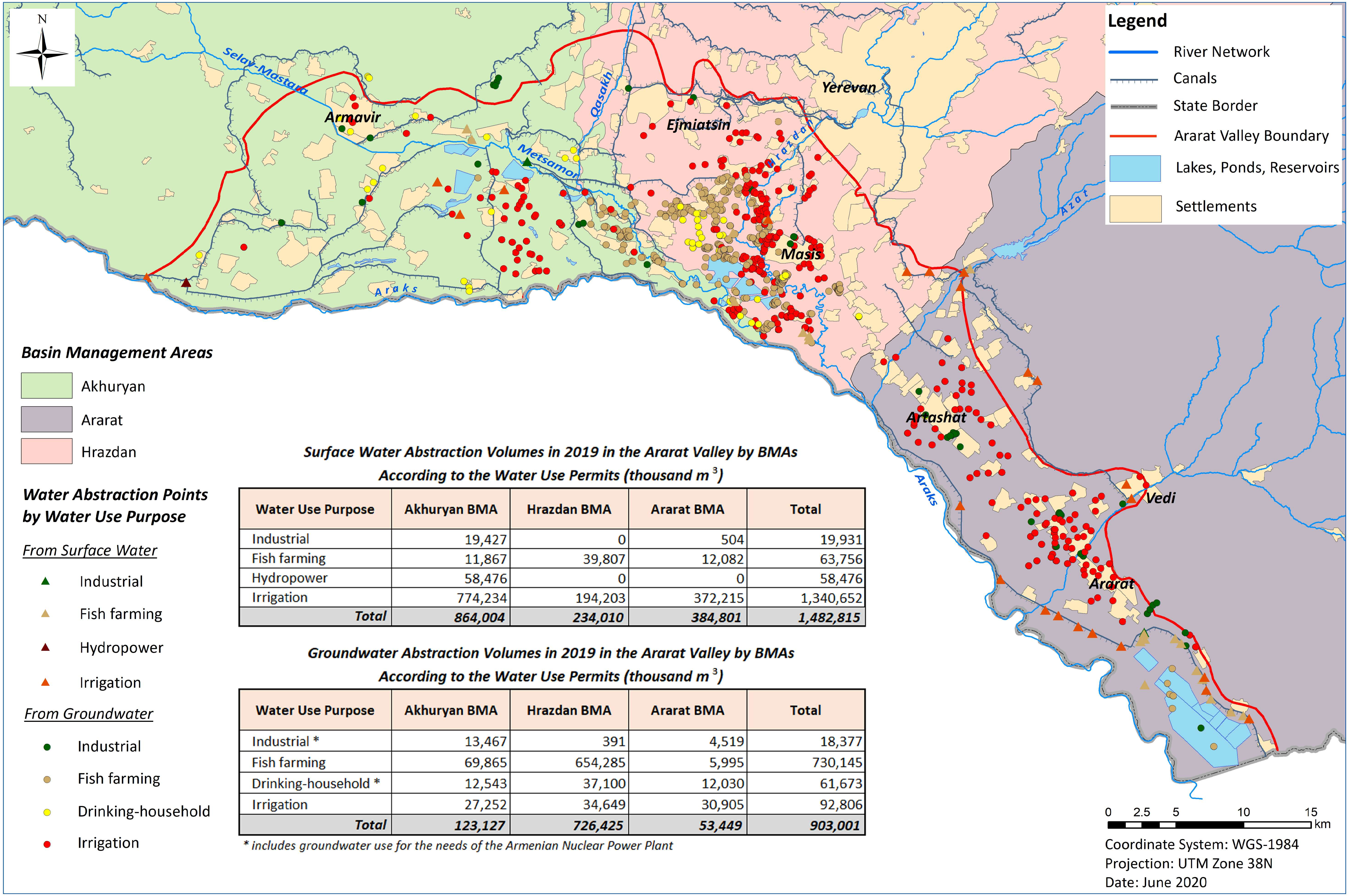
Surface Water and Groundwater Abstraction in the Ararat Valley in 2019 According to the Water Use Permits Issued by the Ministry of Environment



Surface Water Abstraction Volumes in 2019 in the Ararat Valley by BMAs According to the Water Use Permits (thousand m^3)

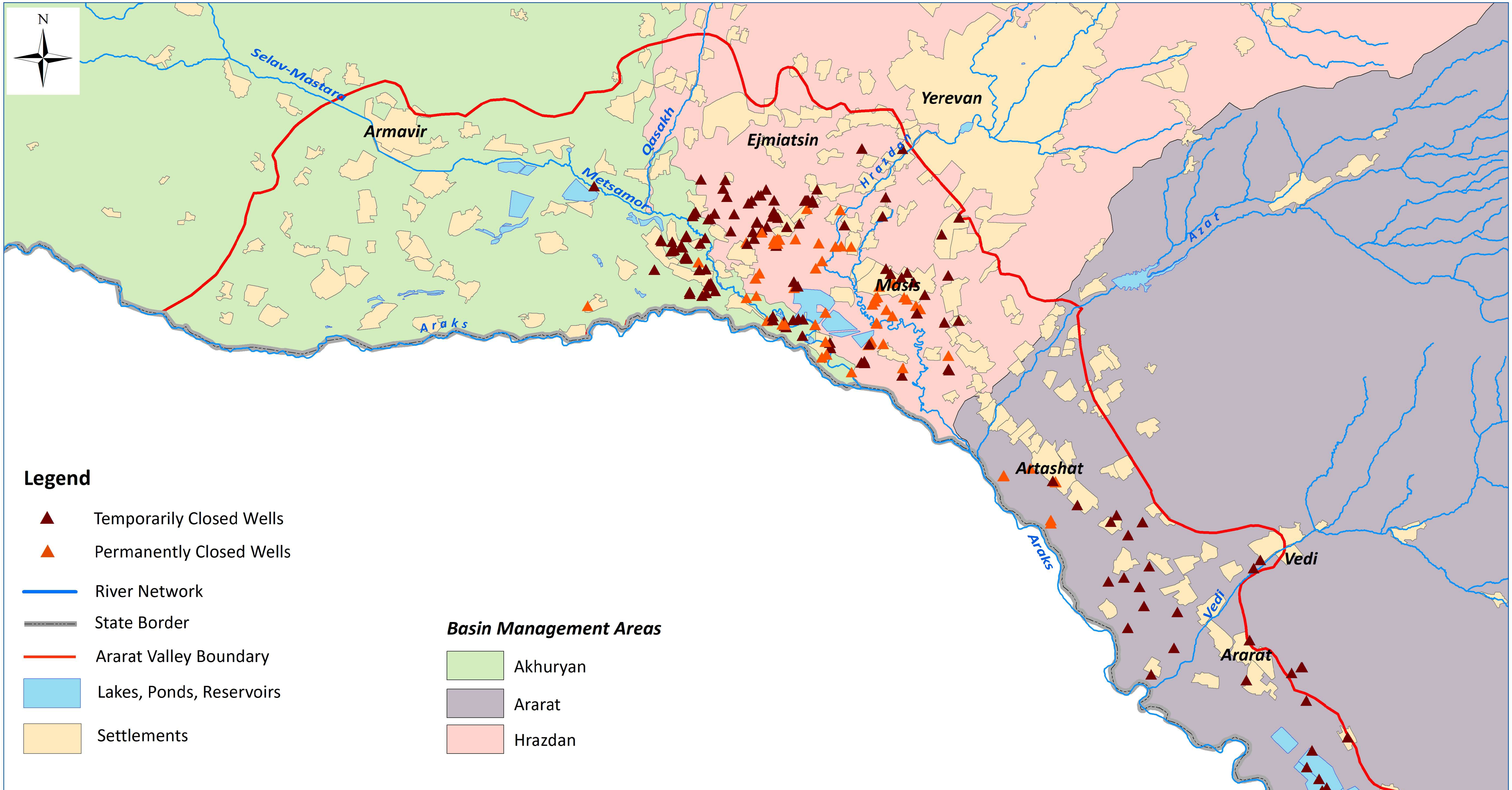
Water Use Purpose	Akhuryan BMA	Hrazdan BMA	Ararat BMA	Total
Industrial	19,427	0	504	19,931
Fish farming	11,867	39,807	12,082	63,756
Hydropower	58,476	0	0	58,476
Irrigation	774,234	194,203	372,215	1,340,652
Total	***864,004***	***234,010***	***384,801***	***1,482,815***

Groundwater Abstraction Volumes in 2019 in the Ararat Valley by BMAs According to the Water Use Permits (thousand m^3)

Water Use Purpose	Akhuryan BMA	Hrazdan BMA	Ararat BMA	Total
Industrial *	13,467	391	4,519	18,377
Fish farming	69,865	654,285	5,995	730,145
Drinking-household *	12,543	37,100	12,030	61,673
Irrigation	27,252	34,649	30,905	92,806
Total	***123,127***	***726,425***	***53,449***	***903,001***

** includes groundwater use for the needs of the Armenian Nuclear Power Plant*

Groundwater Wells Temporarily or Permanently Closed in the Ararat Valley During 2014-2020



Number of Groundwater Wells Temporarily or Permanently Closed in the Ararat Valley During 2014-2020 and Resulted Water Saving by BMAs

Wells	Akhuryan BMA			Hrazdan BMA			Ararat BMA			Total		
	Quantity	Saving liter/sec.	Saving million m^3	Quantity	Saving liter/sec.	Saving million m^3	Quantity	Saving liter/sec.	Saving million m^3	Quantity	Saving liter/sec.	Saving million m^3
Temporarily Closed	48	2,054.0	64,783.2	69	1,447.3	45,647.8	36	0.0	0.0	153	3,501.3	110,431.0
Permanently Closed	13	399.5	12,600.2	41	2,214.5	69,845.3	8	196.9	6,210.2	62	2,810.9	88,655.8
Total	***61***	***2,453.5***	***77,383.4***	***110***	***3,661.8***	***115,493.2***	***44***	***196.9***	***6,210.2***	***215***	***6,312.2***	***199,086.8***

0 2.5 5 10 15 km

Coordinate System: WGS-1984
Projection: UTM Zone 38N
Date: June 2020

Section 4. Modeling of the Ararat Valley Groundwater Basin and Assessment of Its State in 2016

Hydrogeologic Structure

The Ararat Valley has a complex tectonic and hydrogeologic structure. The valley represents a superimposed inter-mountain trough of the Araks River's tectonic zone, divided by the subsequent folding process into the following five morphological sub-divisions in west-to-east direction:

1. Hoktemberyan depression
2. Sovetashen uplift
3. Artashat depression
4. Khor Virap uplift
5. Arazdayan depression

The morphologic structures differ in their geological composition, thickness of water bearing rocks, number of aquifers, impermeable layers, and their hydraulic properties.

Pressure Boundaries

The ASPIRED Project conducted an analysis of pressure boundaries of the Ararat Valley groundwater basin (a boundary between the areas with flowing and non-flowing wells) based on the USGS Scientific Investigations Report entitled *Hydrogeologic Framework and Groundwater Conditions of the Ararat Basin in Armenia*. Spatial analysis was performed using GIS software to digitize the pressure boundaries that were generated using data available for 1984. The water level data collected during field inventory in 2007 and 2016 were analyzed to generate a raster grid of the hydraulic heads in both years using GIS software. The 2016 raster grid was then subtracted from the 2007 raster grid to determine the change in hydraulic head between 2007 and 2016. The largest decreases (more than 2 m) in hydraulic head between 2007 and 2016 fell outside the 2016 pressure boundary. Within the pressure boundary, changes in hydraulic heads were generally minimal, or indicated slight increases.

According to datasets from the 2016 well inventory, the non-flowing aquifer conditions were on the edges of the Ararat Valley groundwater basin where the basin depth becomes shallower. The flowing artesian wells were primarily in the central part of the study area. These flowing artesian wells were the primary source of water that sustained the development and growth of the aquaculture industry for the purposes of raising mainly trout and sturgeon. The artesian conditions, generally high water quality, and cool water temperature enabled aquaculture industries to thrive; however, the flowing wells reduced the artesian pressure in the aquifer. As a result, many wells that were flowing before 2000 had ceased to flow by 2016.

Analysis shows that the pressure boundary shrank between 1984 and 2016, indicating that a large area of the Ararat Artesian Basin has been affected by groundwater depletion. The area within the Ararat Valley with flowing wells (within the pressure boundary) was approximately 42,298 ha in 1984. This area decreased to 32,107 ha in 2007 and further to 22,366 ha in 2016. This is approximately a 50% reduction in area between 1984 and 2016.

Main Hydrogeologic Units of the Groundwater Basin and its 3D Model

The 3-dimentional lithologic model of the Ararat Valley groundwater basin was developed and the main hydrogeologic units of the basin were identified, using the ArcHydroGroundwater (AHGW) Tools within the ArcGIS environment. Data logs of about 2,800 wells inventoried in the Ararat Valley in 2016, including the lithologic structure and generalized descriptions of the lithology of the groundwater basin presented in the Assessment Study of Groundwater Resources of the Ararat Valley conducted in 2014 were used in the model.

Among the 2,800 wells, 24 unique lithologic layers were identified, and the water-bearing potential of each of the 24 layers was identified using interpretation of lithologic descriptions (Table 5).

Table 5: Description of the Lithologic Layers of the Ararat Valley Groundwater Basin

#	Lithologic description	Thickness (meters)			Water bearing potential
		Maximum	Minimum	Mean	
1.	Basalt with volcanic slag and sand	82	1	23.7	High
2.	Boulder pebble deposits with clay filling	88.7	1.8	22.9	Moderate
3.	Boulder pebble deposits with coarse – grained sand filling	93.2	4.5	29.1	High
4.	Boulder pebble deposits with sand – clay filling	80	4	30.1	High
5.	Clay sand	8.8	7	7.9	Low
6.	Coarse – grained sand	49.7	6	40.1	High
7.	Dense basalt andesite dacite	61.6	0.5	21.5	Low
8.	Dense clay	60	0.5	8.7	Low
9.	Fine – grained silty sand	14.6	5.8	9.3	High
10.	Gravel	89.5	1	35.0	High
11.	Gravel pebble deposits with clay filling	74.3	10	26.7	Moderate
12.	Gravel pebble deposits with coarse – grained sand and boulder filling	109.8	4	31.2	High
13.	Gravel pebble deposits with sand, clay filling	89	6	39.3	Moderate
14.	Gravel sand	89.5	4	38.7	Low
15.	Gypsiferous salt bearing clay with inter-bedded siltstone and marl and sandstone	2	2	2.0	Low
16.	Highly fractured basalt	147.8	0.2	35.6	Moderate
17.	Loam	56	0.3	5.3	Low
18.	Loam – sandy loam	39.2	3	19.2	Low
19.	Poorly cemented sandstone	11	6	7.4	High
20.	Sandy clay with inter-bedded sand pebbles and gravel	73	1	12.3	Moderate
21.	Sandy loam	70	0.4	10.9	Moderate
22.	Slangs and fragments of volcanic rocks and pumice sand	75	8	24.0	High
23.	Slightly fractured porous basalt	110	2	33.1	High
24.	Volcanic tuff	15	8	11.3	Low

The top elevations of the wells were adjusted with the LandSAT 30-meter digital elevation model (DEM), available through the USGS Earth Explorer website (https://earthexplorer.usgs.gov). Hydrogeologic unit thicknesses and top and bottom elevations were then adjusted using the updated well top elevations. The final corrected lithologic elevations were used to group the lithologic descriptions into larger units (Figure 9).

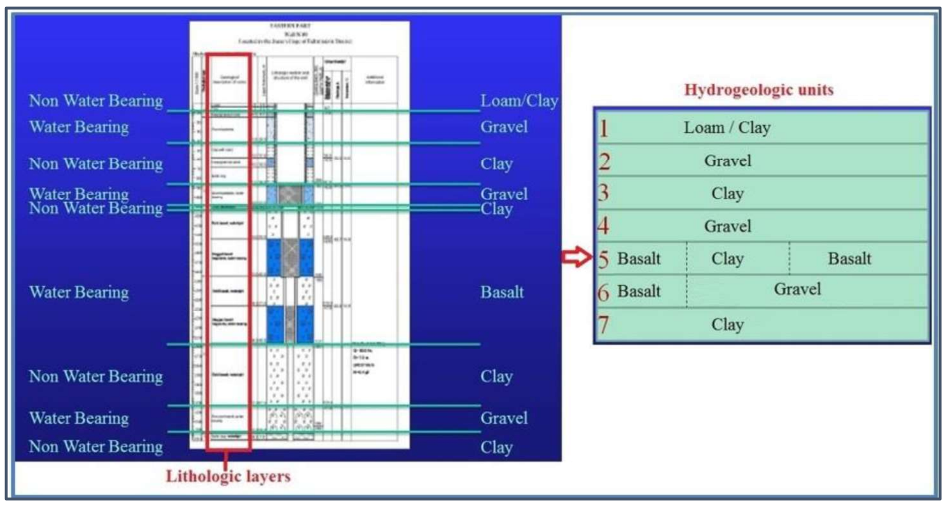


Figure 9: Grouping the Lithologic Layers into the Main Hydrogeologic Units

As a next step, the lithologic structures of each of the 2,800 wells were grouped into the seven main hydrogeologic units (Figure 10).

