SUPPORTING REPORT D

Groundwater

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D GROUNDWATER

D.1 General Hydrogeological Conditions in Bulgaria

All kinds of groundwater reservoirs are presented in Bulgaria: porous, fissured and karstic. Porous aquifers are widespread at lower altitudes: within lowlands and kettles, along rivers. Fissured and karstic groundwater reservoirs are usual in mountain regions. Where present, carbonate deposits (marble, limestone, dolomite) are fissured and somewhere karstified.

From hydrogeological point of view, the country is divided into 3 regions:

- Low-Danube artesian (in North Bulgaria),
- Intermediate, and
- Rilo-Rhodopian (Figure D.1.1)

D.1.1 Hydro-geological Map(s)

Two kinds of maps are available for the territory of Bulgaria in scale 1:200,000:

- Map groundwater flow and natural groundwater resources (1979);
- Map of ‘groundwater safe yield’ or ‘exploited resources’ (1981).

(1) The Groundwater Flow Maps

These maps give quantitative characteristics of the main aquifers and aquifer systems containing fresh groundwater suitable for public water supply. These maps show average long-term values of groundwater discharge. It should be emphasized that groundwater discharge values, characterizing the natural productivity of aquifers or aquifer systems, are the major indicator of groundwater resources availability in an area (Zektser & Everett, 2004). These maps present estimates for the total potential of groundwater resources.

Generally, natural groundwater resources are expressed by ***module of groundwater flow***, which is defined as groundwater flow discharge from a unit of catchment area, given in liters per second per 1 km^2 (Zektser, 2002; Zektser & Everett, 2004).

Additional characteristics may be groundwater runoff/precipitation ratio and ratio of groundwater discharge to total river runoff.

In Bulgaria, the regional assessment and mapping of the natural groundwater resources has been made with support of Russian hydrogeologists. A map of natural groundwater resources is available in the scale 1:200 000 (1979).

The legend includes:

- Age of aquifers;
- Long-term value of module of groundwater flow (in $l/s/km^2$);
- Areas of recharge of confined (deep) aquifers (in layer, mm);

- Other symbols (areas with TDS content > 1 g/l; open karst area; areas with intensive evaporation from groundwater and salinization of soils; losing streams, etc.)

(2) The Map of 'Groundwater Safe Yield' or 'Exploited Resources'

This map is a prognostic map that presents a part of natural resources (of the total potential of groundwater resources) that may be used for water supply. It is based on the regional evaluation of safe yield. The map compiled for Bulgarian territory in 1981 contains 28 map sheets in scale 1:200 000.

The legend includes:

- **A.** Modules of 'exploited resources' (in l/s/km^2) that are given in seven gradations and presented by different colors. Regions defined as practically without 'exploited resources' are with grey color. For low confidence of data, only presumed values are given; they are marked with vertical lines. Regions with groundwater development mainly through tapping of spring are delineated.
- **B.** Modules characterizing additional (induced) recharge from rivers under exploitation (linear module – l/s/km) are given in five gradations.
- Transmissivity values (m^2/d) – in seven gradations.
- Spring discharge (l/s) – in six gradations.
- Characteristics of exploitation wells (depth, m; productivity, l/s) – in five gradations.
- Other symbols (age of aquifer, open karst, large groundwater abstractions, groundwater unfit for water supply, etc.).

It should be emphasized that this map refers to groundwater resources that have not been explored, but only estimated based on regional consideration and available data, without additional field works. Based on this map, areas favorable for the resources formation may be defined. To explore the groundwater resources, especial research is needed.

Some elements of the above mentioned map (1981) had been transferred to GIS-maps by JICA Study team – "Distribution of transmissivity" for WABD and EABD, and for Bulgaria as a whole.

(3) Other Hydrogeological Maps

For some regions of Bulgaria, hydrogeological maps are available in scale 1:25,000. The preparation of these maps was commissioned by the Committee of Geology and Mineral Resources in the period 1992-1997. The legend includes different hydrogeological aspects including transmissivity values in the applied gradations, depth to groundwater levels and sometimes equipotential lines.

(4) New Hydrogeological Map

Digital groundwater map of Bulgaria, 1:500 000 – the new groundwater map of Bulgaria (P. Pentchev et al.) is intended for a wide range of users. It gives a general idea of the groundwater in Bulgaria including mineral waters.

Four classes according to groundwater productivity and four subclasses depending on the porosity type of water-bearing rocks have been used to categorize the hydrogeological formations:

- Major aquifers (class A), major aquifers (class B), minor aquifers (class C), and non-aquiferous formations (class D);
- Porous aquifers (subclass 1), fractured aquifers (subclass 2), fractured-karst aquifers (subclass 3), and porous-karst aquifers (subclass 4).

The separate classes are identified by the different letter indices and colours, while the separate subclasses by the different numerical indices and patterns.

There are presented explanatory notes on stratigraphic levels, names of aquifers, and the official litho-stratigraphic units to which these are associated. The map reveals the lithological type of the water-bearing formations. It includes only the most significant groundwater springs and mineral water sources. The map has been prepared as a digital model in GIS – MapInfo. Nevertheless, it presents all aquifers in the only GIS-layer, and does not show stratified aquifers in depth.

D.1.2 Groundwater Aquifers and Their Characteristics

Danube river are good groundwater reservoir with transmissivity values from 500-1000 m^2/d or more (see Figure D.1.2). The aquifers are built from the Quaternary alluvial deposits (sand and gravels) with thickness 10-20 m, overlain by low permeable layer (silty loam, loam, loess, etc.).

Alluvial aquifers along rivers are characterized by similar structure, but with lower thickness and transmissivity (usually from 100 to 500 m^2/d).

In NW Bulgaria, within Lomski sub-region, there is a stratified system of aquifers, mainly porous (sands).

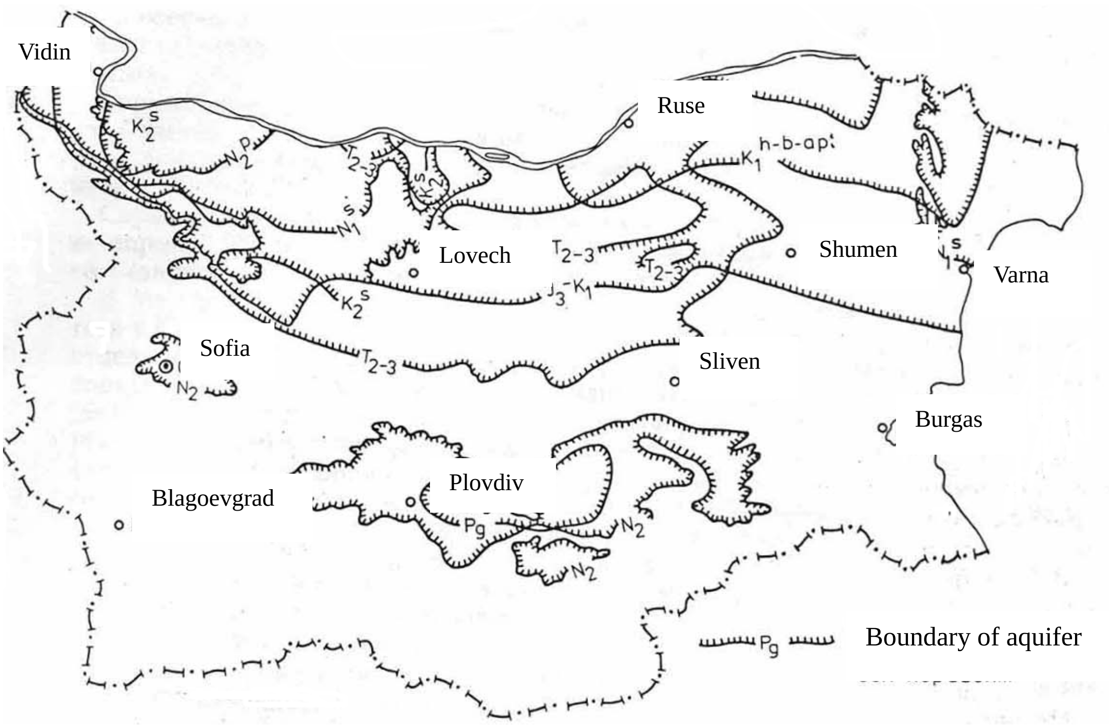
Large porous aquifer is formed in South artesian basin from the Intermediate region. The alluvial and proluvial deposits in the valley of the Maritsa River are characterized with high transmissivity value (from 500 to 2000 m^2/d).

Important porous aquifers are related to kettles filled in with alluvial and proluvial deposits.

In NE part of the country, carbonate deposits are widespread. There a huge and deep groundwater reservoir is formed in Mesozoic formations, which is referred both to the Danube and the Black Sea river basins. Its groundwater divide is oriented NE – SW. The limestone formations are highly heterogeneous. Other aquifers in younger carbonate formation overlay partially this aquifer. The upper aquifer is the Sarmatian in the Black Sea river basin, with very high permeability, which is not protected from contamination. The deepest and the upper aquifers are transboundary, shared between Bulgaria and Romania.

Within the Rilo-Rhodopian and Intermediate regions, many important local karst basin occur, which are discharged mainly by karst springs.

The major part of the aquifers occurs in the northern part of the country, within the Moesian platform (see figure below). Local groundwater systems prevail in Bulgaria; in many regions there are no large aquifer systems.



Sketch Map of the Principal Deep Aquifers in Bulgaria (Kehajov et al., 1988)

The basic manual for many generations of students-hydrogeologists is the book "Groundwater in the Republic of Bulgaria " by Antonov and Danchev (1980). More recent information is presented in General Master Plans (2000).

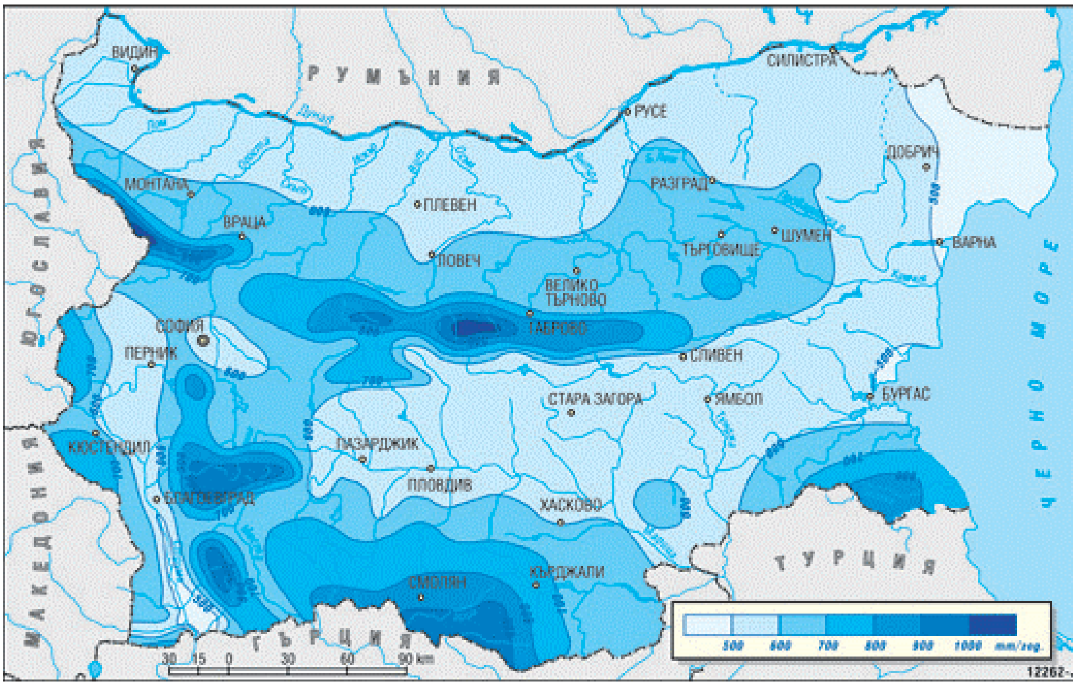
D.1.3 General Tendency of the Potential of Groundwater Resources

The highest values for modules of the groundwater flow (more than 10-20 l/s/km^2) are related to karstified limestone in mountain areas. Here enhanced precipitation values (due to orographic effect) along with high permeable formations make the best combination for abundant groundwater recharge. Proterozoic marbles in the Rhodopes and Pirin are the most outstanding examples. Many of such karst reservoirs are not well protected against contaminations, but in high mountains the anthropogenic impact is usually low.

