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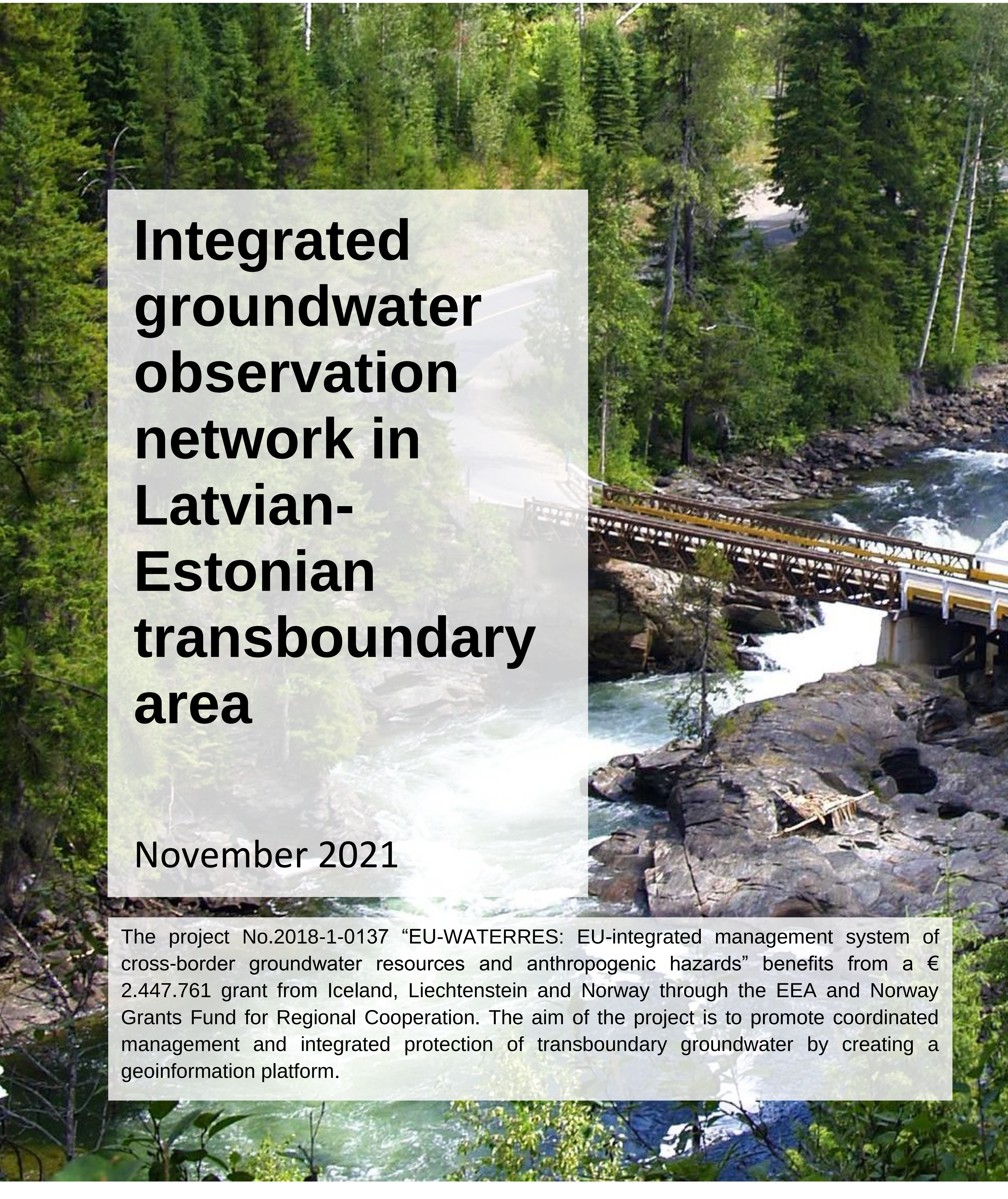

# Integrated groundwater observation network in Latvian-Estonian transboundary area

November 2021

The project No.2018-1-0137 “EU-WATERRES: EU-integrated management system of cross-border groundwater resources and anthropogenic hazards” benefits from a € 2.447.761 grant from Iceland, Liechtenstein and Norway through the EEA and Norway Grants Fund for Regional Cooperation. The aim of the project is to promote coordinated management and integrated protection of transboundary groundwater by creating a geoinformation platform.

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Document summary

The aim of this report was to develop the principles of designing the Polish-Ukrainian and Estonian-Latvian transboundary groundwater monitoring network in relation to the needs of assessing their quantitative and chemical status. The recommendations were developed taking into account the potential of the existing national networks and the requirement of EU law. This report is the implementation of the first stage of creating the internationally integrated monitoring of transboundary groundwater reservoirs. The development of a joint program for monitoring the state of transboundary aquifers, which is also the task of the EU-WATERRES project. The developed guidelines of the organization of the transboundary groundwater monitoring network are aimed at helping the national authorities responsible for monitoring groundwater in implementing the issue of transboundary monitoring. In addition, the key target group are the institutions responsible for the management of transboundary groundwater reservoirs at the national and international level and the organizations responsible for the environmental issues in terms of transboundary impacts.

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## Preface

This report, on the principles of designing Polish-Ukrainian and Estonian-Latvian transboundary groundwater monitoring networks in terms of the need to assess their quantitative and chemical status, was created as part of the EU-WATERRES (EU-integrated management system of cross-border groundwater resources and anthropogenic hazards) project.; www.eu-waterres.eu), financed by the EEA and Norway Grants Fund for Regional Cooperation.

The work on the report was coordinated by the Latvian Environment, Geology and Meteorology Centre as part of work package 3 - Developing of methodology of harmonized monitoring of groundwater in 2 pilot areas. The guidelines were developed by working groups representing the national authorities responsible for groundwater monitoring in 4 countries:

- Estonia - Geological Survey of Estonia (*Team leader: Andres Marandi);*
- Latvia - Latvian Environment, Geology and Meteorology Centre (*Team leader: Ieva Bukovska*);
- Ukraine – Zahidukrgeologiya (*Team leader: Dmytro Panov*) and Ukrainian Geological Company (*Team leader: Volodymyr Klos*);
- Poland - Polish Geological Institute – National Research Institute (*Team leader: Tomasz Gidziński*).

The report is a precursor to the establishment of a Polish-Ukrainian and Estonian-Latvian transboundary groundwater monitoring network. The presented recommendations concern the establishment of common rules for the creation of a transboundary groundwater monitoring network and a proposal regarding the criteria for qualifying national monitoring points to this network and an indication of locations with prospects for its development.

The guidance is based on studies of best practices for monitoring and assessing the status of groundwater and the results of the assessment of transboundary groundwater flows. (Output 1 of the EU-WATERRES project entitled “Assessment of the resources of transboundary groundwater reservoirs for the 2 pilot areas”).

The report has been divided into two parts with regard to the individual pilot areas:

- Part 1. Principles of development of a Polish-Ukrainian transboundary groundwater monitoring network: methodological foundations and practical solutions (*Polish – Ukrainian Team leader: Tatiana Solovey*);
- Part 2. Principles of development of a Latvian-Estonian transboundary groundwater monitoring network: methodological foundations and practical solutions (*Latvian – Estonian Team leader: Jekaterina Demidko*).

This report is the implementation of the first stage of creating an internationally integrated monitoring of transboundary groundwater reservoirs. Once the rules for this network have been established, EU-WATERRES is also scheduled to develop a joint program to monitor the state of transboundary aquifers.

November 2021,

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*Coordinator* EU-WATERRES

Polish Geological Institute – National Research Institute (PGI-NRI)

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## Abbreviations

EU – European Union

GWB – Groundwater Body

RBD – River basin district

RBMPs – River basin management plans

UNECE – United Nations Economic Commission for Europe

UNESCO – United Nations Educational, Scientific and Cultural Organization

WFD – Water Framework Directive (2000/60/EC)

# Introduction

Groundwater management is a very comprehensive and complex long-term process, given that this resource is very extensive and not limited by national borders. Changes in the quantity and quality of groundwater are usually slow and the processes most often occur over large areas. In order to identify such changes in groundwater, assess the impacts of pressures, as well as manage groundwater on a national scale more efficiently, it is required to establish a groundwater monitoring network and a monitoring program. The main objective of aquifer management is to control the impacts of groundwater abstraction and pressures, and to monitor this objective, the monitoring of aquifer response and quality trends is key.

If national groundwater management is successfully implemented in most Member States in accordance with the EU requirements, then much more effort and challenges are required for transboundary groundwater management, which requires close cooperation between the countries involved. Cooperation between countries which are sharing water resources plays an important role in establishing transboundary groundwater monitoring. In this context, The Convention of the United Nations Economic Commission for Europe on the Protection and Use of Transboundary Watercourses and international Lakes (Water Convention, 1992) plays important role, by defining a legal and institutional co-operation framework and requires Parties to prevent, control and reduce transboundary impact, use transboundary waters in a reasonable and equitable way and ensure their sustainable management.

According to groundwater monitoring, the main instrument for integrated groundwater management implementation in Latvia and Estonia is the WFD, which sets requirements for groundwater management, including the development of monitoring. WFD also imposes requirements on transboundary groundwater management and monitoring. The establishment of high-quality long-term monitoring programs is essential to achieve the WFD goals. In both Latvia and Estonia, groundwater monitoring at the national level has been carried out for many years in accordance with EU requirements, by observing the quantity and quality of groundwater and developing monitoring programs. However, no monitoring has been carried out so far in the frame of common transboundary groundwater resources. The EU-WATERRES project is a very important platform to promote cooperation between Latvia and Estonia to improve the common transboundary groundwater management.

In this report, common principles for selecting the transboundary groundwater monitoring points in Latvia and Estonia were developed. Report contains the compliance assessment of the existing monitoring points for the transboundary groundwater monitoring purposes, identifying areas with significant transboundary groundwater flows and intense anthropogenic pressures. Based on the previous, the prospective monitoring site locations in Latvian-Estonian pilot area were identified for improvement of the monitoring network.

# 1 Analysis of the situation

According to the WFD, the Member States which have identified transboundary GWBs should carry out joint activities to monitor, share data and assess the chemical and quantitative status of these GWBs. According to WFD Annex V 2.2.2. and 2.4.2. requirements, transboundary GWBs should be provided with a sufficient number of monitoring points to assess the direction and the flow rate of the groundwater through the member state boundary, as well as track groundwater quality, timely identify and control transportation of potential pollutants (WFD, 2000).

Particular attention must be paid to GWBs that have been identified as GWBs at risk, stated or objected to with intense anthropogenic pressure. Member states located in the transboundary area should carry out all the necessary measures (including monitoring network installation) to prevent, limit and reduce any negative transboundary impacts. General requirements for the development of the groundwater monitoring network are mainly determined by guidance Nr.15 "Guidance on Groundwater Monitoring" and Nr.7 "Monitoring under the Water Framework Directive" (European Communities, 2007; European Communities, 2003), however more detailed information is available in "Guidelines on monitoring and assessment of transboundary groundwaters" and documents "State of the art on monitoring and assessment of groundwater" (Uil H. et al, 1999; UNECE, 2000). There are also a number of other recommendations and guidelines, most of which are indirectly related to monitoring, but which could be useful for identifying pressures and functions of shared groundwater resources, as well as for identifying problems.

## 1.1 Conditions for the selection of transboundary groundwater monitoring points

To select transboundary monitoring points, firstly it is necessary to identify the hydrogeological conditions (the regime and quality) and potential pollution risks of identified transboundary GWBs. Therefore, the selection/location of representative monitoring points and the selection of appropriate monitoring point density should be based on the conceptual understanding (hydrogeological characteristics and pressures). For transboundary GWBs it is highly recommended that jointly agreed conceptual models are developed using guidance document Nr.26 "Guidance on risk assessment and the use of conceptual models for groundwater" paragraph 3.1 (European Communities, 2010).