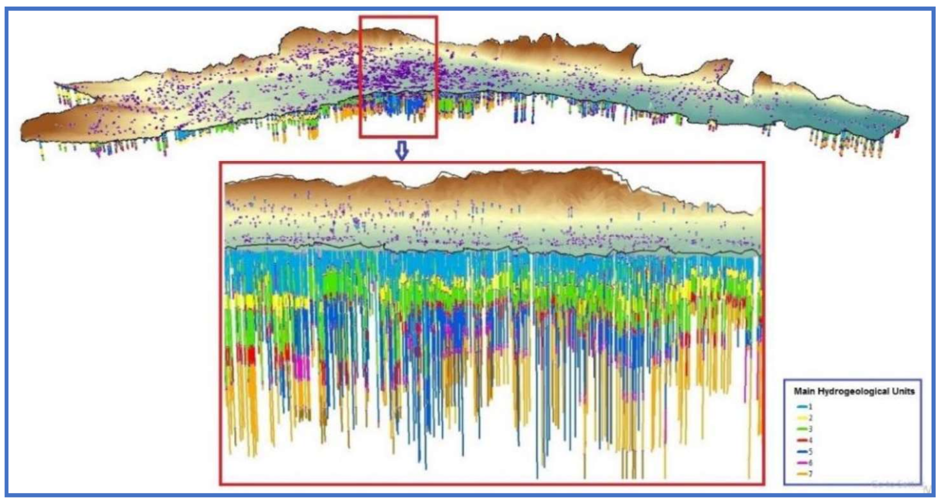


Figure 10: Generating the Main Hydrogeologic Units of the Ararat Valley Groundwater Basin

Finally, the geo-rasters were constructed using the AHGW Tools in the ArcGIS environment, by the following approach:

- The first geo-raster presents the bottom of the deepest hydrogeologic unit;
- The second geo-raster presents the bottom of the second hydrogeologic unit which corresponds to the ceiling of the deepest hydrogeologic unit;
- The last geo-raster presents the bottom of the uppermost hydrogeologic unit which corresponds to the ceiling of the second uppermost hydrogeologic unit;
- The DEM is considered the ceiling of the uppermost hydrogeologic unit.

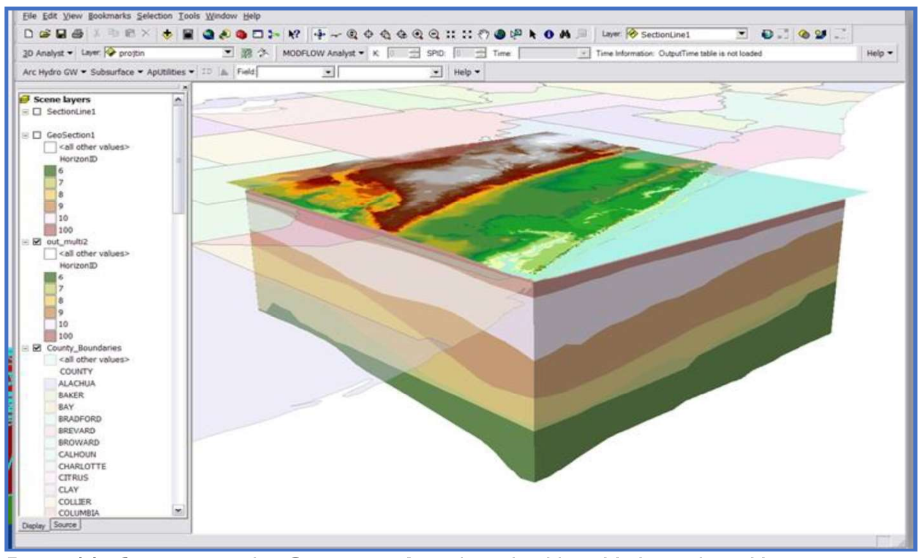


Figure 11: Constructing the Geo-rasters Based on the Main Hydrogeologic Units

Main Outcomes

The modeling of the Ararat Valley groundwater basin identified the following main hydrogeologic units (Table 6).

Table 6: Main Hydrogeologic Units of the Ararat Valley Groundwater Basin

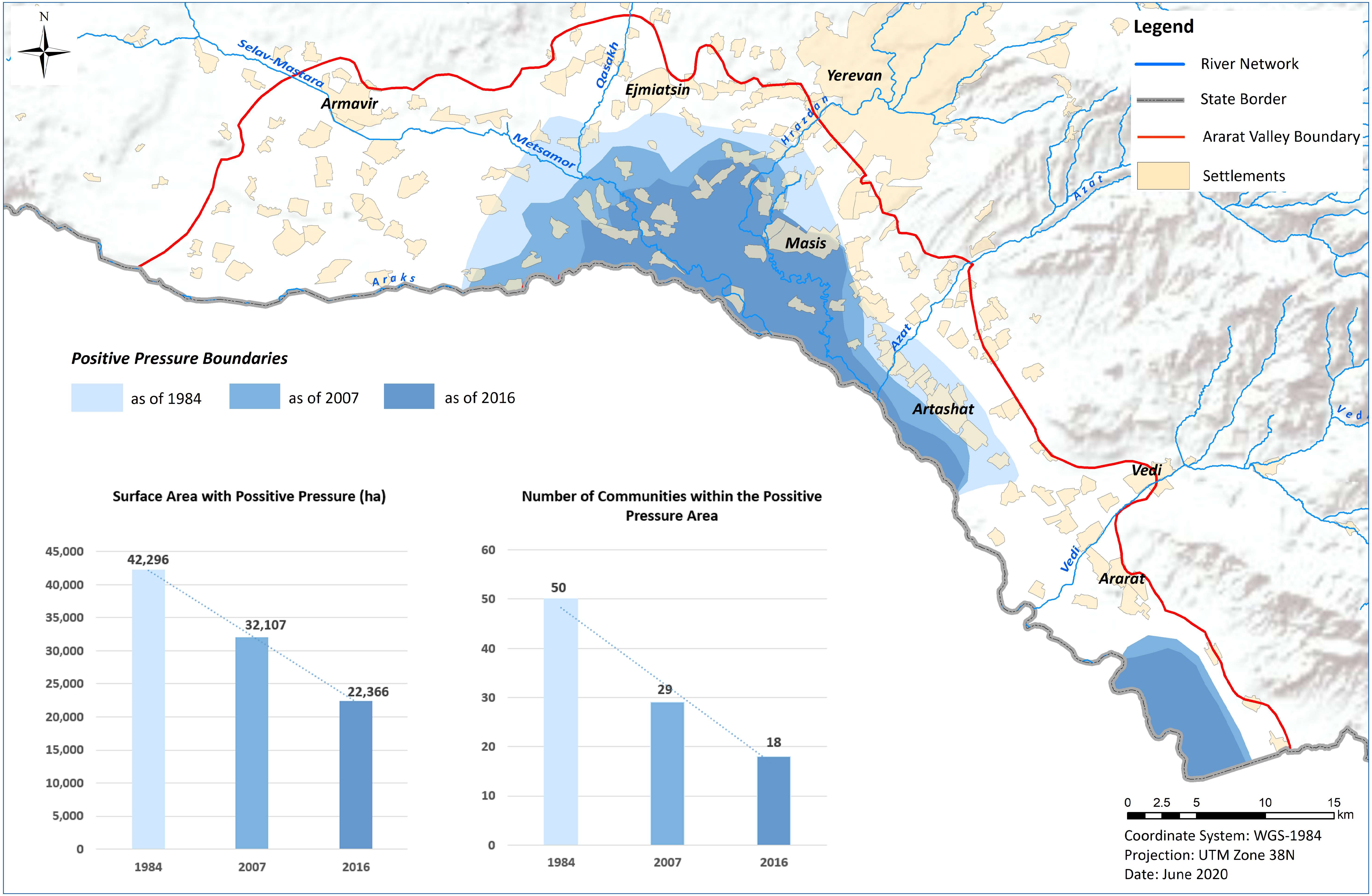
#	Main Geological Material	Type
1	Loam/clay	Under surface layer
2	Gravel	Water-bearing layer (unconfined aquifer)
3	Clay	Non-water-bearing layer
4	Gravel	Water-bearing layer (first confined aquifer)
5	Dense basalt/clay	Non-water-bearing layer
6	Fractured basalt	Water-bearing layer (second confined aquifer)
7	Dense Clay	Non-water-bearing layer

The AHGW Tools and the 3-dimensional model of the Ararat Valley groundwater basin were used to calculate the total and pore volumes of the main hydrogeologic units, as well as values of natural groundwater reserves (storage), natural groundwater resources (recharge) and total usable groundwater resources in the Ararat Valley. The following outputs were obtained:

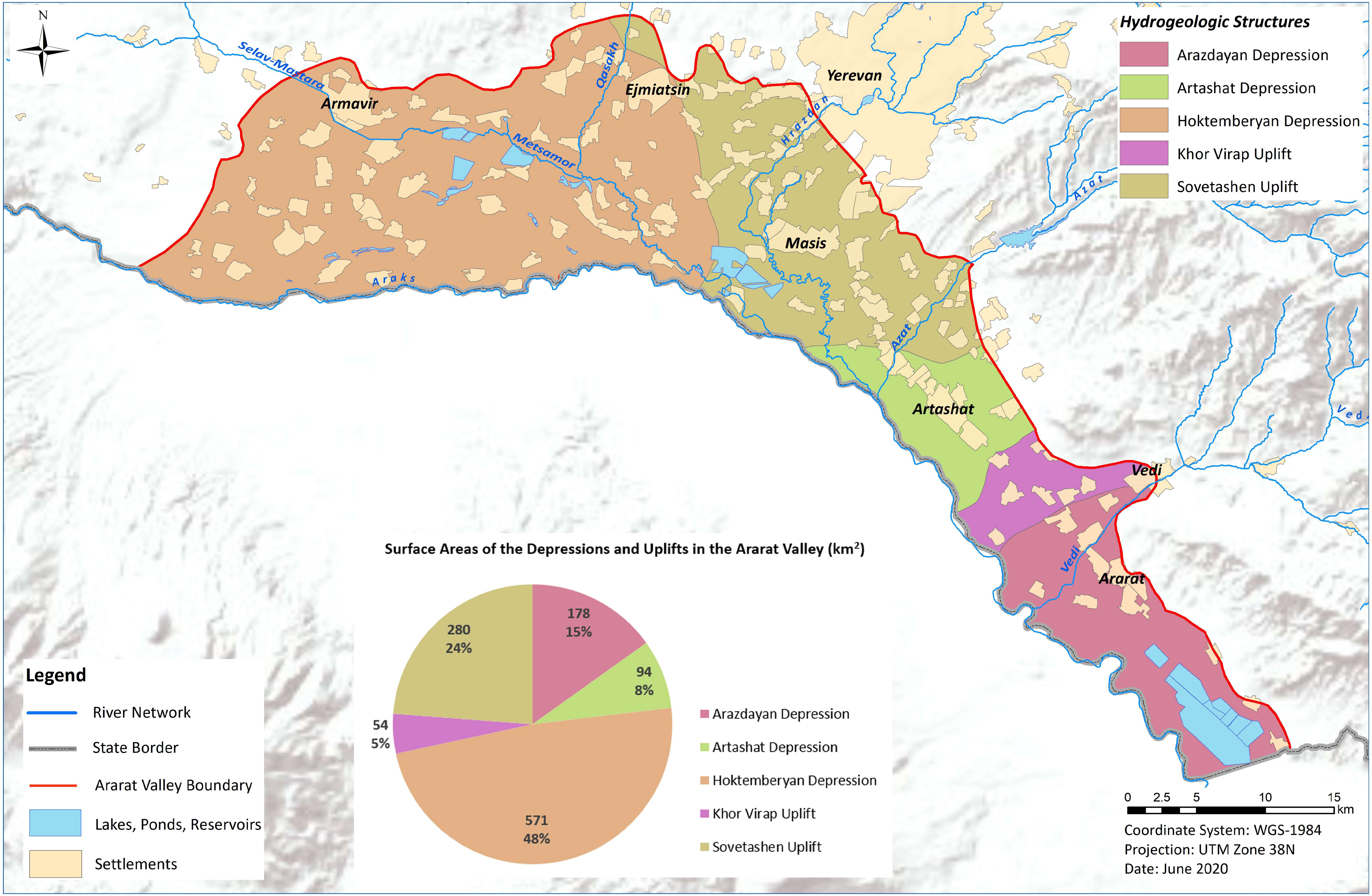
- The **total volume of seven hydrogeologic units** in the Ararat Valley groundwater basin is estimated at over **187.74 billion m³**. Total volume of water-bearing layers in the groundwater basin is about **98.22 billion m³**, while the volume of the non-water-bearing layers is **89.52 billion m³**.
- The **total pore volume of the aquifers in** the Ararat Valley groundwater basin is estimated to be **19.53 billion m³**, out of which **1.96 billion m³** is in the unconfined aquifer, **4.71 billion m³** is in the first confined aquifer, and **12.86 billion m³** is in the second confined aquifer.
- **Total natural groundwater reserves or storage** in the Ararat Valley is estimated at **2,958.71 million m³**, out of which **1,442.13 million m³** is in the unconfined aquifer, **526.70 million m³** is in the first confined aquifer, and **989.88 million m³** is in the second confined aquifer.
- The **recharge** of the Ararat Valley groundwater resources in 2016 comprised **1,490.55 million m³** or **4.08 million m³/day**.
- The estimated value of **total usable groundwater resources** in the Ararat Valley in 2016 was **926.73 million m³** (equivalent to **29.39 m³/s**), which is **15.3% less** than the annual volume of sustainable groundwater abstraction of 1,094.4 million m³ for the Ararat Valley, as approved by the State Commission on Reserves in 1984 and enacted in the Republic of Armenia Law on the National Water Program in 2015.

Maps and relevant statistical information on the hydrogeological structure and pressure boundaries as well as the 3-dimensional model of the Ararat Valley groundwater basin are presented in this section of the Atlas.

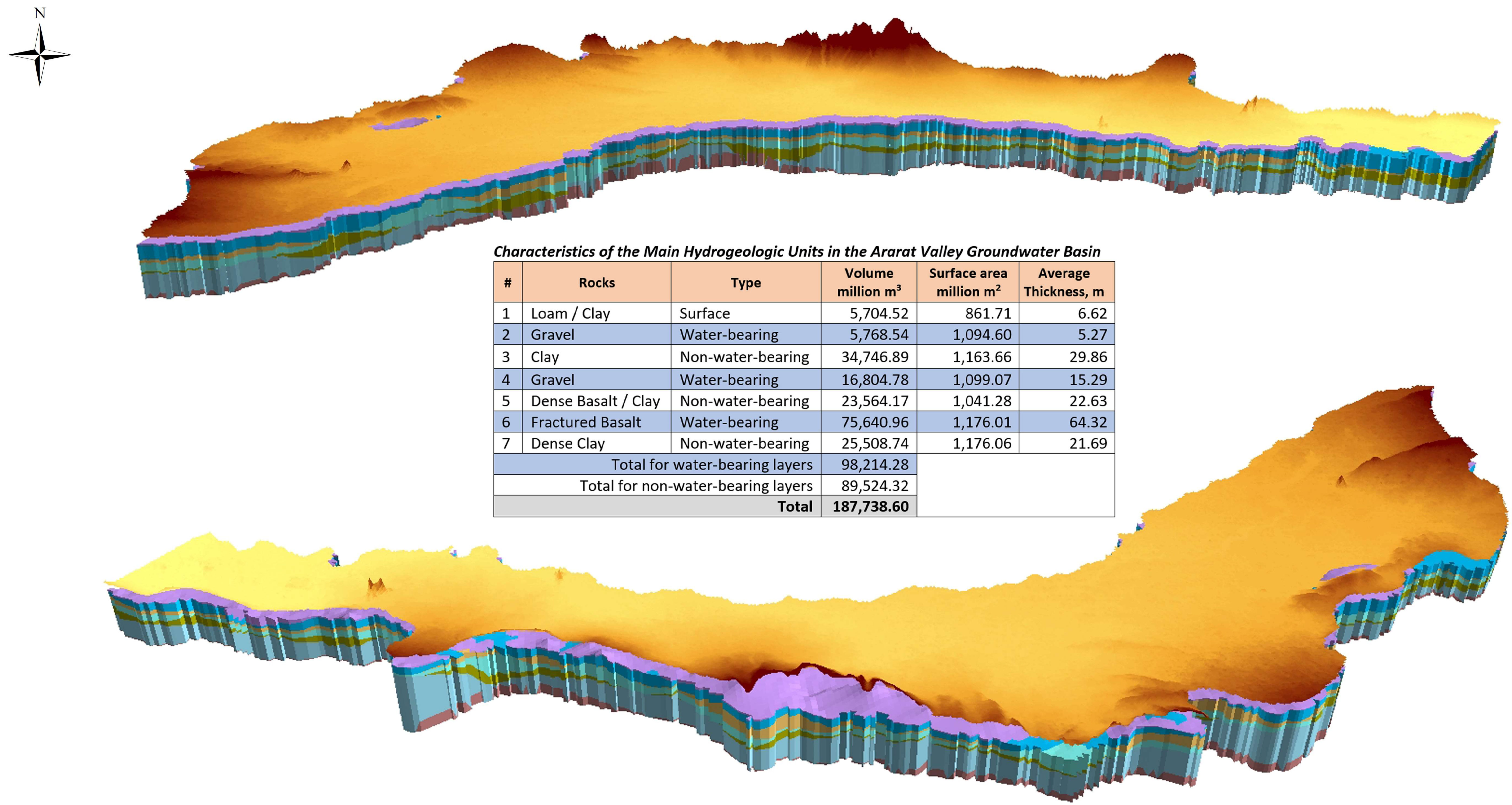
Pressure Boundaries in the Ararat Valley Groundwater Basin