Large groundwater resources are common for porous aquifers along rivers, especially for and kettles filled in with coarse alluvial proluvial sediments and for lowlands near to the Danube river. Here the most common values of the module are 5-7 l/s/km^2.

Low recharge plus low permeable formations make the worst combination. In such areas, the modules of the groundwater flow are below 0.5 $l/s/km^2$. In Bulgaria, such values are usual for southern parts of the country.

Groundwater discharge is a major component of surface water generation in headwater streams.



Precipitation Amounts in Bulgaria (Geography, 2002)

References to Chapter D.1:

1) Antonov H, Danchev D (1980) Groundwater in the Republic of Bulgaria. Sofia, "Technika", 360 p. (in Bulgarian)
2) General Master Plans for utilization of the water resources in Bulgaria. Project supported from Bulgarian
3) Ministry of Environment and Water (2000) Hydrogeological background and assessment of groundwater resources (in Bulgarian) http://www.bluelink.net/water/
4) Geography of Bulgaria, 2002. Academic publication. ForCom, Sofia (in Bulgarian).
5) Zektser IS (2002) Principles of regional assessment and mapping of natural groundwater resources. Environmental Geology, Vol. 42 (2), 270-274.
6) Zektser IS, Everett LG (eds.) (2004) Groundwater resources of the world and their use. IHP-VI, Series on Groundwater No. 6, UNESCO, Paris.

D.2 Groundwater Monitoring Networks

D.2.1 Existing Groundwater Monitoring Networks of NIMH

Nowadays National Institute of Meteorology and Hydrology (NIMH) supports two networks of groundwater monitoring stations (see table below).

- Network of groundwater quantitative monitoring and
- Network of groundwater qualitative monitoring.

Groundwater Stations of NIMH

Kind of the GW station	Quantitative monitoring		Qualitative monitoring	
	Yes/No	Monitoring program	Yes/No	Monitoring program
Well (shaft or borehole)	Yes	H, t	No	-
Artesian well	Yes	Q, t	(Yes)	t, pH, TDS, basic components, **nitrogen forms, phosphates, iron**
Spring	Yes	Q, t	(Yes)	t, pH, TDS, basic components, **nitrogen forms, phosphates, iron**
Well with pumping station	No	-	Yes	t, pH, TDS, basic components, **nitrogen forms, phosphates, iron**

H – groundwater level
Q – discharge
t – water temperature
(Yes) – means: only for the chosen stations

The measurements for groundwater quantity network are on monthly basis for most of the stations; some are on the daily basis.

Sampling for the groundwater quality network – 4 times yearly.

(1) NIMH Wells

Figure D.2.1 "NIMH Monitored Wells" contains wells for the groundwater quantity monitoring:

- Wells (shafts and boreholes) for measurement of groundwater level and temperature;
- Artesian wells (boreholes) for measurement of discharge and temperature; some of them are included into groundwater quality network;

Figure D.2.2 "NIMH Wells with Pumping Stations" refers to:

- Wells with pumping stations for water supply – for groundwater quality monitoring (only some of them are used for groundwater level measurements – only in NE Bulgaria, where GWL is deep, and wells are scarce).

The frequency of the measurement for the category "Wells" is usually once per month. Some stations are measured few times in a month, and only few are supplied with groundwater level recorders (limnigraphs).

(2) NIMH Springs

Figure D.2.3 "NIMH Monitored Springs" contains springs (see table in Chapter D.2.1) that may be divided into:

- Springs with measurements on monthly basis;
- Springs with measurements on daily basis.

For the last category, daily measurements of the stage at hydrometric station are available. Based on rating curve, data on daily discharge are obtained.

National Hydrogeological Networks (NHGN) in Bulgaria is in operation since 1958-1961. They were found with the assistance of Russian hydrogeologists. From the year 2000, the Ministry of Environment and Water supports functioning of the networks. Still, there is no fund for technical improvement of existing equipment.

MOEW does not have data from the groundwater quality network of NIMH during last years.

D.2.2 Existing Groundwater Monitoring Networks of EEA

T The Groundwater monitoring system from the Environmental Executive Agency have data from 1980 year for ground water and from 1989 for surface water. After last increase and improve, it refer to 233 stations for the period 2000 – 2005 (springs, pumping stations, wells, see Figure D.2.4). The frequency of data is usually 4 or 2 times per year. There are some gaps in data series for some stations. For the project, data concerning pesticides and heavy metals is given on different sheets or files.

Data concerning pesticides and heavy metals are on different sheets or files.

All components included into Bulgarian Regulation N 9 for drinking waters are defined. The Regulation N 9 is harmonized with the European Drinking Water Directive (Council Directive 98/83/EC on the quality of water intended for human consumption).

The bulletins issued by the EEA, which is available in its web page, determine problematic stations in terms of the Regulation N 1 for research, utilization and protection of groundwater (ET – ecological threshold; PT – pollution threshold). The different threshold values (the maximum permissible values) according to Regulations N 1, N 9 and Drinking Water Directive are presented in the table below (only for basic components).

Threshold Values according to Different Regulations

Parameters	Symbols	Dimension	Regulation № 1		Dimension	Regulation № 9	Drinking Water Directive
			ET	PT			
Hydrogen ion concentration	pH	pH units			pH units	6.5 - 9.5	6.5 - 9.5
Oxidisability	COD-Mn	mg/l O2			mg/l O2	5.0	5.0
Chloride	Cl	mg/l	30	100	mg/l	250	250
Sulphate	SO4	mg/l	50	150	mg/l	250	250
Sodium	Na	mg/l	50	100	mg/l		200
Calcium	Ca	mg/l			mg/l	150	
Magnesium	Mg	mg/l			mg/l	80	
Iron	Fe	µg/l	50	200	µg/l	200	200
Manganese	Mn	µg/l	20	50	µg/l	50	50
Cadmium	Cd	µg/l	1	5	µg/l	5.0	5.0
Chromium	Cr total	µg/l	5	50	µg/l	50	50
Arsenic	As	µg/l	10	30	µg/l	10	10
Lead	Pb	µg/l	30	200	µg/l	10	10
Copper	Cu	µg/l	30	100	mg/l	2.0	2.0
Zink	Zn	µg/l	200	1000	mg/l	5.0	
Nickel	Ni	µg/l	20	100	µg/l	20	20
Ammonium	NH4	mg/l	0.12	1.2	mg/l	0.50	0.50
Conductivity		µS/cm			µS/cm	2000	2500
Nitrite	NO2	mg/l	0.025	0.125	mg/l	0.50	0.50
Nitrate	NO3	mg/l	10	30	mg/l	50	50
Phosphate	PO4	mg/l	0.1	1	mg/l	0.5	0.50

It should be noticed that the corresponding threshold values according to Regulations N 9 may be lower (for Pb - lead, for example), or higher (for Cu – copper) compared with the threshold of pollution according to Regulations N 1.

(1) Groups of Components or Indicator Parameters

For the purposes of analysis, the parameters had been divided into groups as shown below:

Groups of Indicator Parameters for GIS-Maps

I group	II group	III group	Pesticides	Heavy metals
NO_3 av	Fe max	Conductivity		Cd
NO_3 max	Mn max	SO_4 max		Cr
NO_2 max	pH	Cl max		As
NH_4 max	Na max	Ca max		Pb
PO_4 max		Mg max		Zn
COD-Mn				Ni
				Cu

The first group includes one of the most important pollutants of groundwater – nitrate. This pollutant is widespread in Bulgaria. The basic sources of contamination are: application of fertilizers (agriculture) and lack of wastewater treatment plants WWTPs (from settlement or animal breeding). This group includes all analyzed forms of nitrogen in groundwater and related pollutants/parameters as phosphate and oxidisability.

The main goal of GIS-maps on groundwater quality is to identify problematic areas, aquifers in groundwater bodies, where groundwater does not meet the requirements of the Regulation N 9.

The principal approach is to show the groundwater quality by colour. The main threshold values between "good" and "bad" quality are according to Regulation N 9. The registered maximal values of indicator parameters are used. The respective information is presented for each year from 2000 up to 2005. For nitrate, due to its importance as pollutant, additional threshold value is used (30 mg/l). In addition, for each station the average value of nitrate content is calculated for the period 2000-2005.

(2) Representative and Non-representative Stations and Data

- Unreal data
  - Many of the unreal data refer to the initial stage – the year 2000. Some of the unreal data have been corrected after additional check in Laboratories.
- Violated sampling procedure
  - One of the problems is related to quality of the data due to violated sampling procedure. According to information from the EEA, there are about 10 stations – wells, where sampling is not preceded by pumping (no pumping facilities available). Such stations are non-representative for the corresponding aquifers and/or groundwater bodies. They show high content of Fe, Mn and/or other components (for example, stations N 194 and 195 in Sofia, 234 – Yana, 202 - Stoletovo). The overall list of such stations is lacking.
- Local pollution
  - Some stations are under local impact of pollution. One example is station N 169 – Radomir (at the railway station, where carriages, or coaches are washed). Another examples – station N 203 (Straldzha), situated in the grounds of a factory; station N 99 (Katunitza) situated in the grounds of an alcohol factory.
- Mixed groundwater
  - There are stations, which show mixed water from shallow and deep aquifers. For example, station 206 (Dobrich) refers to a pumping station from 2 deep and 13 shallow boreholes. The corresponding important aquifers are N_1srm and J_3 m-K_1vlg.

D.2.3 New Groundwater Monitoring Plans for River Basin Managements

The New Groundwater Monitoring Plans for RB Managements have been developed in implementation of the requirements of the WFD. The number of monitoring sites to be reported in EU is presented on Table for different River Basins.

Number of Monitoring Sites from the New Monitoring Programs

Monitoring network	EABD	WABD	Danube BD	BSBD
Surveillance	38	33	49	66
Operational	12	-	21	37
Quantitative	41	34	86	63

Quantitative network is planned most usually with frequency of 4, sometimes 12 times per year, and encompasses monitoring of the next parameters:

- groundwater levels in boreholes or wells;
- spring flows;
- discharge from artesian wells and drains.

There are cases of multiple uses of monitoring sites for different networks.

Operational monitoring is planned for all groundwater bodies ‘*At risk*’ along with groundwater bodies ‘*At risk*’ *with low confidence in the risk assessment,* for which additional information is necessary (see table below).

GWBs at Risk and Operational Monitoring

Number of GWBs	EABD	WABD	Danube BD	BSBD
‘At risk’	4	-	21	3
‘At risk’ with low confidence in the risk assessment	3	-	-	7
Total ‘At risk’	7	-	21	10
With operational monitoring planned	7	-	21	10

No groundwater bodies ‘*At risk*’ have been identified in WABD. On the one hand, there is only sparse monitoring data about pollutants in groundwater, and on the other hand the pressure is lower compared to other river basins. As a result, no operational monitoring has been planned up to now in WABD.

RBDs report almost total coverage of GWBs with GW monitoring networks. Because of their importance for national or regional development, **large regional** groundwater systems have received a higher priority than local-scale systems. Only GWBs with local importance and low pressure are not covered by networks. They are usually difficult of access and with low population density.

New Groundwater Monitoring Plans are presented on Figure D.2.5 and D.2.6.

The proposed monitoring frequencies for surveillance monitoring are usually 4 times yearly for the basic physical-chemical indicators, and rarely for specific pollutants. This monitoring is intended to be conducted only 1 year within the operation of the River Basin Plan. For operational monitoring they are usually 1 to 4 times yearly for the specific indicators, which present a real threat. Many of sampling points from surveillance and operative monitoring refer to groundwater for drinking purpose.