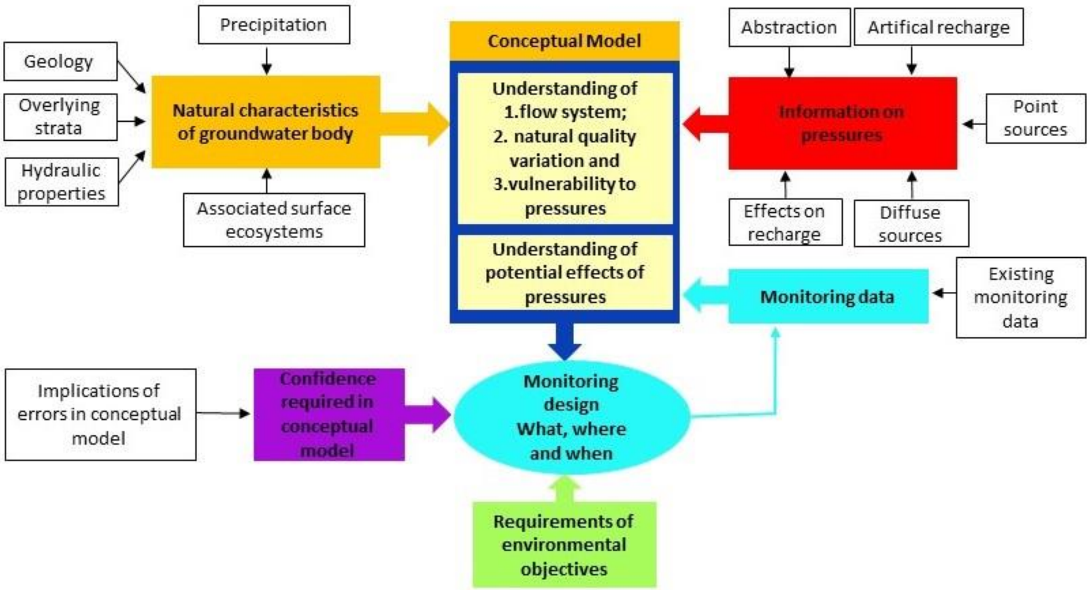


**Figure 1 Link between the conceptual model/understanding and monitoring** (European Communities, 2007)

Therefore, the design of a monitoring network should take into account the three-dimensional nature of the groundwater system and both spatial and temporal variability, especially when determining the location of monitoring sites and the selection of appropriate monitoring site types. The network should have a spatial and temporal density which considers the natural characteristics of the groundwater body (conceptual understanding) and the pollution risks, to help focus monitoring activities in areas where significant pressures combined with higher vulnerability exist (European Communities, 2007).

### 1.1.1. Groundwater quality monitoring points

In general, the locations of transboundary groundwater quality monitoring points should be representative for the defined objectives. The aim of the recommended approach is that the positioning of the observation points should be based on the vulnerability of the groundwater flow system, combined with the functions/uses, threats and problems and the core-elements of water management. The various activities for a specification of the location are:

- characterization of the groundwater systems and the geometry of the principal water bearing formations;
- vulnerability assessment, mainly based on the groundwater flow situation (discharge and recharge areas), soil composition and geology;
- identification of the threats to which the groundwater system is exposed (in particular reflected in land use: agriculture, industry, waste sites, military sites, etc.);
- identification of the problems which affect the aquifer (e.g., acidification, nutrients, salinization, pollution, etc.).

The combination of the vulnerability classification with the identified threats and problems gives the opportunity to concentrate the monitoring effort within the most urgent areas. The vertical position of the observation points should be adjusted to the groundwater flow velocity and the eventual movement of pollution fronts, which is generally very slow in porous unconsolidated formations. However, in consolidated formations with secondary permeability, much higher velocities may occur (Uil H. et al, 1999; UNECE, 2000).

### 1.1.2. Groundwater quantity monitoring points

Probably the most crucial monitoring design aspect of transboundary groundwater quantity monitoring is the specification of the measurement positions in a spatial sense, because this defines an important feature of the observation point, namely its representativity. Technically, the positioning and the number of observation points, which determines the density of the network, is governed by two criteria, namely:

- the specified representativity of the observation points;
- the possibility to determine the spatial trend of the groundwater levels or hydraulic head pressures on the required scale.

The first criterion means in general a specification of the groundwater flow system or unit for which a network should be established. The second depends primarily on the defined technical objectives. For example, for a regional network, a strategic type of monitoring, the objective could be to enable the determination of a regional trend based on the average groundwater levels for a certain period or on the groundwater levels for a specific date. In case of the operational and surveillance type of monitoring, the periods to be considered for trend detection will generally be much shorter and require a higher density of observation points compared to regional monitoring.

Continuous interpretations for describing the groundwater levels and hydraulic pressures in space will also be needed for monitoring of transboundary groundwater systems, which may include strategic as well as operational or surveillance monitoring (Uil H. et al, 1999; UNECE, 2000).

### 1.1.3. Experience of other countries in selecting transboundary groundwater monitoring points

The conditions of transboundary monitoring points selection in WFD are described very generally. Guidelines developed by the European Commission and UNECE recommends more detailed criteria for the development of a monitoring network (selection of monitoring points), based mainly on conceptual understanding of the hydrogeological conditions of the transboundary area and potential pollution threats. The selection of transboundary monitoring points is also influenced by the assigned monitoring tasks/objectives, which specify the acquisition of the necessary information for the management of transboundary GWBs and identify the required size of the monitoring network. It should be noted that the existing level of the cooperation between countries and financial consideration may also have an impact on the construction of transboundary groundwater monitoring networks.

An analysis of available materials on the selection of transboundary monitoring points in other countries shows that no country has developed specific methodologies for setting up a groundwater monitoring network or for identification of transboundary monitoring points. It is considered that the groundwater regime or hydrogeological conditions are the basic criteria for creation of a transboundary monitoring network (Uil H. et al, 1999). Furthermore, there should be selected appropriate existing monitoring points, paying particular attention to those areas which are exposed to negative transboundary anthropogenic impacts. To select the monitoring sites, a set of criteria has been applied by the countries, such as aquifer type and characteristics (porous, karst and fissured, confined and unconfined groundwater) and depth of the GWBs. The flow direction was also taken into consideration by some countries, as well as the existence of associated drinking water protected areas or ecosystems (aquatic and/or terrestrial) (ICPDR, 2008; ICPDR, 2016; Groundwater monitoring and research network, 2021; Nałęcz, 2012; Sadurzki, 2005).

However, it should be noted that in most cases countries are using existing monitoring networks to assess the initial situation in the transboundary area. Then, after getting more detailed information, for example, risk assessment, the existing monitoring network is extended by installing new monitoring points or by integrating already existing monitoring points. It is noted that for deeper GWBs the flexibility in the design of the monitoring network is very limited, so the effort of obtaining as much knowledge using existing capabilities as possible should be made already at the beginning (ICPDR, 2008; UNESCO, 2020).

In addition, it should be noted that transboundary monitoring in the Estonian-Russian and Latvian-Lithuanian border areas is also provided by monitoring points included in the existing national monitoring network; other methodologies for selecting transboundary monitoring points in both countries have not been developed (Estonian-Russian Cooperation, 2020; B-Solutions, 2018).

# 2 Transboundary groundwater monitoring point qualification principles (methodology)

Based on the information collected and analyzed in Chapter 1, the initial step in the design of the transboundary monitoring network is the hydrogeological conceptual model. The conceptual model helps to identify the hydrogeological conditions of the transboundary area, the intensity of the anthropogenic pressure, impacts and risks, as well as helps to identify the purpose of the monitoring and the density of the monitoring network in the transboundary area.

For identification of transboundary groundwater quality and quantity monitoring points and designing of new groundwater monitoring points, extent of conceptual model and knowledge base about the transboundary area are two main base factors. The following principles should be taken into account:

- geological structure and main geological units in the transboundary area: geometry, lithology and groundwater flow paths;
- areas with specific interest – places where the most intense pressures are located and identified (prior knowledge base is needed);
- vulnerability;
- practical considerations: financial aspects, long-term access and security.

In order to make the best use of available resources and knowledge, a step-by-step approach initially should be used and all existing monitoring points located in the transboundary area should be included in the transboundary monitoring network. Step-by-step approach could help to form the strongest cooperation between countries in order to organize the management of transboundary groundwater water resources as efficiently as possible in the future. Existing monitoring points (wells, springs) may serve as surveillance monitoring and provide general information on transboundary GWBs status.

The density of transboundary monitoring points may increase in areas where intensive anthropogenic pressures are identified – a chance of GWB not achieving good groundwater status or being at "risk". The criteria for identifying such areas are given in Table 1. If such chances are low, the density of the transboundary monitoring network can be low while it is still representative of the groundwater body characteristics. Monitoring points that are objected to risk, will already provide operative monitoring. Therefore, the existing monitoring network should be supplemented with the number of strategically located monitoring points (UNESCO, 2020).

**Table 1 Criteria for identifying transboundary areas with intense anthropogenic pressures**

| Selection criteria | Sub-criteria |
|---|---|
| **Geological structure and properties of main geological unit** | - groundwater flow path (based on the results of Output 1, identify areas where continuous and significant cross-border flows are possible). |
| **Areas with specific interest** | - active groundwater intakes (on the basis of collected materials and cartographic information, identify active groundwater abstraction sites/area with significant groundwater intake >100 $m^3/d$);<br>- mining areas (on the basis of collected materials and cartographic information, identify active mining areas and quarries that may have an impact on transboundary hydrogeological conditions);<br>- pollution hotspots (on the basis of the collected materials and cartographic information, identify polluted or potentially polluted sites that may have an impact on transboundary groundwater quality). |
| **Vulnerability (is mandatory in cases when a significant pollution pressure has been identified)** | - based on available cartographic information identify areas at high risk of pollution |

Existing monitoring network may be expanded by installing new monitoring points. But as previously mentioned the flexibility in the design of monitoring networks for deeper GWBs is very limited due to financial aspects, therefore integrated monitoring will contribute significantly to cost-efficient monitoring by making best use of appropriate components of existing monitoring networks serving different objectives. Monitoring points for groundwater level observations can be wells or boreholes that are not substantially affected by groundwater abstraction in the neighboring areas. For groundwater quality networks, use can be made of already existing monitoring or abstraction wells. It should be noted that springs can also be used as monitoring points, in particular for groundwater sampling purposes. With regard to representative data, one spring can replace a number of monitoring wells.

It is necessary to compile the following information on the monitoring points to be identified, integrated or projected, as set out in Annex 1. However, in order to establish a sustainable and efficient transboundary monitoring system, the fontal monitoring network should be reviewed periodically, gaining new knowledge and developing the existing conceptual model (Figure 2).

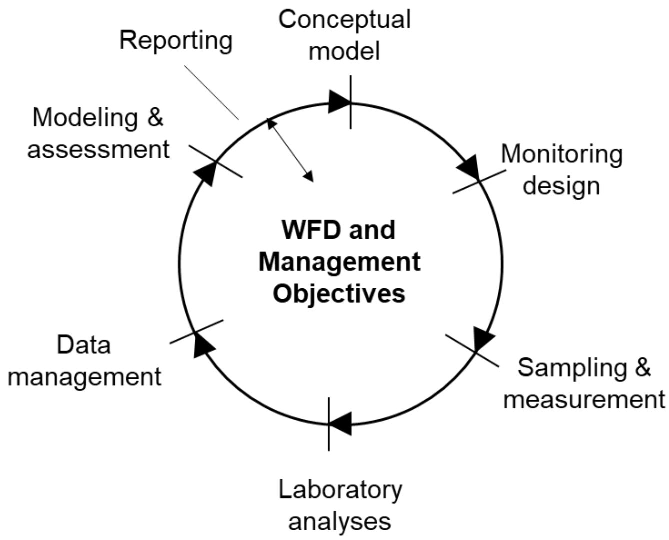


**Figure 2 The monitoring cycle adapted for groundwater monitoring** (European Communities, 2007)

# 3 Transboundary groundwater monitoring point qualification

Until now, close transboundary cooperation has not been established in the Latvian-Estonian transboundary area, and transboundary monitoring points in common groundwater bodies have not been identified. Within the framework of this project, it is planned to identify transboundary monitoring points that will be included in the transboundary monitoring plan in the future in order to more effectively manage and monitor the condition of transboundary groundwater bodies.

## 3.1. Groundwater monitoring in Latvia and Estonia

### 3.1.1. Groundwater monitoring in Latvia

Regular surveys of groundwater quality in Latvia have been conducted since 1959. The objectives and scope of the groundwater monitoring network varied over time, mainly due to changes in regulatory documents as well as global trends in groundwater monitoring. The groundwater monitoring network was mainly set up between 1959 and 1991, initially to assess the water quality of deep pressurized aquifers and their changes, as these aquifers began to be used intensively for centralized drinking water supply not only in cities during this period, but also in populated rural areas. Gradually, it was supplemented by the addition of "level principle" monitoring stations, which consist of well-placed boreholes with filters at various intervals up to a depth of 200-400 meters, and the installation of "balance stations" with shallow boreholes. From 2004, the groundwater monitoring network also included springs.

Groundwater monitoring in Latvia provides systematic, regular and targeted data on the quantitative and chemical status of GWBs. This is the strategic monitoring objective in any year of the monitoring program period - to achieve good groundwater status in all GWBs and to assess the risk of not achieving this objective. Groundwater monitoring is primarily performed at the level of GWBs, while integrating the management of the RBD into a common strategy for achieving environmental quality objectives.