Hydrogeologic Structure of the Ararat Valley Groundwater Basin



Three-Dimensional Model of the Ararat Valley Groundwater Basin



Characteristics of the Main Hydrogeologic Units in the Ararat Valley Groundwater Basin

#	Rocks	Type	Volume million m^3	Surface area million m^2	Average Thickness, m
1	Loam / Clay	Surface	5,704.52	861.71	6.62
2	Gravel	Water-bearing	5,768.54	1,094.60	5.27
3	Clay	Non-water-bearing	34,746.89	1,163.66	29.86
4	Gravel	Water-bearing	16,804.78	1,099.07	15.29
5	Dense Basalt / Clay	Non-water-bearing	23,564.17	1,041.28	22.63
6	Fractured Basalt	Water-bearing	75,640.96	1,176.01	64.32
7	Dense Clay	Non-water-bearing	25,508.74	1,176.06	21.69
		Total for water-bearing layers	98,214.28		
		Total for non-water-bearing layers	89,524.32		
		Total	**187,738.60**		

Main Hydrogeologic Units

- Loam / Clay
- Gravel
- Clay
- Gravel
- Dense Basalt / Clay
- Fractured Basalt
- Dense Clay

Natural Groundwater Reserves of the Ararat Valley

#	*Water-bearing Layer (Aquifer)*	*Capacitive Reserves million m^3*	*Elastic Reserves million m^3*	*Natural Reserves, million m^3*
2	Gravel (unconfined aquifer)	1,442.13	-	1442.13
4	Gravel (first confined aquifer)	154.60	372.10	526.70
6	Fractures Basalt (second confined aquifer)	484.10	505.78	989.88
	Total	**2,080.83**	**877.88**	**2,958.71**

0 2.5 5 10 15 km

Coordinate System: WGS-1984
Projection: UTM Zone 38N
Date: June 2020

Section 5. Assessment of Water Resources Quality in the Ararat Valley

Assessment and classification of the quality of water resources in the Ararat Valley was conducted using monthly data on hydrochemical monitoring collected by the Hydrometeorology and Monitoring Center of the ME in the study area in 2016 and 2017, in accordance with the standards presented below:

- RA Government Decision N: 75-N, dated January 27, 2011, on defining water quality norms for each basin management area, taking into consideration peculiarities of the area;
- Order of the RA Minister of Health N: 876, dated December 25, 2002, on defining N-2-III-A 2-1 sanitary norms and rules for drinking water: hygienic requirements for the centralized systems of water supply, quality control; and
- Water quality standards for irrigation, recommended by the Food and Agriculture Organization (FAO) of the United Nations in 1985.

Surface Water Resources

Assessment of the quality of surface waters in the Ararat Valley was conducted using data on hydrochemical parameters collected by the HMC of the ME in 2016 and 2017 in 8 monitoring points in the Ararat Valley and 2 monitoring points outside the boundaries of the valley. Ecological norms of Armenia were used for water quality classification. According to the methodology defined by the Government Decision N: 75-N, the quality of water in a river corresponds to one of the following classes: Excellent (I), Good (II), Moderate (III), Poor (IV), or Bad (V).

Water quality norms establish the maximum admissible concentrations for each hydrochemical parameter under each water quality class. In a selected monitoring point or section of the river, the water quality class is determined based on the lowest class of the hydrochemical parameters recorded.

Suitability of surface waters for irrigation was assessed in 11 monitoring points of the Ararat Valley, following the standards for irrigation water recommended by the FAO.

The results of the analysis demonstrate the following patterns in surface water quality throughout monitoring points in the Ararat Valley in the period from 2016 to 2017:

- The quality of surface water resources within the Ararat Valley corresponded to the Moderate (III) class and lower, while the quality of water in the same rivers before flowing into the Ararat Valley corresponded to the Good (II) class.
- Water quality in the Hrazdan river along its entire length corresponded to the Bad (V) class.
- Status of Metsamor river along its entire length corresponded to the Bad (V) or Poor (IV) classes.
- In the whole territory of the Ararat Valley with one exception, surface water is suitable for irrigation, according to the standards for irrigation water recommended by the FAO. The exception is the section of the Hrazdan River passing through the Khachpar and Darbnik communities, where water quality was unsuitable for irrigation.

Groundwater Resources

The quality of groundwater resources in the Ararat Valley was assessed in 24 monitoring points of the national reference monitoring network, using data on hydrochemical parameters collected by the HMC of the ME in 2016 and 2017.

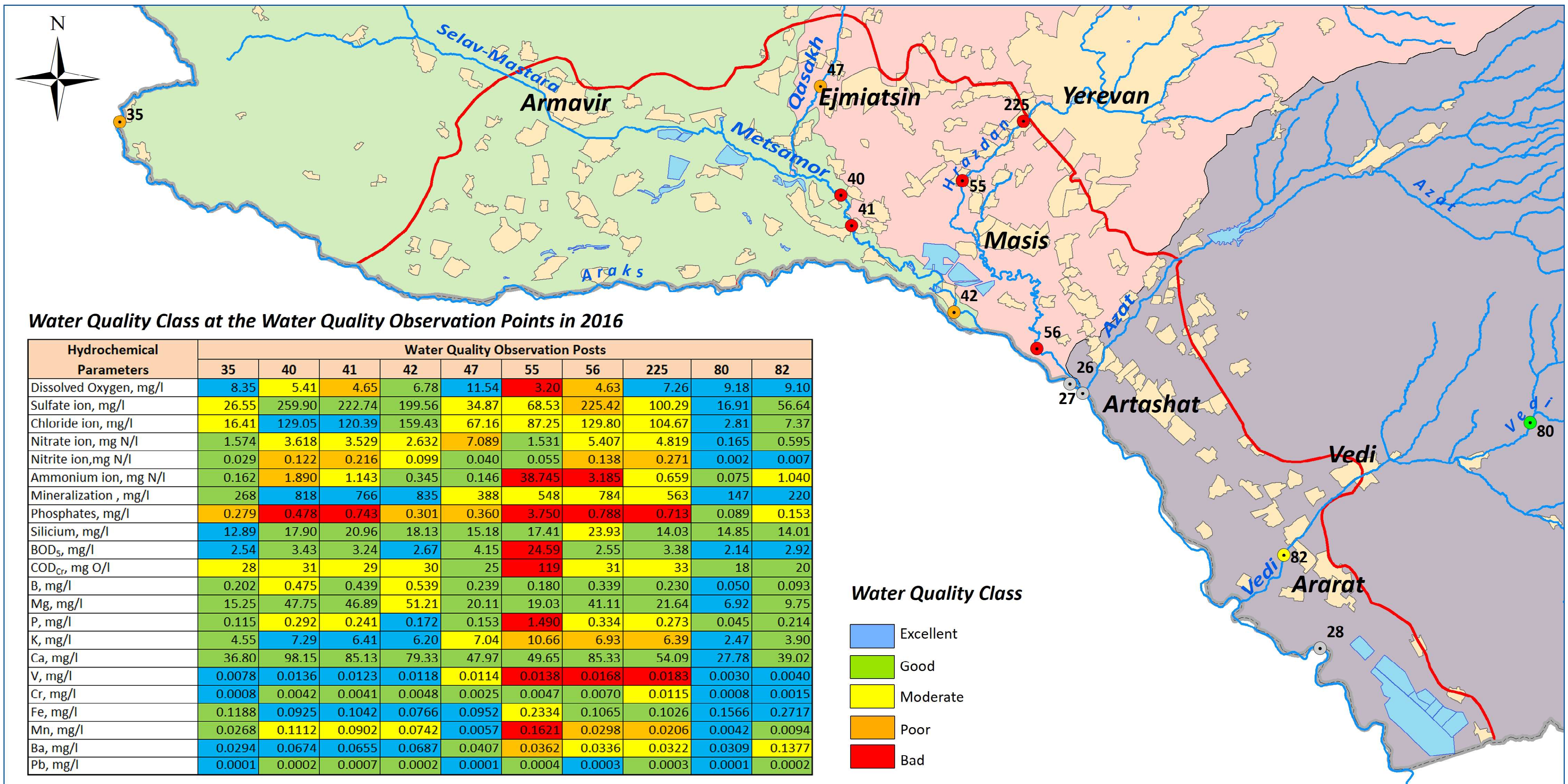
The ASPIRED team assessed the suitability of groundwater resources for drinking and irrigation. Monitoring results of the hydrochemical parameters were compared respectively with the sanitary and hygienic norms for drinking water as defined by the national legislation and water quality standards for irrigation recommended by the FAO. If the value of *at least one* hydrochemical parameter exceeds either the respective sanitary and hygienic norm or water quality standard recommended for irrigation, the water of the observed well was assessed as either unsuitable for drinking or unsuitable for irrigation. If the monitored parameters met all norms and standards defined, the water was assessed as suitable for use for drinking and irrigation purposes.

The results of the analysis demonstrated the following patterns in the quality of groundwater resources throughout monitoring points in the Ararat Valley in the period from 2016 to 2017:

- Groundwater resources in most of the Ararat Valley are suitable for drinking, with exception of those in the central and southeastern parts of the Valley, where concentrations of sulfate, chloride and nitrate ions, as well as the values of water hardness and mineralization, exceed the sanitary and hygienic norms defined by the national legislation.
- A similar spatial picture is observed when assessing the suitability of water for irrigation. In this case, in selected sites in the central and southeastern parts of the Valley, the concentrations of hydrocarbons, sulfate and magnesium ions exceeded the water quality standards recommended for irrigation. In 2016, water in six out of 18 wells was not suitable for irrigation, while in 2017 the quality improved somewhat as water quality in only three wells did not meet the standards for irrigation.
- Both in 2016 and 2017, a high level of mineralization of groundwater (> 3 grams per liter) was observed only in the southeastern part of the Ararat Valley. In other parts of the valley, a low level of groundwater mineralization prevailed (<1 gram / liter).

This section of the Atlas presents one map showing the assessment of surface water quality, and three maps showing the assessment of groundwater quality in the Ararat Valley.

Classification of the Ararat Valley Surface Water Quality and Assessment of Surface Water Suitability for Irrigation in 2016



Water Quality Class at the Water Quality Observation Points in 2016

Hydrochemical Parameters	Water Quality Observation Posts									
	35	40	41	42	47	55	56	225	80	82
Dissolved Oxygen, mg/l	8.35	5.41	4.65	6.78	11.54	3.20	4.63	7.26	9.18	9.10
Sulfate ion, mg/l	26.55	259.90	222.74	199.56	34.87	68.53	225.42	100.29	16.91	56.64
Chloride ion, mg/l	16.41	129.05	120.39	159.43	67.16	87.25	129.80	104.67	2.81	7.37
Nitrate ion, mg N/l	1.574	3.618	3.529	2.632	7.089	1.531	5.407	4.819	0.165	0.595
Nitrite ion,mg N/l	0.029	0.122	0.216	0.099	0.040	0.055	0.138	0.271	0.002	0.007
Ammonium ion, mg N/l	0.162	1.890	1.143	0.345	0.146	38.745	3.185	0.659	0.075	1.040
Mineralization , mg/l	268	818	766	835	388	548	784	563	147	220
Phosphates, mg/l	0.279	0.478	0.743	0.301	0.360	3.750	0.788	0.713	0.089	0.153
Silicium, mg/l	12.89	17.90	20.96	18.13	15.18	17.41	23.93	14.03	14.85	14.01
BOD_5, mg/l	2.54	3.43	3.24	2.67	4.15	24.59	2.55	3.38	2.14	2.92
COD_{Cr}, mg O/l	28	31	29	30	25	119	31	33	18	20
B, mg/l	0.202	0.475	0.439	0.539	0.239	0.180	0.339	0.230	0.050	0.093
Mg, mg/l	15.25	47.75	46.89	51.21	20.11	19.03	41.11	21.64	6.92	9.75
P, mg/l	0.115	0.292	0.241	0.172	0.153	1.490	0.334	0.273	0.045	0.214
K, mg/l	4.55	7.29	6.41	6.20	7.04	10.66	6.93	6.39	2.47	3.90
Ca, mg/l	36.80	98.15	85.13	79.33	47.97	49.65	85.33	54.09	27.78	39.02
V, mg/l	0.0078	0.0136	0.0123	0.0118	0.0114	0.0138	0.0168	0.0183	0.0030	0.0040
Cr, mg/l	0.0008	0.0042	0.0041	0.0048	0.0025	0.0047	0.0070	0.0115	0.0008	0.0015
Fe, mg/l	0.1188	0.0925	0.1042	0.0766	0.0952	0.2334	0.1065	0.1026	0.1566	0.2717
Mn, mg/l	0.0268	0.1112	0.0902	0.0742	0.0057	0.1621	0.0298	0.0206	0.0042	0.0094
Ba, mg/l	0.0294	0.0674	0.0655	0.0687	0.0407	0.0362	0.0336	0.0322	0.0309	0.1377
Pb, mg/l	0.0001	0.0002	0.0007	0.0002	0.0001	0.0004	0.0003	0.0003	0.0001	0.0002

Legend

River Network
State Border
Ararat Valley Boundary
Lakes, Ponds, Reservoirs
Settlements

Basin Management Areas

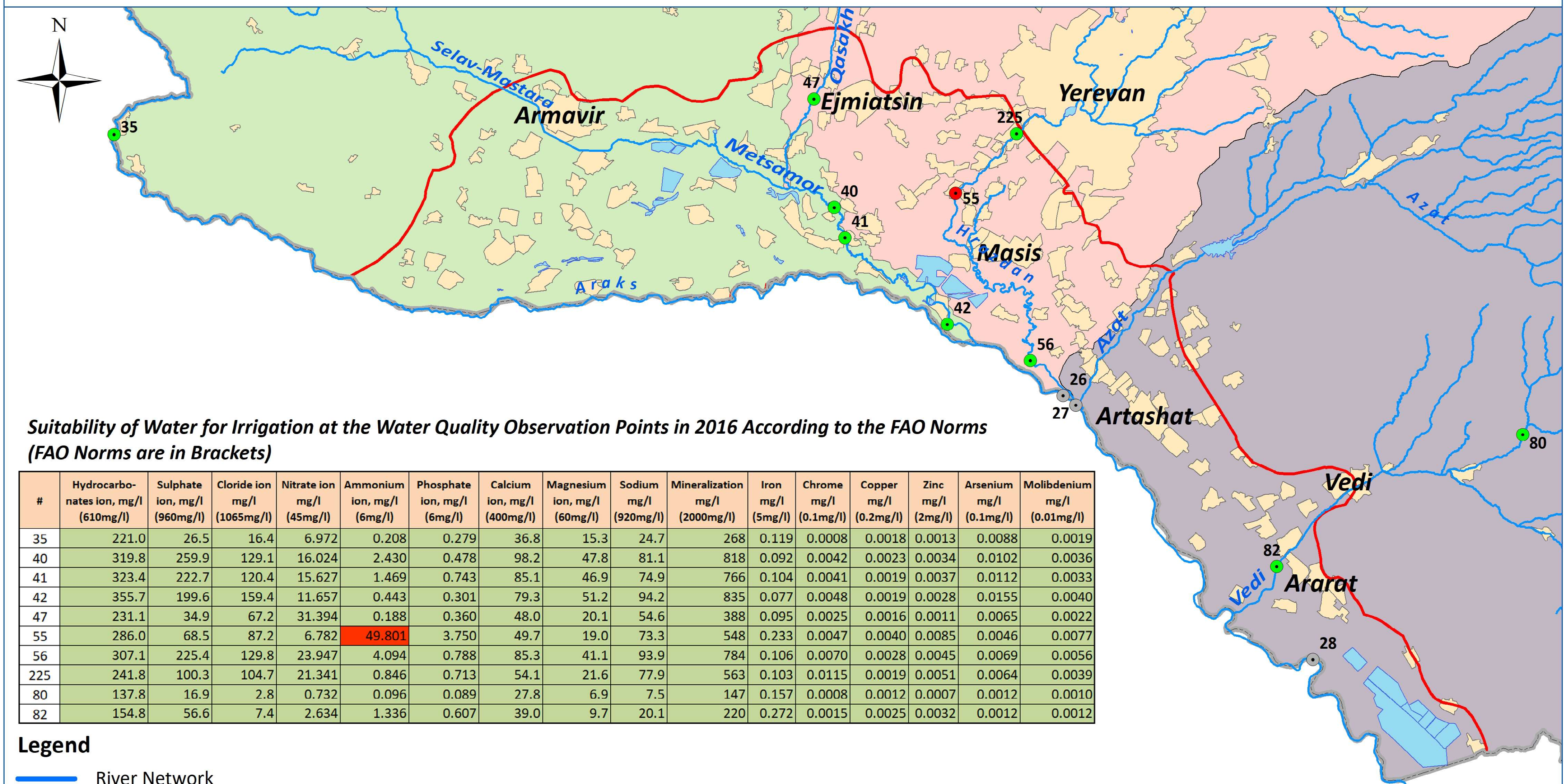
Akhuryan
Ararat
Hrazdan

Water Quality Class According to Ecological Norms of the RA

Good
Moderate
Poor
Bad
No data

0 4 8 16 24 km

Coordinate System: WGS-1984
Projection: UTM Zone 38N
Date: June 2020



Suitability of Water for Irrigation at the Water Quality Observation Points in 2016 According to the FAO Norms (FAO Norms are in Brackets)