Short Description of the Used Approaches

Practically, the approach used by RBDs in preparing new monitoring programs was based on the existing networks – on one hand, and on the requirements of the WFD – on the other hand. Where appropriate, the existing monitoring stations were adopted (mainly these of NIMH for quantitative monitoring and these of EEA – for qualitative monitoring). Inadequate stations have been discarded (as those boreholes that cannot be duly purged – from the GW qualitative network).

Owing to the efforts of RBDs, available wells and boreholes have been found to be included in the new monitoring work, mainly private. Using of such boreholes is a cost-effective practice largely used in EU. For GWBs with no available boreholes, RBDs have given reasons for new drillings.

In general, the available data and results from the existing GW networks have been taken into account. The main approach was searching for better stations and extending of networks in non-monitored areas.

Much preparatory work has been done. Probably different options for monitoring programs have been considered, but not described. Unfortunately, there is no written information about real data needs. Nowadays groundwater monitoring in Bulgaria is not *de facto* integrated in water resources management and environmental protection. The proposed new monitoring programs have the same shortcoming.

D.2.4 Recommendations for Improvement of the Groundwater Monitoring

(1) Evaluation of the Proposed New Monitoring Programs. Problems Identified

The proposed groundwater monitoring programs by EABD and WABD are very ambitious. Its overview shows some weaknesses and obstacles, some of them foreseen by the RBDs. The difficulties marked by RBDs are as follows:

- Possible cooperation with NIMH and WSCs has no legal basis – no agreements signed between MOEW and NIMH.
- Laboratories have low human resource to respond to increasing tasks due to insufficient staff. Several vacancies are in Laboratories in Blagoevrad and Sofia.

In our opinion, additional problems are:

- technical infrastructure for GW quantity measurements is lacking;
- need for trained technical staff;
- need of hydrogeological work that requires involvement of experienced staff.

The staff of the RBDs has made preliminary agreement of the owners of private wells concerning access for the monitoring purposes. Later clear arrangements should be made with them.

At present the proposed groundwater monitoring programs do not fully correspond to the existing capacity of RBDs. Here general recommendations are presented, which are related to improvement of GW monitoring.

(2) General Recommendations

- 1. RBDs are institutions engaged in GW monitoring. To fulfill this task, **capacity building** is the most important prerequisite. Monitoring requires knowledge and experience. There is a need of experienced hydrogeologists, dealing with groundwater issues, involved in planning and implementation of GW monitoring. On the other hand, technical staff is necessary, which should be well trained.
- 2. **Analysis of institutional setting** is necessary. RBDs are institutions having the responsibility and mandates for groundwater monitoring. Possible involvement of other institutions (NIMH, WSCs or other) through delegated tasks to them should be considered. Roles and administrative responsibilities should be clear.
- 3. To furnish **GW monitoring handbook** (for quantitative monitoring) that documents procedures, which must be followed to ensure good quality and integrity of the data collected.

(3) Some Practical Recommendations

- Gradual growth of the monitoring network from low profile to the right level of groundwater monitoring, always adjusted to the needs.
- To begin with small number of points.
- To plan carefully tasks.
- To provide for high standard and full documentation concerning implementation of the monitoring program.

Important aspects of GW monitoring are presented below. Groundwater monitoring programs should be developed based on inventory of **data needs** and specification of the **objectives**. Here some of the possible objectives are presented:

- 1. Characterisation of the groundwater system(s);
- 2. Identification of possible trends in relation to groundwater use;
- 3. Estimation of the potential for further groundwater development;
- 4. Provision of historical and reference values for detailed investigations;
- 5. Meeting the requirements of the WFD;
- 6. Early warning system for GW related problems.

GW monitoring programs are developed taking into account **specific data needs** and are based on **conceptual model** for HG systems. The data needs are often related to possible or identified GW related problems. Evidently, additional work is necessary.

- Need of additional preparatory work

  - List of (main) stakeholders;
  - Inventory of data needs - what data for what needs, for what stakeholders;
  - To set priorities of data needs;
  - To set priorities of monitoring points;
  - Inventory of available wells with compiled fact sheets (information passports/sheets).

- Need of thorough hydrogeological work
  - Preparation of **conceptual model** for HG systems. To a large extent, the conceptual model represents a statement by the professional hydrogeologist on how the groundwater system being studied "works".
  - Analysis of the available data for GW quantity and quality;
  - Synthetic representation of the above mentioned aspects (maps, cross-sections, tables, graphs, problem statement);
  - Preparation of options for GW monitoring. Good practice says that groundwater monitoring programs should be adopted based on considering and weighting **different options**.

This work may be done in parallel with implementation of the first stage of the monitoring program.

(4) Recommendations for 3 Specific Cases

- For unconfined aquifers that are subject to diffuse pollution from the land surface, a reference monitoring point should exist within non-impacted zones (i.e. forests, protected areas) for comparative assessments.
- To prioritize the monitoring points, it is worthwhile to assess whether the measured value is a limiting factor for GW management or not.
- For alluvial aquifers along rivers, GW levels are usually close to the water stage in the river. In this case, an option of complex monitoring including surface and GW has to be considered. High accuracy of topographic measurements is necessary.

Documentation of groundwater monitoring is an important aspect. **Examples of standard forms** may be found in Annex E (Guideline, 2006), and are enumerated below. A proper monitoring program should encompass:

- A monitoring handbook that documents procedures which must be followed to ensure good quality and integrity of the data collected;
- A monitoring station file of each well that contains all important information;
- A field report form sheet that must be filled out upon arrival at the site and contains all relevant information about the fieldwork conducted.

(5) Conclusion

Establishing of appropriate GW monitoring network is a gradual and iterative process. Good idea is to apply a phased start of the GW monitoring programme. Such approach will allow for more gradual investments and means **prioritizing monitoring efforts.**

Our proposal is to prepare GW monitoring program for the period up to 1.VII.2008, and to continue work for the next period. Much preparatory work should be done to propose a good and feasible monitoring program.

The design of GW monitoring starts with **defining of objectives**. In our opinion, the main objective should be: "*Groundwater monitoring integrated in water resources management and environmental protection*". That is why it is important to know specific data needs. State of the art presumes the design of the GW monitoring network to be based on conceptual model of the hydrogeological system. On the other hand, the monitoring program has to be feasible. Different examples of approaches used in designing GW monitoring in Europe may be useful.

(6) General Recommendation for the New Groundwater Monitoring Plan

- To prioritize monitoring efforts based on specific data needs;
- to reconsider feasibility of the plans;
- to revise fact sheets of sites in respect of their long-term use in the networks;
- to reconsider involvement of other institutions through delegated tasks to them.

(7) Some Recommendations for the New Groundwater Monitoring Plans of EABD and WABD:

- To reconsider the new plan for quantitative monitoring – who will measure and data flow;
- to pay special attention to quantitative monitoring of Blagoevgrad GWB – '*At risk'*;
- to use existing data on chemical composition from reports (for assessment of specific natural GW quality in mountain regions impacted by ore mineralization – for reference) – for Upper Struma region, for example.
- Special attention to the region of the winter resort Bansko (WABD) and related impacts.

References to Chapter D.2:

1) Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 15. Guidance on Groundwater Monitoring
2) Guideline on: Groundwater monitoring for general reference purposes (Utrecht, 2006) (http://igrac.nitg.tno.nl/docs/WG1-Guideline.pdf)
3) Monitoring Report. Worldwide review on groundwater monitoring practice based on data from the questionnaire. IGRAC (http://igrac.nitg.tno.nl/gpm_practices.html)
4) National Report in implementation of the requirements of Art. 8 from the WFD 2000/60/EC http://www.moew.government.bg/recent_doc/waters/National_report_art8WFD-Bulgaria.pdf

D.3 Conditions of Groundwater and the Problematic Areas

D.3.1 Groundwater Quantity and the Problematic Areas

(1) Groundwater Table of Wells

Some of problematic areas in terms of groundwater quantity are related to extremely shallow groundwater.

Besides unfavorable conditions for agriculture and building, they make a premise for concentration (increase of TDS) of groundwater due to high evapotranspiration, and thus frequently coincide with problematic areas in terms of groundwater quality. Groundwater level close to the land surface hampers aeration of the soil, and may result in anaerobe conditions.

Areas with extremely shallow groundwater level are presented in Figure D.3.1 based on the groundwater quantity network from NIMH for the period 2000-2005. The depth to GWL is given as multi-annual average for the given period.

During severe floods in August and September 2005, measurement of some stations from the eastern part of the country was impossible due to inundated areas. Substantial rise of the groundwater table have been registered in wells near to the Danube River (see Figure D.3.2). Within the Danube lowlands, groundwater tables above the land surface have been registered both in April and in August 2005, due to direct hydraulic connection with the Danube River and high river stages for the river.

In other parts of the country, high GW tables have been registered only in April 2005.

In general, the year 2005 is characterized with high groundwater levels, especially in comparing with very dry year 2001.

<u>Shift of Shallow Groundwater Systems under Human Impact</u>

A case of evident impact from irrigation on GWL in shallow groundwater has been registered for the region of Ivajlo, west from Plovdiv (EABD). The groundwater tables have been observed before and after planting of rice crops and starting of the associated intensive irrigation.

In Figure D.3.3, GWL hydrographs are presented for the two periods: 1956-1959 and 1981-1984. There is a clear difference in patterns of the hydrographs for the two periods. An evident shift of the groundwater regime from natural to agricultural occurred as a result of new land use - rice crops with associated irrigation (Boteva et al., 1986).

Another case that demonstrates considerable change of groundwater regime refers to the Slivenski proluvial fan (EABD). Important groundwater recharge of the Quaternary aquifer here is due to waters of perennial river Asenovska that partly looses water within the proluvial fan. Such recharge produced considerable rise of the groundwater table. In this region observational well N 310 showed large amplitude in groundwater level fluctuations (up to 10 –12 m) – see Figure D.3.4.

The peaks of high groundwater levels (GWL) on Figure D.3.4 indicate more intensive recharge events. Such events are manifested with enhanced amplitude for the respective year (Figure D.3.5). Low recharge values lead to decrease of the amplitude - during 1972, 1976 and since 1989.

Evident decrease of recharge occurred. One very probable cause is drought period (1982-1994), and the second – possible result of human impact and decrease of recharge from river Asenovska.

Evidently, the described changes do not present a natural variation of the system, but a shift to other state characterized with worse groundwater recharge conditions from river and consequently, lower resource. It is interesting that for the mean annual groundwater level this shift is almost not expressed. This shift is well noticed however for the amplitude of groundwater variation and high annual values – these variables depend directly from the recharge events.

(2) Groundwater Discharge from Springs

Since the year 2005 was abundant in precipitation amount, spring flows were higher then usually. During the year 2005, high discharge values have been registered for karst springs (Figure D.3.6).

Well-expressed seasonal pattern is due to snowmelt in the high Pirin Mountain. Gradually increase of the mean and extreme discharge values are well expressed from the dry year 2001 to subsequent normal and wet years. Evidently, the reaction of the karst system strongly depends from the recharge conditions.

For karst springs a problem of water shortage during low flow period is actual. This problem affects mainly regions with water supply from karst springs and water intakes from small streams and rivers in mountainside regions. Such water sources are characterized with well-expressed seasonal regime with low flow period during late summer and early autumn. Simultaneously, July and August are the periods with enhanced need of water for irrigation. In rural regions, drinking water *de facto* is used for watering of crops in households. As a result, water shortage is usual event during summer.

Seasonal scarcity of the groundwater resources is inherent to carbonate massifs in mountain areas, drained by karst springs of conduit type. These regions receive much recharge, but the groundwater flow is fast, and the low flow periods are strongly expressed due to limited regulative capacity of the aquifer. Classical example is NW Bulgaria and especially the region of Vratsa .

The same regularity as described above for the spring N 59 is observed for the karst springs N 19 and 600. For spring 19, two graphs are given: remaining spring flow after water abstraction (N 19) and spring flow with added water abstraction from pumps (N 19P). In such way, undisturbed (or natural) spring discharge is estimated. Here, as in many similar cases, the gauge station is situated after the water intake. On the Figure long lasting low flow period may be seen (from August 2001 up to September 2002). The highest discharge value refers to May 2005. The relation Qmax/Qmin is more than 20.