The groundwater monitoring program prepared for each period for the RBD management plans helps to monitor the achievement of environmental objectives, assess the impact of human activity and gain reliable data on the actual environmental status of water bodies. The monitoring points that are monitored each year and the parameters to be monitored for groundwater quality may vary according to the annual monitoring plans. The frequency of groundwater monitoring is variable: the frequency of quantitative observations – two times a day (automatic level measurements) up to four times a year, and the frequency of groundwater chemical observations is four times a year, up to once a year (over a six-year period, it changes from one time in six years to one time each year).

Under the constraints of limited funding, the groundwater monitoring program is being adapted to the requirements of the two directives (Nitrates Directive (91/676/EEC) and WFD), which are not equivalent. The WFD requires the identification of the background level of natural chemical composition and trends in the aquifers used in the main water supply of underground water bodies, which in the case of Latvia are deeper confined water. The current groundwater monitoring program is more adapted to fulfill the requirements of the WFD than to fulfill the requirements of the Nitrates Directive (91/676/EEC).

This monitoring program identifies mainly the following types of groundwater monitoring: groundwater quantity monitoring and groundwater quality monitoring (surveillance and operational). The main tasks of the monitoring program are:

1) to assess the quantitative status and chemical quality of groundwater bodies, and the

direction of trends in changes in the relevant status;

2) to ensure observations regarding the condition of groundwater resources in each delineated groundwater body;
3) to determine the status of the quantity and quality of groundwater at the level of groundwater bodies - to determine whether the chemical status of groundwater within the boundaries of the groundwater body is “bad” or “good”;
4) to identify dangerous trends in the quantity or quality of groundwater bodies in a timely manner;
5) to control the regional changes of groundwater of any origin and to provide background data for all types of observations, determining the regularities of changes in the quantity and quality of groundwater;
6) to assess the condition of groundwater bodies at risk, the tendencies of changes in the environmental quality indicators causing the risk;
7) to provide additional information for the preparation of the program of measures of the water management plan.

Currently, the status of groundwater within the framework of monitoring is observed in 311 wells located in 61 stations and 30 springs. Of these, quality (chemical composition) observations are provided at 53 stations - 218 wells and 30 springs, but quantity (water level) observations - at 60 stations, 305 wells. In the 2021-2026 planning period, it is planned to improve the existing groundwater monitoring network in Latvia by installing 25 new groundwater monitoring stations with a total of 70 wells and improving two existing groundwater monitoring stations (it is planned to renovate 1 well and renovate the old station by adding 4 wells). The new wells are planned to be installed at different depths: 0-5 m, 5-15 m, 5-30 m, >30 m (Quaternary aquifer wells) and the deepest groundwater aquifers or pre-Quaternary sedimentary wells. Also, as far as possible, it is planned to improve the technical condition of the existing wells and include them in the current monitoring network. The location of existing and new monitoring points is visually shown in Figure 3.

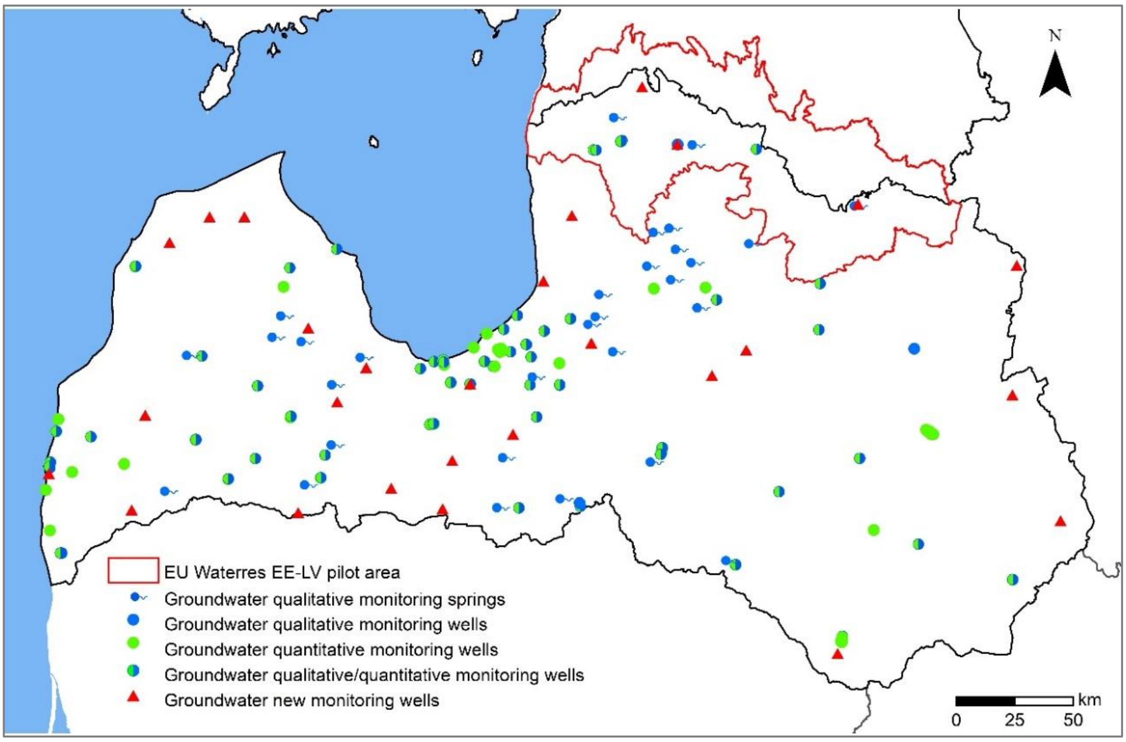


**Figure 3 Groundwater monitoring points in Latvia**

However, it should be noted that the existing groundwater monitoring network mainly allows the assessment of regional groundwater changes and provides background data on the chemical and quantitative status of groundwater at the level of GWBs, mainly by monitoring aquifers used in water supply. Accordingly, monitoring in protected areas (nitrate vulnerable zone and drinking water protected areas) is only partially provided, as well as additional monitoring of these areas is integrated with other monitoring programs.

### 3.1.2. Groundwater monitoring in Estonia

The earliest data of groundwater monitoring in Estonia goes back to the 1960-s during the Soviet times. As geological and hydrogeological mapping started in 1958, many new monitoring wells were created in the following decades. In 1995, the Estonian National Monitoring program started, which was the start of groundwater monitoring in its current form. The Geological Survey of Estonia was responsible for it. Since 2018, the monitoring is done by the Estonian Environment Agency, and the Estonian Environmental Research Centre performs the practical activities.

Before implementing the EU WFD, groundwater status changes were observed in seven areas with different hydrogeological and technogenic conditions and pressure (areas with natural conditions, intensive water use conditions, and areas affected by quarries). In 2000, the progress of forming groundwater bodies was started. First groundwater bodies were confirmed in 2004.

The WFD methodology for the assessment of Estonian groundwater bodies and the determination of threshold values was developed in 2013 (supplemented by the GSE in 2019), and based on it, the status of groundwater bodies (currently there are 31) is assessed every six years (2014 and 2020). This has also had a direct impact on decisions on the national groundwater monitoring plan.

The purpose of monitoring groundwater bodies in Estonia is to monitor the chemical and quantitative status (the trends and changes of quality indicators) of the groundwater bodies. Information from monitoring is used for developing the River Basin Management Plans according to the EU WFD.

Groundwater monitoring in Estonia is a part of the environmental monitoring program. It is divided into two parts: monitoring the groundwater bodies and monitoring the Nitrates Vulnerable Zone. The quantitative and qualitative status of 31 groundwater bodies in Estonia are monitored using a network of monitoring wells. The changes in groundwater bodies are described, changes in groundwater flow caused by water level changes are assessed, conclusions are made about salt or other water intrusions into groundwater bodies, and short-term changes are distinguished. Within the assessment of the qualitative status, the pollutants are detected in groundwater, the chemical status class of each groundwater body is determined, and the changes in the chemical composition of groundwater are described and analyzed.

The status of the groundwater body is good if less than 80% of the values of the quality indicators fixed at the monitoring points of the groundwater monitoring program correspond to the values of quality indicators set out in Regulation No. 48 of the Minister of the Environment of Estonia:

1) the concentrations of chlorides, sulphates, and total dissolved solids measured by electrical conductivity do not show an upward trend indicating anthropogenic pollution or saline inflows;
2) pH range 6-9;
3) the content of dissolved oxygen does not indicate a downward trend due to human activity, or the chemical oxygen demand is ≤ 5 mg $O_2$/l, or if the value of the quality indicator is exceeded, the natural content of dissolved oxygen in the groundwater has been proven;
4) the ammonium content in naturally aerobic groundwater does not exceed 0.5 mg/l or in a

naturally anaerobic aquatic environment does not exceed 1.5 mg/l, or if the value of the quality indicator is exceeded, the natural origin of ammonium in groundwater has been proven;

5) the absence of arsenic, cadmium, lead, mercury, trichloroethylene, tetrachlorethylene, synthetic substances, or their concentration does not exceed the groundwater quality limit values for dangerous substances, or the natural origin of these substances in groundwater has been established;
6) the concentration of pollutants does not impede the achievement of the environmental objectives for the surface water associated with the body of groundwater and does not cause significant damage to the ecological or chemical status of the surface water or to terrestrial ecosystems directly dependent on that body of groundwater.

The status of the groundwater body is bad if less than 80% of the values of the quality indicators fixed at the monitoring points of the groundwater monitoring program correspond to the values of quality indicators.

The groundwater level monitoring network in Estonia includes 257 wells (Figure 4). Depending on the well, the monitoring frequency is once a month, or there are automatic water level measurements. The monitoring network for groundwater chemical status includes 225 wells. A groundwater sample is taken once a year during the low water level in summer to determine physical and chemical quality indicators.

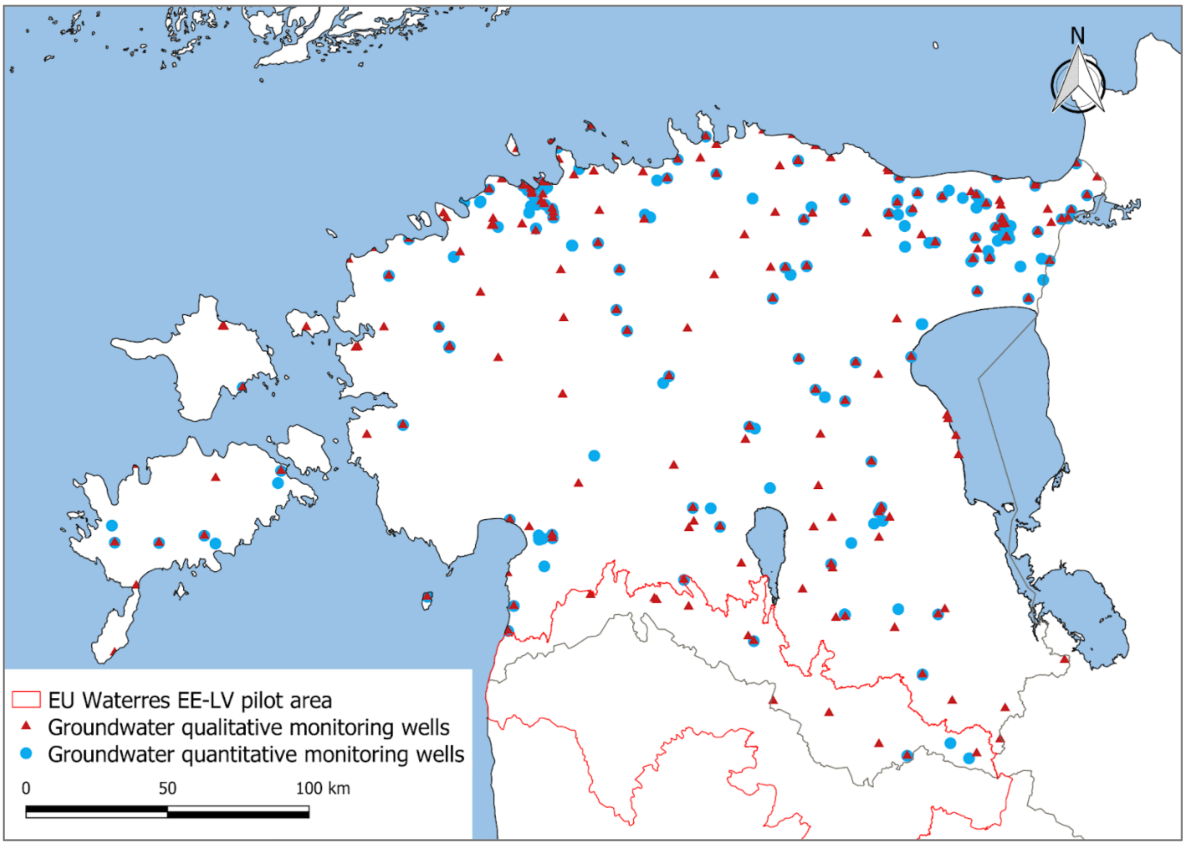


**Figure 4 Groundwater monitoring points in Estonia**

As a result of the data analysis of the monitoring, in addition to the results of chemical analysis, the following indicators of groundwater status are presented as outputs:

1) natural changes in the chemical composition of groundwater;
2) anthropogenic changes in the chemical composition of groundwater;
3) significant and sustained trends in pollutants;

4) the average $NO_3^-$ content of each groundwater body according to the data from this monitoring;
5) the average concentrations of quality indicators and pollutants in the relevant groundwater bodies and an assessment of the compliance of these concentrations with the threshold value established in the Regulation No. 48 of the Minister of the Environment of Estonia;
6) compliance of the content of hazardous substances with the groundwater quality limit values in Regulation No. 39 of the Minister of the Environment of Estonia;
7) compliance of the content of pollutants with Regulation No. 61 of the Minister of Social Affairs of Estonia;
8) an assessment of long-term anthropogenic changes in the chemical composition of groundwater;
9) an evaluation of the achievement of the environmental objectives.

