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

GROUNDWATER MONITORING DEVELOPMENT PLAN 2024

Armenia

Funded by the European Union

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ABOUT THIS REPORT

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ABOUT EU4ENVIRONMENT – WATER RESOURCES AND ENVIRONMENTAL DATA

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

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

https://eu4waterdata.eu

CONTENTS

List of abbreviations

AM ..... Armenia

GE ..... Georgia

CIS ..... Common Implementation Strategy

EaP ..... Eastern Partners

EC ..... European Commission

EPIRB ..... Environmental Protection of International River Basins

EU ..... European Union

EU4WD ..... EU4Environment in Eastern Partner Countries: Water Resources and Environmental Data

EUWI+ ..... European Union Water Initiative Plus

GEF ..... Global Environmental Fund

GW ..... Groundwater

GWB ..... Groundwater Body

RBD ..... River Basin District

RBMP ..... River Basin Management Plan

UBA ..... Umweltbundesamt GmbH, Environment Agency Austria

UNDP ..... United Nations Development Programme

UNECE ..... United Nations Economic Commission for Europe

WFD ..... Water Framework Directive

Country Specific Abbreviations Armenia

CEPA ..... Comprehensive and Enhanced Partnership Agreement

EMIC ..... Environmental Monitoring and Information Centre

HMC ..... Hydrometeorology and Monitoring Centre

MOE ..... Ministry of Environment

SCWS ..... State Committee on Water Systems

SWCIS ..... State Water Cadastre Information System of Armenia

WRMA ..... Water Resources Management Agency

WBMP ..... Water Basin Management Plan

Executive Summary

This Groundwater Monitoring Development Plan 2024 (GW-MDP) is an update of the first plan which was prepared in 2021 within the EUWI+ project. It provides recommendations for the improvement of Armenia's groundwater (quantity and chemical) monitoring infrastructure and activities to further converge to the requirements of the EU Water Framework Directive (WFD). It outlines the necessity and purpose of surveillance and operational groundwater monitoring programs and provides guidance on the selection of monitoring sites, monitoring frequencies and investigated parameters for each monitoring programme.

This update takes regard of the significant progress achieved within the EU4WD programme of the past four years. A new river basin management plan (RBMP) - for the Northern river basin district (RBD) - was drafted and two groundwater surveys were implemented (2022 and 2023) in this river basin with the intention to find appropriate existing sites/wells to be included into the national monitoring network. Furthermore, a transboundary groundwater survey with Georgia at Bagratashen (in the Eastern part of Khrami-Debed river basin district) was performed in 2023 to explore transboundary interlinkages of groundwater and to coordinate and harmonise groundwater sampling procedures and monitoring results

There are still significant efforts needed towards WFD conformity of groundwater monitoring, in terms of network, parameters, frequency as well as data assessment.

1. Introduction and scope

The 'EU Water Initiative Plus' (EUWI+) programme (2016-2021) aimed at improving the management of water resources and strengthening capacities in Armenia, Azerbaijan, Belarus, Georgia, Moldova, and Ukraine. It supported the development and implementation of River Basin Management Plans (RBMPs), building on the improved policy framework and ensuring a strong participation of local stakeholders. The follow-on programme 'EU4Environment in Eastern Partner Countries: Water Resources and Environmental Data' (EU4WD) continued this support since 2021.

River basin management is based on monitoring of groundwater and surface water resources and plays a central role in any RBMP. Groundwater monitoring consists of quantity monitoring (groundwater levels) and chemical monitoring. Both monitoring is needed to supplement and validate the characterisation and risk assessment, to establish the groundwater status of groundwater bodies (GWBs) and to evaluate the effectiveness of the measure which were set in order to achieve and to keep good groundwater quantity and chemical status. In addition, groundwater chemical monitoring is needed to detect the presence of statistically significant and sustainable upward trends in the concentration of pollutants and trend reversal.

Sound monitoring is a powerful basic instrument in good groundwater governance. It provides all stakeholders with up-to-date information about groundwater in the river basin and enables meaningful decisions on groundwater management and a program of measures to achieve the environmental objectives laid down by the Water Framework Directive (WFD).

This document, the Groundwater Monitoring Development Plan (GW-MDP), deals with quantity and chemical monitoring of groundwater in the light of the requirements of the WFD. The comparison with the actual situation lays the groundwork for drawing conclusions and formulating options towards a successful implementation of WFD compliant groundwater monitoring.

On this basis, an outlook and proposal for further development and capacity building to further ensuring sustainability of project efforts beyond EU4WD is provided.

2. WFD Groundwater monitoring

The WFD sets out the requirements for the different groundwater monitoring programs in its Annex V (2.2 and 2.4) and Annex II (2.3). The guidance document No 15 (EC 2007) of the Common Implementation Strategy (CIS) for the WFD, which was jointly elaborated by representatives of the EU Member States, the European Commission and various stakeholders, provides specific guidance and best practice on properly implementing the WFD requirements.

This chapter briefly summarizes the most important cornerstones of WFD compliant groundwater monitoring and picks out selected aspects from CIS guidance document No 15 (EC 2007). These requirements are the targets that the current monitoring situation is compared with.

2.1. Purpose of WFD monitoring

A WFD conform groundwater monitoring must include (EC 2007):

- quantitative monitoring to:
  - supplement and validate the WFD Article 5 characterization and risk assessment procedure with respect to risks of failing to achieve good groundwater quantitative status in all GWBs or groups of bodies and
  - facilitate quantitative status assessment.
- chemical surveillance monitoring to:
  - supplement and validate the WFD Article 5 characterization and risk assessment procedure with respect to the risks of failing to achieve good groundwater chemical status;
  - assess long-term trends in natural conditions and in pollutant concentrations resulting from human activity and
  - to establish, in conjunction with the risk assessment, the need for operational monitoring.
- chemical operational monitoring to:
  - establish the status of all GWBs, or groups of bodies, and
  - identify the presence of significant and sustained upward trends in the concentration of pollutants.
- Appropriate monitoring to support the achievement of Drinking Water Protected Area (DWPA) objectives.

The results of the monitoring must be used to (EC 2007):

- establish the chemical and quantitative status of GWBs (including an assessment of the available groundwater resource);
  - identify whether the available groundwater resource is not exceeded by the long-term annual average rate of abstraction;
  - identify saline or other intrusions resulting from alterations of flow within the GWB;
  - identify impacts on associated aquatic and dependent terrestrial ecosystem;
  - identify exceedances of groundwater quality standards and threshold values;
  - identify impairment of legitimate uses of groundwater;
- assist in further characterization of GWBs;

- validate the risk assessments carried out under WFD Article 5;
- estimate the direction and rate of flow in GWBs that cross Member States' boundaries;
- assist in the design of programs of measures;
- evaluate the effectiveness of programs of measures;
- demonstrate compliance with objectives for DWPA and other protected area;
- characterize the natural quality of groundwater including natural trends (baseline); and
- identify anthropogenically induced trends in pollutant concentrations and their reversal.

Transboundary groundwater bodies: Specific provisions concern those GWBs, which cross the boundary between two or more Member States. Bilateral agreement should be reached on monitoring strategies, which requires coordination of conceptual model development, the exchange of data and QA and QC aspects (in line with the requirements of WFD Article 13(2)). The provisions for surveillance monitoring require transboundary GWBs to be monitored for those parameters, which are relevant for the protection of all uses supported by the groundwater flow. (EC 2007)

2.2. Conceptual models

The monitoring design should be based on conceptual model/understandings, which are simplified representations or working descriptions of the hydrogeological system being investigated. A conceptual model represents the current understanding of the groundwater system based on the knowledge of its natural characteristics (e.g. the aquifer type, three-dimensional structure, dynamics and boundary conditions), perceived pressures and knowledge of impacts. This conceptual understanding is to be tested and validated by monitoring data and improved in a cyclic manner. Consequently, conceptual models do not need to be perfect and definitive, but are instead necessarily always work in progress. The complexity of conceptual models depends on the complexity of the hydrogeological system and the significance of the anthropogenic pressures. (EC 2007)

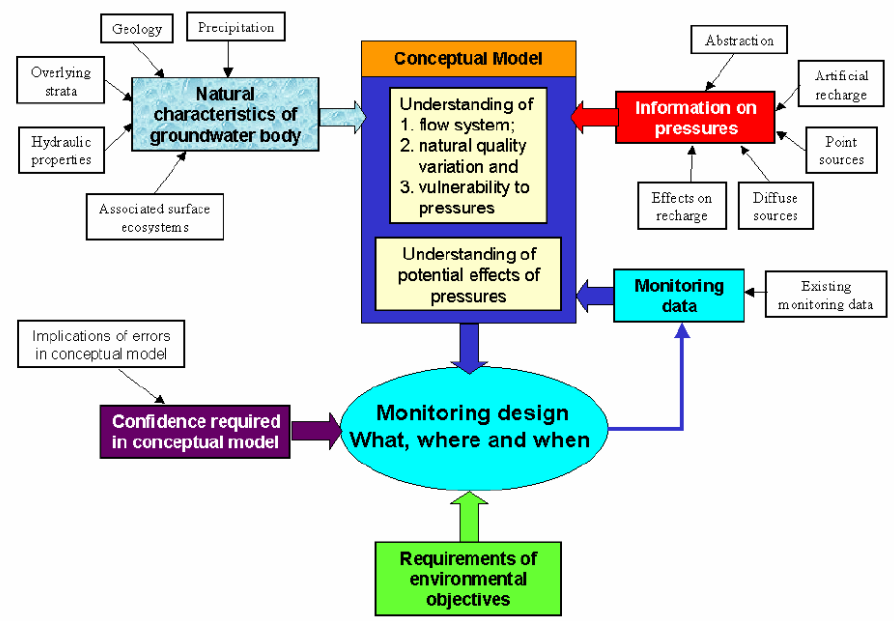

Figure 1: Link between the conceptual model/understanding and monitoring (EC 2004)

2.3. Chemical groundwater monitoring

2.3.1. Surveillance monitoring

Selection of monitoring sites

The selection of sampling sites is of major importance for the results of the later assessment procedure especially as contaminants are often unevenly distributed across a GWB. Additionally, a GWB is three-dimensional and the concentration of contaminants may vary significantly in vertical and lateral direction.

The distribution of surveillance monitoring sites within a GWB should be representative of the whole GWB. The selection of sites should be based on the conceptual model considering the hydrogeological properties, the distribution of different anthropogenic pressures and practical considerations relating to the suitability of individual sampling points (e.g. easily accessible, secure and able to provide long-term access agreements). (EC 2007)

Within the elaboration of recommendations for WFD conform statistical methodologies for the aggregation of chemical monitoring data and the assessment of groundwater pollution trends it was concluded that due to statistical reasons a minimum number of 3 monitoring sites per GWB is recommended. (EC 2001)

Monitoring parameters

The following core parameters are mandatory by the WFD: oxygen content, pH-value, electrical conductivity (EC), nitrate, and ammonium.

Parameters such as temperature and a set of major and trace ions are not formally required by the WFD but may be helpful to validate the WFD Article 5 risk assessment and the conceptual models. Selective parameters (e.g. heavy metals and relevant basic radionuclides) will be needed for assessing natural background levels. Additional indicators of anthropogenic contaminants typical of land use activities in the area and with the potential to impact on groundwater will also be required on an infrequent basis to provide additional validation of WFD risk assessments and to check for any new identified pressure.

In addition, at all sites monitoring of the water level is recommended in order to describe (and interpret) the 'physical status of the site' and to interpret (seasonal) variations or trends in chemical composition of groundwater. (EC 2007)

Monitoring frequency

According to the WFD, surveillance monitoring must be undertaken during each planning cycle. No minimum duration or frequency is specified for the surveillance program.