The spring N 600 is fed additionally by river waters, and shows lower seasonal variation.

Water regime is usual in the areas where water supply is based on karst or surface waters that are vulnerable to droughts. High spring flow during winter and spring often remains unused, with water shortage during low flow periods.

In 2007, water regime was introduced in July and August in many settlements of district of Vratsa, Lovech, Gabrovo, Targovishte, Kotel, etc. The measures were hard somewhere – in some settlements water supply was twice per week, or even once within 5 days. Population has been provided with water tanks.

An example of Kotlenski springs near Kotel town (in East part of the country) is given below. The discharge of these karst springs is highly variable (from 40 l/s to about 20 m^3/s). Quick response to changes in the recharge conditions have been registered (Figure D.3.8).

The seasonal distribution of spring flow shows a well expressed low flow period from July to October. For some years the karst spring discharge decreases considerably as a result of winter and/or summer droughts (Figure D.3.9). Droughts during cold period (mild winters) have strong negative influence on the discharge of Kotlenski springs. The reference period for average monthly data is 1961-1990. The spring flow showed its high vulnerability to droughts (Orehova & Benderev, 2004).

(3) Deep Aquifer - Long Lasting Decline of the Groundwater Level

The Upper Jurassic - Lower Cretaceous aquifer in NE Bulgaria is the most productive in Bulgaria. It is a transboundary aquifer shared between Bulgaria and Romania. It receives main recharge in the territory of Bulgaria. The calcareous formation is up to 1000 m thick and highly karstified locally. The aquifer is characterized with high degree of heterogeneity. All the Bulgarian part of this aquifer takes large area (14000 km^2) including sub-thermal waters in its deep peripheral parts.

The Upper Jurassic - Lower Cretaceous (sometimes called as Malm-Valanginian) aquifer in northeast Bulgaria forms huge hydrogeological reservoir with regional importance. Many water supply systems withdraw groundwater mainly for water supply of towns and surrounding villages in the region, partly for industrial purposes, and very little – for agricultural needs. Deep groundwater level (from 20 to more than 100 m) for large areas hampers the aquifer development.

Since 1960-1975 small dams have been built that reduced natural recharge to the aquifer. This was possibly one of the reasons, together with the 1982-1994 drought period and active aquifer development, for the registered decline of water levels in observational wells in south part of the region, with average rate 0.5 m per year during 1982-1996 (see Figure D.3.10). There was no decline of heads at the seaside.

The Upper Jurassic – Lower Cretaceous aquifer belongs both to the Danube and the Black Sea river basins. The boundary follows the groundwater divide with direction SW- NE. Within the Black Sea river basin, the discharge is through large Devnia springs. At the seashore, artesian wells are discharging hot water. Another part of the groundwater flow goes to submarine discharge. The aquifer is highly heterogeneous. There are no observational wells for GWL measurements in the recharge zone of the aquifer.

The most appropriate way to understand this complicated system is to apply groundwater modeling. Lack of systematic observations in the central parts of the aquifer where recharge occurs, hampers the overall research, as well as lack of real data on dynamics in groundwater abstraction and recharge from rivers. Modeling of a part of this aquifer showed high heterogeneity with huge transmissivity near its main discharge zone on the cross-section of many faults.

After long lasting groundwater level decline, some stabilization has been observed as an evidence of a new equilibrium. During the year 2005, intensive recharge occurred, which is well expressed on Figure D.3.11 that shows amplitudes of GWL variations.

Good management of the Upper Jurassic - Lower Cretaceous aquifer should be based on groundwater models. Much work is to be done to relate groundwater balance and dynamics in this karst reservoir that interacts with other aquifers from NE Bulgaria.

(4) Problematic Areas in terms of Groundwater Quantity

A map showing groundwater bodies at risk (quantity aspect) defined by River Basin Directorates is presented in Figure D.3.12. Groundwater body at risk from the Black Sea River Basin is under risk of sea intrusion. For the Groundwater body at risk from WABD, the permissions for groundwater abstractions are close to the assessed groundwater resources. GWB at risk in EABD in Yambol-Elhovo region is defined due to the fact that related to it surface water body is at risk.

<u>Groundwater Overdraft – Decrease of Baseflow</u>

Depletion of groundwater owing to human activity is reported in other countries. In Bulgaria, water supply systems are widely ground on headwaters. The upper parts of watersheds are abundant in clear water.

Under pristine conditions, this is a resource for surface runoff as well as for groundwater recharge.

Under moderate rates of withdrawal, local surface waters and ecosystems are moderately affected. Reduction of recharge to groundwater occurs. The first and most direct impact is the decrease of baseflow. The last can trigger loss of riparian vegetation and depending ecosystems; gaining stream may become a losing stream.

Surface runoff has potential to convert into groundwater. Thus, every uptake of surface water has negative impact on groundwater.

The present state of the groundwater quantity at national level is analyzed based on the network of monitoring stations for the period 2000-2005 and before it.

In general, problems related to groundwater quantity aspects arise in cases of:

- Low groundwater resources;
- Strongly expressed seasonal scarcity of the groundwater resources;

- Groundwater levels close to the land surface (susceptible to swamping, and inundation);
- Very deep groundwater levels (hampered access to groundwater);
- Substantial change in groundwater levels due to natural or anthropogenic impacts (especially continuous falling of groundwater levels as a result of groundwater exploitation).

Low groundwater resources may be (or become) insufficient, with needs to apply artificial recharge or to search for alternative sources for water supply. Several zones of low groundwater resources may be seen on the maps of Bulgaria.

The main causes of low groundwater resources are:

- low values of precipitation amount;
- low values of evapotranspiration;
- low permeability of outcropping rocks;
- flat relief;
- lack of substantial recharge from surface waters.

Some of the above mentioned factors simultaneously lead to low values of the river runoff in the same area. As an example, Kalnitza River – right tributary of the Tundzha River, which is characterized with low values of both modules: of the river runoff (Bojilova, 2006) and of the groundwater flow.

Another unfavorable aspect for the areas with low values of the groundwater flow is related to generally low rates of groundwater flow, with inherent longer residence time and consequently groundwater enriched by salts and trace elements.

Under pristine conditions, many ecosystems along rivers used to be considerably dependent from water supply from the upper parts of the watershed. During springtime, large territories in middle and low river course have been flooded every year. This process contributed to additional groundwater recharge. Abstraction of surface water from the Tundzha River has led to lower groundwater recharge of the porous aquifer along the river.

References to Chapter D.3.1

1) Bojilova, E. (2006) Tundja River Basin – Hydrological Assessment For The 1961-2002 Study Period. BALWOIS 2006 – Conference on Water Observation and Information System for Decision Support Ohrid, Republic of Macedonia (http://balwois.mpl.ird.fr/balwois/administration/full_paper/ffp-460.pdf)
2) Orehova, T., A. Benderev (2004) Impact of climate variability on groundwater in Bulgaria (An example of Kotlenski springs region). 22nd Conference of the Danube Countries, Brno, Czech Republic.

D.3.2 Groundwater Quality and the Problematic Areas

The distribution of total dissolved solids (TDS) for groundwater in Bulgaria is presented in Figure D.3.13 (T. Kehajov, 1972). The lowest values are registered for intrusive and metamorphic rocks within high mountains, and the highest – for clays and marbles in the lowest parts of the country.

(1) Shallow Groundwater

The groundwater quality of Bulgaria is characterized based on data from groundwater quality network from EEA for 2000-2005, which have been analyzed and visualized in GIS-maps, where appropriate, additional information have been used. The used threshold values are from Regulation N 9 for drinking water.

The network of groundwater quality stations from EEA is rather sparse, and thus unable to reflect all important features and spatial variability in chemical composition of groundwater in details. Large territories are not covered by monitoring.

(a) Nitrate

Excess nitrate is the most common problem in Bulgaria related to groundwater quality (see Figure D.3.14). It is mainly due to over-fertilizing of crops in past time, animal breeding (lagoons, liquid waste) and lack of WWTP in many settlements. Zones with nitrate pollution in groundwater for South Bulgaria are related to specific soils (Vertisols) vulnerable to application of nitrate fertilizers.

In order to protect groundwater from nitrate pollution from agricultural activity, Nitrate Vulnerable Zones (NVZ) has been delineated in implementation of Regulation N 2 from 16.10.2000 (on the protection of water from nitrate pollution from agricultural sources). Geographical extent of these NVZ is rather wide. This Figure presents an initial designation of NVZ. Additional designation (or revised designation) should be made in Bulgaria before August 2008.

High concentrations of nitrate pose a serious problem for the drinking water supply. Shallow groundwater is the most affected. The registered maximal values of nitrate and other indicator parameters for the year 2000 is presented on Figure D.3.15, and for the period 2000-2005 – on Figure D.3.16. The average nitrate content in groundwater for the period 2000-2005 is given on Figure D.3.17.

On the last map, the average values of the nitrate content are given in brackets. In the same map trends in nitrate content are presented. Increasing trend indicates progressive pollution of groundwater for the period 2000-2005 (with red arrows), and decreasing trend – improving of the groundwater quality (with blue arrows). The red arrows prevail over the blue ones. In average for the country, concentrations of nitrate in groundwater are predominantly below 30 mg/l (green color) or in the range 30-50 mg/l (yellow color) – see Figure D.3.17.

Figure D.3.16 shows that for many stations maximal nitrate concentrations over 50 mg/l (red color) or even 100 mg/l (black color) have been registered. On this map only stations with nitrate content above the threshold value (50 mg/l) are presented.

Comparing Figure D.3.16 and D.3.17 one can conclude that in many sites only temporary increase in nitrate content is registered. Simultaneously, enhanced average values of nitrate over 30 mg/l and increasing trend both undoubtedly testify to anthropogenic pollution.

Nitrate content in drinking water presents a real problem in some areas, ***problematic*** in respect of nitrate content:

- 1) Extremely vulnerable to pollution is area in North-East Bulgaria, where shallow groundwater is related to Sarmatian limestone formation (fractured and karstified) that is weakly protected from pollution. This is a fragile environment, where groundwater receives its recharge from precipitation along with pollution load from widespread sources of contamination, including agricultural activities. Specific feature of this region is lack of perennial surface runoff. All temporary streams enter into the aquifer along with inherent pollutants. Taking into account its strong vulnerability to pollution, this territory needs to be monitored and managed with particular care.
- 2) Groundwater in the Plovdiv-Pazardzhik area, which is characterized with high anthropogenic impact from different origins. This is the region with abundant groundwater in porous alluvial-proluvial Neogene and Quaternary sediments. The aquifer in Quaternary deposits is unconfined, close to the land surface with shallow GWL, and is vulnerable to pollution. The deeper Neogene aquifer is confined, and it is better protected from pollution. The different kinds of pollution include agricultural impact both from fertilizers and animal breeding, pollution from numerous towns and villages without WWTPs, and industrial activities.
- 3) Stara Zagora area is characterized with shallow groundwater in low permeable sands, with high levels of nitrate. It is considered that specific soils in the area (namely Vertisols) are responsible to accumulation of nitrate in groundwater. This process is related to activity of specific bacteria. For these soils, over-fertilizing is fatal and leads to high nitrate in groundwater. The same soils are developed south to Yambol and in Bourgas region. Nitrate is mobile, and has tendency to be accumulated in water under evaporation. Uncontrolled use of nitrogen fertilizer in agriculture is especially dangerous for Vertisols and should be stopped. Good practices in agricultural activities within NVZs need to be applied.

(b) Nitrite and Ammonium

Nitrite and ammonium testify to fresh pollution, mainly from wastewater. They occur episodically.

(c) Phosphates

Phosphate in groundwater may be due to application of fertilizers, from industry and of geogenic origin. It is not a constant pollutant (see Figure D.3.15 and D.3.16).

Main occurrences of phosphate minerals in Bulgaria are presented in Figure D.3.18 (by A.Y.Kunov, 2005). The apatite (23) is most frequently found mineral. A significant part of the phosphates is concentrated in the Eastern Rhodopes, and less –

in Central and Eastern Srednogorie Zone. Most of phosphates have been found during the investigation of ore mineralizations (Zn-Cu-Pb and other). Lately, the interest to geochemistry of the phosphorus is high in relation to possible process of eutrophication.