## 3.2. Groundwater monitoring point qualification

The Latvian-Estonian cross-border area belongs to the central part of the BAB, where diverse aquifers are found in layers of different ages. The aquifers of the pre-Quaternary sediments are separated from each other by both local and regional aquitards or cage layers – regional Narva aquitard and Silurian-Ordovician layers. Regional aquitards divide the entire sedimentary cover into three practically isolated parts: in the active, slowed-down and stagnant groundwater exchange zone. Water overflow between these zones is possible only in small areas at cracks and fractures. Within the framework of the EU-WATERRES project, only the active water exchange zone up to the Narva regional aquitard is relevant, as it contains freshwater resources in the whole study area, which are exploited and will continue to be exploited in water supply, mainly as drinking water. It should also be taken into account that the largest groundwater flow between national borders has been identified for the aquifer complexes belonging to the active water exchange zone, therefore this part needs increased attention to changes in transboundary groundwater resources.

The active water exchange zone includes two aquifer systems: Pļaviņas-Ogre aquifer system, which characterizes three transboundary groundwater bodies - D6, D8 and 26, as well as the Aruküla-Amata aquifer system, which characterizes four transboundary groundwater bodies - A8, A10, 23, 24 and 25. Quaternary aquifers are included in uppermost groundwater bodies, where they are exposed on the ground surface. It should be noted that the use of Quaternary groundwater as drinking water in the chosen transboundary area is insignificant, so increased attention is paid only to previously mentioned confined aquifer systems. More detailed information on aquifer systems and hydrogeological conditions of the study area can be found in WP3 Output 1 “Assessment of the resources of transboundary groundwater reservoirs for the 2 pilot areas” (Solovey et al., 2021). Further, the data analysis is based on the criteria specified in paragraph 2 and based on the step-by-step principle, as well as the objectives or tasks of cross-border monitoring were taken into account:

1) to provide regional observations on the status of groundwater resources in each transboundary groundwater water body;
2) to assess the initial qualitative and quantitative status of transboundary groundwater, taking into account the impact/capacity of anthropogenic pressures;
3) to improve cooperation between countries and to establish sustainable management of groundwater resources.

### 3.2.1. Existing groundwater monitoring points

There are currently 22 monitoring points in the Latvian-Estonian transboundary area, of which 13 monitoring points - wells are located in the territory of Estonia and 9 monitoring points (3 springs and 6 wells in 2 stations) in the territory of Latvia (Figure 30). Monitoring points characterize Pļaviņas-Ogre and Aruküla-Amata aquifer systems or transboundary water bodies - 26, D6, D8 and A8, A10, 23, 24 and 25, and provide mostly continuous quantity and/or quality monitoring. The exception is 4 monitoring points in the territory of Estonia, which are not currently active and have not been monitored in recent years (Figure 5).

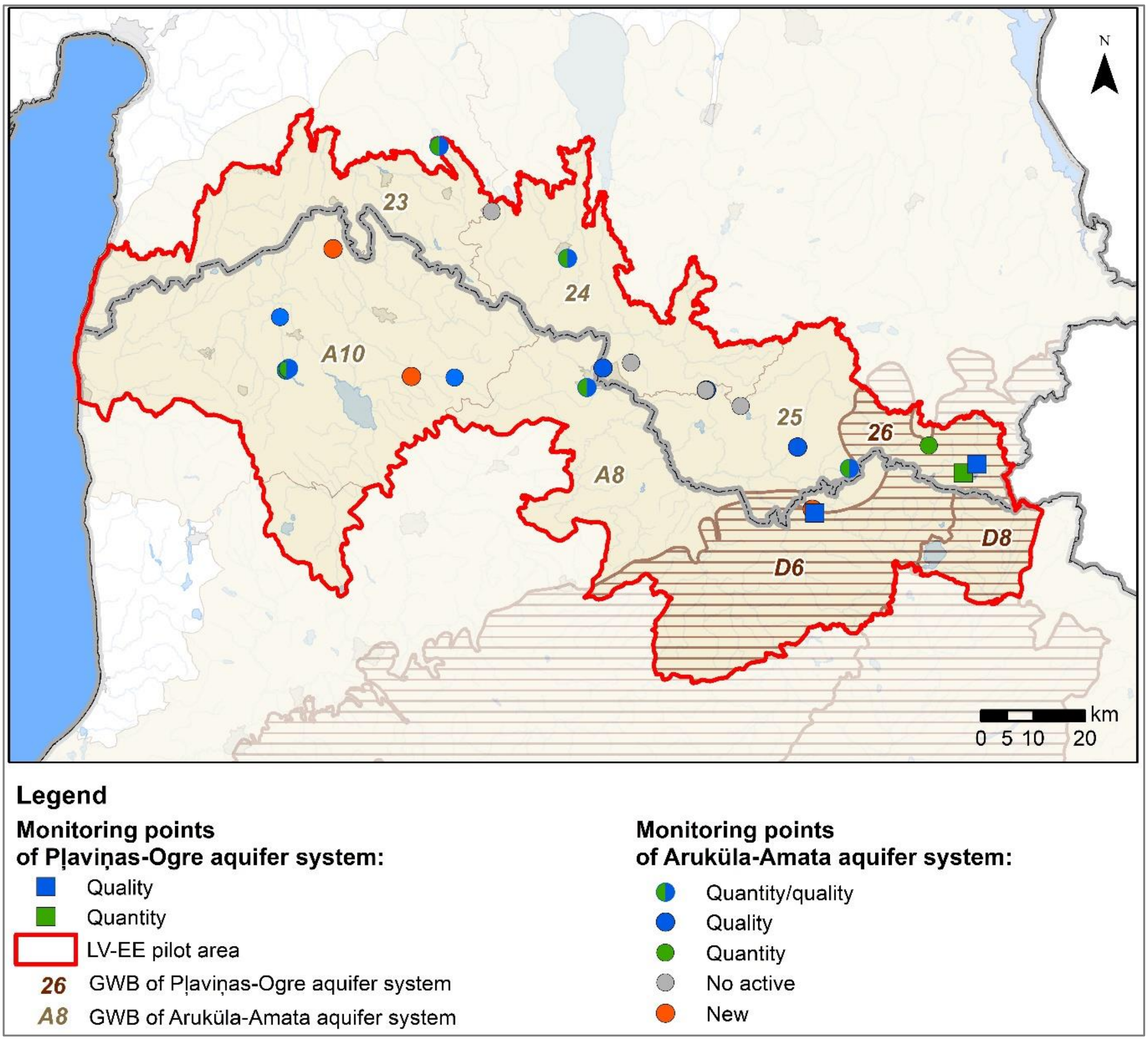


**Figure 5 Location of existing monitoring points in the Latvian-Estonian pilot area**

It should be noted that by 2027 it is planned to improve the existing groundwater monitoring network in Latvia by installing 3 monitoring stations with 6 wells, which will improve the density of the monitoring network in the Aruküla-Amata aquifer system and further ensure both quantitative and qualitative monitoring. The new wells are planned to be installed at different depths, which would characterize the Quaternary and deeper aquifers. Information on all 22 existing monitoring points and types of monitoring is presented in Table 2, but more detailed information is provided in Annex II.

**Table 2 Existing monitoring points in the Latvian-Estonian transboundary area**

| Aquifer system | GWB | Type of monitoring | | Total number of points (springs/wells) |
|---|---|---|---|---|
| | | Qualitative | Quantitative | |
| **Pļaviņas-Ogres** | **26** | 1 | 1 | 3 (1/2) |
| | **D6** | 1 | - | |
| | **D8** | - | - | |
| **Aruküla-Amata** | **23** | 2 | 1 | 19 (2/17) |
| | **24** | 3 | 2 | |
| | **25** | 5 | 2 | |
| | **A8** | 1 | 1 | |
| | **A10** | 5 | 5 | |
| | **Total:** | **18** | **12** | **22 (3/19)** |

It should be noted that the existing monitoring network coverage mainly allows assessing only the qualitative (chemical) status of groundwater, as it is not possible to achieve the quantitative target set by the WFD with the current monitoring network coverage (according to WFD Annex V 2.2.2. requirements, transboundary GWBs should be provided with a sufficient number of monitoring points to assess the direction and flow rate of the groundwater through the Member State boundary).

In order to achieve this goal, it would be necessary to set up a significant number of new monitoring points, which would not be financially adequate. However, in the context of the transboundary area in question, the establishment of such a new and expanded monitoring network would not be adequate and rational, as no significant groundwater intake pressure was identified in the area following data collection and analysis, which could lead to changes in the regional hydrogeological regime (see Chapter 3.3.3) and such an increase is not expected in the future either (the transboundary area is sparsely populated with a declining tendency). Another much more adequate and appropriate solution to assess the direction and flow rate of the groundwater through the Member States boundary would be the establishment of a joint numerical hydrogeological model between the two Member States, through which different scenarios could be modeled, taking into account groundwater intake intensity, which is a key factor in changing the transboundary hydrogeological regime. But, as it was mentioned above, in case of the Estonia-Latvian transboundary groundwater intake pressure is localized and no increase in this pressure is expected.

### 3.2.2. Groundwater flow path

Based on the calculations made by the University of Latvia (Project partner No. 6), two territories have been identified in the Latvian-Estonian transboundary area, where a relatively significant flow of groundwater between the state borders has been noted: in the eastern part of the transboundary area, in the Gauja-Koiva river basin district, a defined area in which groundwater flows at a relatively high speed; as well as a defined area with a lower groundwater flow between national borders in the central part of the transboundary Salaca-Salatsi river basin district. In the rest of the area, insignificant flows have been identified or not observed at all in some places (Figure 6).