The monitoring frequency has to be selected accordingly in order to characterize the variability of groundwater quantity and quality adequately. It is recommended, to select an appropriate monitoring frequency based on the conceptual understanding; in less dynamic groundwater systems (confined aquifers) two (or even one) sample(s) per year may be sufficient initially for surveillance monitoring. In more dynamic systems (shallow aquifers) four samples per year are recommended. (EC 2007)

2.3.2. Operational monitoring

Selection of monitoring sites

The operational monitoring network should be based on the monitoring sites that are part of the surveillance monitoring network and consider the potential integration of additional monitoring site from other monitoring networks for different purposes (e.g. drinking water, specific ecosystems). (EC 2007)

Monitoring parameters

In addition to the WFD core parameters, selective parameters will need to be monitored at specific locations, or across GWBs, where the risk assessments indicate that they are at risk of failing to achieve relevant objectives. These parameters will have to be considered when establishing groundwater threshold values and in the assessment of chemical groundwater status.

The sets of chemical monitoring parameters must be reviewed on a regular basis to ensure that they provide representative information and data on groundwater quality and fully support the risk assessment process. (EC 2007)

Monitoring frequency

According to the WFD, operational monitoring must be carried out at least once a year during periods between surveillance monitoring for all GWBs that are identified at risk of failing to achieve good chemical status objectives. Operational monitoring must be as sufficient as necessary to establish the status of GWBs at risk and the presence of significant and sustained upward trend in pollutant concentrations.

As for surveillance monitoring, it is recommended to select the appropriate monitoring frequency on the basis of the conceptual understanding of each GWB, the seasonal effects of pollutants, the seasonal use or application of pollutants.

2.4. Quantitative groundwater monitoring

Selection of monitoring sites

As with other networks, the selection of monitoring points should be based on a conceptual understanding of the groundwater system and the pressures. The key elements of the quantitative conceptual understanding are: assessment of recharge and water balance; and/or existing groundwater level or discharge assessments and relevant information on the risks for groundwater dependent surface waters and groundwater dependent terrestrial ecosystems.

Monitoring parameters

Although the WFD identifies the metric of water levels only in assessing the quantitative status, it is highly recommended to also consider spring flows, flow characteristics and/or stage levels of surface watercourses during drought periods or stage levels in significant groundwater dependent wetlands and lakes.

Monitoring frequency

The amount and frequency of monitoring is required to be sufficient ad will be determined by the data needed to determine risk and status, and where necessary to support the design and assessment of a program of measures. Frequency of monitoring predominantly depends of the characteristics of the water body and the monitoring site respectively. Sites with significant annual variability should be monitored more frequently than sites with only minor variability. In general, monthly monitoring will be sufficient for quantity monitoring where variability is low. (EC 2007)

3. Groundwater monitoring in Armenia – current state

Armenia is divided into six river basin districts (RBD): Akhuryan, Ararat, Hrazdan, Sevan, Northern and Southern. The EPRIB project (2012-2016) focused at the Akhuryan RBD, in EUWI+ (2016-2021) focus was put on the Hrazdan and the Sevan RBDs and under EU4WD (2021–2024) the groundwater activities focused at the Northern RBD.

After the process of identifying and delineating groundwater bodies (GWBs) in the RBDs, the existing groundwater monitoring networks were analysed and described. Main efforts were spent on the development of groundwater chemical monitoring of GWBs because their current scope and level of operation is rather limited and the scope of improvement is demanding. Less focus was put on groundwater quantitative monitoring as the existing monitoring capacities in terms of monitoring networks, assessment strategies, equipment and staff are better developed due to their long-lasting experience and continuous operation and the aspects of quantitative monitoring are not as challenging as for chemical monitoring.

For quantitative and chemical monitoring, it was a particular challenge to consider the interpretation and the delineation of GWBs and the distribution of monitoring points and the representativeness of the overall monitoring network in the light of the newly delineated GWBs, which are the management units of groundwater under the WFD.

The legal requirements on WFD conform monitoring, the particular purposes of the different types of groundwater monitoring as well as guidance for site selection, the selection of monitoring parameters and frequency of monitoring is provided in relation to their respective objectives and they are described in more detail in chapter 2.

The existing monitoring and sampling equipment and the needs of investment were discussed since 2019 and refined considering the conclusions drawn in the different EUWI+ and EU4WD groundwater assessment studies and surveys.

The following technical reports were elaborated under EUWI+ and EU4WD:

- Delineation and characterisation of GWBs and the design of a groundwater monitoring network in the Hrazdan and Lake Sevan RBDs in Armenia (EUWI+ 2018);
- Development of a national methodology for an assessment of the available groundwater resources in mountainous regions and the implementation of this methodology in the Hrazdan and Sevan RBDs (EUWI+ 2021)
- Groundwater surveys 2018 and 2019 (EUWI+ 2020);
- Specific manual for surveys in groundwater (EUWI+ 2020).
- General manual for chemical freshwater sampling (EUWI+ 2020)
- Groundwater survey 2022 (EU4WD 2023);
- Groundwater survey 2023 (EU4WD 2023);
- Groundwater transboundary survey 2023 (Armenia-Georgia) (EU4WD 2024);
- Transboundary GWB report – Armenia-Georgia (EU4WD 2024)
- Audit report: Groundwater sampling – Armenia (EU4WD 2024)

3.1. Legal background

After over two decades of no operation due to the collapse of the former Soviet Union, groundwater monitoring in Armenia was re-vitalized in accordance with the RA Government Resolution N 1616 of 08.09.2005, but regular monitoring started in 2010.

On November 24, 2017 the European Union and Armenia signed an agreement aimed at significantly deepening relations between of parties. Signatures to the document entitled the Comprehensive and Enhanced Partnership Agreement (CEPA) were put by High Representative of the European Union for Foreign Affairs and Security Policy Federica Mogherini and Armenia's Foreign Minister Edward Nalbandian. Armenia and all EU member states have completed the ratification process of CEPA between the EU and Armenia and it officially entered into force in March 2021. The Armenian government aims to adopt RBMPs for all six river basins districts by the end of 2024 and ensure their harmonised implementation from 2025.

With this agreement Armenia has taken obligations to approximate its legislation to the EU acts and international instruments. In the field of water quality and resources management, this approximation includes five Directives: Water Framework Directive, Floods Directive, Urban Wastewater Directive, Drinking Water Directive and Nitrates Directive.

According to the CEPA and its roadmap[1], the following WFD related water monitoring activities are envisaged to be implemented:

- Revision of the RA Government Decision N 549-N (29.05.2008) "On Establishment of Water Balance Elements of the RA River basins as well as Allocation of the Water Resources and Resources";
- Revision of the RA Government Decision N 23 N (14.01.2010), "On Establishment of Water Resources Management and Storage Facility" by Introducing Water bodies according to status of classification requirements set out in the WFD;
- Revision of the RA Government Decision N 639-N (22.05.2003) on "Approving Water Resources Monitoring and Reports Registration Procedures" in order to comply with Water Resources Monitoring Requirements set out in the WFD;
- Establish new water resources monitoring programs, taking into account the requirements of the WFD;
- Strengthening the capacity of water resource monitoring agencies (by technical re-equipment of water resources monitoring system, development of methodologies, organization and holding of trainings / trainings of specialists;

[1]) Decree No 224-L of the Ministry of Environment of the Republic of Armenia (July 10, 2020) on Ensuring the implementation of the water quality and resources management area of the roadmap of implementation of CEPA.

Résumé

The CEPA and its roadmap stipulate a broad range of reviews and revisions of the water monitoring related legislation and strategy of Armenia. The products elaborated under EUWI+ and EU4WD support the development of the monitoring capacities for whole Armenia towards WFD compliance and fulfilment of CEPA obligations.

Key to sustainable groundwater monitoring is a solid legal basis and long-term secured and sufficient budget exclusively devoted to groundwater monitoring considering all aspects of network, equipment, maintenance of both, operating materials (e.g. gasoline) and consumables (e.g. calibration standards) and all aspects of staff availability as sufficient posts, good payment, regular training.

3.2. Administrative setup

The Hydrometeorological and Monitoring Centre (HMC), which includes the former Environmental Monitoring and Information Centre (EMIC) and Hydrometeorological Service (HMS), is the organization in the Ministry of Environment of the Republic of Armenia (MOE) which is responsible for groundwater monitoring (quality and quantity). The Ministry of Economy is responsible for monitoring mineral GWBs.

The monitoring of groundwater chemistry is carried out in a subset of the wells which are subject to groundwater quantity monitoring. The chemical analyses are performed by the laboratory of the HMC.

The quantity data for a given month are entered into an MS Excel spreadsheet before 15th of the following month. Each month the average monthly groundwater quantity values are sent to the Division of State Cadastres, Maintenance of Registers and Monitoring of the Department for Licenses, Permits, and Compliances of the MOE.

In each quarter, a summary report is produced, and a final report on the chemical and quantitative changes of groundwater of the RBDs are submitted to the MOE at the end of the year.

Résumé

The administrative setup of groundwater monitoring seems to work well in the Republic of Armenia. The responsible institutions are experienced in successful operation of monitoring networks and in the management of monitoring data. It has to be ensured that the groundwater monitoring of different institutions follow the same principles and QA/QC requirements are comparable and that the monitoring data are mutually exchanged. The groundwater database could be improved to allow for integrating data from other sources.

3.3. Groundwater bodies

In conformity with the stepwise implementation procedure of the WFD, the projects EPIRB, EUWI+ and EU4WD identified, delineated and characterised in total 51 GWBs in the following four RBDs:

- Akhuryan: 9 GWBs under EPIRB
- Hrazdan: 12 GWBs under EUWI+
- Sevan: 6 GWBs under EUWI+
- Northern: 24 GWBs under EU4WD

These 51 GWBs together with a representative groundwater monitoring network build the basis of future WFD inspired groundwater management in the four RBDs, which are briefly displayed in the following sub-chapters.

Main parts of groundwater resources are formed within the complex of volcanic rocks, and their accumulation and discharge take place in the volcanic rocks and lacustrine-river formations. Therefore, the main GWBs are identified in local water-bearing complex of Pliocene-Quaternary volcanic rocks and in the water-bearing Quaternary lacustrine-river formations. The GWBs were delineated based on the conditions of their formation, accumulation, discharge and use.

In March 2023, transboundary GWBs with Georgia were jointly identified and briefly characterised as a preparatory step for a joint transboundary survey. The joint survey was implemented in autumn 2023.

Résumé

51 GWBs have been delineated for four of six RBDs, Akhuryan, Hrazdan, Sevan and Northern, according to the specifications of the WFD. Although the GWB delineation is based on CIS guidance 2 the delineated GWBs of the Northern RBD cover only distinct regions and large areas are not covered by any GWB. In comparison, the Hrazdan and Sevan RBDs are completely covered by GWBs. It is suggested to harmonize the delineation approach. Furthermore, it should be endeavored to extend this work for the remaining two RBDs Ararat and Southern in Armenia with the same approach and to continue the bilateral harmonisation/coordination of transboundary aquifer systems and groundwater bodies.

A uniform GWB coding system should be established and applied to all existing and new GWBs in Armenia.