(d) Heavy metals

Heavy metal pollution of groundwater is usually related to the heavy metal pollution of soils. In the next introductory section, basic features of this pollution are presented.

(i) Industrial Pollution of Soils (Konishev et al.)

This problem has become actual for Bulgaria since the early 1960s.

(ii) Heavy Metal Pollution of Soils

The most regularly occurring metals in soils are copper, zinc, lead, and cadmium. Other heavy metals - nickel, chromium, mercury - have been found at significant levels only rarely. Their heavy concentrations are usually related to ore mining or are concomitant emissions of the main pollutant (copper, zinc, and lead).

Bulgarian soils are low in organic matter and relatively high in clay. Clay minerals are highly reactive with different pollutants, and the heavy metals in particular. The most mobile forms of the heavy metals occur in relatively high concentrations in the acid soils and in lower concentrations in the calcareous soils.

Some important sources of pollution from metallurgy:

- ***Lead-zinc smelter*** at Plovdiv: operating since 1962; capacity about 50,000 - 60,000 t Pb/year;
- ***Iron smelter***, combined with floatation and coking operations, near the city of Sofia operating since 1962; emissions and effluents containing a wide range of pollutants.

(iii) Irrigation with Polluted Surface Waters

Nearly all the country's rivers are affected, particularly in their middle and lower reaches. The rivers receive effluents from mining, ore-processing, and metallurgy. Typically this results in high rates of heavy metal accumulation in irrigated lands. The affected area is estimated at between 8,000 and 10,000 hectares. The most significantly affected rivers are the Topolnitsa, Teamok, Ogosta, and Arda.

The registered maximal values of heavy metals in groundwater: lead (Pb), zinc (Zn), nickel (Ni), chromium (Cr), cadmium (Cd), arsenic (As) for the period 2000-2005 are presented in Figure D.3.19. On this map only stations with heavy metal content above the threshold value are presented.

In Bulgaria there are numerous ore deposits that are developed (Pb-Zn, Cu, poly-metallic, etc.). Mines in operation and abandoned mine sites pollute groundwater. Principal ore mineralizations occur in mountain regions, where stations for groundwater quality network are almost lacking.

The widespread pollution by **lead** in the Plovdiv-Pazardzhik area is most likely related to the above mentioned lead-zinc smelter at Plovdiv operating since 1962. Other possible sources are from industry. As Topolnitsa river is polluted from mining and ore-processing (as previously mentioned), the irrigated areas from this influent are polluted as well.

As was mentioned above, heavy metals occur in lower concentrations in the calcareous soils. Possibly, this is the cause of lower prevailing heavy metal pollution in porous groundwater and generally no problems in carbonate terrains. Unfortunately, there are exclusions. For the stations 130, 84 and 224 from NE Bulgaria, concentrations of lead above threshold have been registered.

Copper is below the threshold value of 2 mg/l everywhere.

Chromium in groundwater naturally occurs in Bulgaria. It is known that enhanced values of Cr are common in Norh Bulgaria within the Danube plain and near Bourgas. Figure D.3.19 gives only slight idea of these features. In Southern Bulgaria, in the region of the Eastern Rhodopes, there are small ore mineralizations of Cr that are not extracted.

Iron and **manganese** are naturally occurring in groundwater. The main production of Fe is from Sofia region.

The occurrence of manganese in groundwater in Bulgaria is presented in Figure D.3.20 (Kehajov, 1986). Bulgaria is rich in manganese ores. The most well known ore mineralizations are near Varna.

The occurrence of Fe and Mn in groundwater is governed by redox potential (Eh value). The other limiting factor is the low solubility of carbonates. Thus, Fe and Mn are more usual for porous groundwater, not for karstic (Figure D.3.21 and 22). Iron smelter near the city of Sofia may be responsible to pollution of groundwater.

In general, the analyzed groundwater quality network does not represent adequately the general features of groundwater that are well known from the data of Water Supply Companies based on long-term chemical analyses.

(iv) Pollution from Old Mine Tailings

Large territories in Bulgaria are not covered by monitoring, especially in mountain regions. Nevertheless, these regions contain numerous ore mineralizations, and produce both natural and anthropogenic geochemical anomalies related to mining activities including abandoned mines.

Some of "hot spots" related to groundwater quality are due to old tailings from past mining activities, and remobilisation of pollutants. Evidently, abandoned mine lands need specific management.

(v) Pollution from Ore Mineralizations and Abandoned Mine Sites – Hot Spots

Mines in operation and abandoned mine sites pollute groundwater. Remaining tailings continue to impact the environment. Remobilization of pollutants may occur. Two hot spots are presented below.

- 1) In the Chiprovtsi area, NW Bulgaria, tailing impoundment waste is the main pollutant for the environment (soil, water and vegetation). Chiprovtsi was ore mining settlement already in XIII–XVI centuries. Nowadays, this is abandoned mine that still pollutes environment. The basic pollutant for waters is **arsenic** (As), and for soils – arsenic and lead (Pb). Some remediation of the area has been made, but it did not stop pollution of waters from waste piles. The pollution is registered downstream, in the Ogosta reservoir, which is used for irrigation. The threat is related to drifting away of pollutants all around.
- 2) **Arsenic** in drinking waters in Poibrene village (EABD) has been registered soon. It is situated downstream from mining area, with rich copper deposits, some of them with high arsenic content. During last years mineral processing is not in operation in this area. The most possible source of the groundwater pollution is from old tailing. The pollution appeared after heavy rainfall events. Evidently, waste materials present a threat to environment. Abandoned mine sites' inventory, investigation and remediation are necessary. There are known cases of low quality rehabilitation of mining areas. An appropriate cleanup program will improve water quality and enhance public safety.

(vi) Balkan Endemic Nephropathy (BEN) Zone

Balkan endemic nephropathy (BEN) is a dangerous chronic disease. It was first described in Serbia and in Bulgaria (NW part of the country). In Bulgaria, BEN was described in 1956.

Etiology remains the major problem of BEN. There are different hypotheses of risk factors for this disease, such as environmental pollution in endemic settlements, including groundwater pollution.

(e) Pesticides

Registered content of pesticides in groundwater for the period 2000 – 2005 is presented in Figure D.3.23.

The total number of stations with available data from EEA on pesticides in groundwater is 116 (for the period 2000 - 2005). In the table below, only 17 stations are included, which showed registered content of pesticides in groundwater >0.05 μg/l.

Stations with the Highest Registered Values of Pesticides in Groundwater (μg/l) – by Station for the Years 2000-2005

St. N	2000	2001	2002	2003	2004	2005	Total – max	Year/ max	RB
389	**>0.1**	**<0.1**	**No data**	**>0.1**	**>0.1**	**No data**	**2.189***	2003	D
379	**<0.1**	**>0.1**	**>0.1**	**>0.1**	**=0.1**	**No data**	**0.244**	2003	D
280	**No data**	**No data**	**>0.1**	**>0.1**	**No data**	**<0.1**	**0.191**	2002	D
188	**No data**	**No data**	**>0.1**	**<0.1**	**<0.1**	**<0.1**	**0.143**	2002	D
391	**<0.1**	**<0.1**	**No data**	**>0.1**	**<0.1**	**No data**	**0.141**	2003	D
29	**<0.1**	**<0.1**	**=0.1**	**>0.1**	**<0.1**	**No data**	**0.108**	2003	D
330	**	**No data**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**0.093**	2002	EA
174	**<0.1**	**No data**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**0.091**	2002	EA
25	**<0.1**	**No data**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**0.090**	2000	D
385	**<0.1**	**No data**	**No data**	**No data**	**No data**	**No data**	**0.078**	2000	WA
81	**	**<0.1**	**	**<0.1**	**No data**	**No data**	**0.073**	2001	EA
11	**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**No data**	**0.073**	2001	EA
223	**	**No data**	**<0.1**	**<0.1**	**<0.1**	**<0.1**	**0.072**	2002	EA
226	**	**No data**					**0.069**	2002	EA
334	**	**No data**	**No data**	**No data**	**<0.1**	**No data**	**0.062**	2004	EA
24	**	**<0.1**	**	**<0.1**	**<0.1**	**No data**	**0.053**	2001	EA
23	**	**No data**	**<0.1**	**<0.1**	**No data**	**<0.1**	**0.051**	2002	EA

* extremely high value of total content of pesticides. For the station N 389, the registered value of Ametryn is 0.904 in 2003 and 0.6 in 2004.
** Simazine, Atrazine and Propazine not measured.

Some of the stations were sampled 1 or 2 times during this period, so there is a lack of data for some years. "No data" is usual for the years 2001 and 2005. During 2000, there were many stations with data lack concerning the most important pesticides: Simazine, Atrazine and Propazine.

The number of stations with registered content of pesticides in groundwater above the indicator level (0.1 μg/l, according to the Drinking Directive) is 7 for the country.

Number of Stations with Registered Content of Pesticides >0.05 μg/l

River basin	>1 μg/l	>0.1 μg/l	0.05 - 0.1 μg/l	Total >0.05 μg/l
Danube RB	**1**	**6**	**1**	7
Black Sea RB	**0**	**0**	**0**	0
WARB	**0**	**0**	**1**	1
EARB	**0**	**0**	**9**	9
Total for Bulgaria	**1**	**6**	**11**	17

Pesticides have been found in groundwater within lowlands along the Danube River, in the Sofia kettle, in NW part of the country. In southern part of the country, in Plovdiv-Pazardjik region, many stations showed the value close to the threshold value of 0.1 μg/l.

There are other data on pesticides in groundwater besides from EEA stations. Unfortunately, there are registered values of 0.5 μg/l for Razgrad in NE Bulgaria (project – Ministry of Health). This territory was not covered by stations from EEA at all.

(2) Deep Groundwater and Springs

Deep groundwater is characterized generally with enhanced temperature. The temperature value of groundwater at 500 m depth (Figure D.3.24 – from Atlas, 2002) shows many positive anomalies, and one large negative anomaly in NE Bulgaria. The last is generated by descending groundwater flows and refers to the most productive and deep transboundary aquifer (shared between Bulgaria and Romania). It is related to carbonate Upper Jurassic - Lower Cretaceous sediments. The aquifer is largely used for water supply.

Along flow paths to the east, TDS content changes from 0.4 g/l up to 3.5 g/l. In the same direction, the systematic change of the groundwater chemistry and increase of temperature are registered that testify to longer residence time of groundwater. Near the seashore, groundwater is rich in H_2S, showing reducing conditions.

Deep aquifers from the Northern part of the country (the Moesiane platform) have inherent high TDS content and enhanced temperature.

In Bulgaria there are many thermo-mineral occurrences that are not described here.

The most common problems associated to water quality for karst springs are pollution from nitrate, nitrite and ammonium along with possible bacterial pollution, especially for highly karstified terrains with sinkholes or for springs fed additionally from river runoff. The same problems are inherent to shallow groundwater in lowlands that are subject to inundations. One specific problem related only to karst springs is water turbidity during high spring flows.

(3) Problematic Areas of Groundwater Quality

Groundwater in Bulgaria shows evident features of anthropogenic pollution. Shallow groundwater is the most concerned. Groundwater bodies at risk by River Basin Directorate (quality aspect) are available on Figure D.3.25. Evidently, there was no adequate coordination between the River Basin Directorates and universal methodical approach.

To characterize groundwater problematic areas, other information besides GW quality network has to be involved. The groundwater quality data for 2000-2005 have been analyzed and visualized in GIS-maps.

The primary problematic areas in terms of groundwater quality are indicated (see Figure D.3.26):

- North-East Bulgaria - Sarmatian limestone formation - nitrates.
- Groundwater in the Plovdiv-Pazardzhik, Haskovo and Sofia areas – nitrates, heavy metals, iron and manganese.
- Stara Zagora; south from Yambol and Bourgas areas – nitrates (Vertisols).
- Razgrad – nitrates.