#	Hydrocarbo-nates ion, mg/l (610mg/l)	Sulphate ion, mg/l (960mg/l)	Cloride ion mg/l (1065mg/l)	Nitrate ion mg/l (45mg/l)	Ammonium ion, mg/l (6mg/l)	Phosphate ion, mg/l (6mg/l)	Calcium ion, mg/l (400mg/l)	Magnesium ion, mg/l (60mg/l)	Sodium mg/l (920mg/l)	Mineralization mg/l (2000mg/l)	Iron mg/l (5mg/l)	Chrome mg/l (0.1mg/l)	Copper mg/l (0.2mg/l)	Zinc mg/l (2mg/l)	Arsenium mg/l (0.1mg/l)	Molibdenium mg/l (0.01mg/l)
35	221.0	26.5	16.4	6.972	0.208	0.279	36.8	15.3	24.7	268	0.119	0.0008	0.0018	0.0013	0.0088	0.0019
40	319.8	259.9	129.1	16.024	2.430	0.478	98.2	47.8	81.1	818	0.092	0.0042	0.0023	0.0034	0.0102	0.0036
41	323.4	222.7	120.4	15.627	1.469	0.743	85.1	46.9	74.9	766	0.104	0.0041	0.0019	0.0037	0.0112	0.0033
42	355.7	199.6	159.4	11.657	0.443	0.301	79.3	51.2	94.2	835	0.077	0.0048	0.0019	0.0028	0.0155	0.0040
47	231.1	34.9	67.2	31.394	0.188	0.360	48.0	20.1	54.6	388	0.095	0.0025	0.0016	0.0011	0.0065	0.0022
55	286.0	68.5	87.2	6.782	49.801	3.750	49.7	19.0	73.3	548	0.233	0.0047	0.0040	0.0085	0.0046	0.0077
56	307.1	225.4	129.8	23.947	4.094	0.788	85.3	41.1	93.9	784	0.106	0.0070	0.0028	0.0045	0.0069	0.0056
225	241.8	100.3	104.7	21.341	0.846	0.713	54.1	21.6	77.9	563	0.103	0.0115	0.0019	0.0051	0.0064	0.0039
80	137.8	16.9	2.8	0.732	0.096	0.089	27.8	6.9	7.5	147	0.157	0.0008	0.0012	0.0007	0.0012	0.0010
82	154.8	56.6	7.4	2.634	1.336	0.607	39.0	9.7	20.1	220	0.272	0.0015	0.0025	0.0032	0.0012	0.0012

Legend

River Network
State Border
Ararat Valley Boundary
Lakes, Ponds, Reservoirs
Settlements

Basin Management Areas

Akhuryan
Ararat
Hrazdan

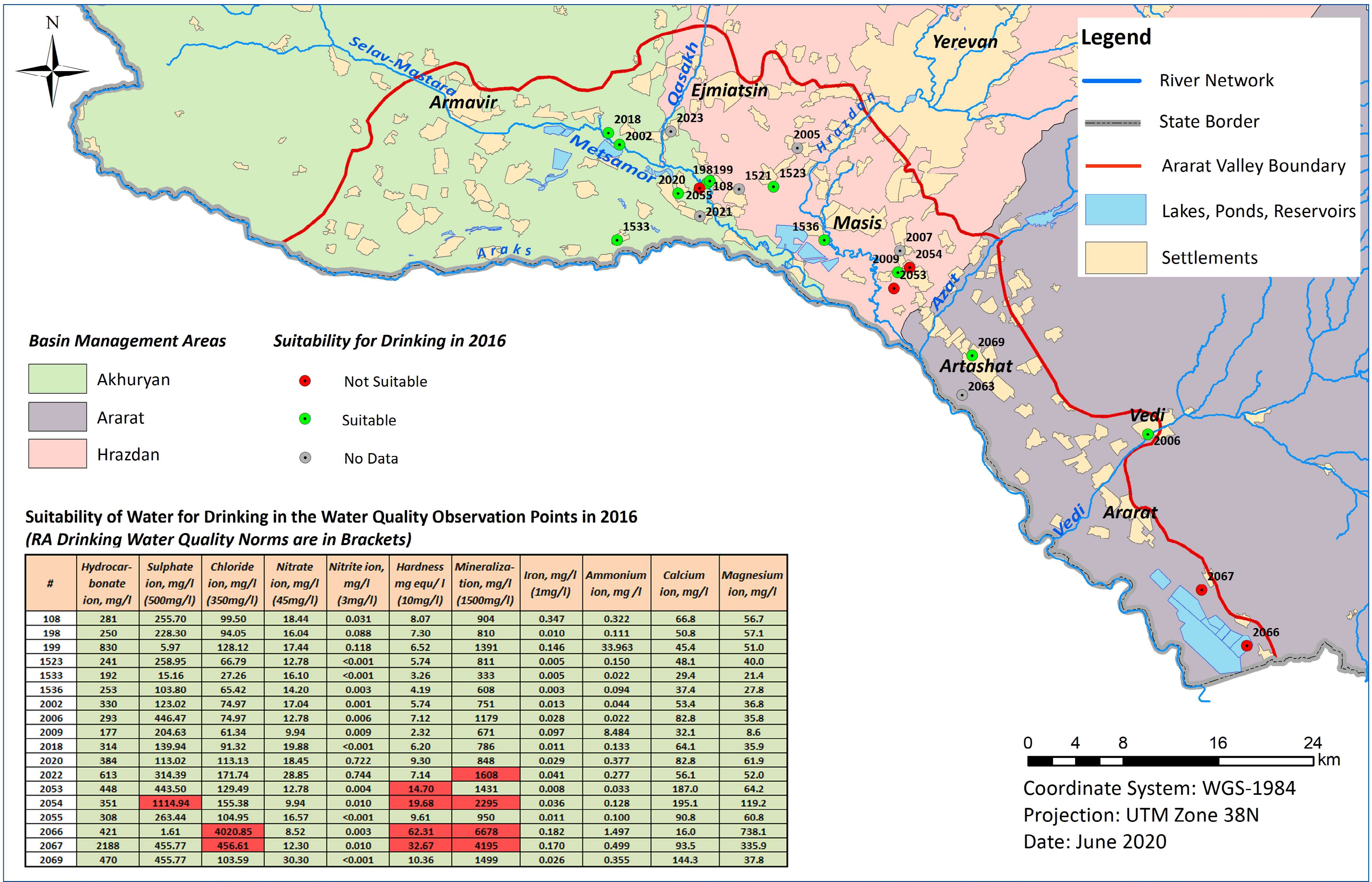
Suitability for Irrigation According to FAO Norms

Not Suitable
Suitable
No Data

0 4 8 16 24 km

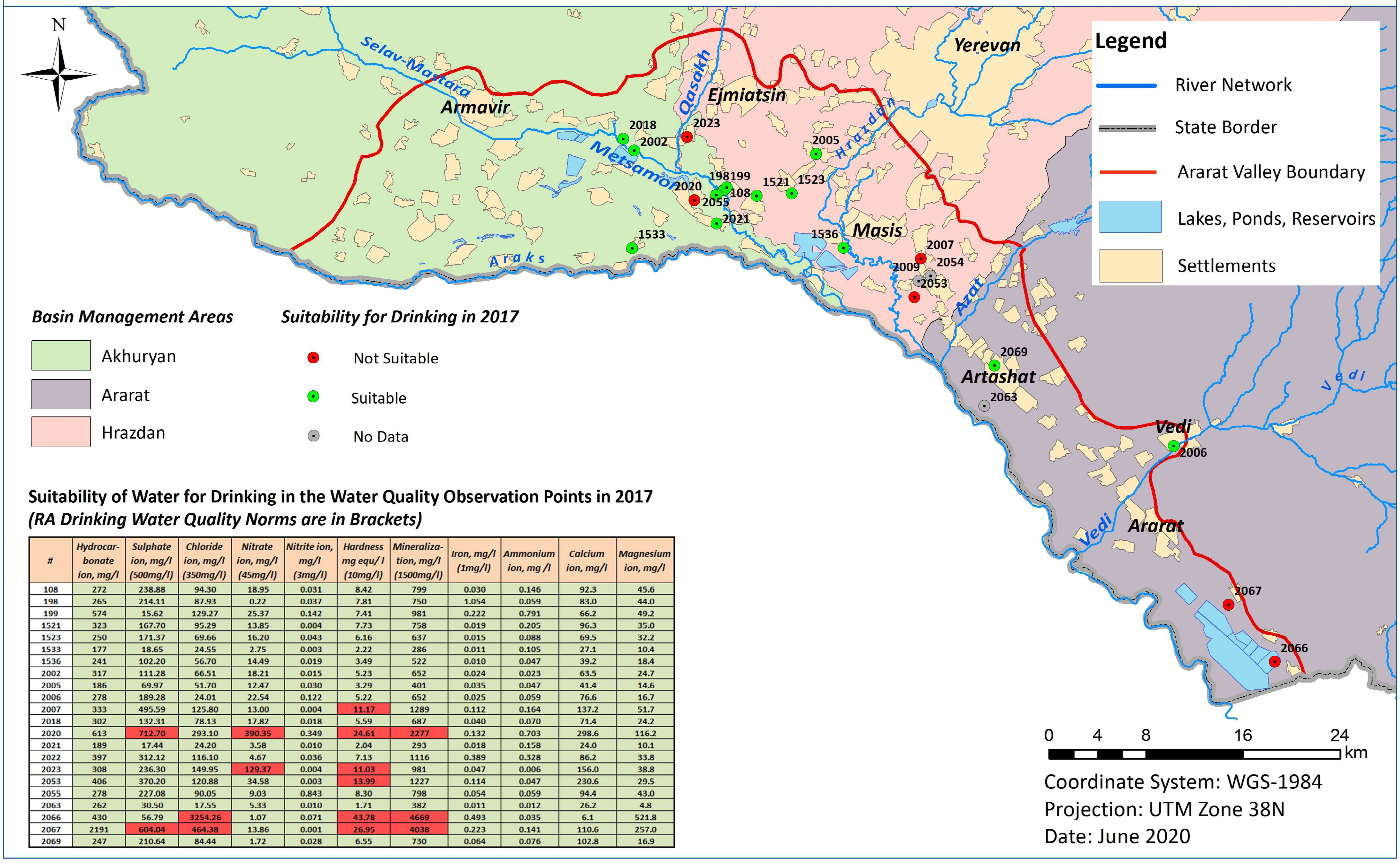
Coordinate System: WGS-1984
Projection: UTM Zone 38N
Date: June 2020

Classification of the Ararat Valley Groundwater Resources in Terms of Suitability for Drinking in 2016 and 2017



Suitability of Water for Drinking in the Water Quality Observation Points in 2016
(RA Drinking Water Quality Norms are in Brackets)

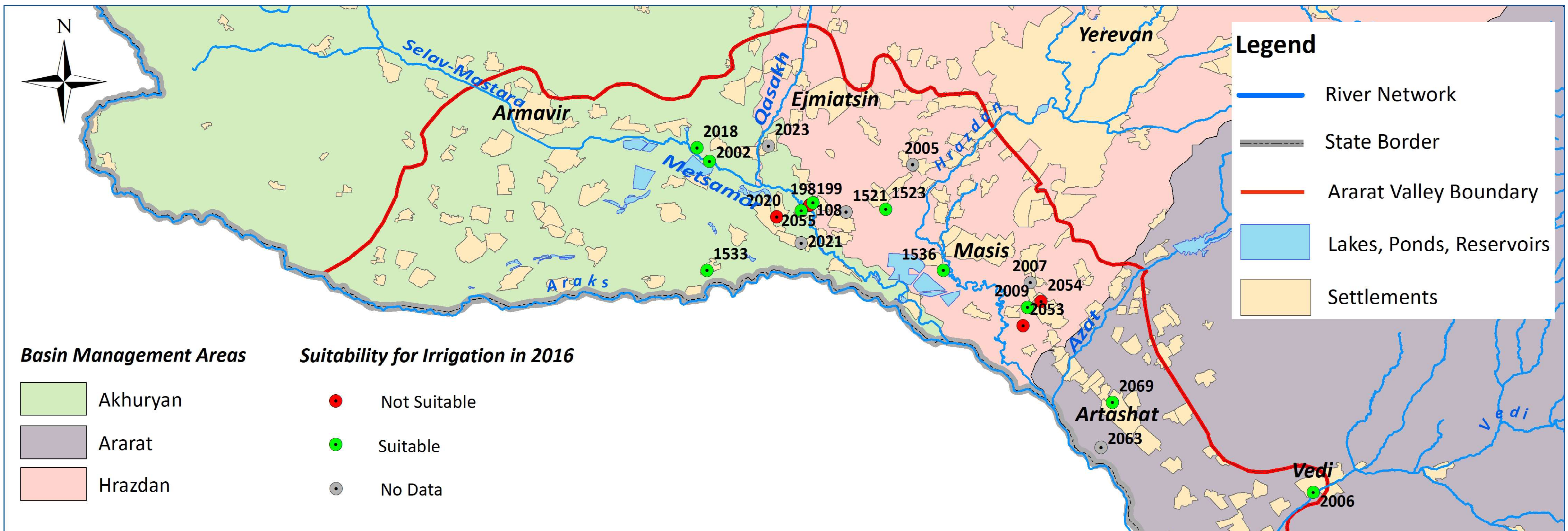
#	Hydrocar-bonate ion, mg/l	Sulphate ion, mg/l (500mg/l)	Chloride ion, mg/l (350mg/l)	Nitrate ion, mg/l (45mg/l)	Nitrite ion, mg/l (3mg/l)	Hardness mg equ/ l (10mg/l)	Mineraliza-tion, mg/l (1500mg/l)	Iron, mg/l (1mg/l)	Ammonium ion, mg /l	Calcium ion, mg/l	Magnesium ion, mg/l
108	281	255.70	99.50	18.44	0.031	8.07	904	0.347	0.322	66.8	56.7
198	250	228.30	94.05	16.04	0.088	7.30	810	0.010	0.111	50.8	57.1
199	830	5.97	128.12	17.44	0.118	6.52	1391	0.146	33.963	45.4	51.0
1523	241	258.95	66.79	12.78	<0.001	5.74	811	0.005	0.150	48.1	40.0
1533	192	15.16	27.26	16.10	<0.001	3.26	333	0.005	0.022	29.4	21.4
1536	253	103.80	65.42	14.20	0.003	4.19	608	0.003	0.094	37.4	27.8
2002	330	123.02	74.97	17.04	0.001	5.74	751	0.013	0.044	53.4	36.8
2006	293	446.47	74.97	12.78	0.006	7.12	1179	0.028	0.022	82.8	35.8
2009	177	204.63	61.34	9.94	0.009	2.32	671	0.097	8.484	32.1	8.6
2018	314	139.94	91.32	19.88	<0.001	6.20	786	0.011	0.133	64.1	35.9
2020	384	113.02	113.13	18.45	0.722	9.30	848	0.029	0.377	82.8	61.9
2022	613	314.39	171.74	28.85	0.744	7.14	1608	0.041	0.277	56.1	52.0
2053	448	443.50	129.49	12.78	0.004	14.70	1431	0.008	0.033	187.0	64.2
2054	351	1114.94	155.38	9.94	0.010	19.68	2295	0.036	0.128	195.1	119.2
2055	308	263.44	104.95	16.57	<0.001	9.61	950	0.011	0.100	90.8	60.8
2066	421	1.61	4020.85	8.52	0.003	62.31	6678	0.182	1.497	16.0	738.1
2067	2188	455.77	456.61	12.30	0.010	32.67	4195	0.170	0.499	93.5	335.9
2069	470	455.77	103.59	30.30	<0.001	10.36	1499	0.026	0.355	144.3	37.8



Suitability of Water for Drinking in the Water Quality Observation Points in 2017
(RA Drinking Water Quality Norms are in Brackets)