3.3.1. Akhuryan RBD

The nine GWBs in the Akhuryan RBD are located in five different aquifers (Table 1, Figure 2)

Table 1: Groundwater bodies in the Akhuryan RBD (Source: EPIRB project)

Name of the aquifer	Water-bearing sediments and rocks	Identified GWB (n)	GWB temporary codes
Alluvial-proluvial lake-river formations and volcanic rocks (Q_{3-4})	Boulders, pebbles, gravel, sand with interlayers of clay and loam	4	G101, G102, G103, G104
Local water-bearing lava complex of Early Pliocene-Quaternary period (N_2^3-Q)	Dacites, andesite-basalt lavas and their pyroclastic varieties, tuffs	1	G201
Local water-bearing complex Meso-Cenozoic sedimentary and volcanic-sedimentary deposits Mz-Cz	Sandstones, clay slates, tuff-sandstones, tuff breccias and porphyrites	1	G301
Local low water-bearing and impermeable complexes of Cretaceous-Paleogene carbonate sedimentary aquifers (K_2-P_2)	Limestone, marl, sandstone with interlayers of volcanic rocks	2	G401, G402
Mineral water bodies (Q_{1-2})	Clays, sands, tuff-breccias, tuff-sandstones	1	G501
	Total	9	

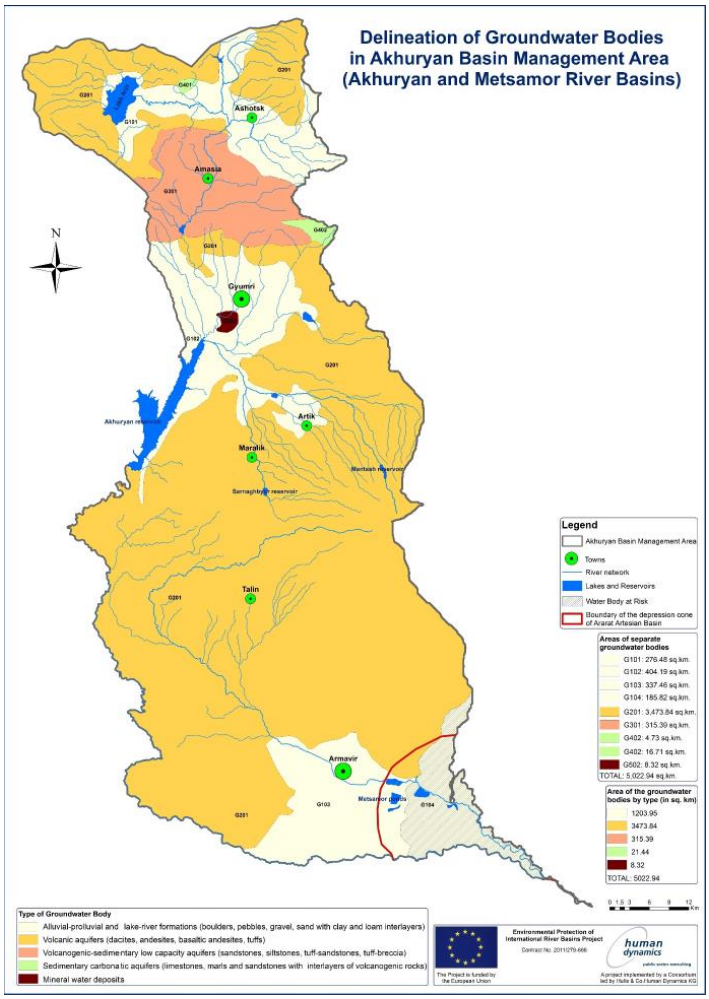

Figure 2: Groundwater bodies in the Akhuryan RBD

3.3.2. Hrazdan RBD

The 12 GWBs in the Hrazdan RBD include three mineral GWBs (see Table 2 and Figure 3).

Table 2: Groundwater bodies in the Hrazdan RBD

GWB Name	GWB Code	Type of Water Abstraction Structure	Surface Area, km^2
Aragats-Mulki	2G-1	wells	96
	2G-2	wells	408
Meghradzor	2G-3	wells	38
Arzakan	2G-4	wells	12
Aparan-Ashtarak	2G-5	Mainly springs and wells with negligible water consumption	862
Jrarat-Yerevan	2G-6	Mainly springs and wells with negligible water consumption (about 400l/sec)	1555
Mravyan-Solak	2G-7	springs	36
Lusagyugh-Aghavnadzor	2G-8	springs	300
Voghjaberd	2G-9	springs	189
Hankavan MGWB	2G-10	mineral water wells	0.8
Bjni MGWB	2G-11	mineral water wells	0.1
Arzni MGWB	2G-12	mineral water wells	1.5

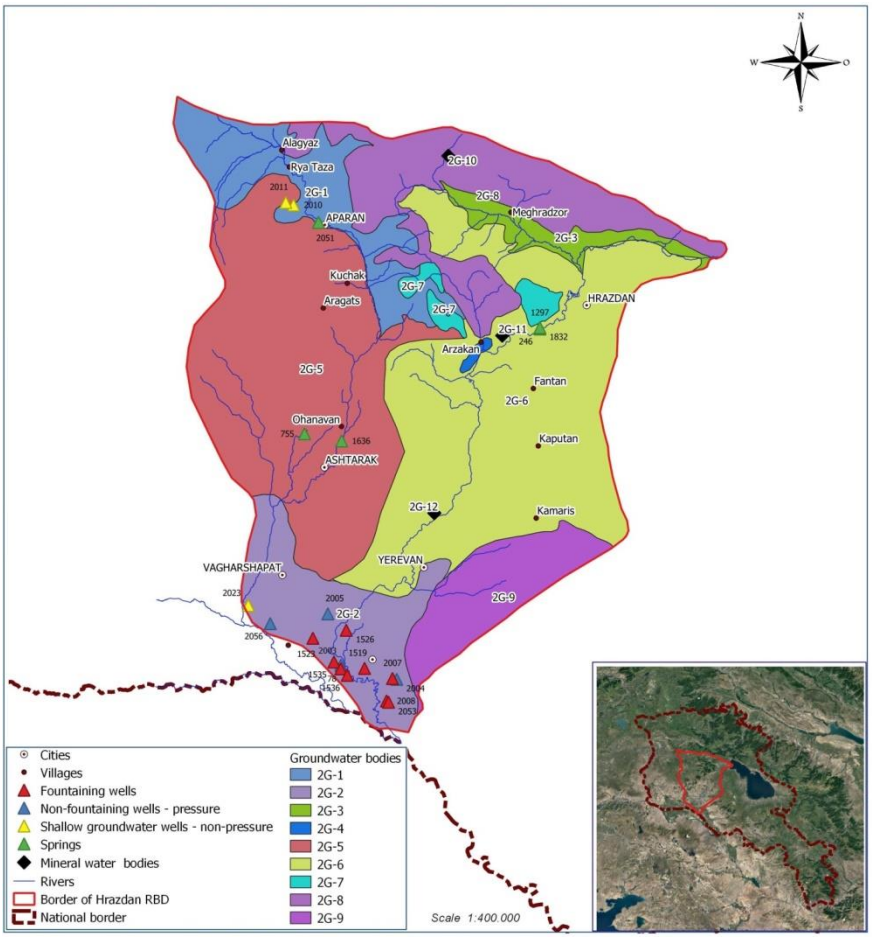

Figure 3: Groundwater bodies in the Hrazdan RBD

3.3.3. Sevan RBD

The 6 GWBs in the Sevan RBD belong to 5 different aquifer systems (see Table 3 and Figure 4).

Table 3: Groundwater bodies in the Sevan RBD

GWB Name	GWB Code	Discharge, l/s	Mineralization, g/l	Type of Water Abstraction
Dzknaget-Areguni	3G-1	35	0.16	springs
Lchashen-Gavar-Shatjrek	3G-2	4,771.3	0.44	wells
Shorja-Sotk	3G-3	16.1	0.54	springs
Vardenis or Masrik	3G-4	960	0.32	spring-well
Sevan (Gavar)	3G-5	10.0	3.5	mineral water wells
Lichk	3G-6	74,0	3.9 – 4.2	mineral water wells

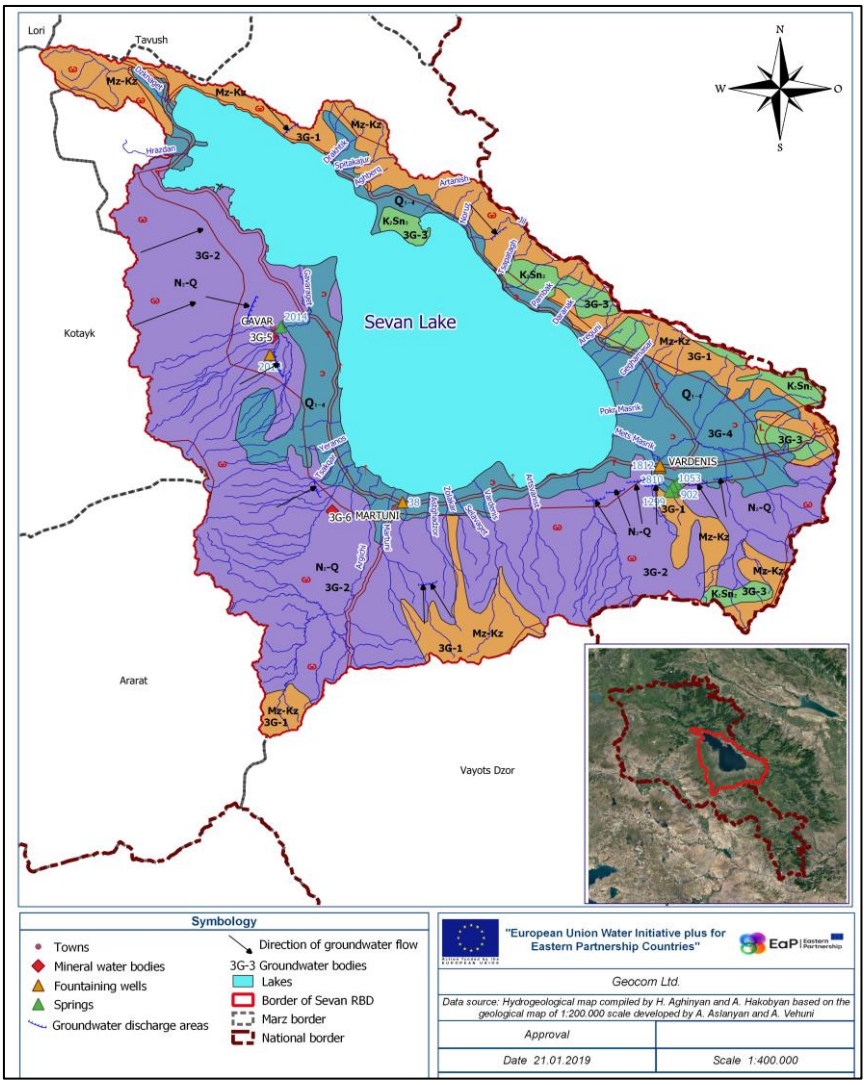

Figure 4: Groundwater bodies in the Sevan RBD

3.3.4. Northern RBD

Within the Northern RBD 24 GWBs have been identified and two of them are mineral GWBs.

Table 4: Delineated groundwater bodies in the Northern RBD

GWB Code	GWB Name	Discharge, l/sec	Total mineralization, g/l	Type of water abstraction structure	Number of monitoring sites
6G-1	Jrashen	512.5	0.4 – 0.5	wells	-
6G-2	Shirakamut	400	0.4 – 0.45	wells	-
6G-3	Lernajur	90	0.4	drainage	-
6G-4	Arjut	91.5	0.3 – 0.47	wells	-
6G-5	Lori	2248	0.1 – 0.5	wells - springs	-
6G-6	Svertli	138.1	0.1 – 0.4	springs	-
6G-7	Agarak	90	0.5 – 0.6	springs	-
6G-8	Chakhkali	30.1	0.8	springs	-
6G-9	Darpas- Taron	207.7	0.7	wells	-
6G-10	Lernapat- Tsovasar	81.2	0.4 – 0.5	springs	-
6G-11	Qober	18	0.6	springs	-
6G-12	Bagratashen	120	0.8	wells	-
6G-13	Margahovit	242.4	0.5	wells	-
6G-14	Shamakhyan	3.5	0.35 – 0.4	springs	-
6G-15	Hovq	16	0.6 – 0.7	springs	2
6G-16	Khashtarak	23	0.6	springs	-
6G-17	Chambarak	34.5	0.4 – 0.5	wells	-
6G-18	Navur	2.5	0.5	springs	-
6G-19	Berd	0.8	0.6	springs	-
6G-20	Chinari	23	0.1 – 0.5	wells	-
6G-21	Baghanis	0.8	0.4	springs	-
6G-22	Berdavan	21	0.9 – 1.2	wells	-
6G-23	Dilijan MGWB	1.5	1.1 - 2.9	wells	-
6G-24	Vanadzor MGWB	2.0	5.5 - 8.9	wells	-