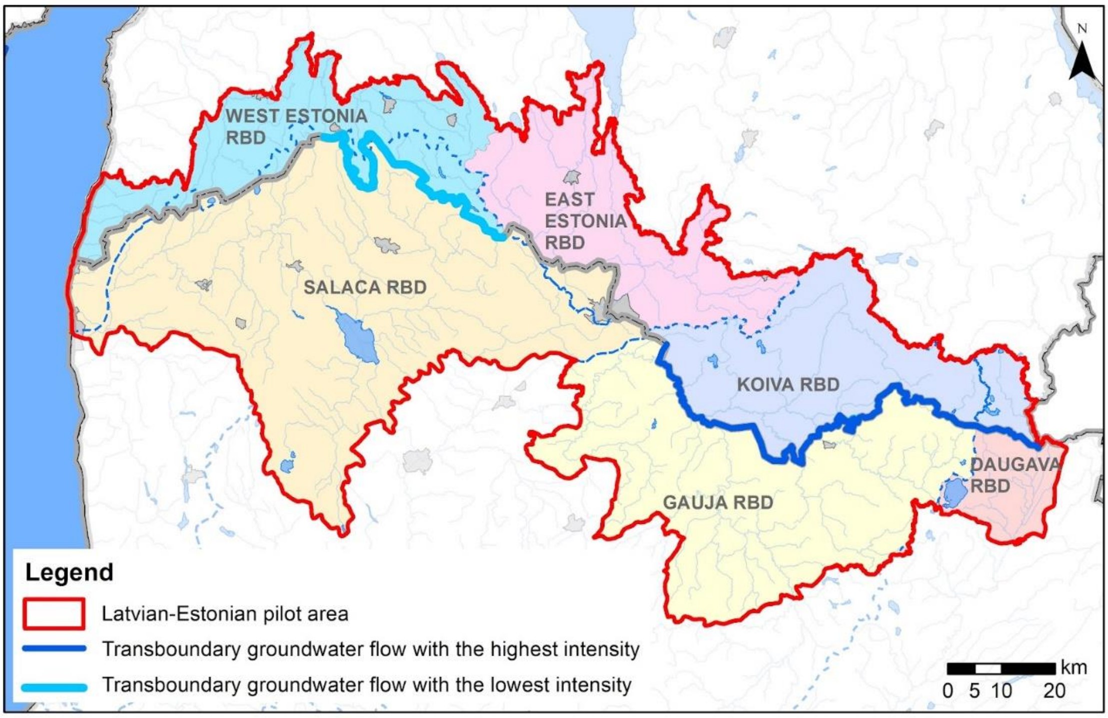


**Figure 6 Areas with significant groundwater flows between national borders**

However, it should be noted that the intensity of groundwater flow varies not only at the national boundaries, but also at the depth boundaries of the aquifer systems. It can be noted that a higher groundwater flow between national borders has been identified in the eastern part of the Aruküla-Amata aquifer system, where groundwater flows from Latvia to Estonia (in green) with relatively high intensity, while in the central part of the transboundary area waters flow at a lower intensity than in the eastern part of the territory from Estonia to Latvia (in red) and in many parts of the transboundary territory there are no significant groundwater flows across the border - especially in the western part of the territory and in some areas in its central part. (Figure 7).

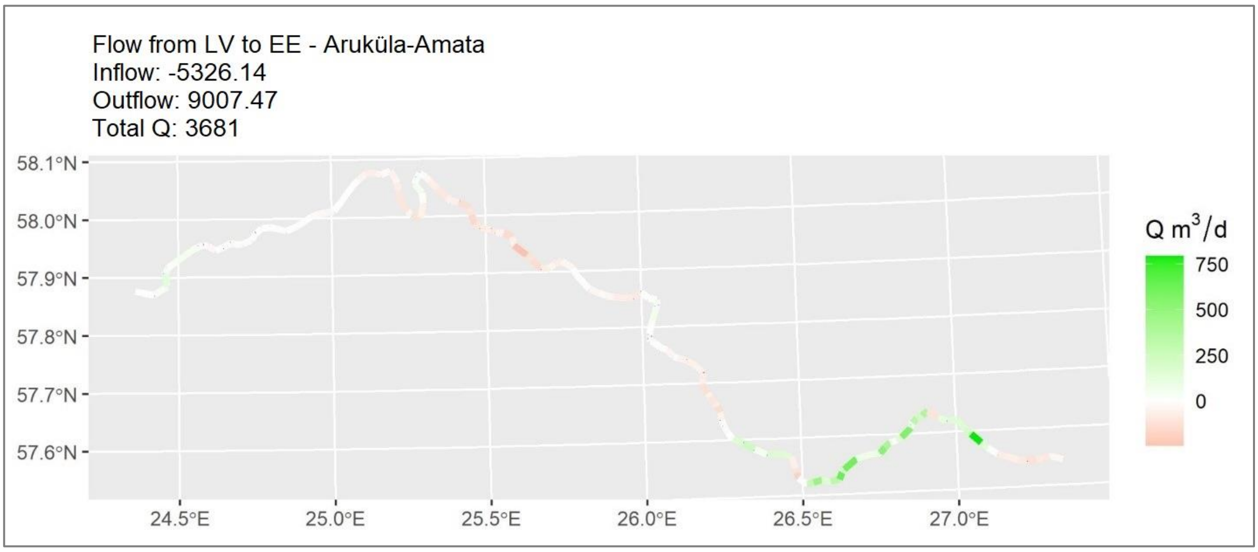


**Figure 7 Estimated transboundary groundwater flows across Estonian-Latvian borderline in Aruküla-Amata aquifer system** (Solovey et al., 2021)

In the Pļaviņas-Ogre aquifer system, a lower groundwater flow intensity was observed than in the Aruküla-Amata aquifer system between national borders. Within the distribution range of this aquifer system, two areas with relatively significant groundwater flow intensity between national borders have been identified: in the eastern part the most pronounced groundwater flow from

Estonia to Latvia is identified (in red), and towards the center from the eastern part is identified from Latvia and Estonia (in green), but with a much lower intensity. In the rest of the area, the flow is not observed at all or is insignificant (Figure 8).

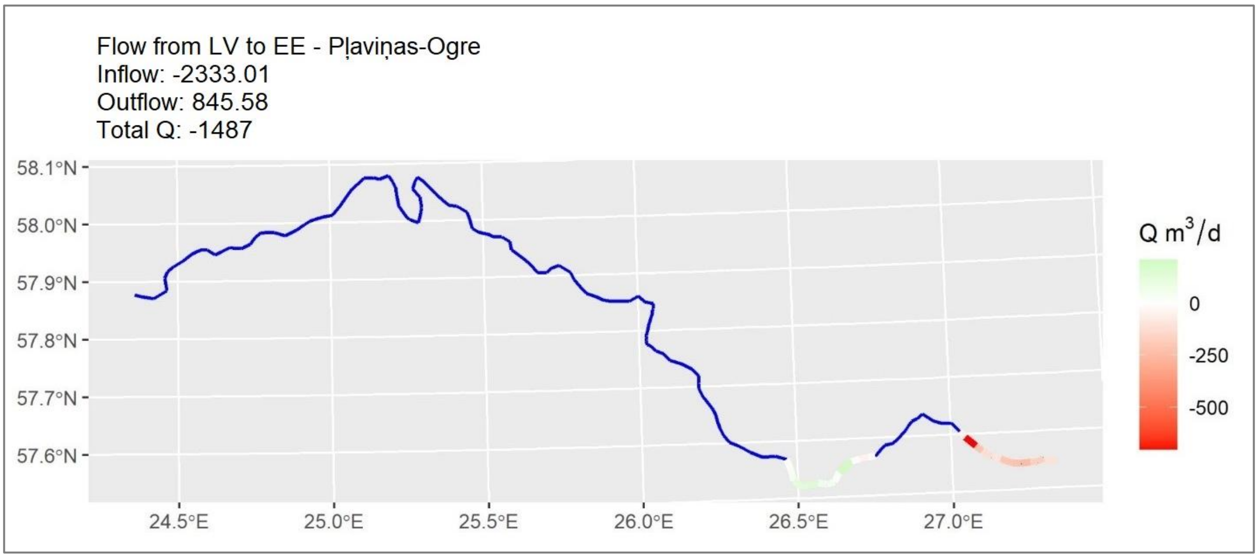


**Figure 8 Estimated transboundary groundwater flows across Estonian-Latvian borderline in Pļaviņas-Ogre aquifer system (blue borderline sections - no aquifer system present)** (Solovey et al., 2021)

The identified zones/areas mainly determine the priority for the selection of monitoring points, especially in cases where intensive anthropogenic pressures or pollution objects that could affect the quality and/or quantity of groundwater have been identified in these areas. Accordingly, the monitoring points located in these areas will make it possible to identify and control the movement of potential pollutants from one country to another in good time.

### 3.2.3. Estimation of anthropogenic pressure in EE-LV pilot area

In order to identify regions of the transboundary area where intense anthropogenic pressure have been identified that may endanger the quantitative and/or qualitative status of transboundary GWBs, as a result of which the good status of these GWBs may not be achieved, information was collected for the period 2014-2019 (6-year cycle) from the following information sources:

- Latvian State Geological Fund;
- Latvian Register of Mineral Deposits;
- Latvian state statistical report forms "No.2-Water. Reports on the Use of Water Resources";
- Latvian Environment, Geology and Meteorology Centre, report “3rd cycle Gauja River Basin Management Plans”;
- Estonian Environmental Research Centre, report “Residual Pollution Sites 2014-2015. Compilation and Analysis of Data”;
- Geological Survey of Estonia, “The Status of Estonian Groundwater bodies in 2014-2019”.

In order to estimate the anthropogenic pressure in the Estonian-Latvian transboundary area, the following criteria were considered.

**Active groundwater intakes.** The Pļaviņas-Ogre aquifer system is distributed only in the eastern part of the pilot area and is mainly operated for decentralized water supply or individual water abstraction needs. In the period from 2014 to 2019, water abstraction from wells in the examined area ranged from 0.1 m$^3$/d to 65 m$^3$/d (mainly up to 25 m$^3$/d), the total groundwater abstraction in the territory was about 200-300 m$^3$/d. There are no groundwater well fields in the territory with approved groundwater resources and/or active groundwater intake sites with an amount above 100 $m^3$/d (Figure 9). The largest number of groundwater intake wells has been identified in the vicinity of the city of Alūksne, where an area with total water intake above 100 $m^3$/d has been identified (maximum total water intake from 4 wells is about 130 $m^3$/d). However, it should be taken into account that in recent years (2018-2019) groundwater intake was done only from 2 wells, the amount of which did not exceed 40 $m^3$/d.

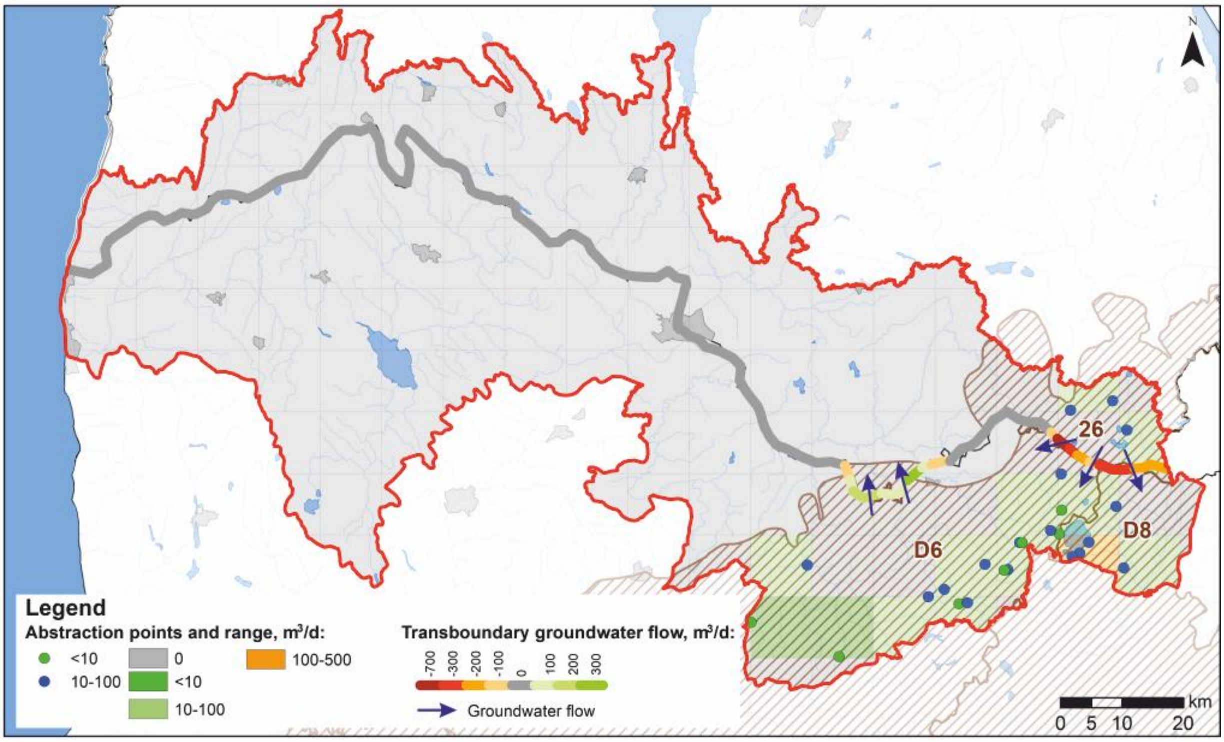


**Figure 9 Groundwater intake points in Pļaviņas-Ogre aquifer system and their maximum water intake volumes in the period from 2014 to 2019**

The Aruküla-Amata aquifer system is distributed throughout the pilot area and in the eastern part of the territory it lies under the Pļaviņas-Ogre aquifer system. Accordingly, this system is mainly used in those areas where it lies immediately below the Quaternary sediments and is less exploited in the rest of the transboundary area. The Aruküla-Amata aquifer system is intensively operated for both centralized and decentralized groundwater supply, as well as in the individual sector. Areas with intensive groundwater intake pressure were identified in the examined area in those areas where the largest number of intake wells has been identified or intake from wells of groundwater well fields have been observed – groundwater intake in these areas does not exceed 200 $m^3$/d, and only in Valka-Valga cities it increases up to 4000 $m^3$/d and in the vicinity of Rūjiena - up to 400 $m^3$/d (Figure 10). In total, 7 groundwater well fields with approved groundwater resources and only three active groundwater intake sites with intake above 100 $m^3$/d have been identified in the transboundary area, while no significant water intake has been identified or observed at all in the rest of the transboundary area.

