’25.1” Y=44^{O} 19’32.3”	103.0	101.0	100.0	98.0	100.0	103.0	110.0	111.0	110.0	104.0	2011/117.0	-13.0
				+3.8	+3.8	+3,7	+3.7	+3.7	+3.8	+4.1	+4.1	+4.1	+3.9	+4.3	-0.4
2	Gai Vahan Azatyan	2 0 830.0	X=40^{O} 05’30.0” Y=44^{O} 19’30.2”	46.0	44.0	44.0	44.0	44.0	44.0	45.0	44.0	44.0	44.3	2011/51.0	-6.7
				0	0	0	0	0	0	0	0	0	0	0	0
3	Gai Marine Nazaryan	3 0 838.0	X=40^{O} 05’33.7” Y=44^{O} 19’33.1”	131.0	131.0	131.0	131.0	130.0	130.0	132.0	132.0	132.0	131.1	2011/132.0	-0.9
				0	0	0	0	0	0	0	0	0	0	0	0
4	Gai Kalipse Manukyan	4 0 833.0	X=40^{O} 02’48.8” Y=44^{O} 24’21.3”	84.0	83.5	83.5	83.0	83.0	83.0	83.0	83.0	83.0	83.2	2011/85.0	-1.8
				0	0	0	0	0	0	0	0	0	0	0	0
5	Gai Vladimir Mkrtchyan	5 0 832.0	X=40^{O} 05’42.6” Y=44^{O} 19’44.0”	39.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.1	2011/42.0	-3.9
				+4.4	+4.3	+4.3	+4.3	+4.3	+4.3	+4.3	+4.3	+4.3	+4.3	+4.7	-0.4
6	Gai	6 2/3 829.2	X=40^{O} 03’58.3” Y=44^{O} 21’38.0”	75.0	76.0	78.0	83.0	84.0	84.0	85.0	84.0	84.0	81.4	1981/190.0 2005/162.0 2011/75.0	-108.6 -80.6 +6.4
				+6.1	+6.1	+6.3	+6.7	+6.8	+6.8	+6.9	+6.8	+6.8	+6.6	1981/+15.48 2005/+13.2 2011/+6.1	-8.88 -6.6 +0.5
7	Gai	7 3/3 829.4	X=40^{O} 03’59.9” Y=44^{O} 21’21.3”	21.0	21.0	21.0	22.0	22..0	23.0	25.0	25.0	25.0	22.8	1981/170.0 2005/132.0 2011/21.0	-147.2 -109.2 +1.8
				+1.9	+1.9	+1.9	+2.0	+2.0	+2.1	+2.4	+2.4	+2.4	+2.1	1981/+15.43 2005/+12.0 2011/+1.9	-13.33 -9.9 +0.2
8	Gai	8 4/3 829.7	X=40^{O} 04’01.2” Y=44^{O} 20’57.4”	54.0	54.0	55.0	55.0	56.0	56.0	57.0	57.0	57.0	55.7	1981/137.0 2005/78.0 2011//55.0	-81.3 -22.3 +0.7
				+6.0	+6.0	+6.1	+6.1	+6.2	+6.2	+6.3	+6.3	+6.3	+6.2	1981/+15.31 2005/+8.85 2011/+6.1	-9.11 -2.65 +0.1
9	Gai	9 2/4 829.95	X=40^{O} 04’41.1” Y=44^{O} 20’19.5”	79.0	80.0	80.0	81.0	83.0	84.0	85.0	86.0	85.0	82.6	1981/160.0 2005/115.0 2011/80.0	-77.4 -32.4 +2.6
				+7.3	+7.4	+7.4	+7.5	+7.7	+7.8	+7.9	+8.0	+7.9	+7.7	1981/+14.91 2005/+10.72 2011/+7.4	-7.21 -3.02 +0.3

10	Gai	10 3/4 830.3	X=40^{O} 04’57.6” Y=44^{O} 20’15.7”	105.0	105.0	105.0	107.0	109.0	111.0	113.0	115.0	114.0	109.3	1981/180.0 2005/140.0 2011/105.0	-70.7 -30.7 +4.3
				+8.8	+8.8	+8.8	+8.9	+9.1	+9.3	+9.4	+9.6	+9.5	+9.1	1981/+15.02 2005/+11.68 2011/+8.8	-5.92 -2.58 +0.3