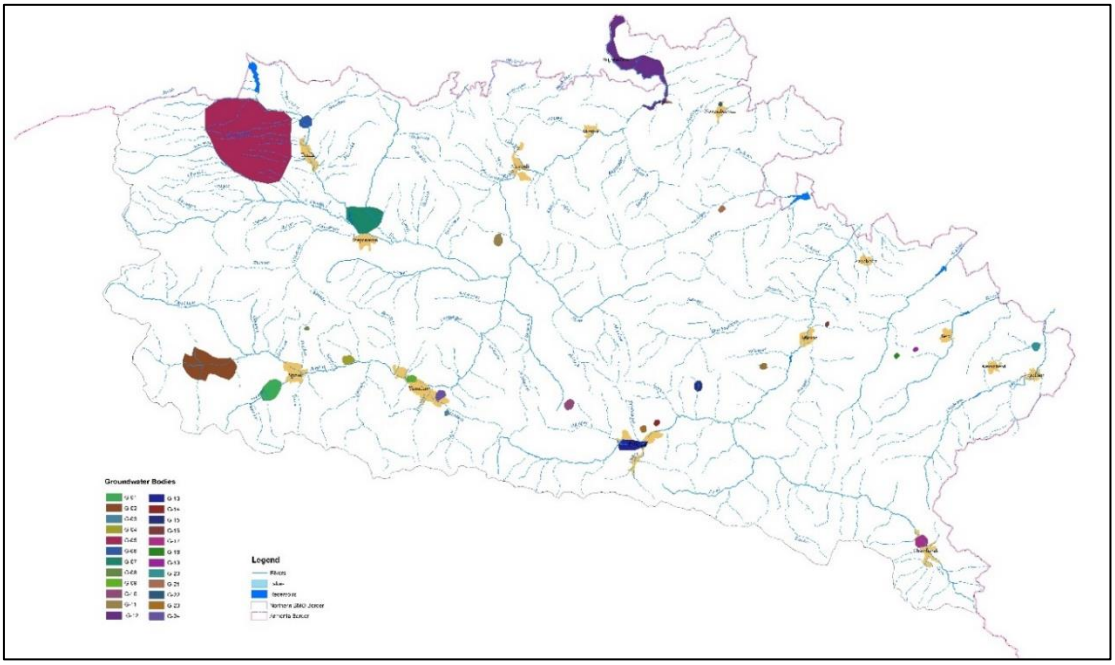

Figure 5: Groundwater bodies in the Northern RBD

3.4. Groundwater monitoring design

3.4.1. Monitoring network

The groundwater monitoring network was more extensive until the collapse of the Soviet Union. Regular hydrogeological observations were suspended from 1993 to 2009. The observation network was then restored but with a lower number of observation points, and not covering all river basins. Regular monitoring started in 2010. In 2020 the monitoring network covered 40 chemical and 100 quantitative monitoring sites for the whole Republic of Armenia and the limiting factor is the available budget.

The following 4 sub chapters show the current state of the GW monitoring network in the 4 RBDs where GWBs have been identified and delineated.

Résumé

The current GW monitoring network in Armenia does not meet the WFD requirements. Looking at the four RBDs where GWBs were identified and delineated, the GW network does not cover all GWBs and in GWBs where GW monitoring exists, the network is not representative and the number of monitoring sites is too small.

After review of the GWBs in the Northern RBD and the delineation of GWBs in the remaining RBDs not yet covered by EPIRB, EUWI+ and EU4WD, the existing GW monitoring network in whole Armenia shall be reviewed and revised/developed.

It is also necessary to cover all GWBs with monitoring sites and not to forget the shallow GWBs which are not the main source of drinking water supply for a large number of people but nevertheless an essential source of drinking water for the population not connected to central water supply

EUWI+ supported the refurbishment of 13 existing monitoring sites and the establishment of 12 new sites which was only a first step to be continued in the coming years.

The technical condition of each existing monitoring site needs to be checked whether it is suitable for sampling and can provide reliable and representative monitoring data. The existing and appropriate monitoring sites need to be maintained and/or refurbished. When searching for new monitoring sites, preference should be given to finding and integrating appropriate existing objects (wells/springs) instead of drilling new monitoring wells.

Finally, it is necessary to continue the bilateral coordination of identifying suitable monitoring sites for transboundary monitoring and establish harmonized and bilaterally agreed regular data exchange.

Akhuryan RBD

According to the Akhuryan RBMP, there was no groundwater monitoring in the Akhuryan RBD in 2014, due to lack of financial resources. In 2014 HMC submitted a proposal to extend the GW monitoring network and received GoA's approval (Protocol session resolution #43 of Oct. 16, 2014). Thus, since January 2015, 30 additional GW monitoring sites have been added - 13 springs and 17 wells. In the Metsamor river basin GW monitoring restarted in 2009 at 7 wells, where 3 are located in the same area (Aknashen village).

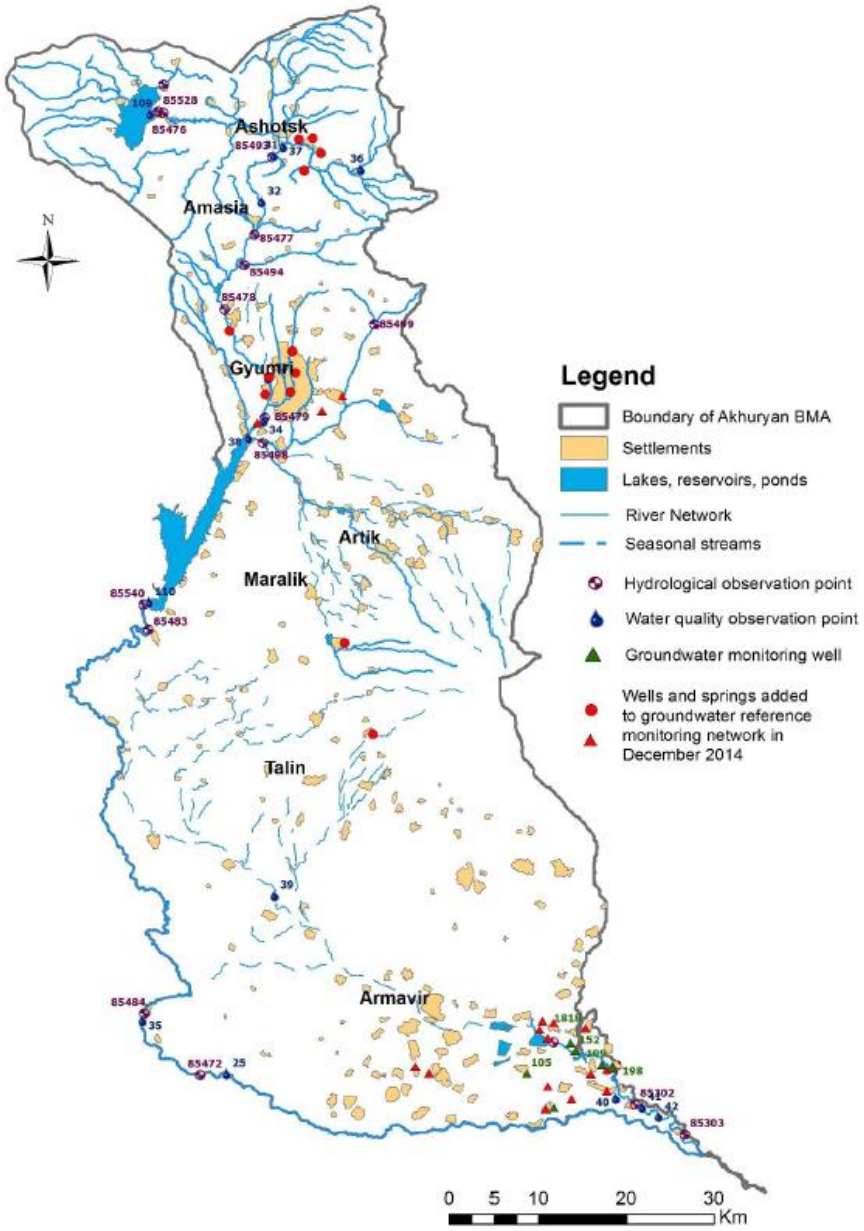

Figure 6: Groundwater monitoring sites in the Akhuryan RBD

Hrazdan RBD

There are 22 operating monitoring sites in the Hrazdan RBD, 6 springs, 9 fountaining wells, 3 shallow wells, 4 non fountaining wells (under pressure). All wells are located in the lower flow zone of Hrazdan River or in the Ararat Artesian Basin.

Until end of 2020 only 4 of the 12 GWBs in the Hrazdan RBD were subject to GW monitoring. 11 of the 22 monitoring sites were operational but needed refurbishment. The following map shows that the monitoring sites are concentrated in the southern part (Figure 7).

In the year 2019/2020 EUWI+ supported the refurbishment of 9 monitoring sites (6 fountaining wells and 3 springs) and the construction of 7 new sites (6 springs and 1 well) which was finalised end of 2020 and which is just a first step towards a representative GW monitoring network.

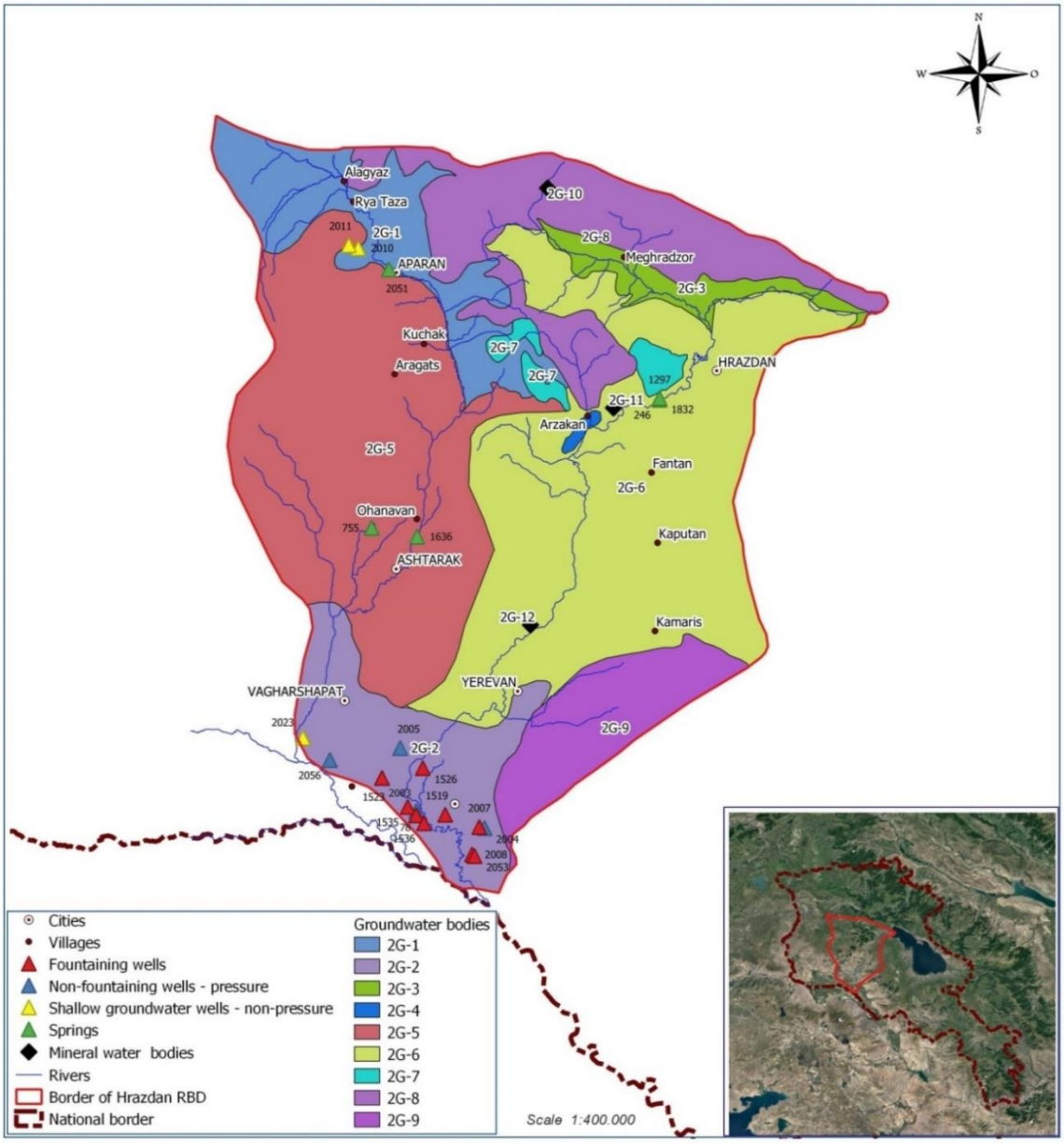

Figure 7: Groundwater monitoring sites in the Hrazdan RBD

Sevan RBD

The GW monitoring network in the Sevan RBD consists of 11 monitoring sites, which are all located in the Sevan Depression – 2 sites in GWB 3G-2 and 9 sites in 3G-4. The GWBs 3G-5 and 3G-6 are mineral GWBs and monitored by the Ministry of Energy Infrastructures and Natural Resources. Two GWBs are not monitored.