In addition, territories that is ***under threat of flooding*** are vulnerable to pollution. They are situated in low lands with shallow groundwater levels. During floods, all pollution loads within the flooded areas may be remobilized and mixed with fresh water.

Such areas with risk from flooding are situated along the river courses, especially in their lower reaches (available in Figure 3.10 in p. 261, Geography of Bulgaria, 2002). In general, they frequently coincide with areas with extremely shallow groundwater level. On Figure D.3.1 such areas with shallow GWL are presented based on limited data from the NIMH groundwater network.

Especially dangerous is flooding with polluted waters. The example is Topolnica dam polluted from mine activities. Flooding occurs on the Plovdiv-Pazardzhik area, which is characterized with high anthropogenic impact from different origins.

Inundation presents a critical period. The last serious floods occur in August 2005. Many low lands in different regions of Bulgaria were affected. Groundwater receives many pollutants including pathogens from the land surface, and becomes insecure for drinking purposes.

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D.4 Directions for Groundwater Management (Some Recommendations)

D.4.1 . General Recommendations

Some general ***problems*** exist that hamper real work:

- The inter-institutional interaction and cooperation are not sufficient and efficient in some cases. This hampers effective work in the domain of the environment protection.
- Access to data is rather difficult and costly (e.g. the geological record office "Geofond" at MOEW).
- Young people are low motivated to be employed in Laboratories and Institutes.

May be the only positive example of free data access in Internet is "General Master Plans for utilization of the water resources in Bulgaria", 2000 available in web-page (http://www.bluelink.net/water/) prepared jointly by NGO "ECOSOUTHWEST" with assistance of Ministry of Environment and Water and Institute of Water Problems at Bulgarian Academy of Sciences. Public accessibility of data was realized thanks to assistance of the Bluelink electronic network.

(1) General Recommendations

- To improve inter-institutional interaction and cooperation, to ameliorate data exchange, to set information networks where appropriate.
- To make easier access to available reports, data, publications etc. This will facilitate competence development of the staff in RBDs, institutes, universities and private companies, and contribute to timely solving of pressing problems.
- To find ways for motivation of personnel and attracting of young people in RBDs.
- To find forms for proper education of young staff in RBDs – balance between Bulgarian traditions and new European practice. Involvement of retired specialists in some activities is desirable under appropriate form.
- Special attention to protection of groundwater resources. Control on the protection of water supply wells. Work on abandonment for unused wells.
- Abandoned mine sites inventory and cleanup program for investigation and remediation are necessary.

(2) Recommendations related to Providing Data for GW Models

Different groundwater related problems might arise, both regional and local.

Groundwater modeling is a powerful tool for solving a variety of groundwater problems concerning groundwater flow, resources and contamination. Data acquisition is important initial phase preceding modeling. River Basins are of will be interested in solving groundwater related problems by modeling, and are capable to collect many of the necessary data.

Before the proper application, the model should be calibrated. Different data are necessary both for calibration of the model and for forecasts based on GW modeling:

- Right GW abstraction value for water supply wells, including its variability;

- Data on GWL drawdowns both in observational and water supply wells;
- GWL in monitoring stations expressed in altitudes a.s.l. For the purpose, exact altitude of the measuring (reference) point is necessary;
- Water stage in rivers (expressed in altitudes a.s.l.);
- Spring discharge (if applicable), along with its inherent variability.
- River discharge, especially during low flows;
- GW quality parameters.

To expedite preparatory work for the model, many data have to be obtained. Data that are not registered on time are lost. Here is stressed on the necessity of correct and comprehensive documentation.

Many details are important: details related to construction of wells; details of GW supplies. Monitoring stations should provide reference heads for a GW model. They are reference heads (locations where the head is known).

Modeling is useful for a variety of applications. In some countries models are widely used in GW management. River Basin Directorates might give assistance in providing data for groundwater models. Reliable and complete information is a prerequisite of a good model.

In general, good documentation concerning different groundwater use aspects is necessary. If possible, different databases should be made.

D.4.2 Specific Recommendations for EABD

- Main ore mineralizations are concentrated in EABD. There are old tailings that present threat to ecological safety. Database and GIS-map of old pollutions, especially tailings, is necessary. Abandoned mine sites inventory and cleanup program for remediation are especially important for EABD. There are cases of low quality rehabilitation of mining areas. An appropriate cleanup program will improve water quality and enhance public safety.
- The problem with arsenic in drinking waters in Poibrene village is not yet solved. It is situated downstream from mining area; pollution from old tailing may occur from there. It is a hot spot problem. To assist Water Supply Company in solving this problem.
- To apply good agricultural practices to reduce nitrate content in the region of Stara Zagora.
- To plan regional model of the groundwater flow in the region of Yambol-Elhovo area.

D.4.3 Specific Recommendations for WABD

- To pay special attention to quantitative monitoring of Blagoevgrad GWB – '*At risk*'.
- Groundwater research and modeling should be planned to re-assess groundwater resources of this groundwater body.
- To use existing data on chemical composition from reports (for assessment of specific natural GW quality in mountain regions impacted by ore mineralization – for reference) – for the Upper Struma region. Database if possible.
- To control carefully groundwater abstractions in the region of the winter resort Bansko.

Supporting Report D

Figures

Figure D.1.1 Hydrogeological Regions in Bulgaria by MOEW(Scale 1:2,000,000)