#	Hydrocar-bonate ion, mg/l	Sulphate ion, mg/l (500mg/l)	Chloride ion, mg/l (350mg/l)	Nitrate ion, mg/l (45mg/l)	Nitrite ion, mg/l (3mg/l)	Hardness mg equ/ l (10mg/l)	Mineraliza-tion, mg/l (1500mg/l)	Iron, mg/l (1mg/l)	Ammonium ion, mg /l	Calcium ion, mg/l	Magnesium ion, mg/l
108	272	238.88	94.30	18.95	0.031	8.42	799	0.030	0.146	92.3	45.6
198	265	214.11	87.93	0.22	0.037	7.81	750	1.054	0.059	83.0	44.0
199	574	15.62	129.27	25.37	0.142	7.41	981	0.222	0.791	66.2	49.2
1521	323	167.70	95.29	13.85	0.004	7.73	758	0.019	0.205	96.3	35.0
1523	250	171.37	69.66	16.20	0.043	6.16	637	0.015	0.088	69.5	32.2
1533	177	18.65	24.55	2.75	0.003	2.22	286	0.011	0.105	27.1	10.4
1536	241	102.20	56.70	14.49	0.019	3.49	522	0.010	0.047	39.2	18.4
2002	317	111.28	66.51	18.21	0.015	5.23	652	0.024	0.023	63.5	24.7
2005	186	69.97	51.70	12.47	0.030	3.29	401	0.035	0.047	41.4	14.6
2006	278	189.28	24.01	22.54	0.122	5.22	652	0.025	0.059	76.6	16.7
2007	333	495.59	125.80	13.00	0.004	11.17	1289	0.112	0.164	137.2	51.7
2018	302	132.31	78.13	17.82	0.018	5.59	687	0.040	0.070	71.4	24.2
2020	613	712.70	293.10	390.35	0.349	24.61	2277	0.132	0.703	298.6	116.2
2021	189	17.44	24.20	3.58	0.010	2.04	293	0.018	0.158	24.0	10.1
2022	397	312.12	116.10	4.67	0.036	7.13	1116	0.389	0.328	86.2	33.8
2023	308	236.30	149.95	129.37	0.004	11.03	981	0.047	0.006	156.0	38.8
2053	406	370.20	120.88	34.58	0.003	13.99	1227	0.114	0.047	230.6	29.5
2055	278	227.08	90.05	9.03	0.843	8.30	798	0.054	0.059	94.4	43.0
2063	262	30.50	17.55	5.33	0.010	1.71	382	0.011	0.012	26.2	4.8
2066	430	56.79	3254.26	1.07	0.071	43.78	4669	0.493	0.035	6.1	521.8
2067	2191	604.04	464.38	13.86	0.001	26.95	4038	0.223	0.141	110.6	257.0
2069	247	210.64	84.44	1.72	0.028	6.55	730	0.064	0.076	102.8	16.9

Classification of the Ararat Valley Groundwater Resources in Terms of Suitability for Irrigation in 2016 and 2017

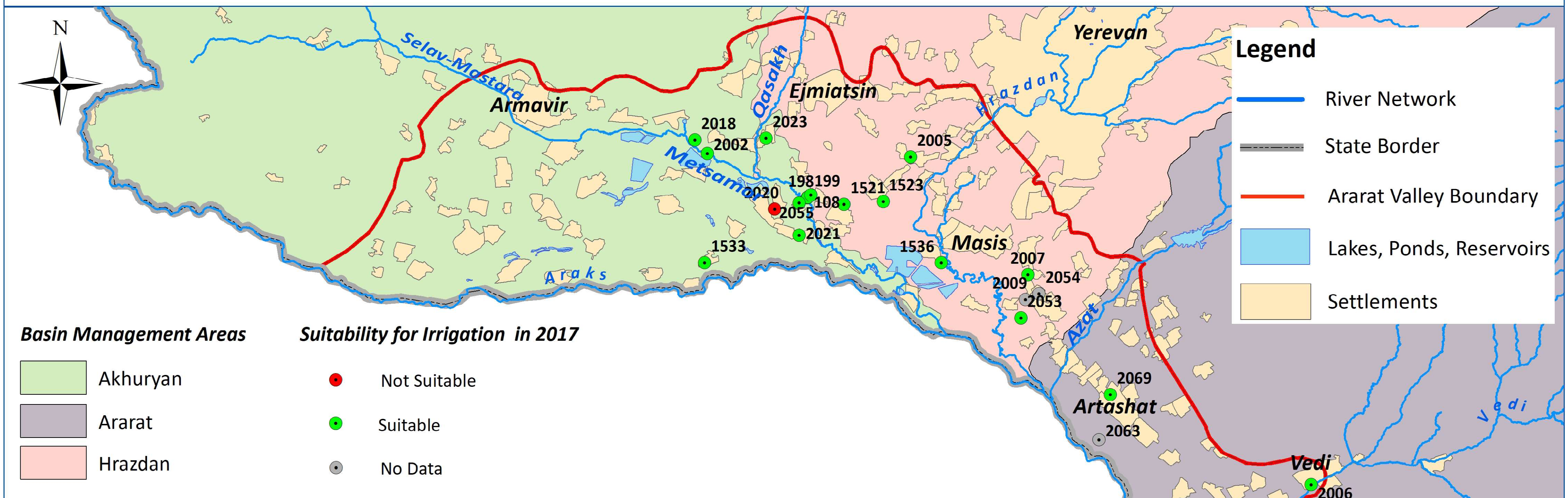


Suitability of Water for Irrigation at the Water Quality Observation Points in 2016 According to the FAO Norms
(FAO Norms are in Brackets)

#	Hydrocarbonate ion, mg/l (610mg/l)	Sulphate ion, mg/l (960mg/l)	Chloride ion, mg/l (1065mg/l)	Nitrate ion, mg/l (45mg/l)	Hardness mg/ l (10mg/l)	Mineralization, mg/l (2000mg/l)	Iron, mg/l (1mg/l)	Ammonium ion, mg /l (6mg/l)	Calcium ion, mg/l (400mg/l)	Magnesium ion, mg/l (60mg/l)
108	280.7	255.7	99.5	18.44	8.07	904	7.6	0.322	66.8	56.7
198	250.2	228.3	94.0	16.04	7.30	810	8.1	0.111	50.8	57.1
199	829.9	6.0	128.1	17.44	6.52	1391	8.0	33.963	45.4	51.0
1523	241.0	259.0	66.8	12.78	5.74	811	6.9	0.150	48.1	40.0
1533	192.2	15.2	27.3	16.10	3.26	333	8.3	0.022	29.4	21.4
1536	253.2	103.8	65.4	14.20	4.19	608	7.1	0.094	37.4	27.8
2002	329.5	123.0	75.0	17.04	5.74	751	8.1	0.044	53.4	36.8
2006	292.9	446.5	75.0	12.78	7.12	1179	7.7	0.022	82.8	35.8
2009	177.0	204.6	61.3	9.94	2.32	671	10.6	8.484	32.1	8.6
2018	314.3	139.9	91.3	19.88	6.20	786	8.2	0.133	64.1	35.9
2020	384.4	113.0	113.1	18.45	9.30	848	8.2	0.377	82.8	61.9
2022	613.3	314.4	171.7	28.85	7.14	1608	7.3	0.277	56.1	52.0
2053	448.5	443.5	129.5	12.78	14.70	1431	7.3	0.033	187.0	64.2
2054	350.9	1114.9	155.4	9.94	19.68	2295	7.1	0.128	195.1	119.2
2055	308.2	263.4	105.0	16.57	9.61	950	7.9	0.100	90.8	60.8
2066	421.0	1.6	4020.9	8.52	62.31	6678	8.4	1.497	16.0	738.1
2067	2187.6	455.8	456.6	12.30	32.67	4195	7.0	0.499	93.5	335.9
2069	469.9	455.8	103.6	30.30	10.36	1499	7.4	0.355	144.3	37.8

0 4 8 16 24 km

Coordinate System: WGS-1984
Projection: UTM Zone 38N
Date: June 2020



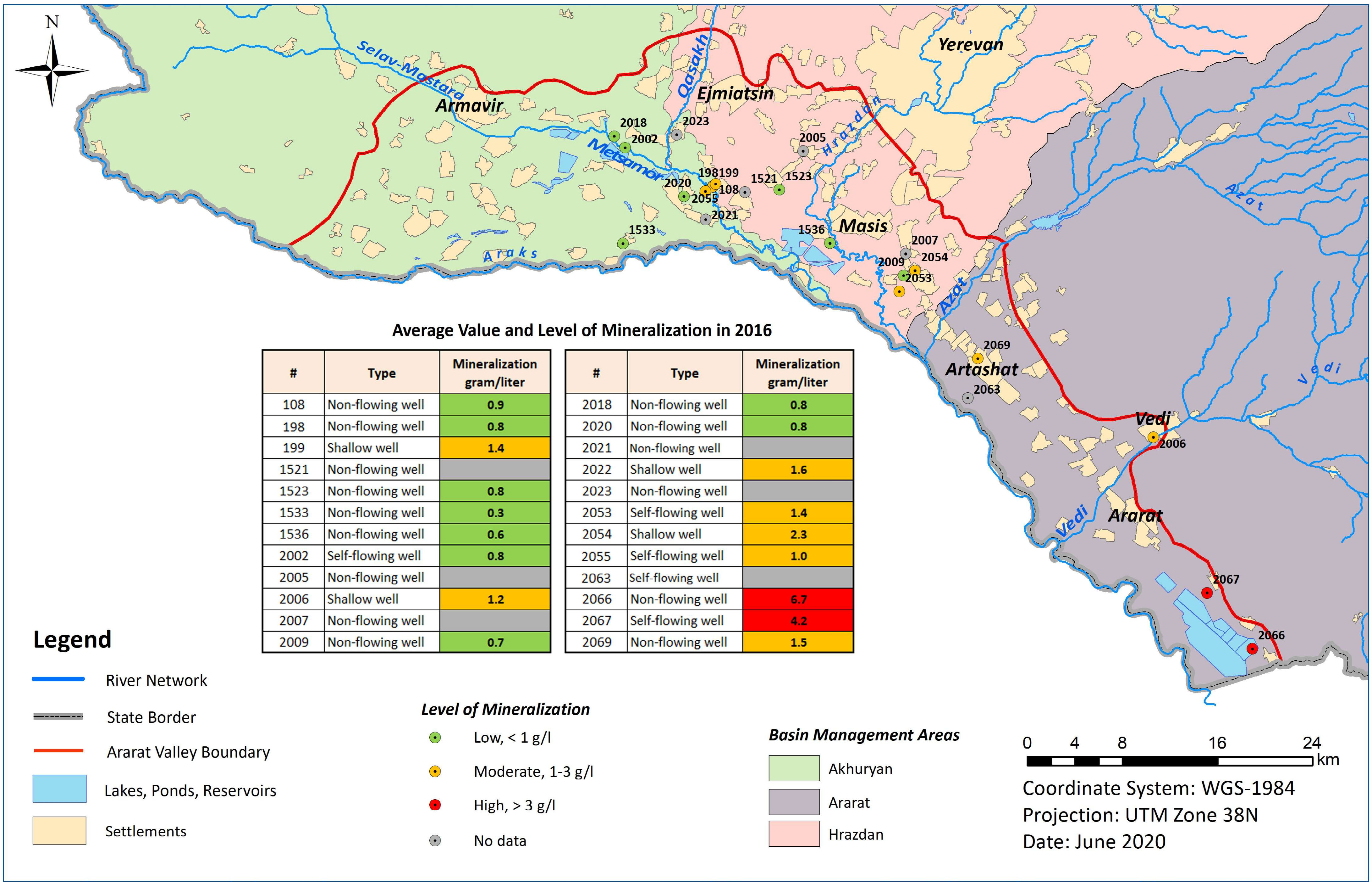
Suitability of Water for Irrigation at the Water Quality Observation Points in 2017 According to the FAO Norms
(FAO Norms are in Brackets)

#	Hydrocarbonate ion, mg/l (610mg/l)	Sulphate ion, mg/l (960mg/l)	Chloride ion, mg/l (1065mg/l)	Nitrate ion, mg/l (45mg/l)	Hardness mg/ l (10mg/l)	Mineralization, mg/l (2000mg/l)	Iron, mg/l (1mg/l)	Ammonium ion, mg /l (6mg/l)	Calcium ion, mg/l (400mg/l)	Magnesium ion, mg/l (60mg/l)
108	271.5	238.9	94.3	18.95	8.42	799	7.02	0.146	92.3	45.6
198	265.4	214.1	87.9	0.22	7.81	750	7.25	0.059	83.0	44.0
199	573.6	15.6	129.3	25.37	7.41	981	7.94	0.791	66.2	49.2
1521	323.4	167.7	95.3	13.85	7.73	758	7.29	0.205	96.3	35.0
1523	250.2	171.4	69.7	16.20	6.16	637	6.80	0.088	69.5	32.2
1533	177.0	18.7	24.5	2.75	2.22	286	7.84	0.105	27.1	10.4
1536	241.0	102.2	56.7	14.49	3.49	522	7.12	0.047	39.2	18.4
2002	317.3	111.3	66.5	18.21	5.23	652	7.54	0.023	63.5	24.7
2005	186.1	70.0	51.7	12.47	3.29	401	6.96	0.047	41.4	14.6
2006	277.6	189.3	24.0	22.54	5.22	652	7.57	0.059	76.6	16.7
2007	332.6	495.6	125.8	13.00	11.17	1289	7.14	0.164	137.2	51.7
2018	302.0	132.3	78.1	17.82	5.59	687	7.59	0.070	71.4	24.2
2020	613.3	712.7	293.1	390.35	24.61	2277	7.19	0.703	298.6	116.2
2021	189.2	17.4	24.2	3.58	2.04	293	7.69	0.158	24.0	10.1
2022	396.6	312.1	116.1	4.67	7.13	1116	7.57	0.328	86.2	33.8
2023	308.2	236.3	149.9	129.37	11.03	981	7.22	0.006	156.0	38.8
2053	405.8	370.2	120.9	34.58	13.99	1227	7.04	0.047	230.6	29.5
2055	277.6	227.1	90.1	9.03	8.30	798	7.31	0.059	94.4	43.0
2063	262.4	30.5	17.5	5.33	1.71	382	7.61	0.012	26.2	4.8
2066	430.2	56.8	3254.3	1.07	43.78	4669	8.70	0.035	6.1	521.8
2067	2190.6	604.0	464.4	13.86	26.95	4038	6.78	0.141	110.6	257.0
2069	247.1	210.6	84.4	1.72	6.55	730	7.84	0.076	102.8	16.9

0 4 8 16 24 km

Coordinate System: WGS-1984
Projection: UTM Zone 38N
Date: June 2020

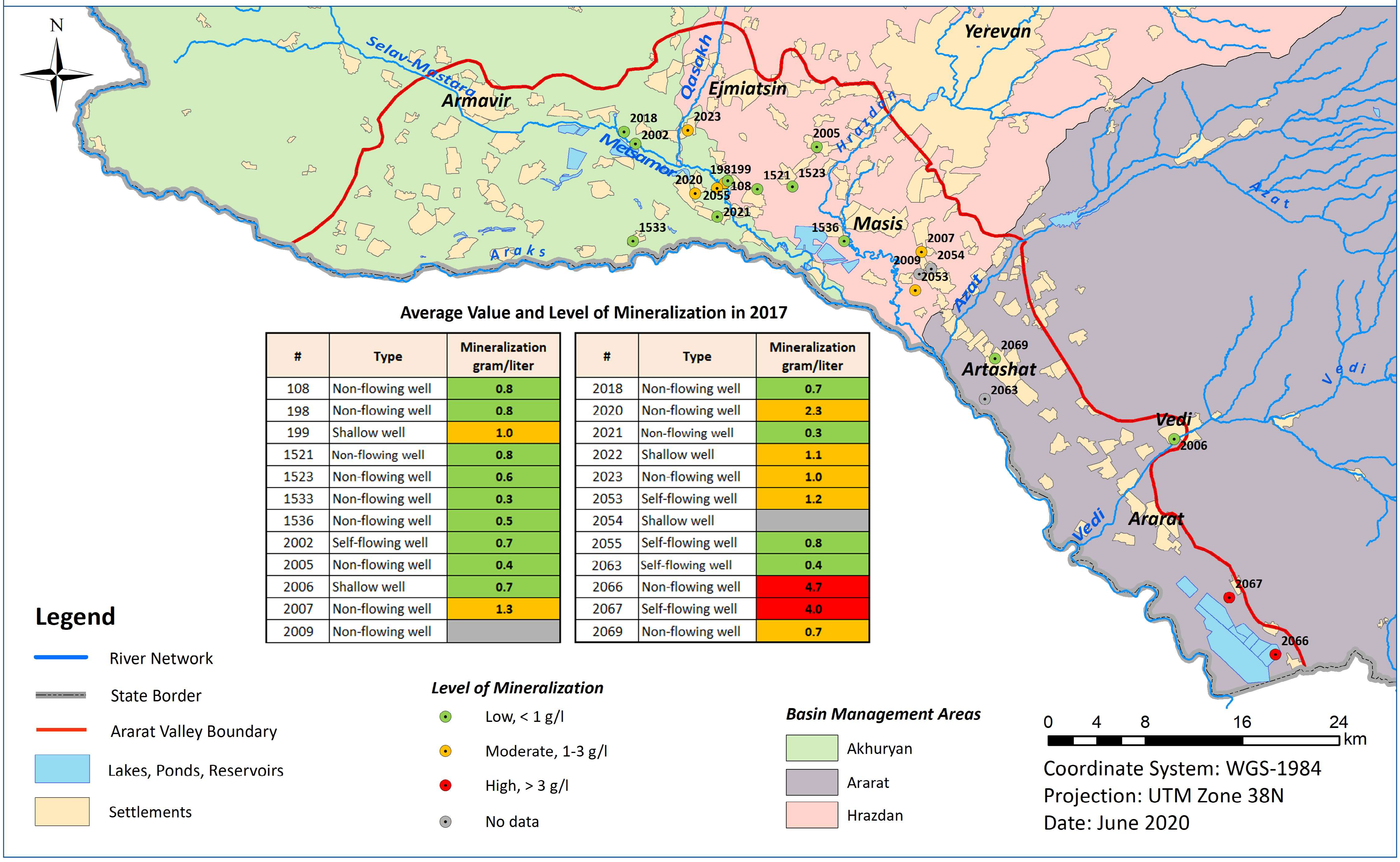
Classification of the Ararat Valley Groundwater Resources by Level of Mineralization in 2016 and 2017