11	Haykashen	11 5/3 830.8	X=40^{O} 04’06.5” Y=44^{O} 19’59.4”	77.0	80.0	80.0	81.0	82.0	84.0	85.0	85.0	85.0	82.1	1981/130.0 2005/94.0 2011/80.0	-47.9 -11.9 +2.1
				+8.1	+8.4	+8.4	+8.5	+8.6	+8.8	+8.9	+8.9	+8.9	+8.6	1981/+13.63 2005/+9.5 2011/+8.4	-5.03 -0.9 +0.2
12	Haykashen	12 6/3 831.1	X=40^{O} 04’08.2” Y=44^{O} 19’46.7”	113.0	113.0	114.0	114.0	116.0	118.0	121.0	123.0	122.0	117.1	1981/225.0 2005/143.0 2011/115.0	-107.9 -25.9 +2.1
				+6.7	+6.7	+6.8	+6.8	+6.9	+7.0	+7.1	+7.3	+7.2	+6.9	1981/+13.31 2005/+8.46 2011/+6.8	-6.41 -1.56 +0.1
13	Haykashen	13 7/3 831.1	X=40^{O} 04’20.5” Y=44^{O} 19’44.4”	16.0	16.0	17.0	18.0	19.0	20.0	21.0	21.0	21.0	18.8	1981/187.0 2005/180.0 2011/17.0	-168.2 -161.2 +1.8
				+1.1	+1.1	+1.2	+1.3	+1.3	+1.4	+1.5	+1.5	+1.5	+1.3	1981/+13.03 2005/+12.54 2011/+1.2	-11.73 -11.24 +0.1
14	Haykashen	14 8/3 831.0	X=40^{O} 04’18.6” Y=44^{O} 19’57.9”	11.0	11.0	11.0	12.0	12.0	13.0	14.0	14.0	14.0	12.4	1981/130.0 2005/70.0 2011/12.0	-117.6 -57.6 +0.4
				+1.1	+1.1	+1.1	+1.3	+1.3	+1.4	+1.5	+1.5	+1.5	+1.3	1981/+13.5 2005/+7.27 2011/+1.3	-12.2 -5.97 0
15	Haykashen	15 9/3 829.9	X=40^{O} 04’15.4” Y=44^{O}20’17.8”	87.0	87.0	88.0	89.0	91.0	92.0	94.0	95.0	94.0	90.8	1981/178.0 2005/150.0 2011/95.0	-87.2 -59.2 -4.2
				+6.7	+6.7	+6.9	+7.0	+7.2	+7.2	+7.3	+7.4	+7.3	+7.1	1981/+13.85 2005/+11.67 2011/+7.4	-6.75 -4.57 -0.3
16	Haykashen	16 10/3 829.8	X=40^{O} 04’12.6” Y=44^{O}20’38.3”	130..0	130.0	132.0	134.0	135.0	136.0	137.0	137.0	137.0	134.2	1981/200.0 2005/175.0 2011/133.0	-65.8 -40.8 +1.2
				+9.1	+9.1	+9.2	+9.4	+9.4	+9.5	+9.6	+9.6	+9.6	+9.4	1981/+13.96 2005/+12.21 2011/+9.3	-4.56 -2.81 +0.1
17	Haykashen	17 11/3 829.7	X=40^{O} 04’30.9” Y=44^{O}20’26.2”	164.0	164.0	165.0	166.0	167.0	166.0	168.0	167.0	167.0	166.0	1981/200.0 2005/172.0 2011/164.0	-34.0 -6.0 +2.0
				+11.7	+11.7	+11.8	+11.8	+11.9	+11.9	+12.0	+12.0	+12.0	+11.9	1981/+14.36 2005/+12.3 2011/+11.7	-2.46 -0.4 +0.2

18	Jrarat Vardanik Poghosyan	18 0 833.0	X=40^{O} 03’42.9” Y=44^{O}17’06.7”	36.0	35.0	35.0	34.5	35.0	35.0	35.0	35.0	35.0	35.1	2011/68.5	-33.4
				0	0	0	0	0	0	0	0	0	0	0	0
19	Apaga Zoya Pogosyan	19 0 837.0	X=40^{O} 06’17.2” Y=44^{O}14’21.1”	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	2011/30.2	-30.2
				0	0	0	0	0	0	0	0	0	0	0	0