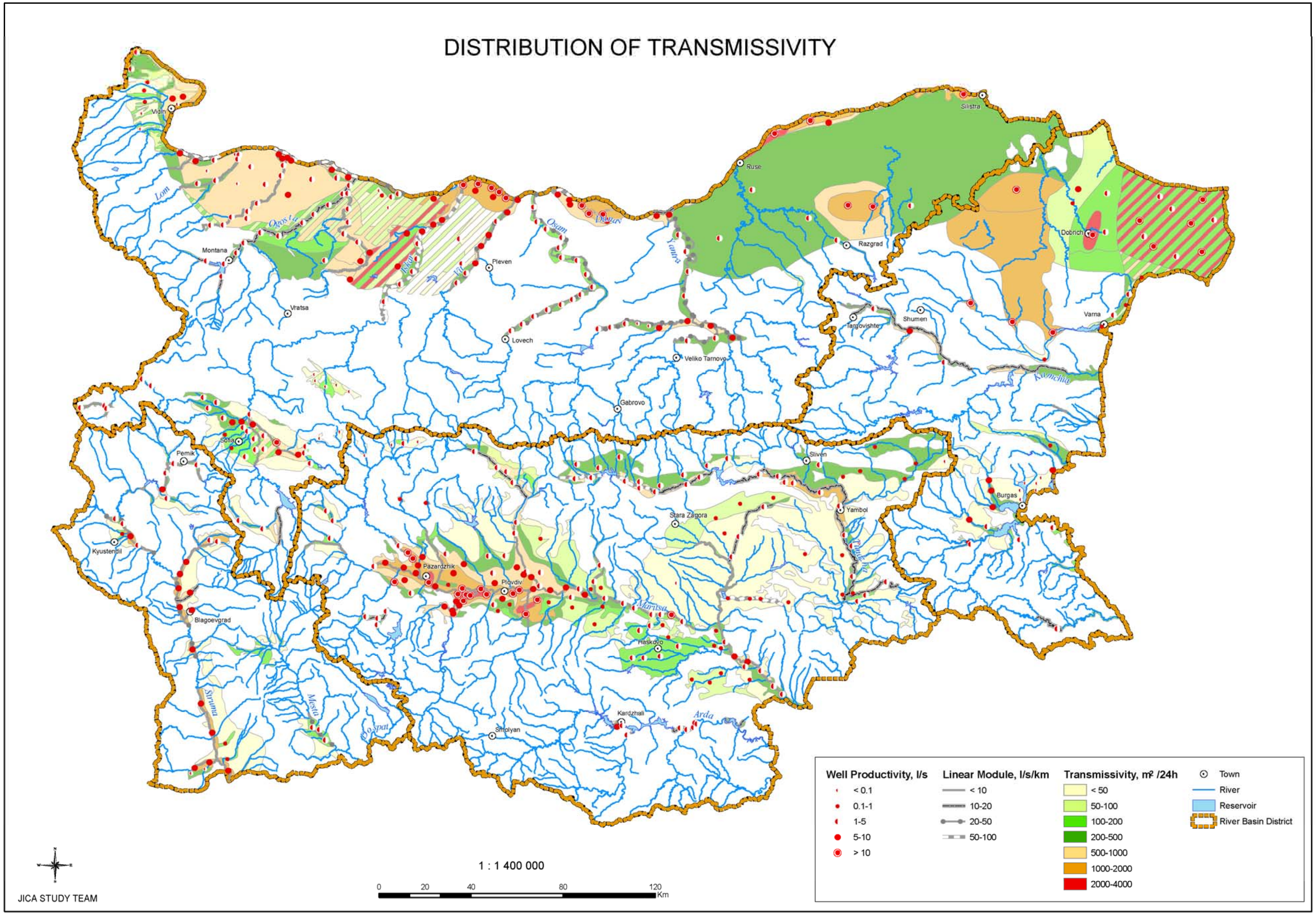

Figure D.1.2 Distribution of Transmissivity

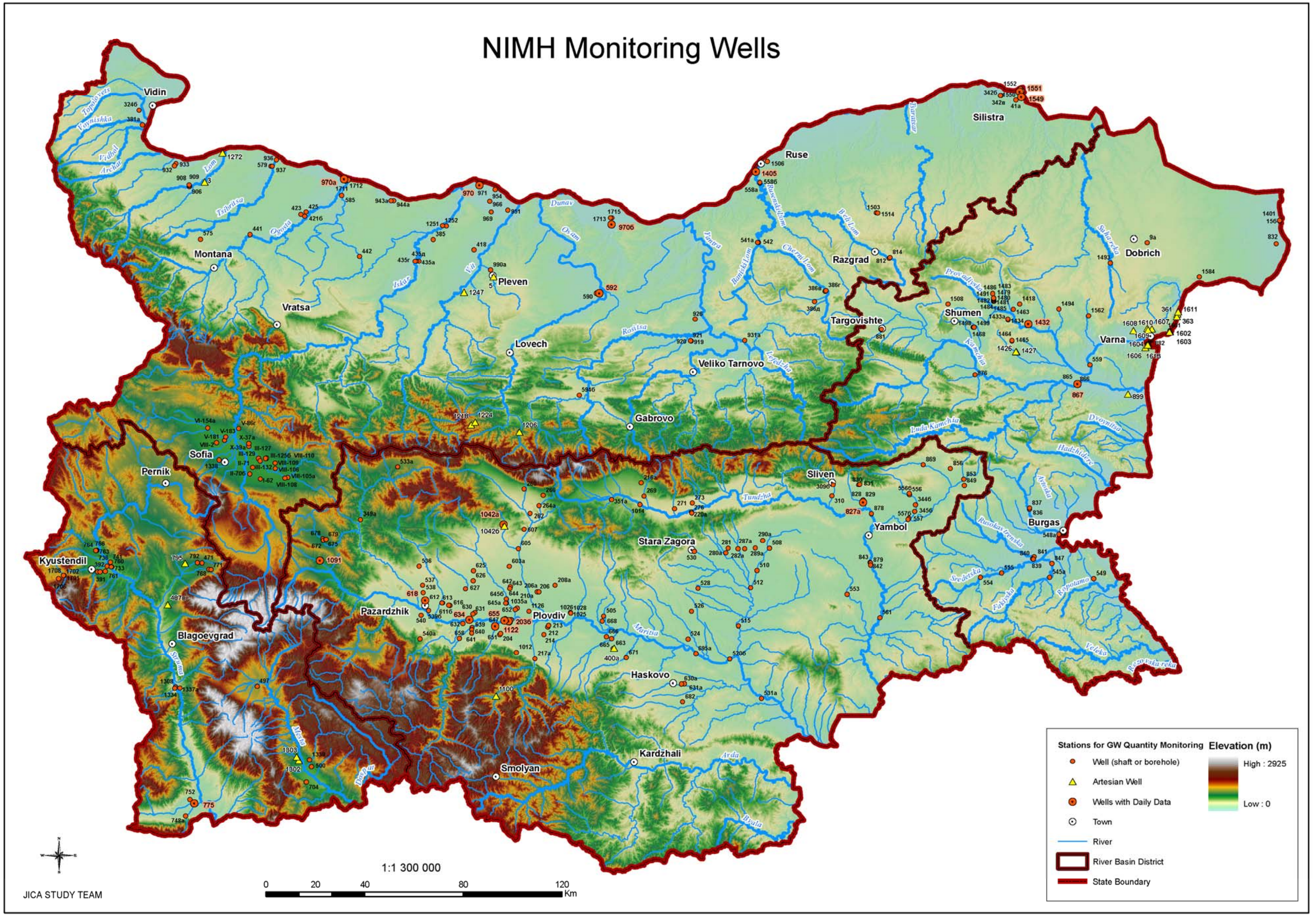

Figure D.2.1 NIMH Monitoring Well

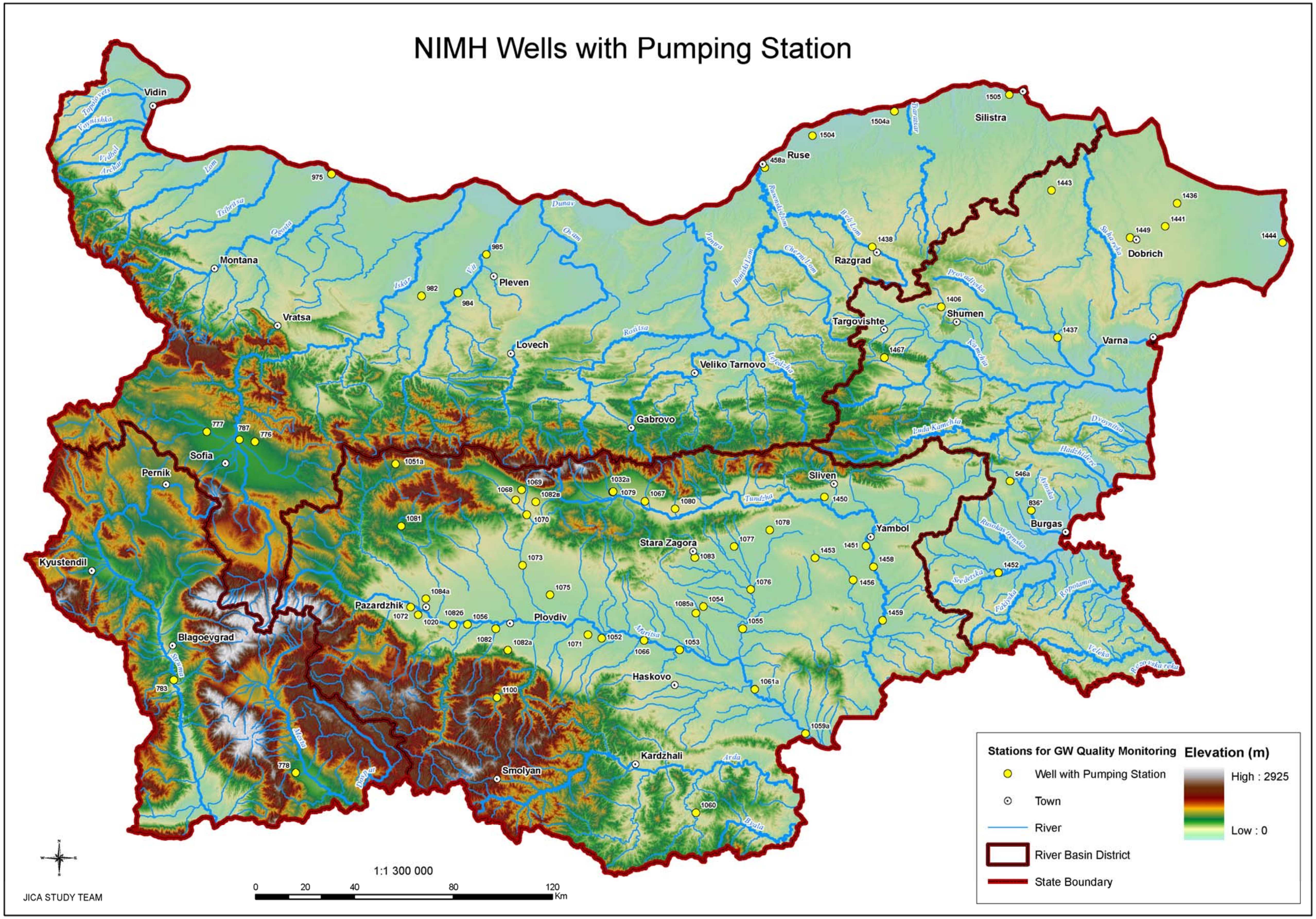

Figure D.2.2 NIMH Wells with Pumping Station

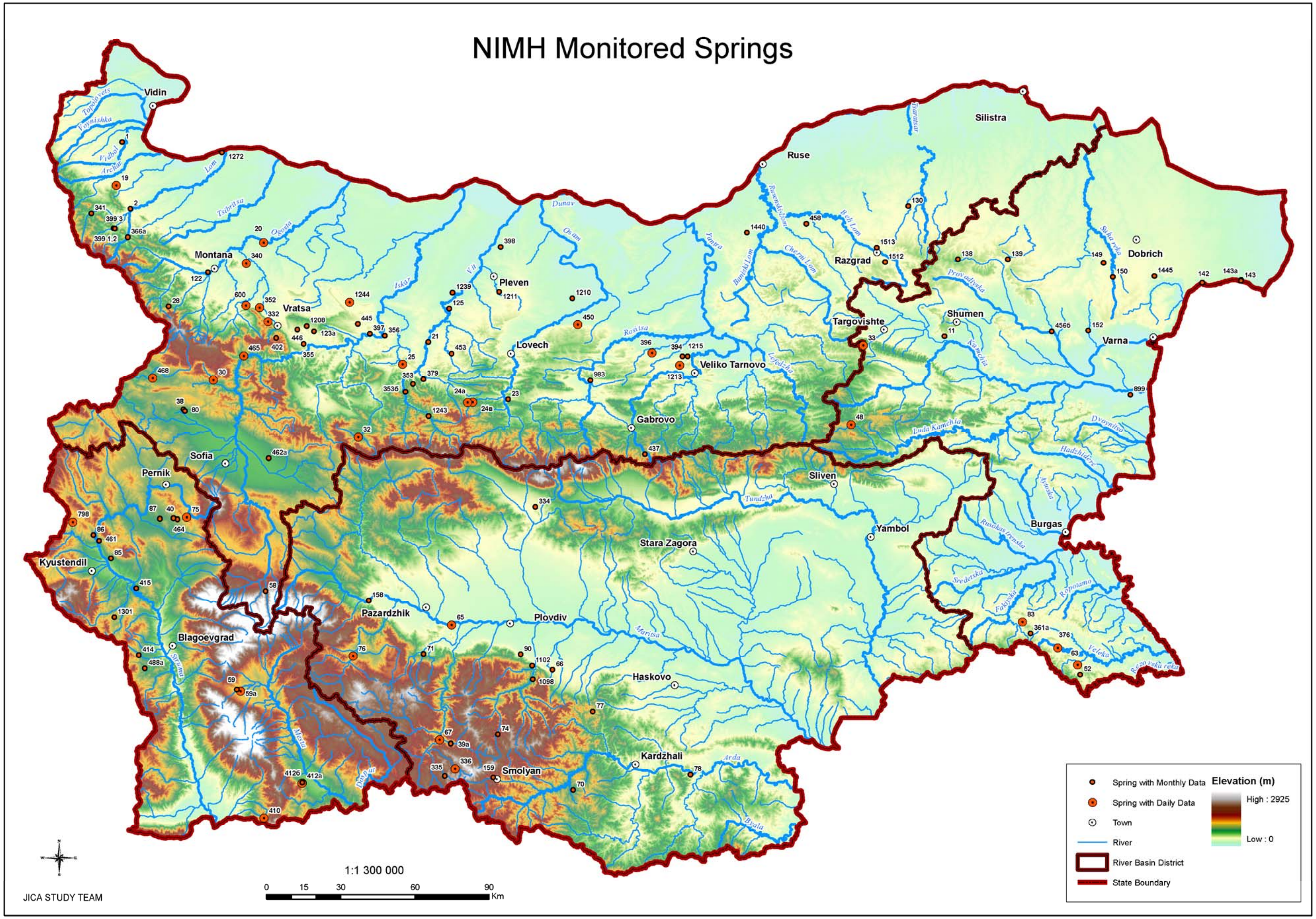

Figure D.2.3 NIMH Monitoring Springs

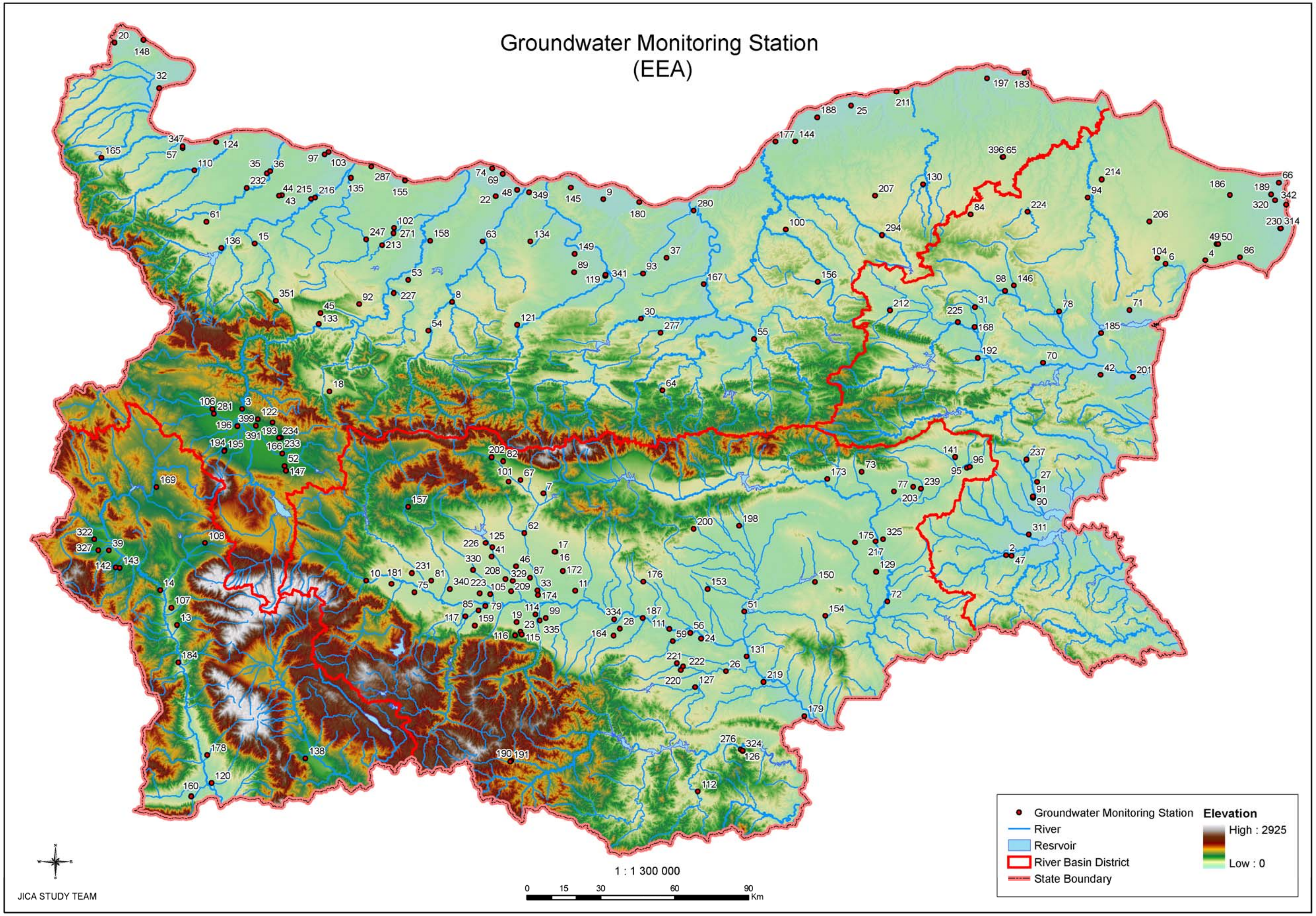

Figure D.2.4 Groundwater Monitoring Station (EEA)