Average Value and Level of Mineralization in 2016

#	Type	Mineralization gram/liter
108	Non-flowing well	0.9
198	Non-flowing well	0.8
199	Shallow well	1.4
1521	Non-flowing well	
1523	Non-flowing well	0.8
1533	Non-flowing well	0.3
1536	Non-flowing well	0.6
2002	Self-flowing well	0.8
2005	Non-flowing well	
2006	Shallow well	1.2
2007	Non-flowing well	
2009	Non-flowing well	0.7

#	Type	Mineralization gram/liter
2018	Non-flowing well	0.8
2020	Non-flowing well	0.8
2021	Non-flowing well	
2022	Shallow well	1.6
2023	Non-flowing well	
2053	Self-flowing well	1.4
2054	Shallow well	2.3
2055	Self-flowing well	1.0
2063	Self-flowing well	
2066	Non-flowing well	6.7
2067	Self-flowing well	4.2
2069	Non-flowing well	1.5



Average Value and Level of Mineralization in 2017

#	Type	Mineralization gram/liter
108	Non-flowing well	0.8
198	Non-flowing well	0.8
199	Shallow well	1.0
1521	Non-flowing well	0.8
1523	Non-flowing well	0.6
1533	Non-flowing well	0.3
1536	Non-flowing well	0.5
2002	Self-flowing well	0.7
2005	Non-flowing well	0.4
2006	Shallow well	0.7
2007	Non-flowing well	1.3
2009	Non-flowing well	

#	Type	Mineralization gram/liter
2018	Non-flowing well	0.7
2020	Non-flowing well	2.3
2021	Non-flowing well	0.3
2022	Shallow well	1.1
2023	Non-flowing well	1.0
2053	Self-flowing well	1.2
2054	Shallow well	
2055	Self-flowing well	0.8
2063	Self-flowing well	0.4
2066	Non-flowing well	4.7
2067	Self-flowing well	4.0
2069	Non-flowing well	0.7

Section 6. Assessment of the Impact of Climate Change on the Ararat Valley Catchment Area

The ASPIRED team conducted an assessment of the climate change impacts in the Ararat Valley catchment area, as a key element in the framework of the USAID ASPIRED Project on identification and management of climate risks. The study combined two main components: (a) assessment of historic trends showing change in climatic elements; and (b) downscaling climate change projections and assessment of natural surface flow changes in the Ararat Valley. In particular, the dynamics of change of climatic elements were assessed at the meteorological stations and hydrological observation points of the Ararat Valley during the analysis period of 1991-2016 against the baseline period of 1961-1990. Projected average annual values of air temperature, atmospheric precipitation and natural surface flow in the Ararat Valley were calculated for the time periods of 2011-2040, 2041-2070 and 2071-2100 by applying the RCP6.0 and RCP8.5 scenarios of CO_2 gas emissions proposed by the Intergovernmental Panel on Climate Change (IPCC), the expert group working under the auspices of the United Nations (definitions are available at URL: https://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html).

The analysis utilized time-series data on hydro-meteorological observations for the period of 1961-2016, as well as geo-spatial datasets of boundaries of the Ararat Valley and its catchment area, and locations of the representative 4 meteorological stations and 5 hydrologic observation posts.

Historic Trends

Climate change impact studies for Armenia demonstrate that the Ararat Valley is highly vulnerable to climatic changes, relative to other regions of Armenia. Tables 7-9 below compare annual climatic elements for the established baseline period of 1961-1990 and the analysis period of 1991-2016 in the representative meteorological stations and hydrological observation posts for the Ararat Valley, and the dynamics of change of these main climatic elements.

Table 7: Changes in Average Annual Temperature at the Meteorological Stations

Meteorological Station	1961-1990 Average Annual Temperature °C	1991-2016 Average Annual Temperature °C	Deviation of the Average Annual Temperature	
			°C	%
Ararat	12.4	12.9	0.5	4.3
Armavir	11.5	12.0	0.5	4.4
Artashat	11.9	12.5	0.6	5.2
Yerevan Agro	11.4	12.3	0.8	7.4

Table 8: Changes in Average Annual Precipitation at the Meteorological Stations

Meteorological Station	1961-1990 Average Snnual Precipitation mm	1991-2016 Average Annual Precipitation mm	Deviation of the Average Annual Precipitation	
			mm	%
Ararat	235.7	230.7	-5.1	-2.1
Armavir	248.3	268.8	20.5	8.2
Artashat	241.6	246.1	4.5	1.8
Yerevan Agro	302.1	321.0	19.0	6.3

Table 9: Changes in Average Annual Natural Surface Flow at the Hydrologic Observation Posts

Hydrologic Observation Post	1961-1990 Average Annual Natural Surface Flow million m^3	1991-2016 Average annual Natural Surface Flow million m^3	Deviation of the Average Annual Natural Surface Flow	
			million m^3	%
Vedi-Urtsadzor	61.8	49.9	-12.0	-19.4
Azat-Garni	146.7	139.0	-7.8	-5.3
Hrazdan-Yerevan	596.7	595.3	-1.5	-0.2
Qasakh-Ashtarak	222.9	202.8	-20.2	-9.1
Metsamor-Taronik	631.7	526.5	-105.1	-16.6
Total	**1,659.9**	**1,513.5**	**-156.4**	**-9.4**

As a result of the analysis, the following conclusions can be made about changes in the Ararat Valley for the period of 1991-2016 compared to the 1961-1990 baseline period:

- average annual temperature in the Ararat Valley increased by 0.6°C;
- average annual precipitation in the Ararat Valley increased by 9.7 mm; and
- average annual value of natural surface inflow to the Ararat Valley decreased by 156.4 million m^3.

Projections

The latest assessments of climate change impacts in Armenia utilized the Community Climate System Model (CCSM4) and Mesoscale Transport and Stream (METRAS) models in accordance with the IPCC recommended RCP 6.0 and RCP 8.5 scenarios for CO_2 emissions. As per the RCP 6.0 scenario (equivalent to the B2 scenario of the IPCC Special Report on Emission Scenarios), which implies implementation of mitigation measures, the CO_2 concentration will be 670 parts per million by 2100. According to the RCP 8.5 scenario (equivalent to the A2 scenario of the IPCC Special Report on Emission Scenarios), which implies continuation of current trends and human economic behavior with no mitigation measures, the CO_2 concentration will be 936 parts per million.

Projections of changes in air temperature and precipitation in the Ararat Valley for the periods of 2011-2040, 2041-2070 and 2071-2100 compared to the baseline period of 1961-1990 were developed for the RCP 6.0 scenario of the IPCC, utilizing the CCSM4 model, and the RCP 8.5 scenario, utilizing both the CCSM4 and METRAS models. Results are presented in Tables 10 and 11.

Table 10: Projected Changes in Average Annual Air Temperature in the Ararat Valley

Time Period	Deviation of the Average Annual Air Temperature, °C RCP 6.0 Scenario	Deviation of the Average Annual Air Temperature, °C RCP 8.5 Scenario	
	CCSM4 Model	CCSM4 Model	METRAS Model
By 2040	+ 1.7	+ 1.8	+ 1.4
By 2070	+ 2.3	+ 3.2	+ 3.1
By 2100	+ 3.1	+ 4.7	+ 4.5

*Table 11: Projected Changes in Annual Precipitation in the Ararat Valley**

Time Period	Deviation of the Average Annual Precipitation, mm RCP 6.0 Scenario	Deviation of the Average Annual Precipitation, mm RCP 8.5 Scenario	
	CCSM4 Model	CCSM4 Model	METRAS Model
By 2040	+ 18.9	+ 6.9	- 2.7
By 2070	+ 13.0 (- 5.9 mm compared to the value for 2040)	+ 30.7	- 5.4
By 2100	+ 22.00	+ 4.0 (- 26.7 mm compared to the value for 2070)	- 8.3

* *Considering significant uncertainties in global CCSM4 model for assessing projected values of precipitation that were revealed in the process of preparing Armenia's Third National Communication on Climate Change, the findings on projected changes in precipitation have limitations and should be considered with some caution.*

Analysis of projected values of natural surface flow demonstrate that under the RCP 6.0 scenario (CCSM4 model) the average annual surface inflow to the Ararat Valley will decrease by 10.1 million m^3 by 2040, 20.9 million m^3 by 2070 and 27.4 million m^3 by 2100. Under the RCP 8.5 scenario, using the CCSM4 model, the average annual surface inflow will reduce by 20.5 by 2040, 21.3 by 2070, and 60.2 million m^3 by 2100, while utilizing METRAS model, the average annual surface inflow are projected to decrease respectively by 32.2 million m^3, 65.3 million m^3 and 95.7 million m^3.

Climate change impact analysis results indicate that the Ararat Valley is highly likely to suffer from more frequent heat waves, prolonged droughts, and early frosts, leading to more intensified desertification. Figures 12-15 and Table 12 present the projected values of the natural surface flow (inflow to the Ararat Valley) obtained by running the Climate Change Model of DSS. The values were converted from millimeters to million cubic meters for better presentation.

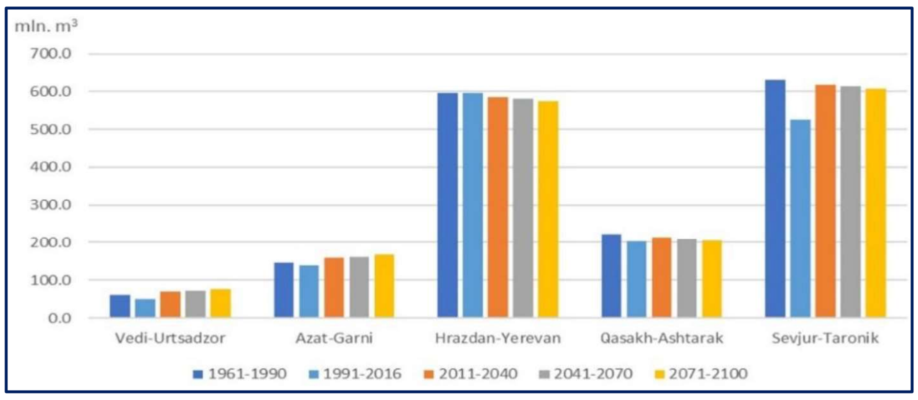


Figure 12: Comparison of the Projected Values of Natural Surface Flow (Inflow to the Ararat Valley) with the Baseline (1961-1990) and Analysis Period (1991-2016) Values, IPCC RCP 6.0 Scenario (CCSM4 Model)

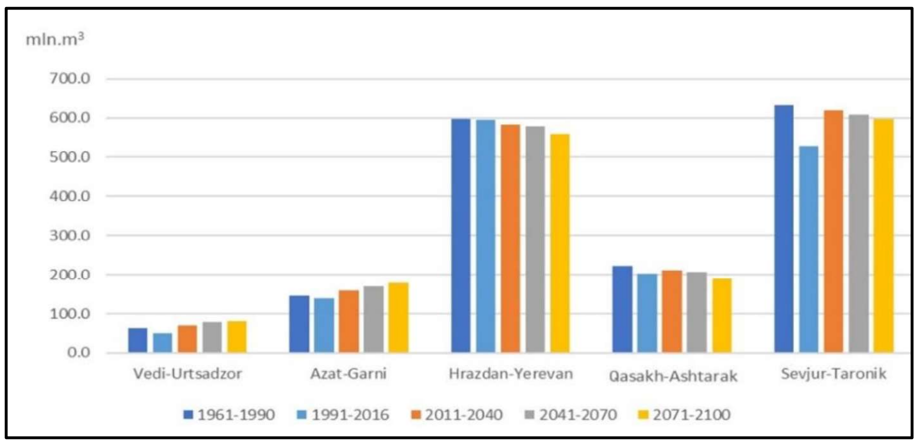


Figure 13: Comparison of the Projected Values of Natural Surface Flow (Inflow to the Ararat Valley) with the Baseline (1961-1990) and Analysis Period (1991-2016) Values, IPCC RCP 8.5 Scenario (CCSM4 Model)

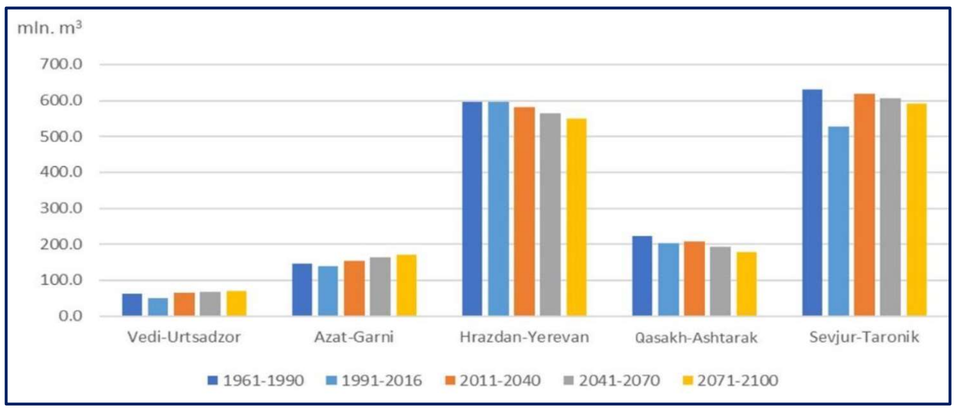


Figure 14: Comparison of the Projected Values of Natural Surface Flow (Inflow to the Ararat Valley) with the Baseline (1961-1990) and Analysis Period (1991-2016) Values, IPCC RCP 8.5 Scenario (METRAS Model)

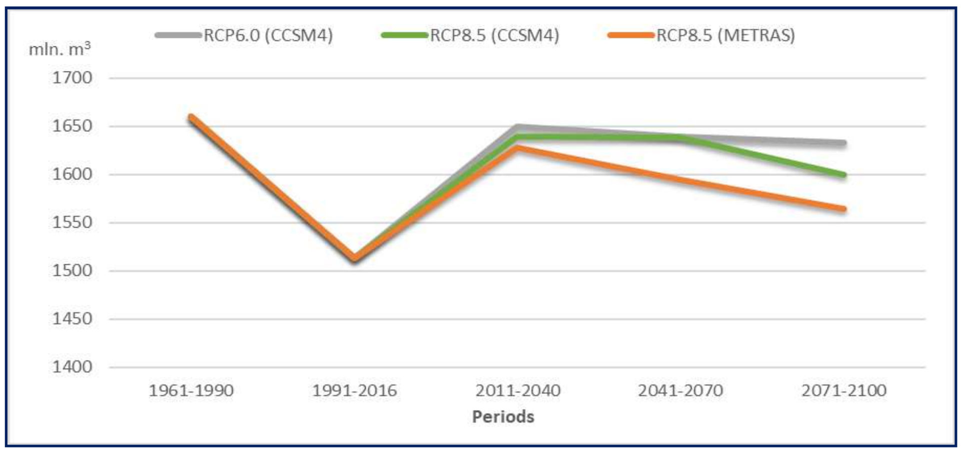


Figure 15: Observed and Projected Values of the Annual Natural Surface Inflow to the Ararat Valley with Application of Various Scenarios

As illustrated in the charts, the decrease in the natural surface inflow during the analysis period (1991-2016) is higher than the projected decrease estimated using IPCC climate change scenarios against the baseline period.

It is envisaged that the decline in surface flow and precipitation combined with the increase in evapotranspiration will lead to changes in water requirements for agriculture. According to studies conducted by the World Bank in 2014 on building resilience to climate change in South Caucasus Agriculture, crop water requirements for winter wheat and vegetables grown in the Ararat Valley are predicted to increase by 9-15% and by 10-17% respectively in the period 2011-2040, and by 19-22% and 19-23%, respectively, by 2100, compared to the baseline period. Irrigation water requirements are projected to increase by 35-36% and 38-42% for winter wheat and vegetables, respectively, by the end of the century.