In the year 2019/2020 EUWI+ supported the refurbishment of 4 monitoring sites (3 fountaining wells and 1 spring) and the construction of 5 new sites (3 springs, 1 well and 1 fountaining well) which was finalised end of 2020 and which is just a first step towards a representative GW monitoring network.

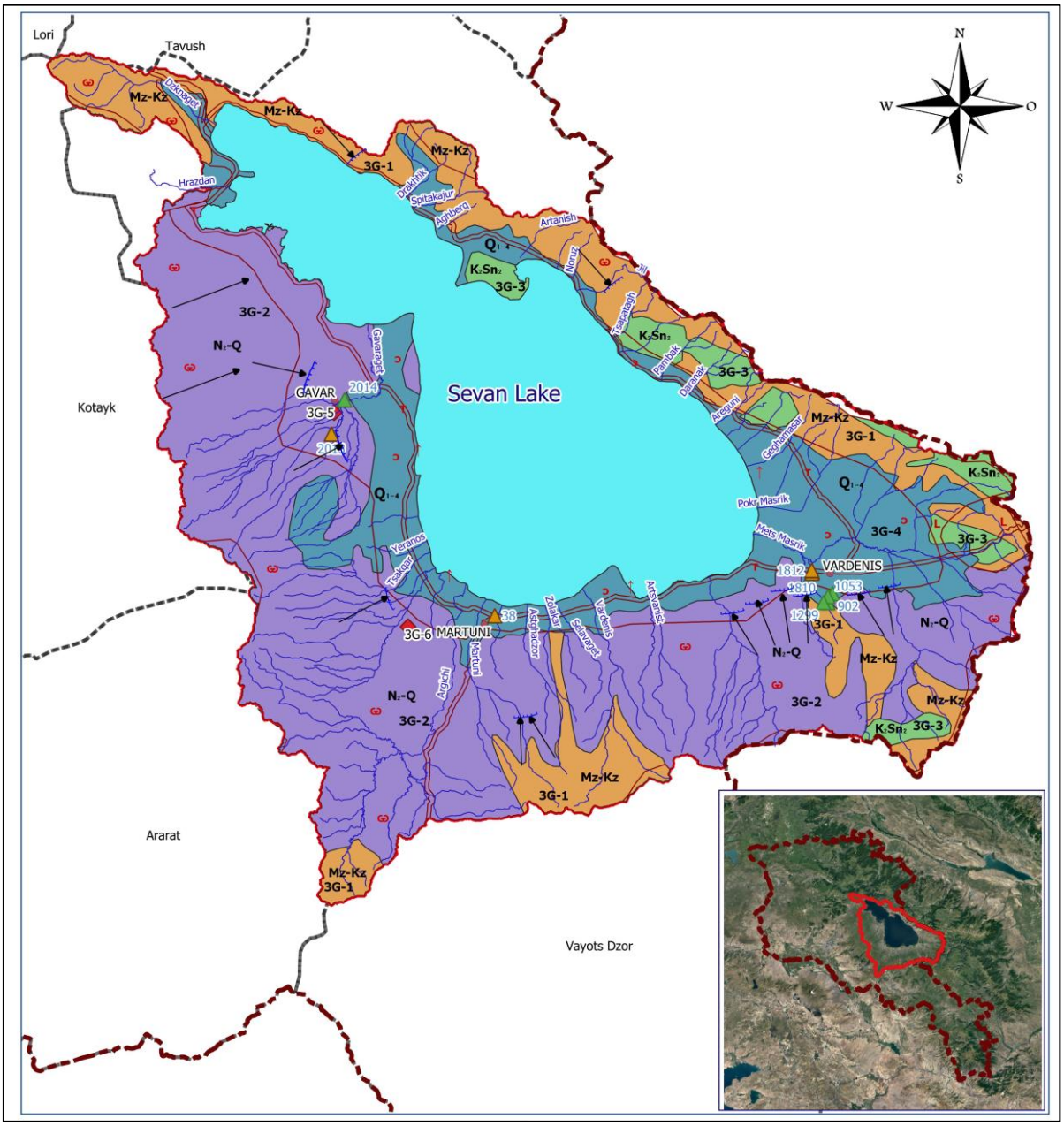

Figure 8: Groundwater monitoring sites in the Sevan RBD

Northern RBD

The groundwater monitoring network consists of only two monitoring sites in the 6G-15 Hovq GWB. None of the other 23 GWBs is actually monitored. In the framework of the EU4WD project two field campaigns were conducted on top of the regular monitoring. Specifically, in 2022, 30 groundwater springs were investigated, followed by the investigation of 32 springs in 2023, all within the Northern RBD. It is planned to include 16 of these sites (8 springs and 8 wells) in the national monitoring network.

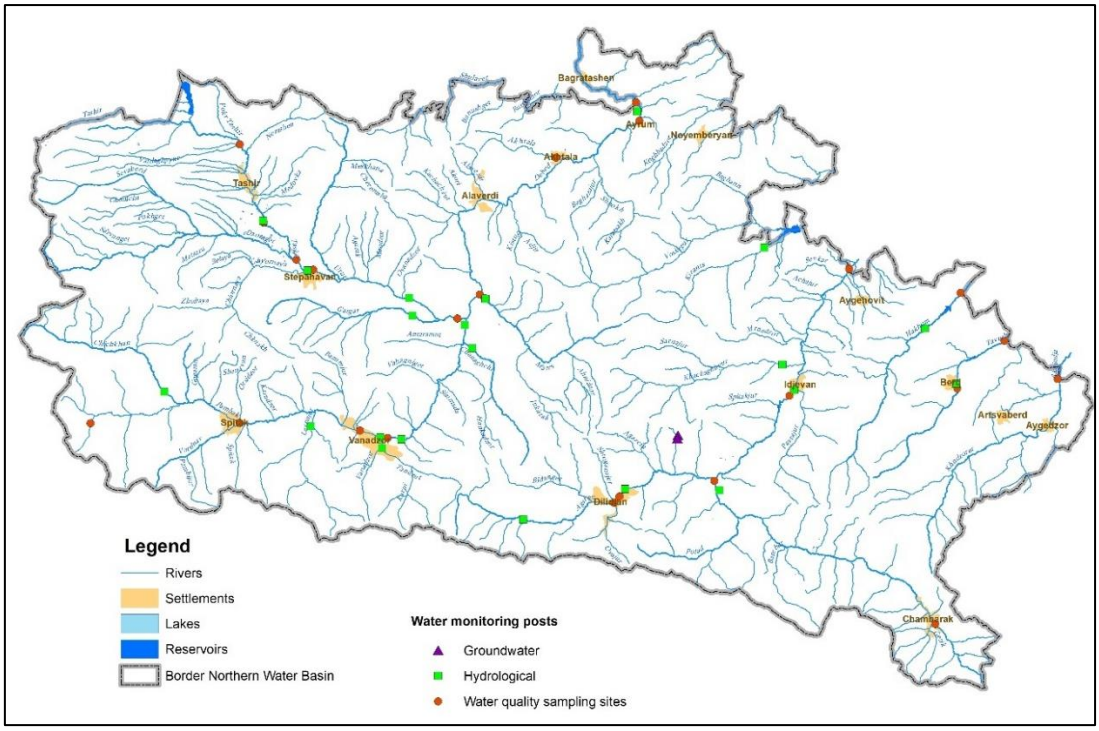

Figure 9: The locations of Surface and Groundwater Monitoring sites in the Northern RBD

Table 5: Recommended Groundwater Monitoring Network

Nr	River basin	River	Location	Spring type	Latitude	Longitude	GWB code
1	Debed	Pambak	Lernavan	Fountain well	40^{O} 47’ 01.2”	44^{O} 09’ 57.7”	6G-1
2	Debed	Pambak	Mec Parni	Fountain well	40^{O} 50’ 38.1”	44^{O} 06’ 27.5”	6G-2
3	Debed	Dzoraget	Saratovka	Fountain well	41^{O} 04’ 29.7”	44^{O} 18’ 42.0”	6G-5
4	Debed	Tashir	Saratovka	Spring	41^{O} 04’ 30.6”	44^{O} 18’ 39.5”	6G-6
5	Debed	Tashir	Tashir	Fountain well	41^{O} 06’ 07.6”	44^{O} 17’ 56.8”	6G-5
6	Debed	Debed	Shamlugh	Spring	41^{O} 09’ 22.7”	44^{O} 43’ 03.5”	6G-11
7	Debed	Debed	Bagratashen	borehole	41^{O} 14’ 14.3”	44^{O} 49’ 02.1”	6G-12
8	Debed	Koghb	Berdavan	ground well	41^{O} 12’ 08.2”	45^{O} 00’ 25.3”	6G-22
9	Small tributaries of Kura RB	Voskepar	Voskepar	Spring	41^{O} 04’ 17.5”	45^{O} 04’ 14.8”	6G-21
10	Small tributaries of Kura RB	Hakhum	Paravaqar	Spring	40^{O} 58’ 56.3”	45^{O} 21’ 59.5”	6G-18
11	Small tributaries of Kura RB	Tavush	Tsaghkavan	Spring	40^{O} 56’ 28.3”	45^{O} 20’ 3.0”	6G-18
12	Small tributaries of Kura RB	Tavush	Berd	Spring	40^{O} 52’ 44.5”	45^{O} 23’ 16.5”	6G-19
13	Aghstev	Aghstev	Lusadzor	ground well	40^{O} 56’ 22.8”	45^{O} 09’ 47.7”	6G-16
14	Aghstev	Aghstev	Hovq	Spring	40^{O} 47’ 30.7”	45^{O} 03’ 43.4”	6G-18
15	Aghstev	Getik	Chambarak	Spring	40^{O} 36’ 17.3”	45^{O} 21’ 26.1”	6G-17
16	Aghstev	Aghstev	Margahovit	borehole	40^{O} 43’ 59.2”	44^{O} 41’ 30.5”	6G-13

3.4.2. Monitoring parameters and frequency

Groundwater quantity monitoring: Observations of water discharge at springs and fountaining wells, temperature, groundwater level at non-fountaining wells and piezometric pressure in fountaining wells are conducted 6 times a month.

Groundwater chemical monitoring: The frequency of water sampling for chemical analyses is 2 times per year, in May and November. A total of 35 chemical elements and compounds are identified during laboratory tests (Basic anions and cations, nitrate, nitrite, ammonia, silicate, heavy metals, TDS, pH).

Résumé

Monitoring frequency and monitoring parameters for groundwater quantity are fully in line with the minimum requirements of the WFD.

Monitoring parameters for groundwater quality monitoring are covering all important basic substances and indicators. Nevertheless, it is recommended to introduce the risk based and tiered approach of the WFD where surveillance monitoring is acting as kind of wider screening monitoring to validate the risk assessment and operational monitoring is putting focus at the substances causing risk of not achieving the environmental objectives for groundwater.

It is recommended to implement a monitoring frequency of 4 times per year for surveillance monitoring to get a more complete picture about the pollution situation at different seasons of the year. Operational monitoring can be implemented at a lower frequency once the variability of pollutants is identified during surveillance monitoring.