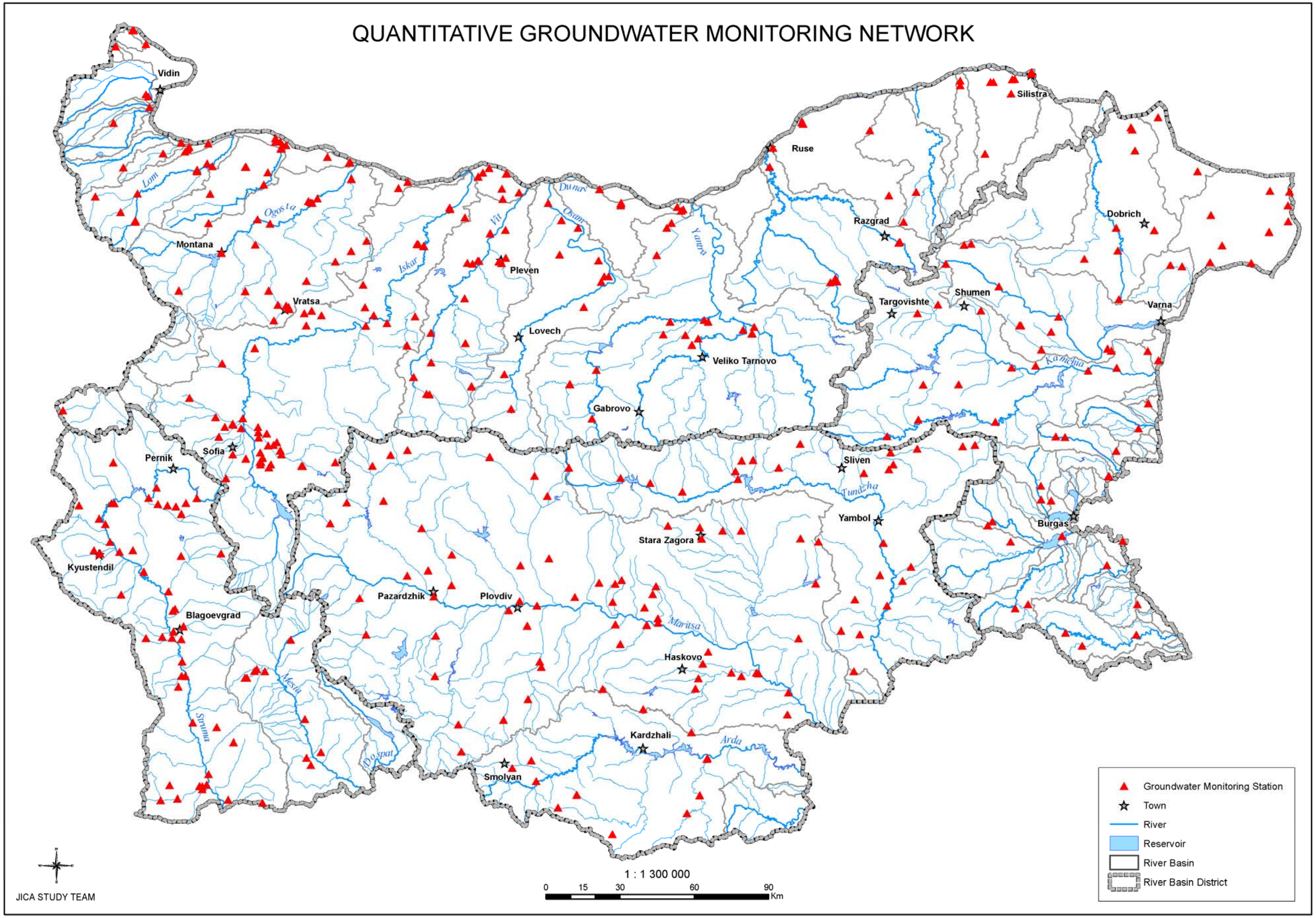

Figure D.2.5 New Quantitative Groundwater Monitoring Network

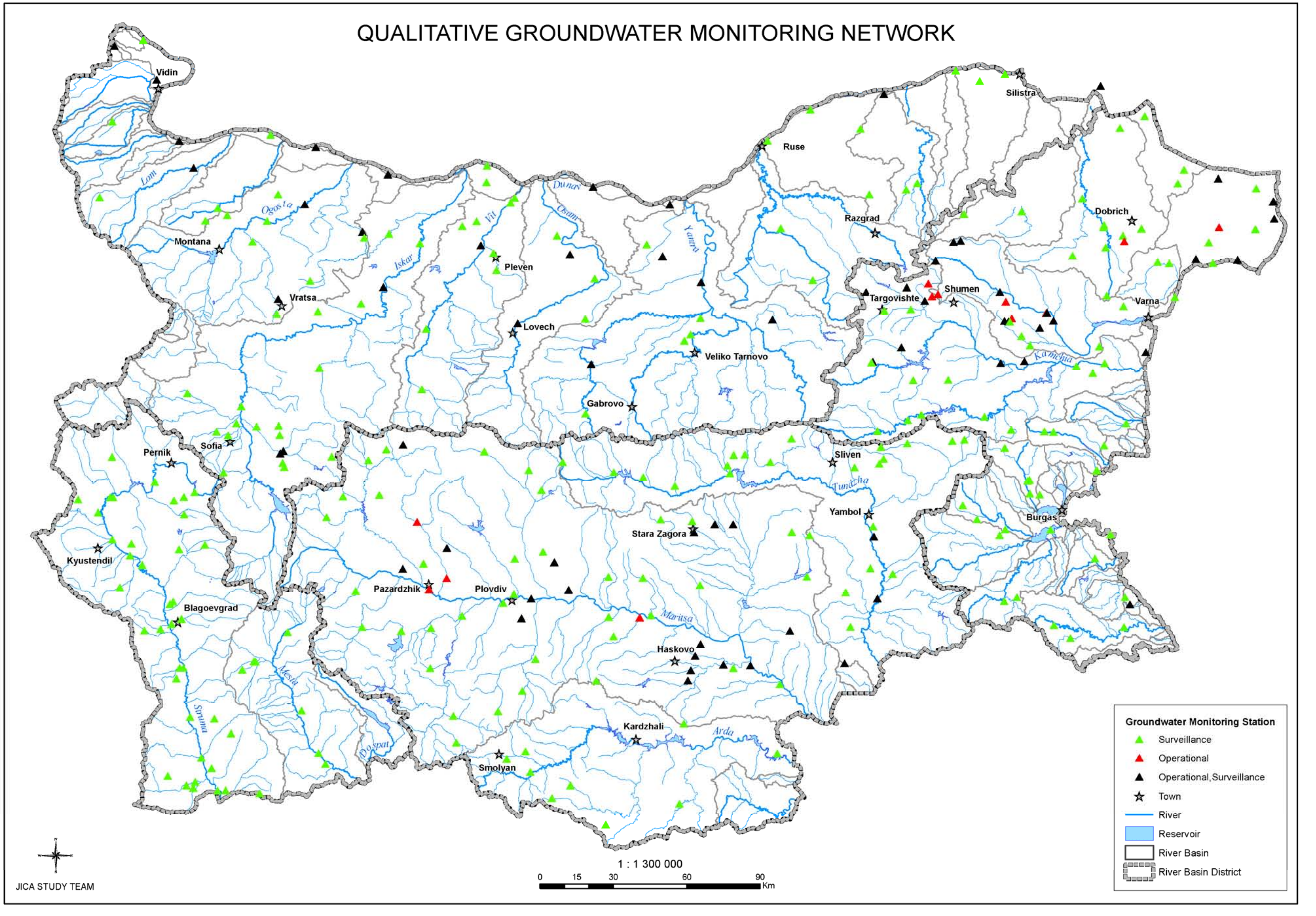

Figure D.2.6 New Qualitative Groundwater Monitoring Network

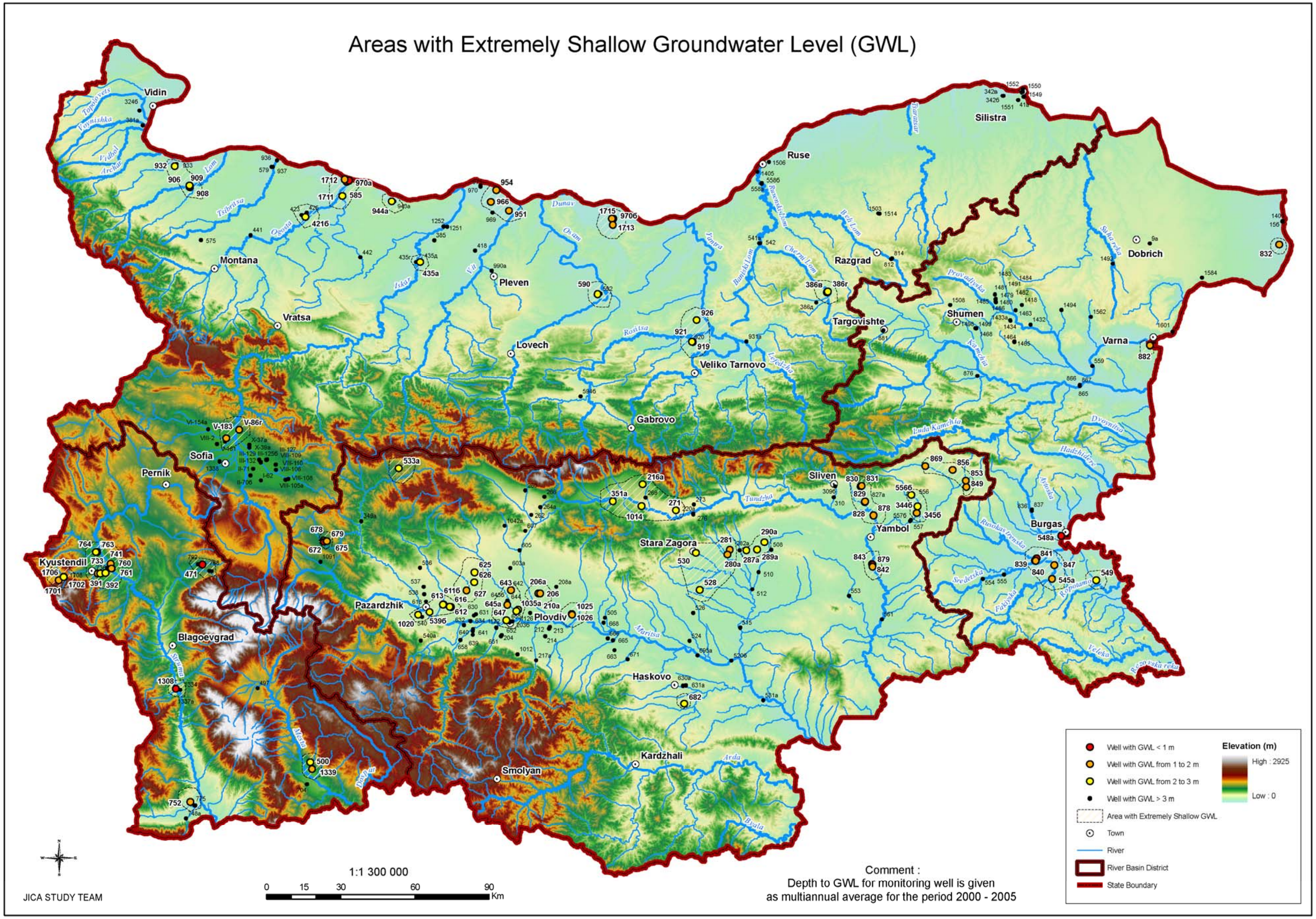

Figure D.3.1 Area with Extremely Shallow Groundwater Level (GWL)