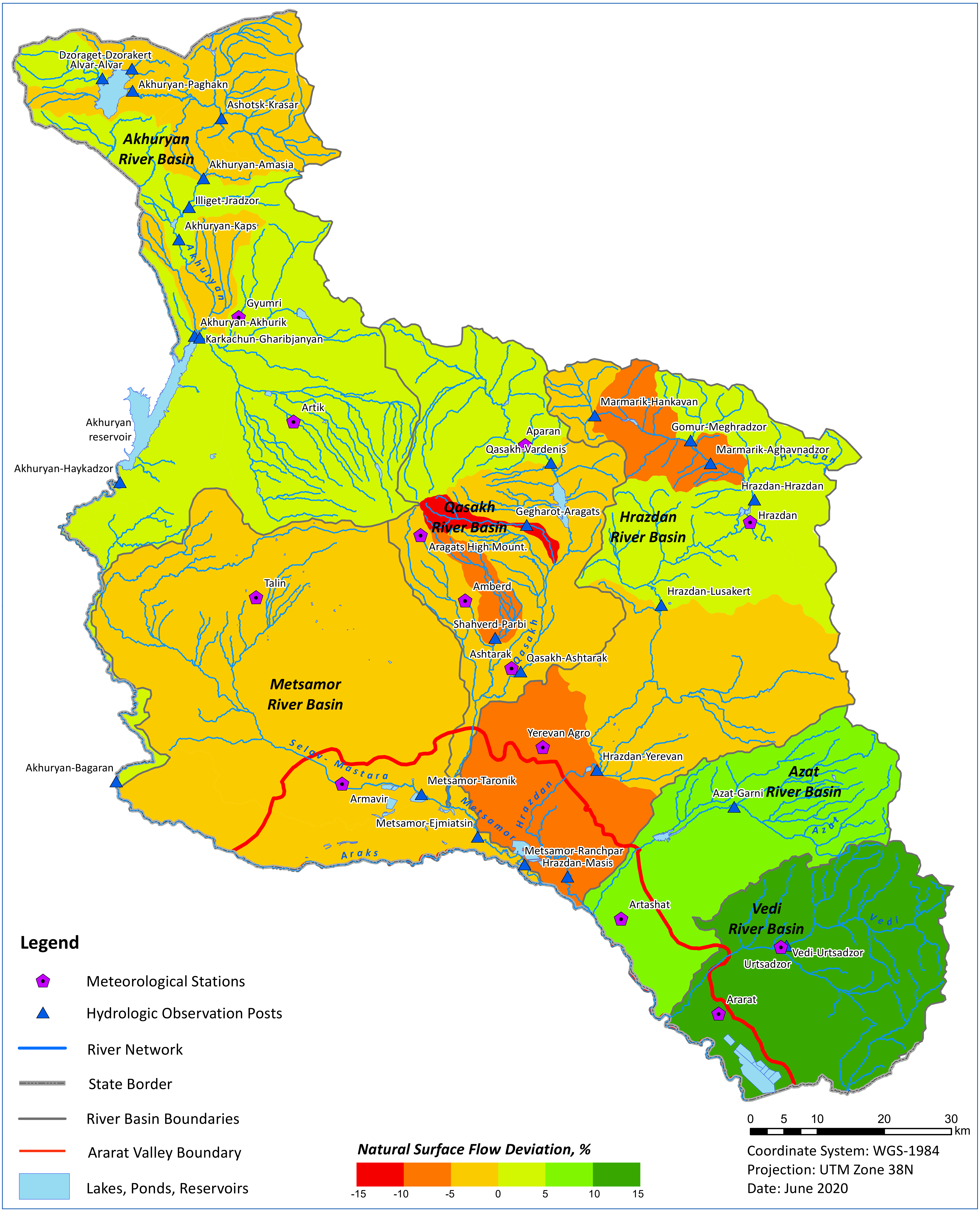
It can be concluded that the anthropogenic impact on the water resources of the Ararat Valley exceed observed global climatic changes, adding an additional layer of challenge to the assessment of future water supply.

This section of the Atlas includes maps on projected deviation of the natural surface flow in the Ararat Valley catchment area by 2040, 2070 and 2100 against the baseline average for 1961-1990, under the IPCC RCP 6.0 (CCSM4 model) and RCP 8.5 scenarios (CCSM4 and METRAS models).

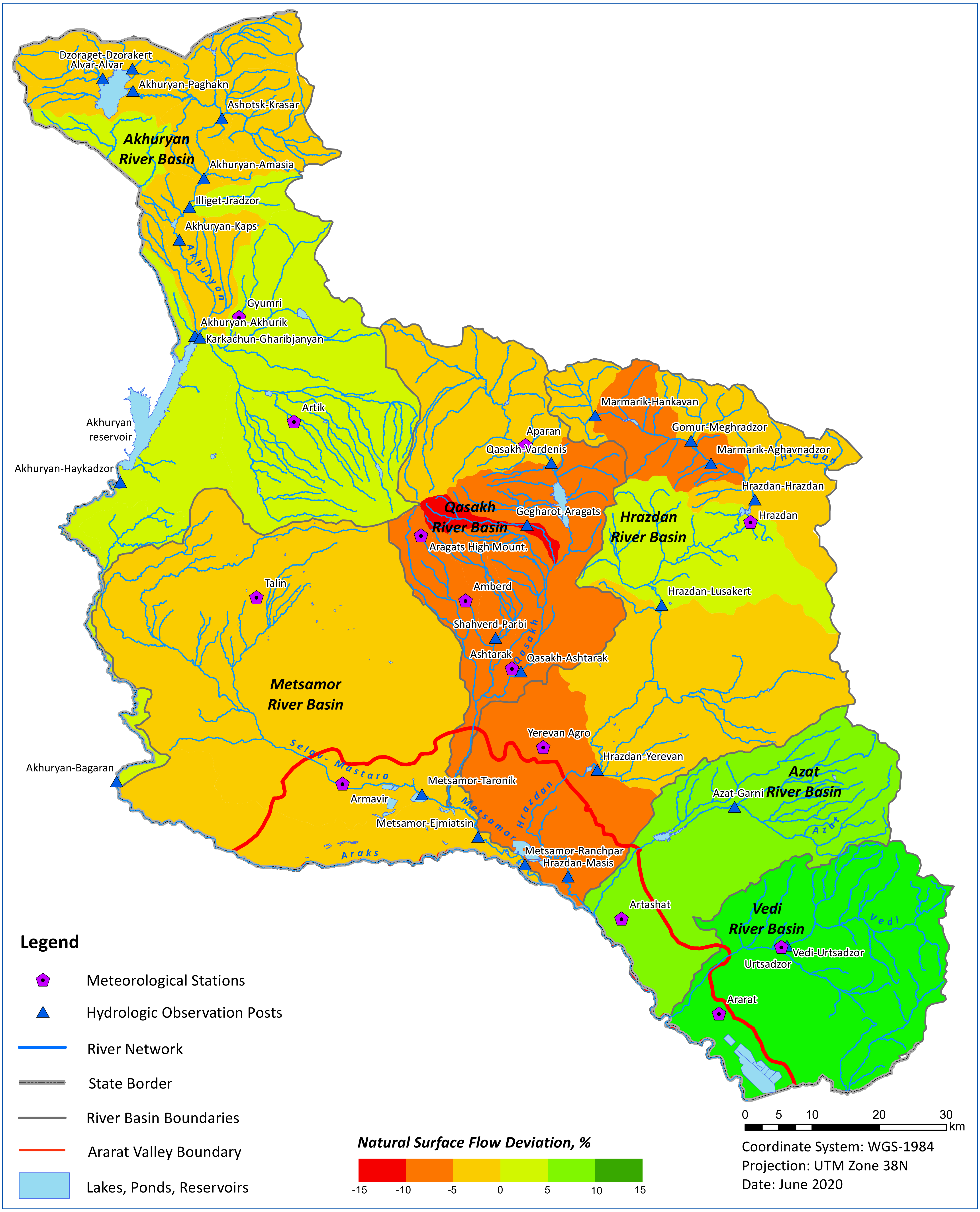
Table 12. Projected Values of the Natural Surface Inflow to the Ararat Valley and Deviation from the Baseline Average Values under Various IPCC Scenarios

Hydrologic Observation Post	Natural Surface Flow, million m^3																		
	Baseline Period	RCP 6.0 Scenario (CCSM4 Model)						RCP 8.5 Scenario (CCSM4 Model)						RCP 8.5 Scenario (METRAS Model)					
	1961-1990	2040	Dev. %	2070	Dev. %	2100	Dev. %	2040	Dev. %	2070	Dev. %	2100	Dev. %	2040	Dev. %	2070	Dev. %	2100	Dev. %
Vedi-Urtsadzor	61.8	70.6	14.2	72.0	16.5	76.0	23.0	69.1	11.8	77.8	25.9	79.2	28.2	64.4	4.2	68.0	10.0	70.9	14.7
Azat-Garni	146.7	159.1	8.5	162.7	10.9	168.5	14.9	158.8	8.2	169.8	15.7	177.3	20.9	154.2	5.1	164.0	11.8	171.5	16.9
Hrazdan-Yerevan	596.7	586.6	-1.7	580.6	-2.7	574.6	-3.7	582.6	-2.4	576.6	-3.4	558.5	-6.4	580.6	-2.7	564.5	-5.4	550.5	-7.7
Qasakh-Ashtarak	222.9	214.2	-3.9	209.1	-6.2	205.0	-8.0	211.1	-5.3	206.0	-7.6	188.7	-15.3	209.1	-6.2	192.8	-13.5	178.5	-19.9
Metsamor-Taronik	631.7	619.3	-2.0	614.6	-2.7	608.4	-3.7	617.8	-2.2	608.4	-3.7	595.9	-5.7	619.3	-2.0	605.3	-4.2	592.8	-6.2
Total	**1,659.9**	**1,649.8**	**-0.6**	**1,639.0**	**-1.3**	**1,632.5**	**-1.7**	**1,639.4**	**-1.2**	**1,638.6**	**-1.3**	**1,599.7**	**-3.6**	**1,627.7**	**-1.9**	**1,594.6**	**-3.9**	**1,564.2**	**-5.8**

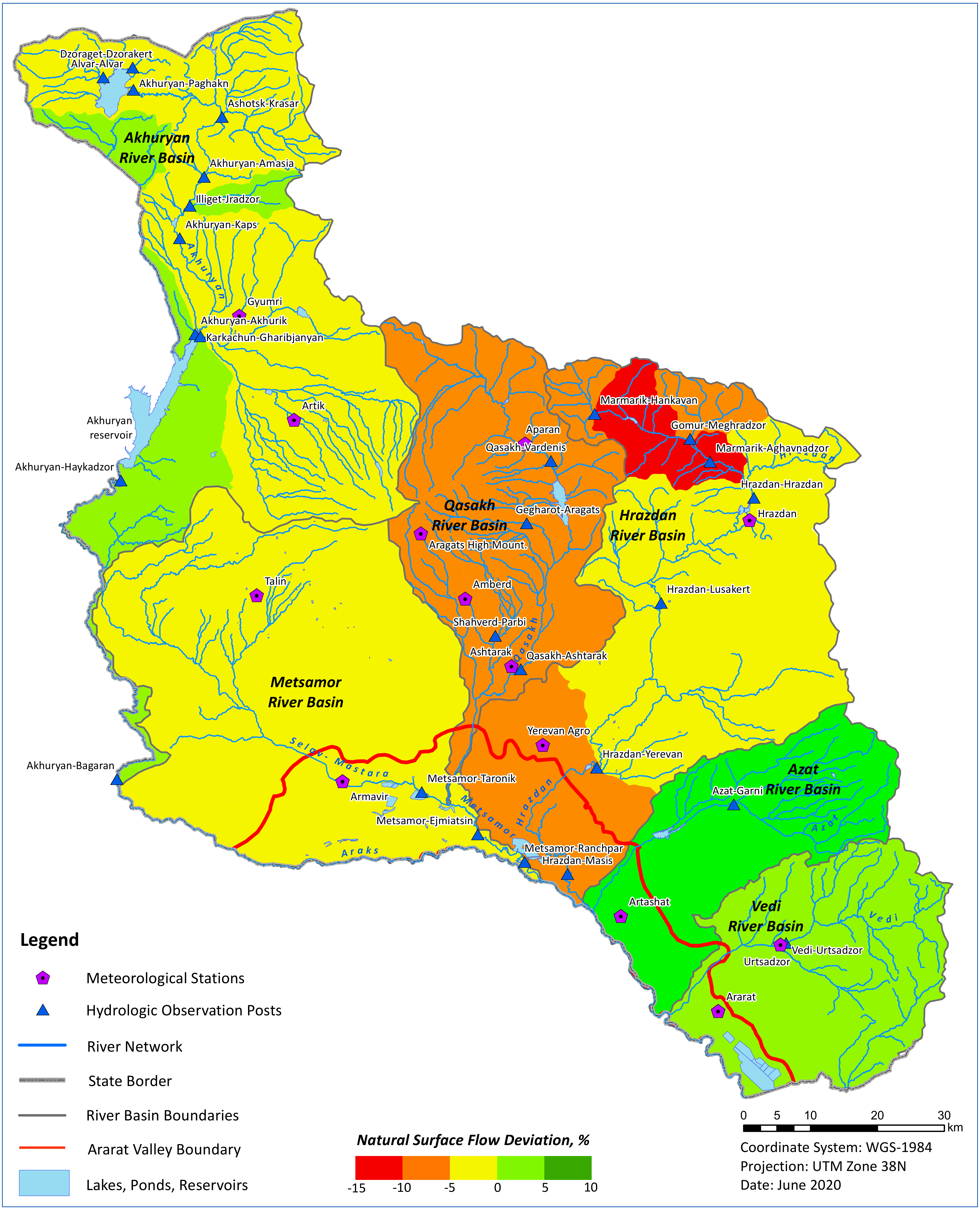
Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2040, Against the Baseline Average for 1961-1990, under the IPCC RCP 6.0 Scenario (CCSM4 Model)



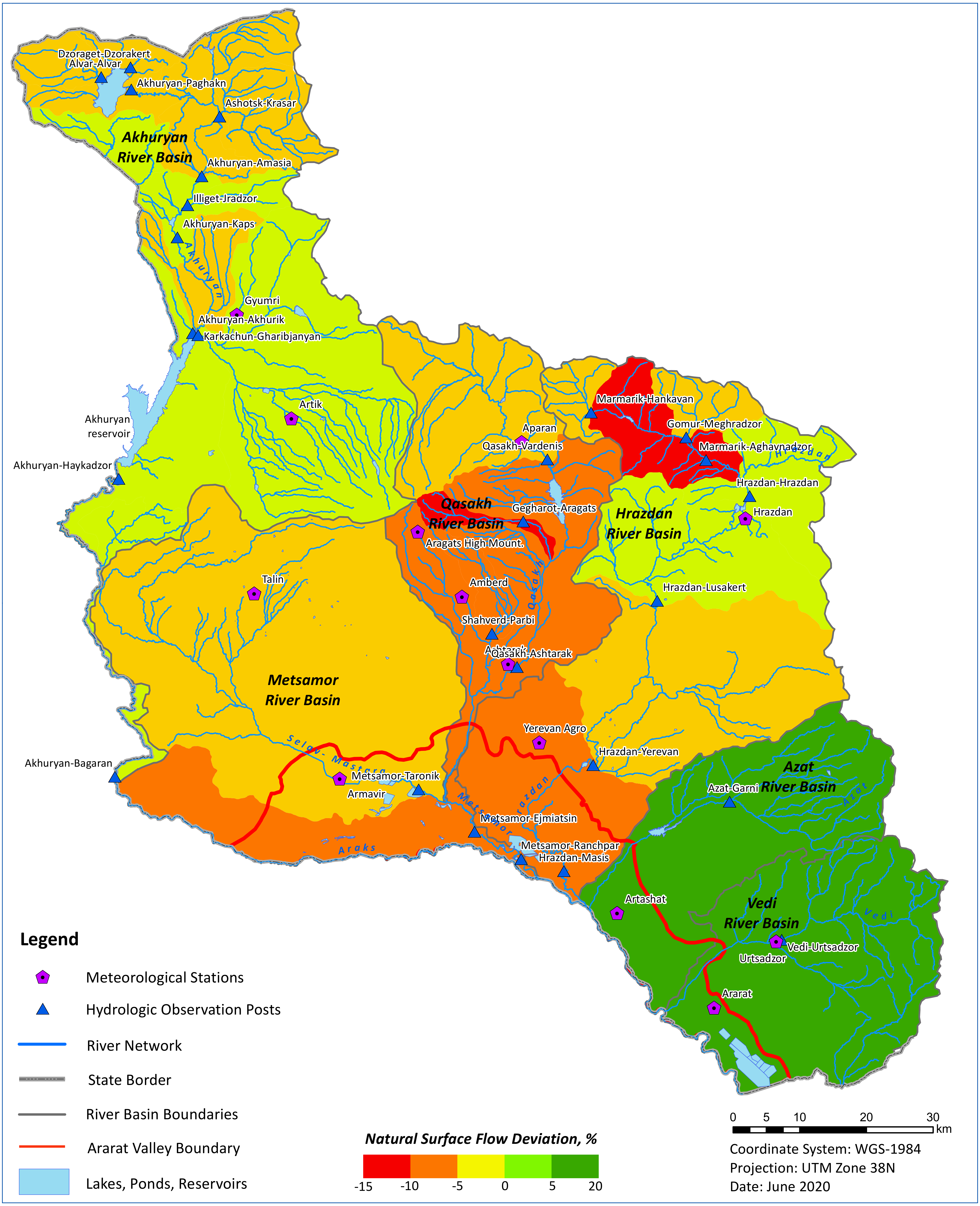
Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2040, Against the Baseline Average for 1961-1990, under the IPCC RCP 8.5 Scenario (CCSM4 Model)