3.5. Equipment and consumables

The existing sampling and monitoring equipment and the needs of investment were discussed in 2018 at the sampling training and during the preparation phase of the EUWI+ groundwater survey 2018. For the preparation of the groundwater survey an inventory of available equipment at HMC, which was responsible for the groundwater sampling at the survey, was prepared (Table 6).

Table 6: Available sampling and monitoring equipment and consumables

Item	Type / Specification	Remark
Bailer	Solinst	
Pump	Small power pump	
Plastic tube for pump	plastic Ø 10	
Gasoline Generator	3 x Gasoline Generator SGW 220	
Ultrasonic flow meter	SIEMENS FUP 1010	
Ultrasonic flow meter	mobile clamp-on flow meter for pipes using ultrasonic transit time measurement, including a main unit, two transducers and any required mounting fixtures or devices	Purchased by EUWI+
Hydrometric current meter	ИСП-1М, Discharges of 80l/s and more	
Groundwater level meter	Solinst Model 101, ≤ 100 m	
Multimeter	YSI Model 556 MPS, El. Cond., temp., pH-value, oxygen	
Mercury thermometer	TM10-2	
Conductometer	ORION model 122	
Cooling box and elements	2-3 Cooling box and 15 cooling elements	
Test stripes	pH, hardness, NH_4	
Various bottles	PE 0.5L, PP 30ml	

Résumé

Appropriate groundwater sampling and field measurement equipment is available. It should be checked in detail, whether the existing sampling equipment and field measurement devices are adequate and sufficient.

EUWI+ purchased an urgently wanted ultrasonic flow meter and several test strips for field measurements.

Some of the monitoring sites could be fitted with automated logging equipment to record quantitative data and some physico-chemical parameters at short intervals. The national groundwater database could be improved, in order to allow integration of data from such automated logging equipment and to facilitate integration with other databases.

3.1. Transboundary coordination

As water does not respect any country borders, the WFD and its river basin approach endeavours for transboundary coordination and harmonisation at several aspects of the directive. Hence, it is very important to strengthen transboundary coordination, to identify transboundary GWBs and to establish transboundary monitoring and data exchange. There should be mutual agreement for a monitoring program with common standards for information exchange and joint assessment of groundwater body status.

The cooperation in this direction has been supported under EU4WD in 2023 with Georgia.

With the support of EU4WD a bilateral agreement in the field of monitoring and exchange of information in the transboundary Khrami-Debed River Basin between Armenia and Georgia was elaborated and finalised in October 2024. This agreement provides the legal basis for joint monitoring activities, information exchange and reporting on the status of water bodies (both surface water and groundwater bodies). Details on monitoring and data exchange are laid down in the guidance document set out in the Annex to this agreement. This final agreement still waits for its adoption by mutual signing.

Résumé

First steps towards transboundary cooperation have been take. Transboundary GWBs have been identified with Georgia and a joint groundwater survey with Georgia has been successfully implemented in 2023. Based on these preparatory activities, a transboundary monitoring agreement between Armenia and Georgia for the Khrami-Debed RBD has been elaborated and finalised with substantial support of EU4WD.

It is recommended to sign this agreement and implement the monitoring activities accordingly. Furthermore, it is recommended to elaborate and adopt such agreements with the other neighbouring countries.

3.1.1. Transboundary groundwater bodies

In March 2023 representatives of Armenia and Georgia identified and briefly characterised transboundary GWBs as well as the current monitoring situation in bilateral coordination workshops.

Armenia and Georgia

The following six transboundary connections of national GWBs were identified between the Northern RBD in Armenia and the Khrami-Debed RBD in Georgia. In addition to these transboundary connections for further national GWBs touching the country border, it was clarified that there is no transboundary interlinkage.

Table 7: Transboundary GWBs between the Northern RBD in Armenia and the Khrami-Debed RBD in Georgia.

No	GWB in Armenia (pink colors)	GWB in Georgia (blue colors)	
1	6G-12 (east) GW flow direction: **AM→GE**	GPK0026	
2	6G-5 (west) GW flow direction: **GE→AM**	GPK0026	
3	6G-6 GW flow direction: **AM→GE**	GFK0030 (only the border part)	
4	6G-22 (eastern part) Will be clarified. Might not be relevant. GW flow direction: **AM→GE**	GKK0032 Only the border part on the eastern side.	

No	GWB in Armenia (pink colors)	GWB in Georgia (blue colors)	
5	Corresponding GWB in the Alaverdi area will be clarified. GW flow direction: **AM→GE**	GKK0032 North of Alaverdi area.	
6	6G-12 GW flow direction: **AM→GE**	GPK0024 Southern part is linked with AM and the other part with AZ	

Transboundary groundwater monitoring

Four GWBs in Georgia are transboundary connected with four GWBs in Armenia. For the joint groundwater survey in October 2023 the GWBs 6G-12 within the Northern RBD of Armenia and GWB GPK0024 within the Eastern part of Khrami-Debed RBD in Georgia were selected. In total 4 monitoring sites have been jointly selected, two wells in Armenia and 2 springs in Georgia. (see Figure 10)

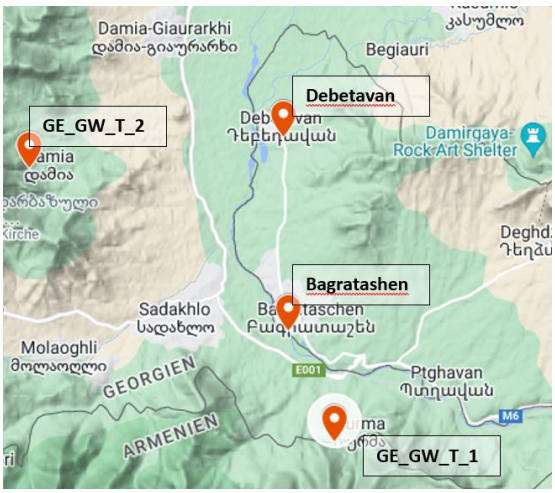

Figure 10: Joint groundwater survey between Georgia and Armenia

4. Support provided by EUWI+ and EU4WD (2018–2024)

4.1. Infrastructure and equipment

The investment in infrastructure and equipment happened during EUWI+ project as follows:

- Modern on-site monitoring equipment (ultrasonic flow meter) was purchased;
- 13 existing monitoring sites were refurbished (6 fountaining wells and 3 springs in Hrazdan RBD and 3 fountaining wells and 1 spring in Sevan RBD);
- 12 new monitoring sites were established (6 springs and 1 well in Hrazdan RBD and 3 springs, 1 well and 1 fountaining well in Sevan RBD);
- Some consumables (test strips, syringes and filters) for onsite measurements during groundwater surveys.

4.2. Trainings

The groundwater training aimed at covering all important steps of groundwater monitoring and assessment, starting from the general principles of the WFD, the identification, delineation and characterisation of GWBs, the identification of transboundary GWBs with neighbouring countries, the pressure and impact (risk) assessment, designing WFD compliant monitoring, quality assured monitoring (sampling, field measurements), transboundary coordination to trainings in the field of GWB chemical and quantitative status assessment, status and trend assessment.

EUWI+ and EU4WD provided know-how and country experiences, guidelines, feedback on sampling procedures (witness audit), manuals and templates to be used for quality assured sampling campaigns, which were adapted to the country needs and administrative setup.

All trainings, except for transboundary harmonisation of field measurements, were arranged nationally with a focus at the Hrazdan, Sevan and Northern RBDs to allow for focusing at the national/basin-specific aspects and needs and to enhance the development of tailored solutions for the local implementation of the WFD and the development of the Hrazdan, Sevan and Northern RBMPs.

It was continuously emphasised that monitoring is not an isolated activity for itself but it is key in targeted and effective groundwater governance and management. The following figure underlines the importance of monitoring as part of the groundwater management cycle and the importance of gathering targeted, reliable, quality assured and timely monitoring data as the foundation of taking informed decisions and response.

The focus of the trainings was groundwater chemical monitoring. Groundwater quantity monitoring has a far longer tradition in Armenia and the knowledge and the capacities are more advanced than for chemical monitoring.

Since the approach followed in EUWI+ and EU4WD aimed at strengthening national and local capacities via cooperation rather than providing technical assistance, the main goal of the trainings was to strongly involve the responsible national and local experts and stipulate active participation. A sub-regional survey was organised and intended to enhance the transboundary cooperation of monitoring experts between Georgia and Armenia. The training concept was based on joint efforts of international consultants and national experts.

The steps of the water management cycle were subsequently covered and reiterated at different workshops/trainings of national and local experts in terms of:

- GWB identification, delineation and characterisation, pressures and impacts (= risk) assessment
- Groundwater monitoring design (network, frequency, parameters)
- Theoretical and practical groundwater sampling training, methods and field measurements, quality assurance and quality control aspects, witness audit and sampling certification;
- Surveys (preparation, survey manual, implementation, documentation);
- Data checking and interpretation, status assessment;
- Transboundary cooperation

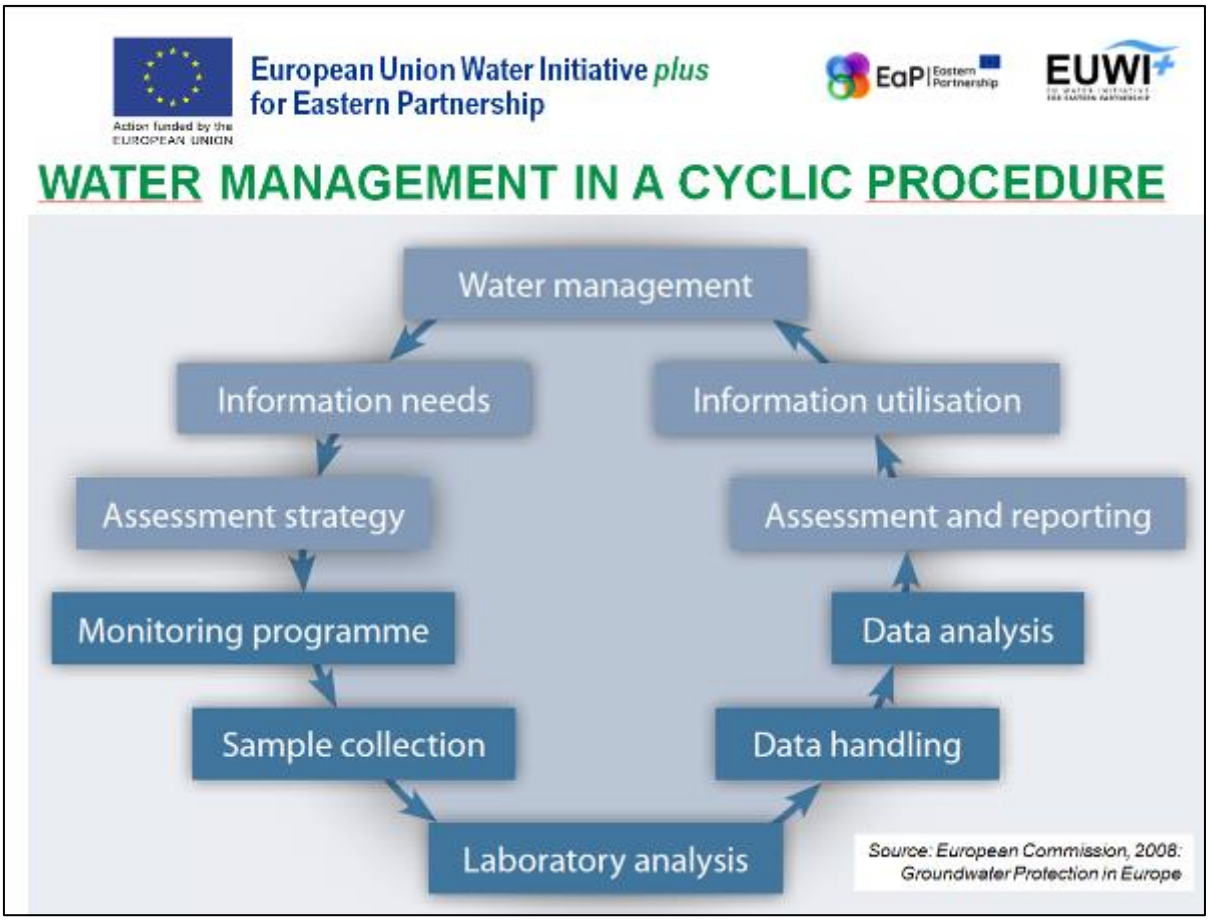

Figure 11: The water management cycle (EC 2008).