20	Apaga Vrejuhi Twvmasyan	20 0 839.0	X=40^{O} 06’08.7” Y=44^{O}14’11.5”	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	2011/27.0	-27.0
				0	0	0	0	0	0	0	0	0	0	0	0
21	Araks Hovakim Hovakimyan	21 0 837.0	X=40^{O} 02’34.4” Y=44^{O}20’02.8”	42.0	40.0	40.0	40.0	39.0	39.0	39.0	39.0	39.0	39.7	2003/90.0 2011/61.0	-50.3
				0	0	0	0	0	0	0	0	0	0	0	0
22	Araks Gagik Poghosyan	22 0 937.0	X=40^{O} 03’27.7” Y=44^{O}16’32.7”	43.0	43.0	43.0	42.0	42.0	42.0	42.0	42.0	42.0	42.3	2011/69.5	-27.2
				0	0	0	0	0	0	0	0	0	0	0	0
23	Aknashen Laert Terteryan	23 0 837.0	X=40^{0} 05’37.3” Y=44^{0}17’33.5”	36.0	35.0	35.0	32.0	32.0	32.0	30.0	30.0	31.0	32.6	2011/44.8	-12.2
				0	0	0	0	0	0	0	0	0	0	0	0
24	Aknashen “Haluf” LLC	24 0 842.0	X=40^{0} 05’54.6” Y=44^{0} 16’58.2”	30.0	30.0	30.0	30.0	29.5	29.5	29.5	29.5	30.0	29.8	2011/30.0	-0.2
				0	0	0	0	0	0	0	0	0	0	0	0
25	Lusaghyug Hovsep Zetilyan	25 0 840.0	X=40^{O} 04’35.53” Y=44^{O} 16’33.33”	28.5	28.0	28.0	26.5	25.0	24.0	21.0	20.5	20.5	24.7	2011/30.5	-5.8
				0	0	0	0	0	0	0	0	0	0	0	0
26	Metsamor Rafik Safaryan	26 0 832.5	X=40^{O} 03’57.7” Y=44^{O}17’37.70”	46.0	44.0	44.0	40.0	38.5	38.5	38.5	38.0	38.0	40.6	2011/67.0	-26.4
				0	0	0	0	0	0	0	0	0	0	0	0
27	Metsamor Gaspar Ayvazyan	27 0 834.5	X=40^{O} 04’28.4” Y=44^{O} 17’38.7”	56.0	55.5	55.5	54.0	50.0	46.0	42.0	42.0	43.0	49.3	2011/64.5	-15.2
				0	0	0	0	0	0	0	0	0	0	0	0
28	Vardanashen	28 192 840.3	X=40^{0}03' 37.7" Y=44^{0}12' 03.3"	0	0	0	0	0	0	0	0	0	0	2009/4.5	0
				-0.12	-012	-012	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12	-0.12	2009/+0.52	-0.64
Ararat Marz															
29	Sayat-Nova “Bigama Frut” LLC	29 0 831.0	X=40^{O} 04’45.0” Y=44^{O}23’42.2”	84.0	83.0	82.0	80.0	79.0	79.0	78.0	78.0	78.0	80.1	2011/119.5	-39.4
				0	0	0	0	0	0	0	0	0	0	0	0
30	Sayat-Nova “Bigama Frut” LLC	30 0 830.7	X=40^{O} 04’46.1” Y=44^{O}23’42.6”	71.0	67.0	67.0	65.0	63.0	63.0	62.0	62.0	62.0	64.7	2011/97.0	-32.3
				0	0	0	0	0	0	0	0	0	0	0	0
31	Sayat-Nova “Yunifish” LLC	31 0 828.0	X=40^{O} 03’04.3” Y=44^{O}24’56.1”	102.0	102.0	102.5	102.0	101.0	101.0	100.0	100.0	100.0	101.2	2011/122.0	-20.8
				0	0	0	0	0	0	0	0	0	0	0	0
32	Zorak, in the field	32 0 830.0	X=40^{O} 04’53.1” Y=44^{O}23’22.3”	121.0	120.0	120.0	120.0	119.0	119.0	119.0	120.0	120.0	119.8	2011/135.0	-15.2