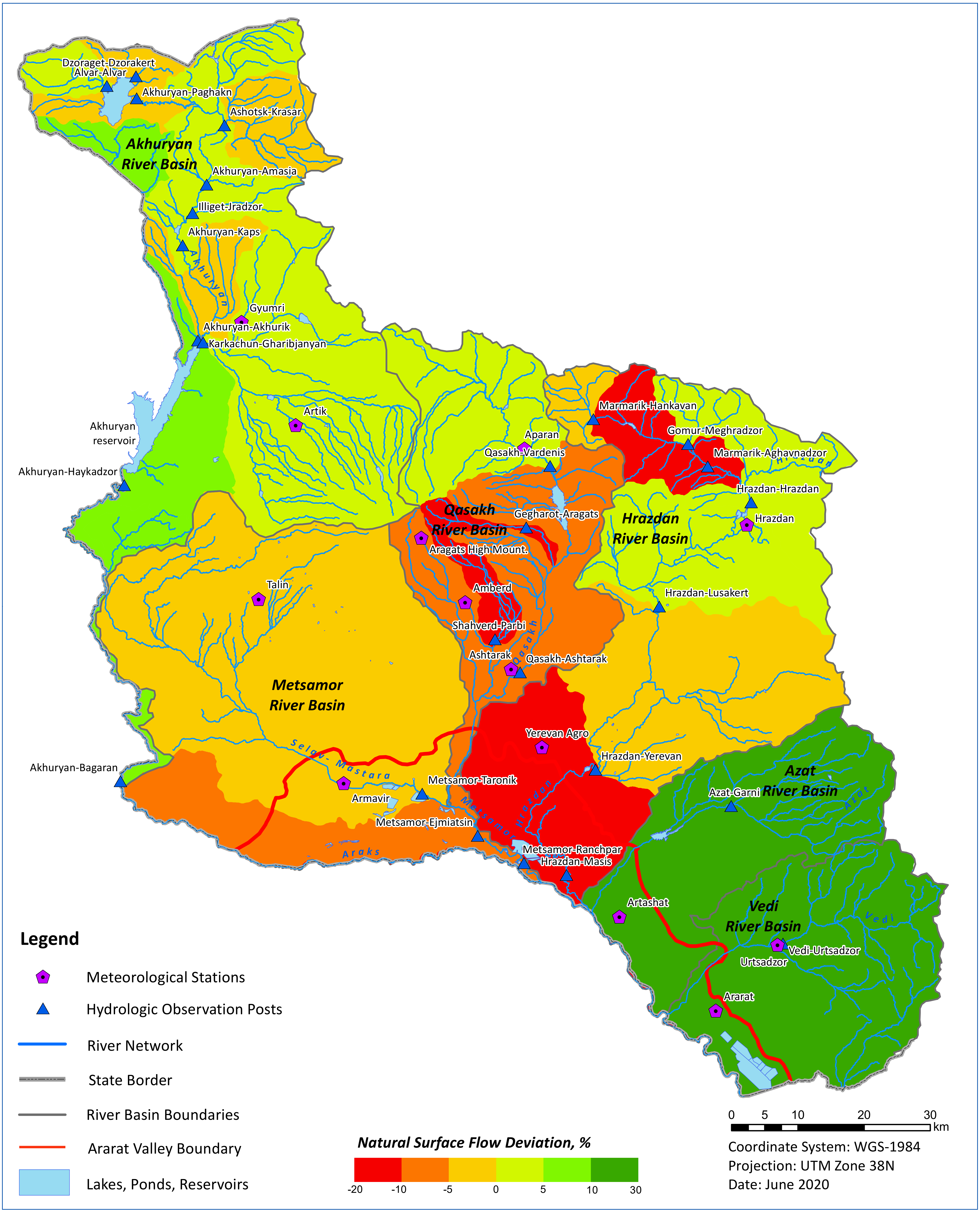
Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2040, Against the Baseline Average for 1961-1990, under the IPCC RCP 8.5 Scenario (METRAS Model)



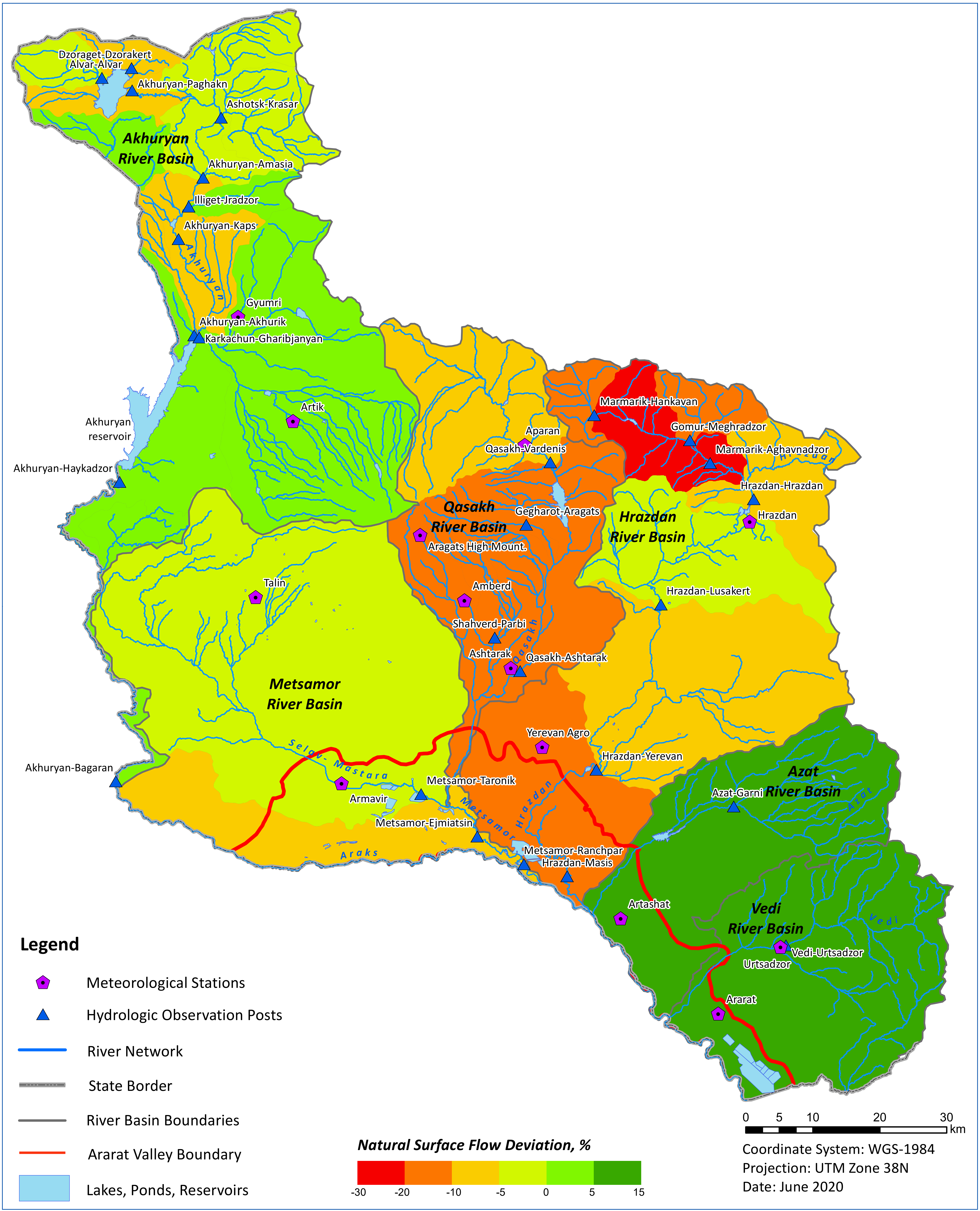
Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2070, Against the Baseline Average for 1961-1990, under the IPCC RCP 6.0 Scenario (CCSM4 Model)



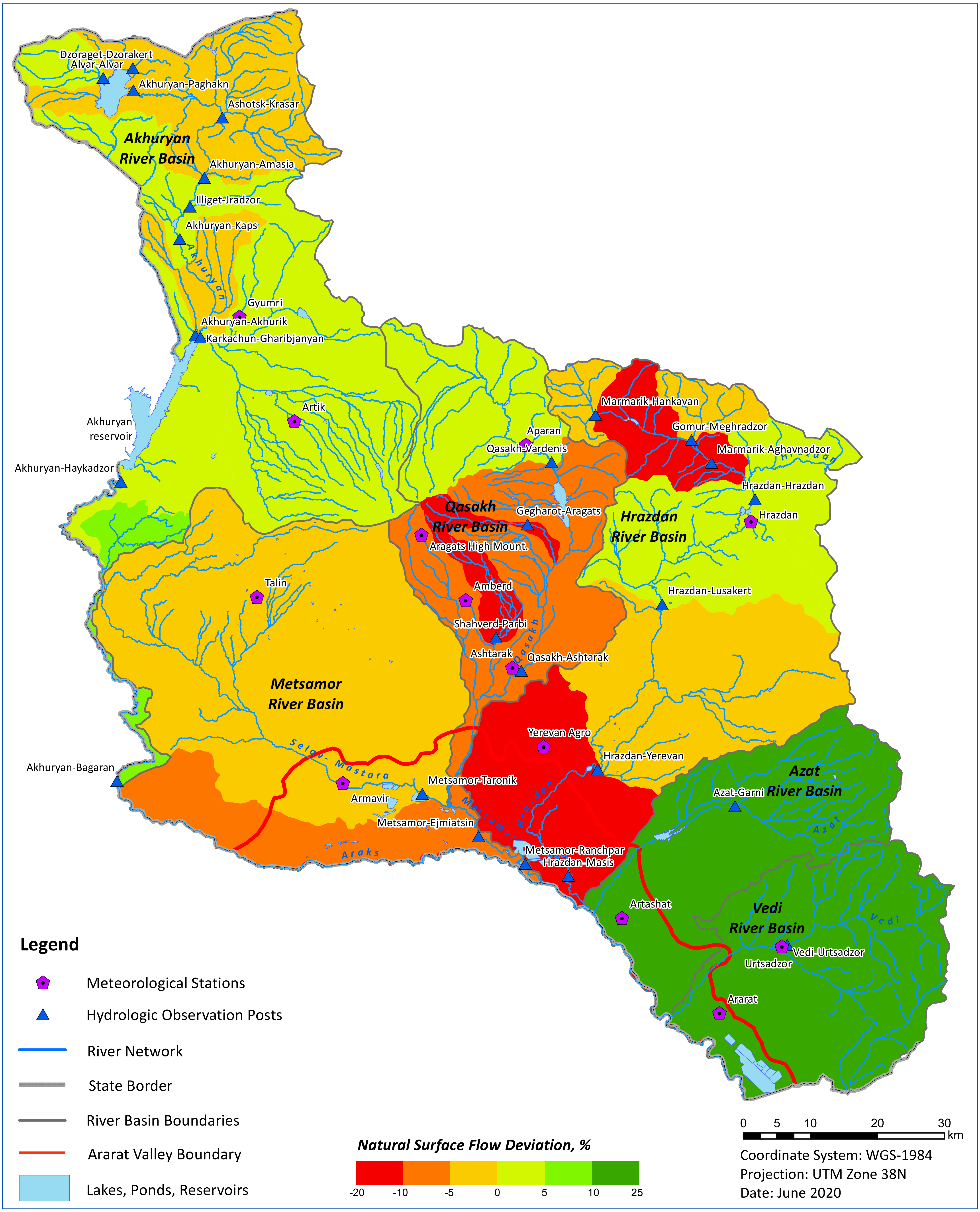
Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2070, Against the Baseline Average for 1961-1990, under the IPCC RCP 8.5 Scenario (CCSM4 Model)



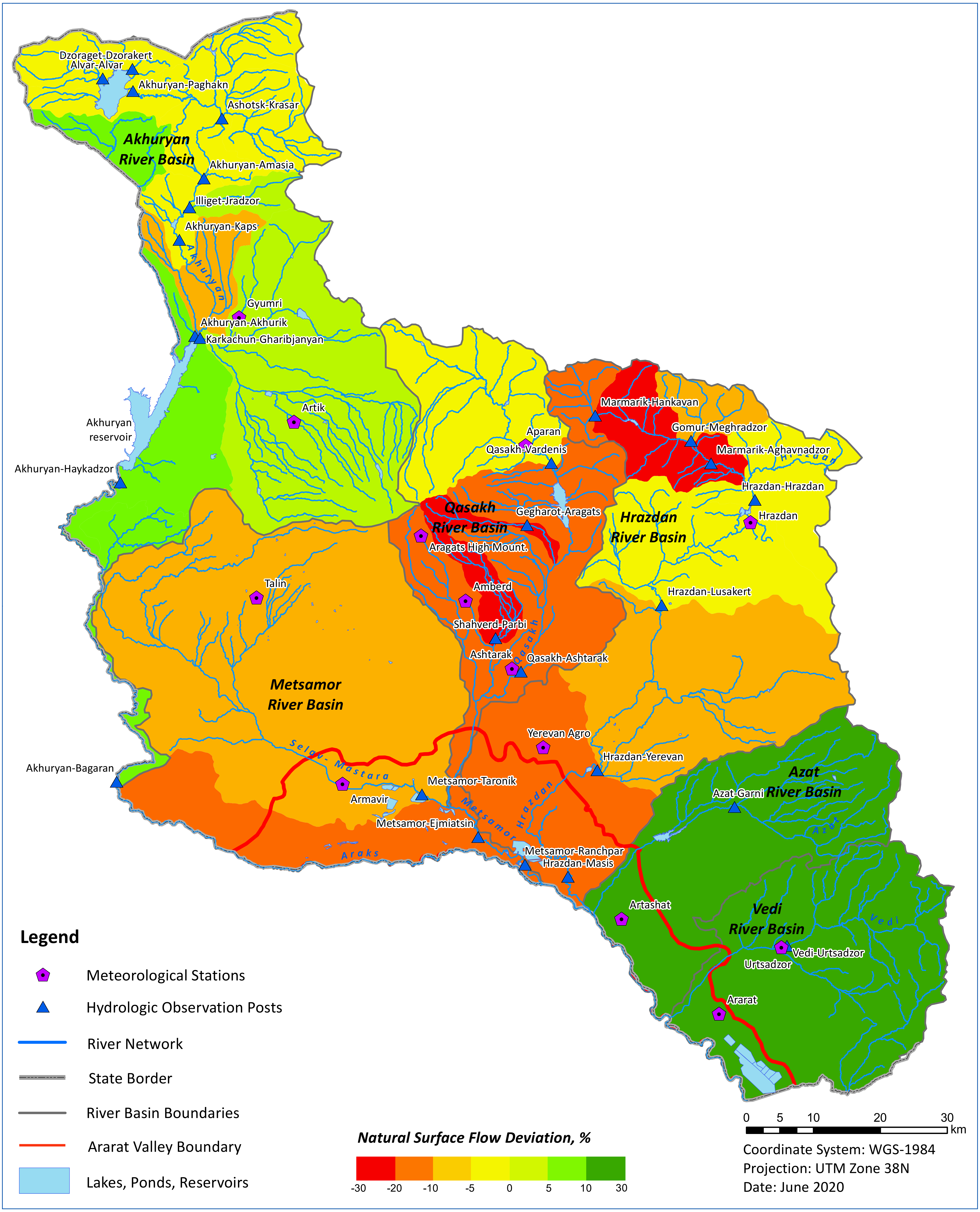
Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2070, Against the Baseline Average for 1961-1990, under the IPCC RCP 8.5 Scenario (METRAS Model)



Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2100, Against the Baseline Average for 1961-1990, under the IPCC RCP 6.0 Scenario (CCSM4 Model)



Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2100, Against the Baseline Average for 1961-1990, under the IPCC RCP 8.5 Scenario (CCSM4 Model)



Projected Deviation of the Natural Surface Flow in the Ararat Valley Catchment Area by 2100, Against the Baseline Average for 1961-1990, under the IPCC RCP 8.5 Scenario (METRAS Model)