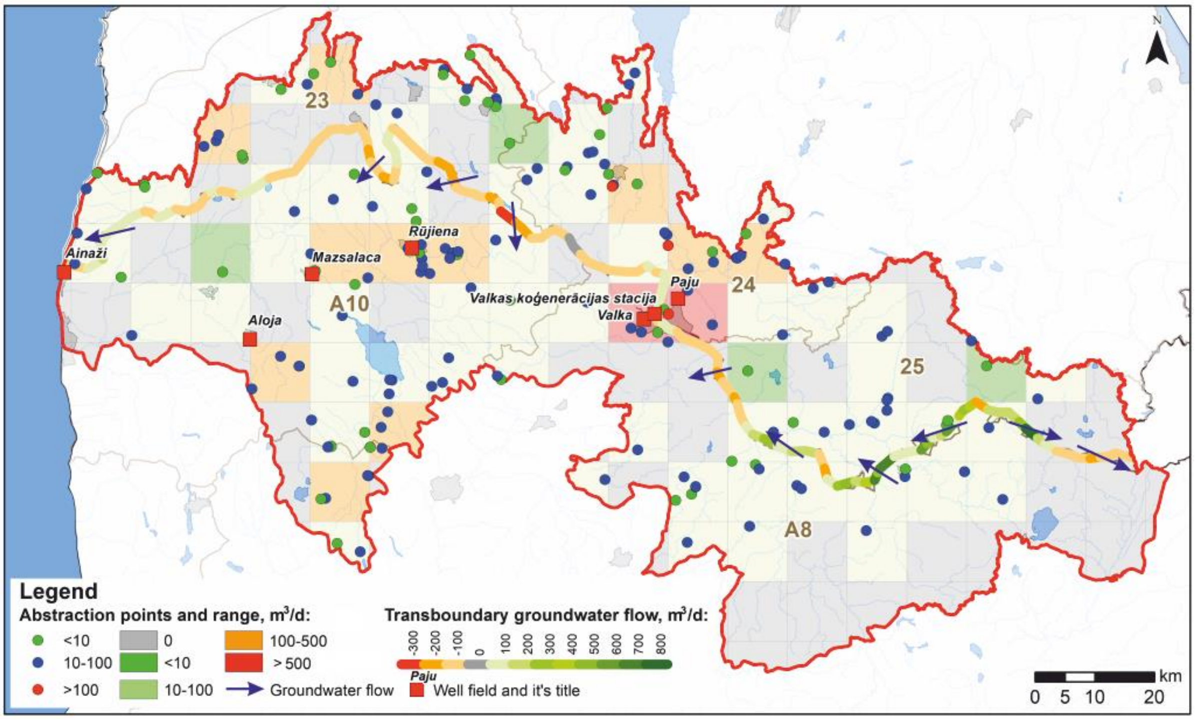


**Figure 10 Groundwater intake points in Arukūla-Amata aquifer system and their maximum water intake volumes in the period from 2014 to 2019**

Table 3 summarizes information on the most significant groundwater intake sites and their maximum intake volumes in the period from 2014 to 2019.

**Table 3 Groundwater well fields and individual wells with groundwater abstraction above 100 $m^3/d$**

| Groundwater well fields and individual wells | Number of wells | Approved resources ($m^3/d$) | Maximum intake (2014-2019, $m^3/d$) | Intake (% from approved resources) |
|---|---|---|---|---|
| Ainaži | 1 (2) | 480 | 37.1 | 7.7 |
| Aloja | 1 (1) | 200 | 83.5 | 41.8 |
| Mazsalaca | 1 (2) | 432 | 67.5 | 15.6 |
| Rūjiena | 1 (2) | 432 | 181.7 | 42.1 |
| Valka | 2 (4) | 1074 | 867.6 | 80.8 |
| Valkas koģenerācijas stacija | 1 (1) | 600 | 220.4 | 36.7 |
| Paju | 5 | 3200 | 2181.2 | 68.1 |
| 8508 | 1 | - | 326 | - |
| 10976 | 1 | - | 162.8 | - |
| 50670 | 1 | - | 161 | - |
| | **Total:** | **6418** | **4300.9** | **56.9** |

In the period from 2014 to 2019, groundwater intake from wells in the examined area ranged from 0.1 $m^3/d$ to 100 $m^3/d$ (mainly up to 50 $m^3/d$), the total intake in the territory was about 5200-6300 $m^3/d$. In groundwater well fields, a smaller volume of groundwater was abstracted than the approved reserves in them, varying from 7.7% in groundwater well field Ainaži to 80.8% in groundwater well fields Valka (56.9% of the total approved groundwater resources were abstracted from 2014 to 2019).

An in-depth collection of information on the above sites suggests that current groundwater intake volumes cannot change the hydrogeological conditions of the transboundary area. Even if all groundwater well fields would start to intake all the approved groundwater resources, the precautionary principle should be taken into account concerning the surroundings of Valka-Valga cities, taking into account the intake volumes.

**Pollution hotspots.** In order to assess the potential impact of point pressure sources on transboundary groundwater resources and their quality, previously prepared data from the River Basin Management Plans developed by each country were collected (RBMPs, 2021; Ministry of the Environment, 2021a; Ministry of the Environment, 2021b) and, in addition, materials from available databases and/or fund materials were collected to describe in more detail the origin of point sources and the extent of their impact. The summarized information on identified point source pollution sites in the Latvian-Estonian transboundary area is provided in Figure 11, spatial locations of pollution sites are given in Figure 12.

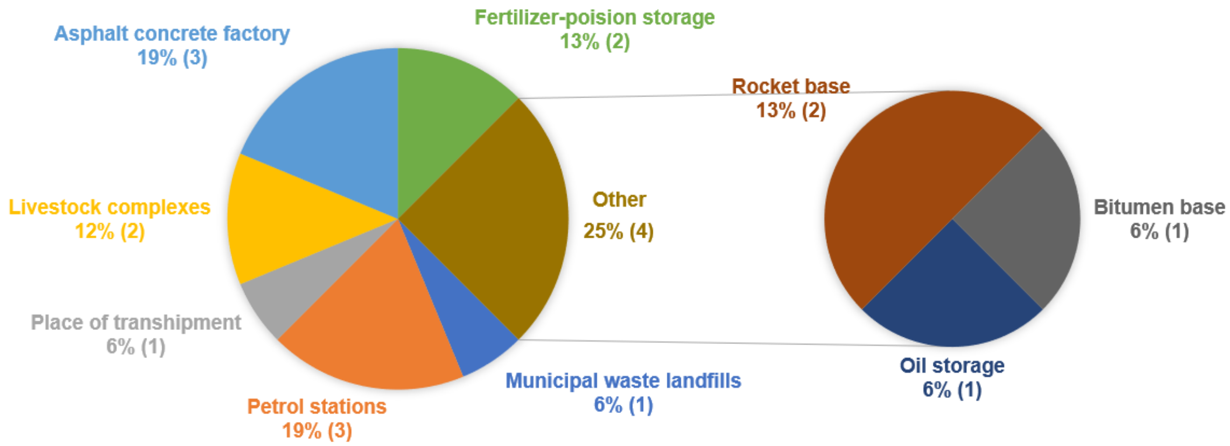


**Figure 11 Point source pollution sites in the Estonia-Latvian transboundary area**

Pollution sites are mainly concentrated around cities and are mainly petrol stations, asphalt concrete factories, livestock complexes, fertilizer-poison storages and former rocket bases, followed by municipal waste landfills, industrial objects (place of transshipment), oil storages and bitumen bases. A total of 16 point-pollution sites have been identified within the Latvian-Estonian transboundary area, of which 3 sites in the Estonian territory have been identified as pollution site areas (Figure 12).

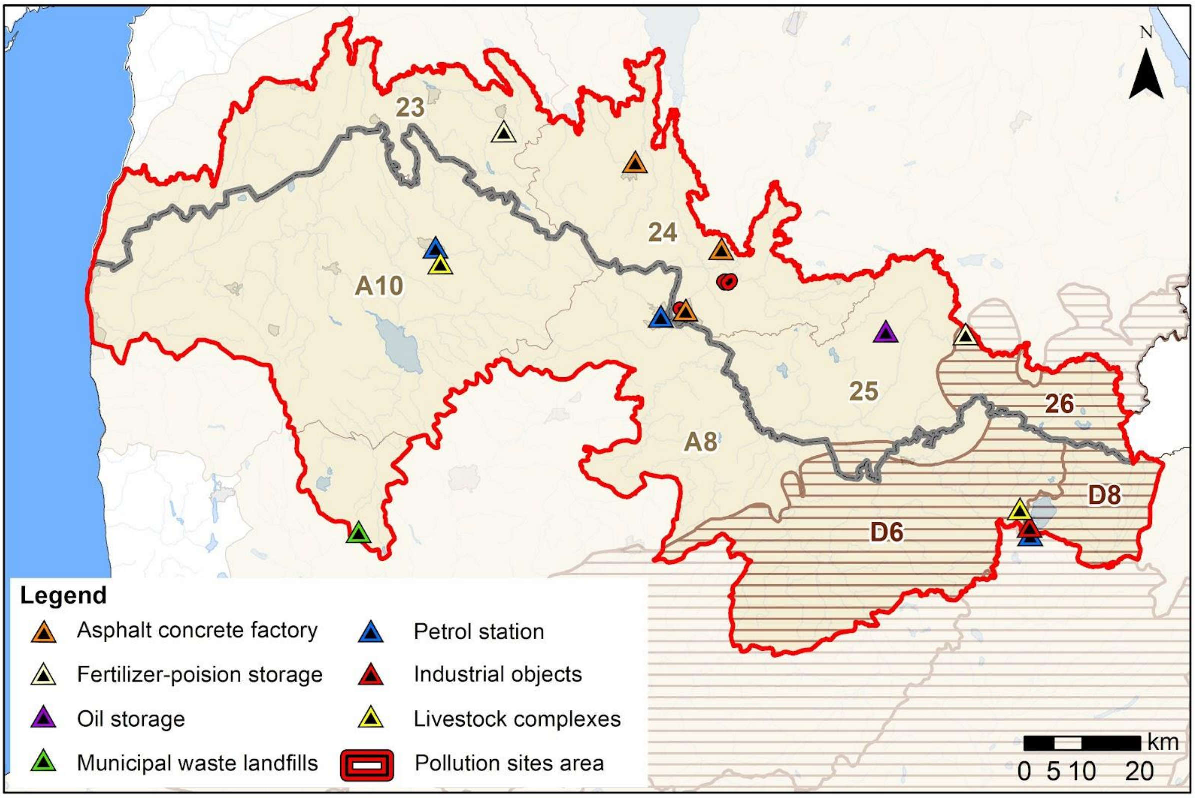


**Figure 12 Pollution sites and pollution areas**

The type and content of pollution in groundwater is different, it directly depends on the activity profile of the identified pollution sites. The main types of pollutants are petroleum products and nitrogen compounds. More detailed information is available in Table 4.

**Table 4 Point source pollution sites in the Estonia-Latvian transboundary**

| Point pollution source | Type of pollution |
|---|---|
| Petrol stations | Petroleum products |
| Municipal waste landfills | $N_{tot}$, $NH_4^+$, COD, electrical conductivity, chlorides ($Cl^-$) |
| Livestock complexes | $N_{tot}$, $NH_4^+$, $P_{tot}$, COD |
| Industrial objects | Petroleum products; Heavy metals (Cr, Cu, Zn, Pb, Ni) |
| Asphalt concrete factory | Petroleum products; Oil shale oil; Polycyclic aromatic hydrocarbons; Phenols |
| Fertilizer-poison storage | Agricultural poisons; Fertilizers |
| Oil storage | Motor oil |

Studies and observations carried out at the pollution sites in Latvia showed that the pollution is associated with shallow groundwater pollution, which is local and often historical in nature (Latvian State Geological Fund, 2021). In turn, the pollution found in the territory of Estonia is related to the pollution of the Aruküla-Amata aquifer system. The main types of pollution are petroleum products, oil and fertilizers. All of the pollution points are residual pollution points which are mostly eliminated (Estonian Environmental Research Centre, 2015).