				0	0	0	0	0	0	0	0	0	0	0	0

33	Zorak, near school	33 0 832.0	X=40° 05’14.3” Y=44°23’28.5”	44.0	42.0	42.0	40.0	39.0	39.0	39.0	39.0	39.0	40.3	2011/52.0	-11.7
				0	0	0	0	0	0	0	0	0	0	0	0
34	Sipanik	34 1/3 829.1	X=40° 04’14.6” Y=44°21’52.1”	127.0	130.0	130.0	134.0	140.0	140.0	142.0	142.0	141.0	136.2	1981/256.0 2005/250.0 2011/127.0	-119.8 -113.8 +9.2
				+8.2	+8.3	+8.3	+8.7	+9.0	+9.0	+9.2	+9.2	+9.1	+8.8	1981/+16.54 2005/+16.2 2011/+8.2	-7.74 -7.4 +0.6
35	Sipanik	35 12/3 829.5	X=40° 04’25.5” Y=44°20’46.4”	10.0	10.5	10.5	10.6	10.8	10.8	11.0	11.0	11.0	10.7	1981/192.0 2005/172.0 2011/14.0	-181.3 -161.3 -3.3
				+0.8	+0.8	+0.8	+0.8	+0.8	+0.8	+0.9	+0.9	+0.9	+0.8	1981/+14.88 2005/+13.33 2011/+1.1	-14.08 -12.53 -0.3
36	Sipanik	36 13/3 829.7	X=40° 04’20.3” Y=44°21’05.1”	11.0	11.0	11.0	12.0	12.0	13.0	14.0	14.0	14.0	12.4	1981/210.0 2005/180.0 2011/12.0	-197.6 -167.6 +0.4
				+0.8	+0.8	+0.8	+0.9	+0.9	+1.0	+1.0	+1.0	+1.0	+0.9	1981/+15.93 2005/+13.65 2011/+0.9	-15.03 -12.75 0
37	Sipanik	37 14/3 829.0	X=40° 04’19.2” Y=44°21’18.5”	138.0	140.0	140.0	143.0	144.0	144.0	146.0	148.0	147.0	143.3	1981/187.0 2005/175.0 2011/154.0	-43.7 -31.7 -10.7
				+12.0	+12.0	+12.0	+12.4	+12.5	+12.5	+12.7	+12.9	+12.8	+12.4	1981/+16.3 2005/+15.25 2011/+13.4	-3.9 -2.85 -1.0
38	Sipanik	38 15/3 829.2	X=40° 04’36.7” Y=44°21’24.2”	62.0	62.0	62.0	64.0	64.0	65.0	67.0	68.0	68.0	64.7	1981/155.0 2005/136.0 2011/70.0	-90.3 -71.3 -5.3
				+6.7	+6.7	+6.7	+6.9	+6.9	+7.0	+7.2	+7.3	+7.3	+7.0	1981/+16.7 2005/+14.6 2011/+7.5	-9.7 -7.6 -0.5
39	Sipanik	39 16/3 829.3	X=40° 04’ 38.2” Y=44° 21’23.9”	25.0	25.0	25.0	26.0	27.0	27.0	29.0	29.0	28.0	26.8	1981/80.0 2005/59.0 2011/32.0	-53.2 -32.2 -5.2
				+5.2	+5.2	+5.2	+5.4	+5.7	+5.7	+5.9	+5.9	+5.8	+5.6	1981/+16.51 2005/+9.77 2011/+6.6	-10.91 -4.17 -1.0
40	Sipanik	40 1/4 829.9	X=40° 04’41.2” Y=44° 20’36.0”	92.0	93.0	93.0	97.0	101.0	101.0	103.0	104.0	104.0	98.7	1981/185.0 2005/141.0 2011/106.0	-86.3 -42.3 -7.3
				+7.7	+7.8	+7.8	+8.3	+8.5	+8.5	+8.7	+8.8	+8.8	+8.3	1981/+15.62 2005/+9.2 2011/+8.9	-7.32
41	Noramarg	41	X=40° 01’46.2”	142.0	142.0	142.0	140.0	140.0	140.0	141.0	142.0	141.0	141.1	0	0