The following Table 8 summarises all training events that were provided by the EUWI+ and EU4WD groundwater experts during the operative project period of 2018–2024. The table lists the training events in chronological order. The scope of training activities was usually national, to ensure targeted discussions to the needs in Armenia. The competence profile outlines the competence of trained participants after the training, based on the previously defined training targets.

Comprehensive training material was prepared and provided including workshop presentations, EU guidance documents, Austrian guidance documents, a Specific Manual for Surveys in Groundwater and a specific GW survey manual template to be used and completed for each individual survey.

It should be considered that at the end of EUWI+ and beginning of EU4WD the Covid crisis suspended all travels and personal meetings, hence, personal trainings were no longer possible in that time.

Table 8: EUWI+ groundwater trainings in Armenia between 2018 and 2024.

Time	Activity / Training	Competence profiles	Training targets	Partici-pants (♀ / ♂)
2018 Q2	Workshop on GWB identification and delineation	• Principal understanding of the WFD, their approach, the implementation steps, the role of GWBs, and their delineation. • Understanding of subsidiary principle in the implemen-tation of the WFD and the need for developing tailored, national approaches.	• Gathering information from national experts about GW management in Armenia. • Presentations of UBA experts on the WFD principles of GWB delineation and characterisation with focus on the tasks and deliverables of the contract for GWB delineation. • Discussion of examples from EU Member States and EU guidance documents. • Hands-on exercise in GWB delineation.	**7** 4 / 3
2018 Q2	Workshop on GWB monitoring	• Principal understanding of the WFD principles and approach, the implementation steps, the role of monitoring and their design. • Understanding of subsidiary principle in the implemen-tation of the WFD and the need for developing tailored, national approaches.	• Gathering information from national experts about GW monitoring in Armenia. • Presentations of UBA experts on the WFD principles of GWB surveillance and operational monitoring with focus on the tasks and deliverables of the contract for GWB monitoring design. • Discussion of examples from EU Member States and EU guidance documents. • Hands-on exercise in GWB monitoring design.	**7** 4 / 3
2018 Q3	Theoretical and practical training on GW sampling. Preparation of GW manual and survey	• Understanding of the role of monitoring in GW management. • Awareness for quality assurance and quality control in field measurements, GW sampling, sample stabilisation and transport. • Practical handling of equipment and check. • Importance of careful survey planning, possible mistakes in sampling and consequences.	• Theoretical training in survey planning, handling and treatment of field equipment, coordination with the laboratory, sample treatment and conservation, documentation. • Practical sampling training in the field. • Discussion of experiences and need for equipment. • Careful preparation of a GW survey. Preparation of a survey manual and discussion of deliverables of the contracted survey.	**8** 2 / 6

Time	Activity / Training	Competence profiles	Training targets	Partici-pants (♀ / ♂)
2019 Q1	Workshop on GW monitoring II and on the available GW resource	• Understanding on how to step-wise improve GW monitoring • Understanding of the role of status assessment of GW quantity.	• Discussion on how to improve the GW monitoring network in Armenia in a step-wise procedure. • Gathering information from national experts about the assessment of GW quantity in Armenia and the specific challenges. • Discussion with UBA experts on how to proceed in the elaboration of a methodology for calculating the available GW resource in mountainous areas.	**3**
2023 Q1	Workshop on GW data interpretation	• Handling with monitoring data	• Simple monitoring data quality checks and data interpretation	**8** 2/6
2023 Q1	Workshop on GWB status assessment.	• Principal understanding of the WFD and the role of GWB status assessment	• WFD needs of GWB status assessment. • Discussion of methodologies for the assessment of chemical and quantitative status of GWB.	**17** 8/9
2023 Q1	Workshop on bilateral coordination of transboundary GWBs with Georgia	• Principal understanding of the WFD, the role of GWBs and the need for transboundary coordination	• Joint agreement on transboundary GWBs • Brief characterisation • Selection of monitoring sites for joint GW survey	**16** 6/10
2023 Q4	Workshop on certified sampling, theory and practise.	• Practical experience in GW sampling. • Practical handling of equipment and check.	• Sampling according to ISO standards. • Awareness of importance of QA/QC in all aspects of GW sampling. • Sampling mistakes and consequences. • Certification of sampling.	**4** -/4
2023 Q4	Joint GW survey with Georgia	• Practical experience in GW sampling. • Practical handling of equipment and check.	• Harmonisation of sampling technics. • Feedback on sampling procedures and proposals for improvement.	**10** 1/9

5. Status quo of groundwater monitoring

Following Table 9 indicates briefly the status quo of WFD compliant groundwater monitoring and the associated aspects in Armenia and the accomplished steps so far.

Groundwater monitoring is not an isolated activity by itself but has to be seen in a wider context. WFD compliant monitoring has to provide evidence whether certain objectives are achieved (status, trends), to provide information about the significance of various pressures and impacts to establish appropriate measures, and it has to demonstrate the effectiveness of measures implemented during active groundwater management.

This overview allows for planning the next steps towards establishing a comprehensive and really WFD compliant monitoring system.

Table 9: Status quo and requirement towards WFD groundwater monitoring.

	Steps		Akhuryan RBD	Hrazdan and Sevan RBD	Northern RBD	Southern and Ararat RBDs
1	Delineate GWBs [A, B]		Completed during EPIRB	Completed during EUWI+	Completed during EU4WD, revision needed	Still needed
2	Characterise GWBs [A, B]		Incomplete	Completed during EUWI+	Completed during EU4WD, revision needed	Still needed
3	Pressure/impact (Risk) assessment for GWB [B]		Completed during EPIRB	Completed during EUWI+	Completed during EU4WD, revision needed	Still needed
4	Quantity monitoring	Legal basis	In line with WFD			
		Operative budget	Seems guaranteed			
		Network density	A review per GWB is needed, once GWBs are delineated			
		Practical implementation	In line with legal requirements			
5	Chemical monitoring	Legal basis	Needs revision in line with CEPA (parameters, frequency)			
		Operative budget	Not fully guaranteed			
		Network density [D]	A review per GWB is needed			
		Practical implementation	In line with legal requirements			
6	Sampling	Training [C]	Completed during EUWI+			
		Equipment	Partly provided by EUWI+ but still needed.			
7	Data management		Started during EUWI+			
8	Set GW threshold values		Still needed			
9	Natural GW background levels		Still needed			
10	Status and trend assessment	Introduction	Accomplished under EU4WD			
		Establish methods	Still needed			
		Perform assessment	Still needed			

EUWI+ and EU4WD deliverables: *(A) Delineation report, (B) RBMP, (C) GW survey manual, (D) Monitoring network reports*

6. Outlook and proposal for further development and capacity building

With the Comprehensive and Enhanced Partnership Agreement (CEPA), which is in force since March 2021, Armenia has taken obligations to i.a. approximate its water monitoring and management capacities to the WFD requirements along a very tight roadmap. The outlook and proposals highlighted in this chapter may support Armenia in achieving the aims of the agreement in a stepwise approach. Based on the assessment of the status of groundwater monitoring and the improvements provided by EUWI+ and EU4WD, several gaps are still evident and highlighted. These gaps are reiterated in the following sub-chapters, and proposals for further improvement of groundwater monitoring are given.

6.1. Groundwater bodies

- It is recommended to delineate GWBs also in the remaining Ararat and Southern RBDs of Armenia.
- It is recommended to revise the GWB of the Northern RBD in a way (GWB as management unit of its recharge area) as it was applied in Hrazdan and Sevan RBDs.
- A national coding system for GWBs should developed and applied in the whole country.
- When the currently existing RBMPs are reviewed and updated, it is recommended to:
  - Review the currently delineated GWBs and check whether they completely fit for the purpose of optimal management of groundwater resources. If the situation is not completely satisfactory, do not hesitate to re-delineate, merge or divide the GWBs.
  - Potentially split the large GWBs (in particular the groups of GWBs) into smaller GWBs, where the pressure situation is not uniform or combine similar GWBs with similar pressure situation to groups of GWBs, to allow for more targeted management.
  - Be aware, that a GWB can only be assigned to only one individual RBD. If this is not possible or practical, then split this GWB.
  - If GWBs are split, grouped or significantly re-delineated, discard the existing GWB codes and assign new codes for the new GWBs. This allows for better traceability and avoids making wrong conclusions when comparing results over time.
  - If GWBs are split, grouped or significantly re-delineated, discard the existing GWB codes and assign new codes for the new GWBs. This allows for better traceability and avoids making wrong conclusions when comparing results over time.
  - Apply the new coding system to all GWBs.
  - Repeat the characterisation and risk assessment after updating the human pressure data.
- It is recommended to commence bilateral cooperation and harmonisation of transboundary aquifers and the delineation of transboundary GWBs with neighboring countries.

6.2. Groundwater monitoring design

6.2.1. Monitoring network

The current groundwater monitoring design is not fully in line with the WFD requirements. The number of monitoring sites is by far too low. The introduction of GWBs as new management units causes the need for network review and adaptation to achieve representative spatial distribution of sites. The WFD CIS guidance 18 recommends at least three monitoring sites for homogenous hydrogeological condition.

The following improvement activities are recommended:

- Assign each monitoring site to exactly one GWB (in particular essential for overlaying GWBs. Do this assessment after a possible revision of in the Akhuryan, Hrazdan, Sevan and Northern RBDs.
- Assess for each individual GWB (of all RBDs) the existing monitoring network on its representative-ness in terms of hydrogeology, spatial coverage and the distribution of existing anthropogenic pressures. Perform the assessment for both aspects separately – for GW quantity and GW quality.
- Check existing monitoring sites, which fit to a representative network, on their technical status in terms of accessibility and allowing for quality assured sampling and field measurements and allowing for delivering reliable and representative monitoring data.
- Continue the refurbishment of suitable sites.
- Where both existing monitoring networks (quantity and chemical) are not sufficient:
  - Check whether existing wells/springs are available and appropriate for inclusion into a representative network. Inclusion of existing is more cost efficient than drilling new wells.
  - When using already existing wells or springs, which are owned and already monitored by other organisations or owners, it is recommended to develop standard rules and contracts, to guarantee long-term access to the wells and/or to the data.
  - Don’t forget to assign a monitoring network also to the shallow GWBs, which are often used to meet private drinking water needs, often in remote areas.
- Finally, frequently revisit and maintain wells/springs and passports.

For the **Sevan RBD** it is indisputable that 11 monitoring sites within an area of around 3,500 km² are insufficient. Since the current operating monitoring sites are mainly characterizing GWBs formed in permeable water-bearing hydrogeological complexes and no monitoring data are available in areas where settlements use the water from the GWBs for potable water supply, the future monitoring network should cover the GWBs used for drinking water supply in those areas. Following is proposed:

- According to the assessment made under EUWI+ 7 of 11 sites needed refurbishment. 4 sites where refurbishment with support of EUWI+ and 3 sites still need refurbishment.
- On a long-term it is proposed to add 15 monitoring sites (13 springs and 2 wells). 2 sites should be located in GWB 3G-1, 6 additional sites in 3G-2, 2 sites in 3G-3, and 5 sites in 3G-4. EUWI+ helped developing the planning documents for 15 additional sites and the construction of 5 new sites (3 springs, 1 well and 1 fountaining well) was procured by the project.

For the **Hrazdan RBD,** the following investments are proposed:

- On a long-term it is proposed to add 19 monitoring sites (13 springs and 6 wells). The planning document for all 19 additional sites was developed in spring 2020. EUWI+ procured the construction of 7 new sites (6 springs and 1 well) and 12 sites still need to be purchased.