The collected data show that the above-mentioned pollution sites cannot significantly affect the quality of transboundary groundwater bodies. In particular, these pollution sites are not located in the areas identified in Chapter 3.2.2 with relatively significant groundwater flows across national borders - accordingly, migration of pollution is not possible.

**Mining areas**. Based on information from the Estonian Land Board (Web Map of Mineral Deposits) and Latvian Register of Mineral Deposits, a total of 269 mineral deposits have been identified in the transboundary area. According to the available data, most of them (240 mineral deposits or 89% of all cases) are Quaternary mineral deposits and only 11% of all cases (29 mineral deposits) – in pre-Quaternary ($D_3$*slp*, $D_3$*pl*, $D_3$*gj*, $D_2$*br*) sediments, which, mainly due to intensive mining and lowering of groundwater levels, may affect the hydrogeological regime of the Pļaviņas-Ogre and/or Aruküla-Amata aquifer systems. However, in 192 mineral deposits, no mining or quarrying activities have been carried out in the last 6 years, of which in 151 cases mining was not undertaken after assessment of the mineral resources.

Respectively, in the period from 2014 to 2019, quarrying and extraction of mineral resources were identified in 77 mineral deposits (74 deposits are related to Quaternary sediments, 3 deposits - to pre-Quaternary sediments). In all cases, except for the dolomite deposit in the vicinity of the town of Ape (in Latvia), the extraction of minerals took place without lowering the groundwater levels (Table 5).

**Table 5 Mineral deposits (quarries) in the Estonian-Latvian transboundary area**

| Aquifer system (GWB) | Country | Number of mineral deposits (active deposits*) | | | Number of deposits where groundwater levels are lowered |
|---|---|---|---|---|---|
| | | Q | pre-Q | Total | |
| Aruküla-Amata (A8, A10, 23, 24, 25) | Latvia | 136 (31) | 8 (0) | 144 (31) | 0 |
| | Estonia | 43 (27) | 0 | 43 (27) | 0 |
| Pļaviņas-Ogre (D6, D8, 26) | Latvia | 61 (16) | 19 (3) | 80 (19) | 1 |
| | Estonia | 0 | 2 (0) | 2 (0) | 0 |
| **Total** | | **240 (74)** | **29 (3)** | **269 (77)** | **1** |

*Mining was performed in the period from 2014 to 2019

Dolomite deposit “Ape" is located about 3 km from the Latvian-Estonian border, the layer of minerals to be extracted in the territory of the deposit lies deeper than the groundwater level. Accordingly, the extraction of minerals can only take place by lowering groundwater levels. The main aquifer, that determines the inflow of water into the quarry, is the Pļaviņas ($D_3$*pl*) aquifer (a permanent Quaternary groundwater aquifer has not been identified in the site and in its immediate vicinity). The results of hydrogeological research, as well as modeling indicate that the radius of the depression cone around the mineral deposit could reach up to 3.2 km at the maximum lowering of the groundwater level in the quarry (final stage of extraction by lowering the water level by 17-18 m). However, it should be noted that in this case a larger depression cone will mainly to form around the quarry itself and only within a radius of 1 km, as a result of which a decrease in groundwater level in the Pļaviņas ($D_3$*pl*) aquifer by 2 m will be observed. The resulting impact on the transboundary area at regional level will be minimal and localized (SIA “Zemes Puse, 2015; SIA “Firma L4”, 2006).

During the last 6 years, the volume of groundwater pumping from the mineral deposit “Ape” ranged from 44.5 $m^3$/d in 2016 to 4274.22 $m^3$/d in 2018, while in 2019 no groundwater pumping was performed (Figure 13). According to the research results and calculations – at the end of the quarry exploitation, groundwater pumping can reach up to 10170 $m^3$/d. According to information from the collected materials, mineral deposit “Ape” is expected to operate intensively in the coming years.

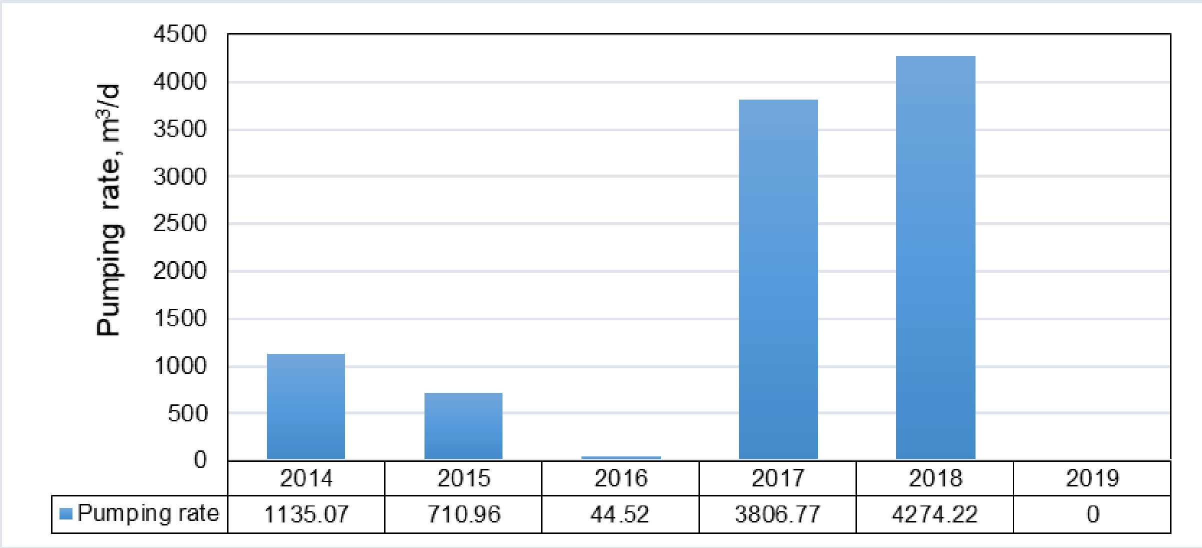


**Figure 13 Groundwater pumping volumes (m$^3$/d) at the dolomite deposit "Ape" in the period from 2014 to 2019**

Based on the collected information, it was concluded that at this moment no active mineral deposits (quarries) have been identified in the Estonian-Latvian transboundary area, which could affect the hydrogeological regime on a regional scale – mining at dolomite deposit "Ape" can only cause changes on a local scale (maximum – within a radius of 3.2 km).

However, it should be noted that two dolomite deposits: "Naha" and "Kalkahju" (in Estonia), have been assessed less than a kilometer from the Estonian-Latvian border (Geological Survey of Estonia, 2013; Engineering Bureau Steiger, 2013). They have not yet been accepted to become active deposits, however, in the future, mining can only take place by lowering the groundwater level, which may affect the hydrogeological regime of the Pļaviņas-Ogre aquifer system. Currently in Latvia, in the Estonian-Latvian transboundary area, quarrying mainly takes place without lowering the groundwater levels of confined and unconfined aquifers as the extraction of minerals takes place before reaching it. However, if extraction of all accepted mineral resources will begin in the future, groundwater lowering in confined and unconfined (in some cases) aquifers will be necessary.

**Conclusion.** The collected materials and cartographic information reflect that no intensive anthropogenic pressure was identified in the transboundary area, which could affect the quality and quantity of groundwater in it - respectively, worsen the condition of transboundary groundwater bodies. No significant groundwater intake was identified in the transboundary area and no regions with mineral deposits (active quarries) that could affect the hydrogeological regime at the regional scale in the transboundary area were identified. Also, no sources of pollution were identified (especially in regions where a relatively significant groundwater flow between the borders of the two countries has been identified) that could affect groundwater quality (Figure 14).

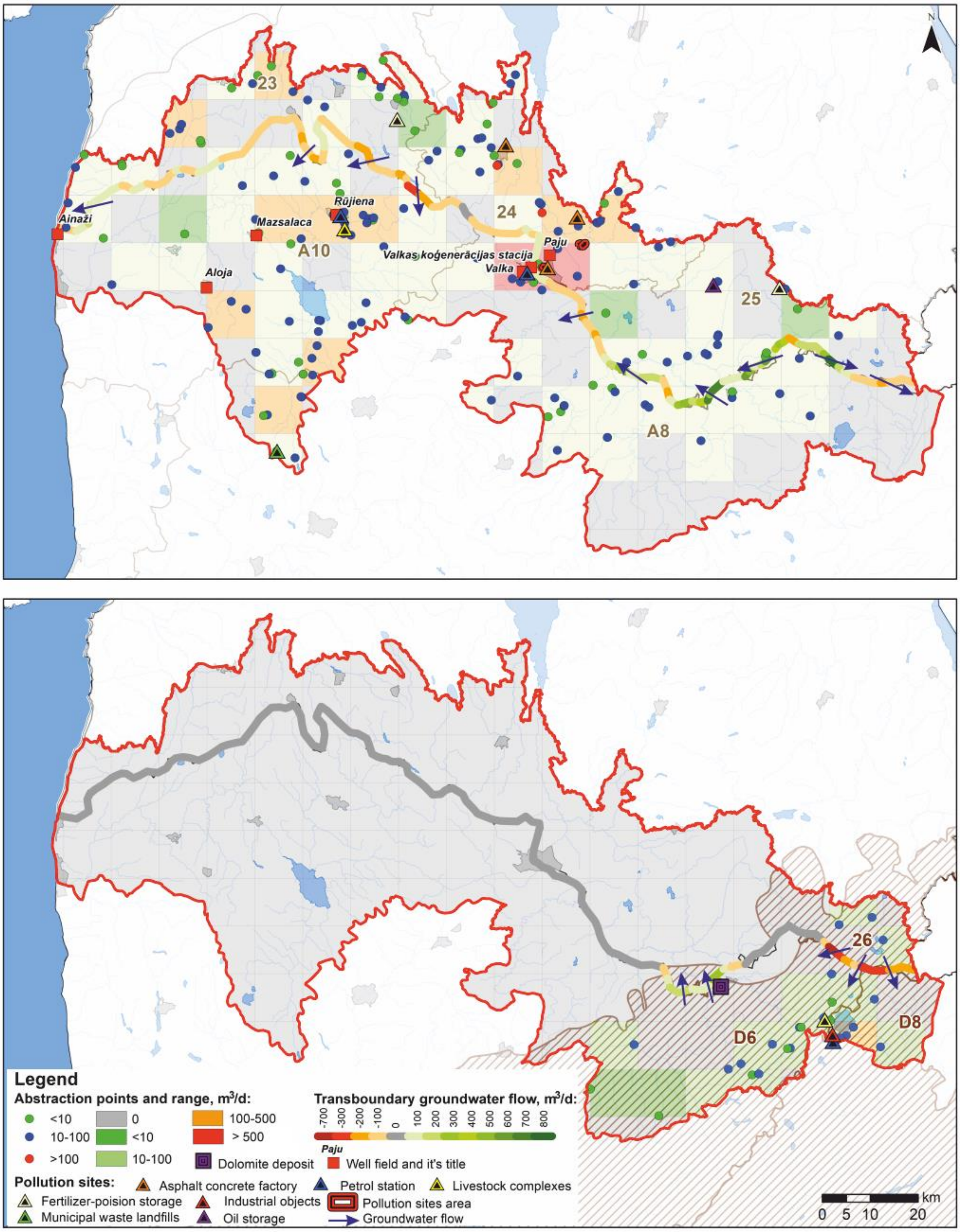


**Figure 14 Anthropogenic pressure and transboundary groundwater flow pattern in Latvian-Estonian pilot area**

Respectively, for the management of transboundary groundwater bodies D6, D8, 26 (characterizing the Pļaviņas-Ogre aquifer system) and A8, A10, 23, 24, 25 (characterizing the Aruküla-Amata aquifer system) are currently sufficient with the existing monitoring points, which can provide transboundary monitoring at regional level and meet the monitoring objectives set. In the future, more attention should be drawn to the Gauja-Koiva river basin district, which is located in the eastern part of the transboundary area, where the highest intensity of groundwater flow between the two countries in both Pļaviņas-Ogre and Aruküla-Amata aquifer system has been identified.

In the future, additional attention should be paid to the Valka-Valga cross-border area, as the most intensive groundwater abstraction and point sources were identified in this area. Although there is currently no intensive groundwater flow between the two countries, given the local hydrogeological conditions in the area, it may be affected by potential changes in groundwater abstraction.