	“Pun Vip Shop” LLC	0 826.0	Y=44°24’46.4”	0	0	0	0	0	0	0	0	0	0	0	0
42	Noramarg Artashes Papikyan	42 0 826.0	X=40° 00’21.0” Y=44°26’11.8”	163.0	163.0	162.0	160.0	160.0	160.0	162.0	162.0	162.0	161.6	0	0
				0	0	0	0	0	0	0	0	0	0	0	0
43	Darbnik, in field	43 0 834.1	X=40° 06’27.8” Y=44°22’41.4”	160.0	159.0	159.0	159.0	157.0	157.0	157.0	159.0	158.0	158.3	2007/180.0	-21.7
				+7.7	+7.7	+7.7	+7.7	+7.6	+7.6	+7.6	+7.7	+7.7	+7.7	2007//+8.7	-1.0
44	Darbnik Smbat Avetisyan	44 0 827.0	X=40° 06’16.32” Y=44° 22’18.6”	136.0	136.0	136.0	135.0	134.0	134.0	134.0	135.0	134.0	134.9	2011/153.0	-18.1
				0	0	0	0	0	0	0	0	0	0	0	0
45	Dashtavan Gagik Babayan	45 0 826.5	X=40° 06’00.4” Y=44°23’05.3”	78.0	76.5	76.5	75.0	74.0	74.0	75.0	75.0	75.0	75.4	2011/89.6	-14.2
				0	0	0	0	0	0	0	0	0	0	0	0
46	Dashtavan Hamlet Babayan	46 0 835.0	X=40° 05’56.5” Y=44°23’04.5”	91.0	88.2	88.2	85.0	83.5	83.5	84.0	84.0	83.5	85.7	2011/220.0	-134.3
				0	0	0	0	0	0	0	0	0	0	0	0
47	Masis	47 0 829.0	X=40° 03’21.8” Y=44°25’38.0”	82.0	82.0	82.0	81.0	80.0	80.0	81.0	82.0	81.0	81.2	2000/128.0	-46.8
				0	0	0	0	0	0	0	0	0	0	0	0
48	Masis	48 0 829.4	X=40° 03’20.5” Y=44°25’31.9”	2.9	2.9	2.9	2.9	2.9	2.9	3.0	3.0	3.0	2.9	2000/15.0	-12.1
				+1.8	+1.8	+1.8	+1.8	+1.8	+1.8	+1.9	+1.9	+1.9	+1.8	2000/+9.5	-7.7
49	Sis Harutyun Harutyunyan	49 0 829.0	X=40° 02’04.5” Y=44°22’52.1”	55.7	54.5	54.5	54.0	52.0	52.0	53.0	53.0	52.0	53.4	2011/56.2	-2.8
				0	0	0	0	0	0	0	0	0	0	0	0
50	Sis Ara Khalatyan	50 0 833.0	X=40° 03’32.4” Y=44°22’55.8”	82.0	80.0	80.0	80.0	81.0	81.0	81.0	80.0	81.0	80.7	2011/77.0	+3.7
				0	0	0	0	0	0	0	0	0	0	0	0
51	Sis	51 1535 834,6	N - 40˚ 03' 47.3" E - 44˚ 22' 38.9"	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2010/2.3	-1.3
				+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	2010/+6.9	-3.9
52	Ranchpar “Arsen Tevuni” LLC	52 0 829.0	X=40° 02’27.2” Y=44°21’48.0”	236.0	233.0	233.0	232.0	230.0	230.0	232.0	231.0	231.0	231.0	2011/246.3	-15.3
				0	0	0	0	0	0	0	0	0	0	0	0
53	Ranchpar “Martirosyan Vilena” IE	53 0 830.0	X=40° 01’30.7” Y=44°22’29.9”	11.2	10.5	10.5	10.0	9.4	9.4	9.5	9.3	9.4	9.9	0	0
				0	0	0	0	0	0	0	0	0	0	0	0
54	Hovtashat Harutyun Vardanyan	54 0 839.5	X=40°06'22.74” Y=44°21'33.36”	153.0	153.0	153.0	152.0	152.0	153.0	153.0	153.0	153.0	152.8	2011/180.0	-27.8