Under EU4WD two groundwater surveys in the **Northern RBD** helped identifying 18 potential sites to be integrated into the national monitoring network. Nevertheless, this number of sites is insufficient for a representative monitoring network. Furthermore, the currently delineated GWBs do not fit to the WFD principles. Hence all network reviews should be implemented once the GWBs are redelineated.

As recommended by respective EU CIS guidance documents, the GW monitoring network should also include wells, springs and points for measuring surface water levels during the dry period as well as waterlogged territories and lakes that are essentially dependent on GW.

- Identify / establish monitoring sites for the transboundary GWBs which should be subject of joint monitoring and mutual data exchange
- Sign the recently (2024) finalized bilateral agreement for joint monitoring and data exchange with Georgia and elaborate similar agreements with other neighbors.

6.2.2. Monitoring parameters and frequency

Groundwater quantity monitoring

The currently applied frequency of measurements of the groundwater level regime is 6 times a month and fully in line with the WFD which requests at least one measurement per year.

The efforts in gradually installing electronic sensors and automatic data loggers offer the possibility of easily gathering monitoring data of higher timely resolution.

Nevertheless, it should carefully be evaluated whether increased frequency of monitoring data always contributes to better conceptual understanding of the GWB, in particular this might not be the case for deep and slowly reacting GWBs, and whether the financial resources should be better invested in enhanced chemical monitoring.

Groundwater chemical monitoring

The current frequency of water sampling and chemical analyses is twice per year. The list of substances covers the main basic parameters.

In terms of GW monitoring, the WFD follows a risk based approach and it is necessary to tailor the scope and frequency of monitoring to the natural properties and to the significance of human pressures affecting groundwater. This means that the national legislation needs to reflect this approach by a certain level of flexibility in its legal requirements.

Starting at the current state of GW chemical monitoring in Armenia, the following aspects should be considered when amending the existing approach (parameters and frequency) towards WFD compliance:

- the need of data to establish comprehensive conceptual understandings of the GWBs;
- the need of data for the establishing natural background levels;
- the need of sufficient data (time series) to perform trend assessments;

- the tiered and risk-based approach of the WFD (surveillance and operational monitoring). It is recommended to implement a higher monitoring frequency for surveillance monitoring (screening of the pollution situation at different seasons of the year). Operational monitoring can be implemented at a lower frequency once the variability of pollutants is identified;
- the need of wider parameter screening in the form of surveillance monitoring every 6 years to validate the risk assessment by e.g.:
  - Identify those pesticides that are used/sold in Armenia in high volumes or most toxic;
  - Identify the dangerous substances linked to the anthropogenic activities (e.g. industry, mining, storage, etc.) which were identified within the risk assessment;
  - Consider isotope screening to enable age dating of groundwater.

Finally, it is necessary to consider the financial efforts and budgetary limitations when developing such a comprehensive monitoring design.

6.2.3. Monitoring equipment

- Prepare an inventory of available means of transport and their technical status, of available and functioning equipment and consumables for field measurements and of available and of appropriate sampling containers for the different parameters.
- Check whether it makes really sense that monitoring sites are fitted with automated logging equipment to record/transmit quantitative data and physico-chemical parameters at short intervals. Experience in other countries showed that such expensive equipment is very often target to vandalism, easily and frequently destroyed or stolen. Furthermore, some data loggers have to replaced completely when the battery is empty. This means that a lot of budget is wasted, and if data loggers are gone, also the data are completely gone - can be long time series. Finally, if equipment cannot be replaced, an alternative measuring approach is instantly needed.
- Provide all necessary precautions for any equipment located unattended in the field or in the laboratory in a way that theft, damage/deterioration or vandalism are prevented to the best possible extent. This can be achieved by locked enclosures (fence, door, storage box), supervision by (voluntary) guards, insurance or similar suitable arrangements.
- Purchase necessary equipment according to the list of deficiencies resulting from the inventory. Foresee back-up equipment.
- Purchase all necessary consumables (e.g. gasoline for cars, filters, stabilizers, calibration standards, batteries or gasoline for pumps) for sampling, stabilization and cooling of samples.
- Check the sampling and field measurement equipment regularly. Calibrate the equipment according to the manuals.
- Please secure good operation, safe storage and regular maintenance of all monitoring equipment.
- Keep records of who is using when and where any valuable device (to be signed upon return).

6.3. Data assessment

To turn the monitoring data into usable information for decision-making, structured methods that aggregate chemical and quantitative monitoring data into reliable assessments of chemical and quantitative status and risk of not to achieve WFD good status objectives, still need to be developed, taking regard of the specifications laid down in the WFD.

- Routinely check monitoring data with simple geo-statistical tools (e.g. ion balance, Pipe-Furtak diagrams) and interpret the data in the light of the hydrogeological characteristics of the GWB.
- Develop national methods for the chemical and quantitative status assessment and for trend assessment, once time series are sufficiently long.

6.4. Personnel and responsibilities

- Assign sufficient, trained and well-paid staff in the central and regional institutions, which are responsible for groundwater sampling.
- Provide regular sampling training to the regional staff.
- Nominate an institute and personnel that is responsible for training sampling personnel.
- The national groundwater database could be improved, in order to allow integration of data from automated logging equipment and to facilitate integration with other databases.
- Establish a national working group on groundwater that brings together the main national expertise in groundwater management (institutes, university and regional administration) to communicate and discuss approaches about the implementation of the groundwater related aspects of the WFD.

6.5. Costs, budget

Improvement and maintenance of monitoring capacities needs a sufficient one-time budget to cover the investment costs and sufficient long-term guaranteed permanent budget to coverage maintenance of infrastructure and equipment and operational costs. The budgets should consider the following costs:

Investment budget:

- Costs for stock-taking of all GW monitoring sites to prove technical status; also include existing sites used for different purposes;
- Costs for refurbishing sites and establishing new sites (most expensive solution);
- Purchase necessary means of transport, equipment for sampling and field measurements.

Permanent long-time guaranteed annual budget:

- Transport costs (e.g. gasoline, rental costs) for regular inspections of the monitoring sites and for sampling according to the mandatory monitoring frequency;

- Costs of consumables for sampling and field measurements (e.g. filters, stabilizers, calibration standards, batteries, tubes and gasoline for pumps etc.);
- Costs of maintenance and regular replacement of equipment;
- Salary costs of trained staff;
- Costs of regular meetings of the sampling staff and for training purposes.

6.6. Trainings

In continuation of the work stipulated by EUWI+ and EU4WD it is recommended to support the successful implementation of the Association Agreement and its roadmap and improvement of the GW monitoring capacities throughout the whole country by follow-up trainings and workshops. The following table provides a rough overview of ideas for trainings which should be arranged in the coming years.

Table 10: EUWI+ Groundwater Training plan Armenia

Activity / Training	Competence profiles	Training targets
Follow-up development of tailored WFD assessment methodologies for risk, status and trends – for GW quantity and chemistry	• Ability to applying methods of data aggregation and interpretation of the results. • Ability to judge methods used by different countries and to conclude on most appropriate national approaches	• Common discussion of the current proposals of (aggregating and) analysing monitoring data and in concluding on the status. • Main emphasis on GWBs with only few data. • Discussion and interpretation of the testing results of different approaches. • Development of national approaches.
Follow-up coordination meeting(s) on transboundary GWB delineation and harmonisation with neighbouring countries	• Understanding of scope and role of transboundary coordination. • Bilateral harmonisation of GWB boundaries and monitoring networks	• Bilateral exchange of approaches for GWB delineation and monitoring design by GW experts from neighbouring countries. Exchange of GIS data and information. • Discussion of the tasks for the identification of common transboundary aquifers/GWBs and common monitoring sites.
Follow-up coordination meetings on transboundary GW monitoring with neighbouring countries.	• Experience in the delineation of transboundary GWBs and the design of groundwater monitoring networks. • Experience in bilateral discussions	• Common discussion and harmonisation of transboundary GW monitoring networks.
Follow-up preparation of joint transboundary groundwater monitoring campaigns with neighbouring countries	• Experience in GW monitoring and in the preparation of surveys.	• Joint design of the monitoring campaign. • Joint elaboration of GW survey manuals, coordination with laboratories, organisation of logistics, equipment etc. • Clearance of transboundary challenges (travelling, border crossing etc.)
Refresher training (theoretical and practical) on GW sampling.	• Solutions for questions raised during routine sampling work. • Awareness for QA/QC in field measurements, GW sampling, sample stabilisation and transport. • Practical handling of equipment and check.	• Refresher training in survey planning, handling and treatment of field equipment, coordination with the laboratory, sample treatment and conservation, documentation. • Witness-check of practical sampling in the field. • Discussion of experiences and need for equipment.

7. Technical reports/ EUWI+ and EU4WD References

EU4WD products

1. EU4WD 2024: Northern River Basin Management Plan. Draft.
2. EU4WD 2024: Groundwater transboundary survey report 2023 (Armenia-Georgia);
3. EU4WD 2024: Transboundary groundwater body report – Armenia-Georgia
4. EU4WD 2023: Transboundary groundwater bodies. Armenia–Georgia.
5. EU4WD 2023: Audit report: Groundwater sampling – Armenia
6. EU4WD 2023: Groundwater survey report 2023 (in Northern RBD);
7. EU4WD 2023: Groundwater survey report 2022 (in Northern RBD);

EUWI+ Product

8. EUWI+ 2020: Draft River Basin Management Plan for Sevan River Basin District in Armenia.
   Available online in English at: https://www.euwipluseast.eu/en/component/k2/item/1269-armenia-sevan-river-basin-management-plan-2020-arm?fromsearch=1
   Available online in Armenian at: https://www.euwipluseast.eu/en/component/k2/item/1277-armenia-sevan-river-basin-management-plan-2020-arm?fromsearch=1
9. EUWI+ 2020: Draft River Basin Management Plan for Hrazdan River Basin District in Armenia.
   Available online in English at: https://www.euwipluseast.eu/en/component/k2/item/1757-armenia-sevan-river-basin-management-plan-2020-arm?fromsearch=1
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10. EUWI+ 2020: Groundwater surveys 2018 and 2019 Report.
    Available online in English at: https://www.euwipluseast.eu/en/component/k2/item/1125-armenia-groundwater-surveys-2018-2019-report-eng?fromsearch=1
11. EUWI+ 2020: General manual for Chemical Freshwater Sampling.
    Available online in English at: https://www.euwipluseast.eu/en/component/k2/item/1548-regional-general-manual-for-chemical-freshwater-sampling-2020-eng?fromsearch=1
12. EUWI+ 2020: Specific manual for surveys in groundwater.
    Available online in English at: https://www.euwipluseast.eu/en/component/k2/item/1550-regional-specific-manual-for-chemical-surveys-in-groundwater-2020-eng?fromsearch=1
13. EUWI+ 2020: Development of a national methodology for an assessment of the available groundwater resources in mountainous regions and the implementation of this methodology in the Hrazdan and Sevan River Basin Districts
    Available online in English at https://www.euwipluseast.eu/en/component/k2/item/1693-armenia-study-on-groundwater-resources-eng?fromsearch=1

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14. EUWI+ 2018: Delineation and characterisation of groundwater bodies and the design of a groundwater monitoring network in the Hrazdan and Lake Sevan River Basin Districts in Armenia. Available online in English at: https://www.euwipluseast.eu/en/component/k2/item/1370-armenia-hrazdan-sevan-groundwater-delineation-report-2018-eng?fromsearch=1

EPIRB products

15. EPIRB 2016: Draft basin management plan for Akhuryan river basin district.

Legislation and Guidance documents

16. EC, 2009: Guidance on Groundwater Status and Trend Assessment. CIS Guidance Document No 18. European Commission.

17. EC, 2008: Groundwater Protection in Europe. The new Groundwater Directive – Consolidating the EU Regulatory Framework. European Commission.

18. EC, 2007: Guidance on Groundwater Monitoring. CIS Guidance Document No 15. European Commission.

19. EC, 2001: Statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results. CIS Technical Report No. 1. European Commission.

20. Directive 2000/60/EC of the European Parliament and of the Council of 23 December 2000 establishing a framework for the Community action in the field of water policy. Official Journal of the European Communities, L 327, 22.12.2000, p. 1–73

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