				0	0	0	0	0	0	0	0	0	0	0	0

55	Hovtashat Misak Hakhverdyan	55 0 834.0	X=40^{O} 06’30.12” Y=44^{O} 21’57.6”	46.0	46.0	46.0	45.0	45.0	45.0	45.0	46.0	45.0	45.4	2011/50.0	-4.6
				0	0	0	0	0	0	0	0	0	0	0	0
56	Hovtashat Ruben Sahakyan	56 0 839.0	X=40^{O} 05’35.1” Y=44^{O} 20’50.7”	68.0	67.0	67.0	65.0	64.0	64.0	65.0	65.0	65.0	65.6	2011/83.0	-17.4
				0	0	0	0	0	0	0	0	0	0	0	0
57	Hovtashat	57 8/4 830.4	X=40^{O} 05’23.6” Y=44^{O}20’32.0”	11.0	11.0	11.0	11.5	11.5	12.0	12.0	12.0	12.0	11.6	1981/83.0 2005/67.0 2011/15.0	-71.4 -55.4 -3.4
				+2.1	+2.1	+2.1	+2.2	+2.2	+2.3	+2.3	+2.3	+2.3	+2.2	1981/+15.6 2005/+12.6 2011/+2.8	-13.4 -10.2 -0.6
58	Hovtashat	58 9/4 830.4	X=40^{O} 05’27.7” Y=44^{O}20’31.1”	49.0	50.0	50.0	51.0	52.0	52.0	52.0	54.0	53.0	51.4	1981/108.0 2005/66.0 2011/55.0	-56.6 -14.6 -3.6
				+7.5	+7.7	+7.7	+7.8	+8.0	+8.0	+8.0	+8.3	+8.2	+7.9	1981/+16.53 2005/+10.1 2011/+8.4	-8.63 -2.2 -0.5
59	Hovtashat	59 10/4 831.8	X=40^{O} 05’29.8” Y=44^{O}20’18.2”	30.0	31.0	31.0	32.0	32.0	34.0	34.0	34.0	33.0	32.3	1981/136.0 2005/68.0 2011/36.0	-103.7 -35.7 -3.7
				+3.1	+3.2	+3.2	+3.3	+3.3	+3.5	+3.5	+3.5	+3.4	+3.3	1981/+14.14 2005/+7.07 2011/+3.7	-10.84 -3.77 -0.4
60	Hovtashat	60 11/4 832.1	X=40^{O} 05’29.2” Y=44^{O}20’09.9”	64.0	66.0	66.0	72.0	74.0	74.0	74.0	74.0	74.0	70.9	1981/120.0 2005/102.0 2011/76.0	-49.1 -31.1 -5.1
				+7.5	+7.7	+7.7	+8.4	+8.7	+8.7	+8.7	+8.7	+8.7	+8.3	1981/+14.07 2005/+12.0 2011/+8.9	-5.77 -3.7 -0.6
61	Arevabuyr	61 195 839.85	N – 40^{0}02'04.2" E – 44^{0}28'20.5"	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	2009/4.2	-4.18
				0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	2009/+0.51	-0.5
62	Artashat	62 0 848.6	X=39^{0}59'35.3 " Y=44^{0}32'59.9"	44.4	44.4	44.4	44.4	44.4	44.4	44.4	0	0	0	0	0
				-39.5	-39.5	-39.6	-39.7	-39.5	-39.6	-39.6	-18.3	-18.3	-18.3	2009/-18.0	-0.3
63	Vosketap	63 0 824.2	X=39^{O} 51’40.9” Y=44^{O}37’56.8”	44.4	44.4	44.4	44.4	44.4	44.4	44.4	0	0	0	0	0
				-43.2	-43.1	-43.3	-43.2	-43.1	-43.2	-43.1	-21.0	-21.0	-21.0	2009/-20.8	-0.2
64	Avshar	64 0 824.8	X=39^{O} 50’36.0” Y=44^{O}40’23.8”	44.4	44.4	44.4	44.4	44.4	44.4	44.4	0	0	0	0	0
				-35.9	-36.0	-36.1	-36.0	-36.2	-36.1	-36.2	-19.3	-19.3	-19.3	2009/-18.9	-0.4