### 3.2.4. Integration of other monitoring points or new monitoring points

In order to improve the coverage of the monitoring network in the transboundary area, it is possible to integrate water intake wells as monitoring points in the transboundary monitoring network and/or to include large debit springs in the monitoring network, as well as to install new monitoring wells. Areas that may be prospective for the development of a transboundary groundwater monitoring network have been identified in the Latvian-Estonian transboundary area (Figure 15).

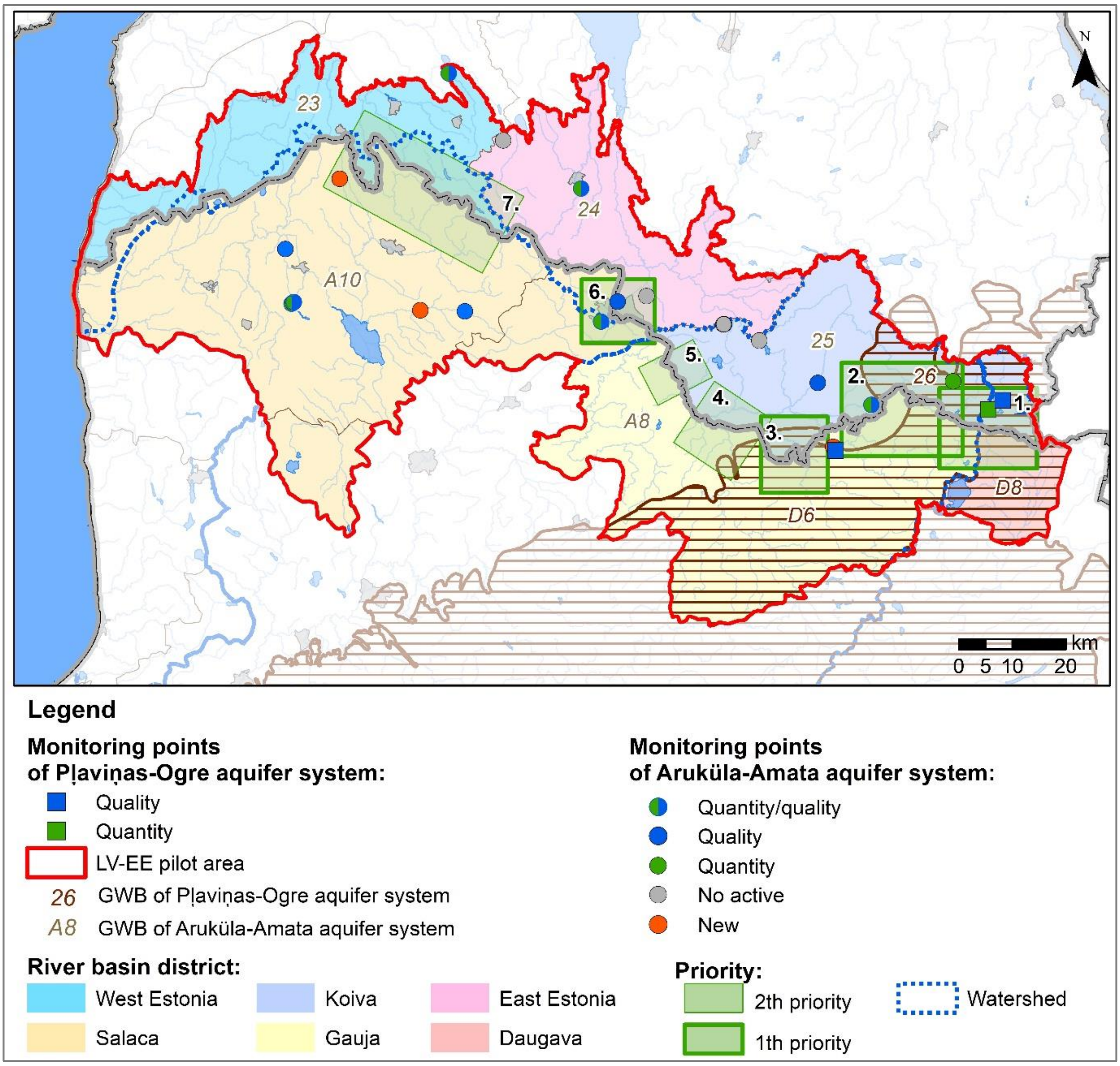


**Figure 15 Location of existing monitoring points and perspective areas for improvement of the transboundary monitoring network**

The existence and intensity of transboundary flows between the two countries was the key factor in identifying prospective sites for transboundary monitoring, as no significant anthropogenic pressures were identified in the area under review (with the exception of Valka-Valga, where larger water abstractions were mainly identified). The conceptual model developed for the Latvian-Estonian transboundary area and the data analysis performed in Chapters 3.2.1-2.3.3 were used as the basis for the selection of these sites. As a result, 7 perspective areas for the improvement of the transboundary groundwater monitoring network have been identified in the study area, which have been given priority based on the flow intensity (Table 6).

**Table 6 Description of perspective territories for Latvian-Estonian transboundary monitoring**

| Site number | Transboundary flow direction | River basins | Criteria | Aquifer for monitoring* |
|---|---|---|---|---|
| **1.** | From Estonia to Latvia | Gauja, Koiva, Daugava | Significant flow, recharge area | $D_3$*pl-dg*, $D_{2\text{-}3}$*ar-am* |
| **2.** | From Latvia to Estonia | Gauja, Koiva | Significant flow, recharge area | $D_{2\text{-}3}$*ar-am* |
| **3.** | From Latvia to Estonia | Gauja, Koiva | Significant flow, | $D_3$*pl-dg*, $D_{2\text{-}3}$*ar-am* |
| **4.** | From Latvia to Estonia | Gauja, Koiva | Less significant flow | $D_{2\text{-}3}$*ar-am* |
| **5.** | From Estonia to Latvia | Gauja, Koiva | Less significant flow | $D_{2\text{-}3}$*ar-am* |
| **6.** | Now significant flow | Salaca, East Estonia | Significant water abstraction rate | $D_2$*ar+br* |
| **7.** | From Estonia to Latvia | Salaca, West Estonia | Less significant flow | $D_2$*ar+br* |

* Recommended, that observations should also be performed in the Quaternary aquifer, especially in areas, where more permeable and vulnerable layers are distributed (3. - 6. site).

However, it should be noted that no significant anthropogenic pressure has been identified in the transboundary area, indicating that the installation of new monitoring wells and the integration of other monitoring networks would be financially unjustified. But it should be kept in mind, that based on the fact that there are not many existing monitoring points in the Latvian-Estonian transboundary area that could be representative in terms of transboundary aquifer research, it is recommended to use the identified areas for further investigations.

Also, the initially identified areas can be specified after new data have been obtained (once a harmonized vulnerability map has been developed, all groundwater-related ecosystems have been identified etc.) for the study area and a new knowledge base has been originated by developing a hydrodynamical numerical model.

## Summary

With the increasing use of groundwater resources worldwide, the need for closer cooperation on transboundary groundwater management has become increasingly important. Countries sharing transboundary groundwater resources (common groundwater bodies have been identified) need to develop cooperation in the management and protection of their transboundary groundwater resources, including the development of a joint monitoring strategy based on existing groundwater status and anthropogenic pressures. Research on transboundary groundwater flows and shared groundwater bodies in the Latvian-Estonian transboundary area, carried out within the framework of the EU-WATERRES project, justifies the need for further transboundary monitoring, especially if intensive anthropogenic pressures will be identified in the transboundary area.

The aim of this report was to form common principles for selecting the transboundary monitoring points in Estonia and Latvia in the need of assessing quantitative and chemical status of groundwater in the Estonian-Latvian transboundary area. Recommendations were developed taking into account the existing knowledge base on the study area and its hydrogeological conditions, as well as the requirements of EU legislation and financial aspects.

The report presents:

- analysis and review of the current EU requirements for the selection of transboundary groundwater monitoring points and experiences of other countries in selecting transboundary groundwater monitoring points;
- methodology of the transboundary groundwater monitoring point qualification in accordance with EU requirements;
- procedure of the transboundary groundwater monitoring point qualification in the Estonian-Latvian transboundary area, including depiction of already existing groundwater monitoring principles and network in both – Estonia and Latvia; as well as qualification of the transboundary groundwater points, which included analysis and review of the existing groundwater monitoring points, groundwater flow path and estimation of anthropogenic pressure in the Estonian-Latvian transboundary area;
- and finally, prospective areas for the establishment of new points of the transboundary groundwater monitoring network.

During the analysis, no intensive anthropogenic pressure was identified in the Estonian-Latvian transboundary area, which could affect the quality and quantity of transboundary groundwater aquifers – no significant groundwater intakes and no regions with active quarries were identified that could affect the hydrogeological regime at the regional scale. Also, no point pollution sources (especially in regions where a relatively significant groundwater flow has been identified) were identified that could affect groundwater quality. The study identified potential areas for further attention to future research on transboundary groundwater resources. These mainly include the transboundary Gauja-Koiva river basin district, where the most intensive groundwater flow between national borders has been identified, and the Valka-Valga area, where the most intensive groundwater abstraction, as well as the highest density with point pollution sources have been identified. In the rest of the transboundary area, less intensive groundwater transboundary flows have been identified, and only in the central part of the transboundary Salaca-Salatsi river basin district there is a negligible increase.

At present, no significant anthropogenic pressures have been identified in the Estonian-Latvian transboundary area, which indicates that the installation of new monitoring wells and the integration of other monitoring networks would be financially unreasonable. Due to the small number of existing monitoring points in the National Monitoring Network in the transboundary

area, it is recommended that further research be carried out to identify transboundary groundwater resources in order to obtain more direct data on the Estonian-Latvian transboundary area.

At present, it is recommended to include all identified monitoring points from the existing National Groundwater Monitoring Networks in the Estonian-Latvian transboundary area in the transboundary monitoring network, mainly in order to strengthen and establish closer cooperation in the field of transboundary groundwater resources management. Existing monitoring points mainly allows assessing only the qualitative (chemical) status of groundwater, but it is not possible to achieve the quantitative target set by the WFD with the current monitoring network coverage. Due to the small amount of groundwater abstraction in the study area compared to the available total groundwater resources, the monitoring of groundwater quantity is given lower priority.

It was also concluded that after obtaining additional data in the Estonian-Latvian transboundary area, the need to improve the existing groundwater monitoring network and the priority of monitoring can be reviewed. Consequently, further cooperation between the two countries is needed to develop a common groundwater vulnerability map, identify the existence of groundwater-dependent ecosystems in the transboundary area and their significance at the level of groundwater bodies, and develop a hydrodynamic numerical model for the study area.

## References


B-Solutions, (2018). B-solutions initiative's pilot action "Lithuanian Geological Survey and Latvian Environment, Geology and Meteorology Centre institutional cooperation on cross-border groundwater management". https://www.meteo.lv/lapas/projekta-b-solutions-informacija?&id=2459&nid=1176

Engineering Bureau Steiger, (2013). Kalkahju dolomite mineral deposit Kalkahju research area study report. https://fond.egt.ee/fond/egf/8411

Estonian-Russian Cooperation, (2020). Estonian-Russian Joint Commission for the Protection and Sustainable Use of Transboundary waters (26.11.2020) *Minutes of the Estonian-Russian Joint Commission for the Protection and Sustainable Use of Transboundary waters XXIII meeting.* https://envir.ee/media/1478/download

Estonian Environmental Research Centre, (2015). Inventory of residual pollution sites 2014–2015. Preparation of assessments and analysis of data. https://envir.ee/media/1014/download

European Communities, (2003). Guidance Document No.7. Monitoring under the Water Framework Directive. Common Implementation Strategy for the Water Framework Directive (2000/60/EC). European Communities, 2003

European Communities, (2007). Guidance Document No.15. Guidance on Groundwater Monitoring. Common Implementation Strategy for the Water Framework Directive (2000/60/EC). European Communities, 2007

European Communities, (2010). Guidance Document No.26. Guidance on risk assessment and the conceptual model for groundwater. Common Implementation Strategy for the Water Framework Directive (2000/60/EC). European Communities, 2010

Geological Survey of Estonia, (2013) Geological study of the Naha research area dolomites in Võrumaa. https://fond.egt.ee/fond/egf/8462

Groundwater monitoring and research network, (2021). Groundwater monitoring and research network. Polish Geological Institute – NRI. https://www.pgi.gov.pl/en/phs/tasks/9006-groundwater-monitoring-and-research-network.html

ICPDR, (2008). Groundwater guidance. International Commission for the Protection of the Danube River (ICDPR). www.icpdr.org

ICPDR, (2016). Groundwater Guidance. International Commission for the Protection of the Danube River (ICDPR). Final Draft of 3rd Edition of 2016. https://www.icpdr.org/flowpaper/viewer/default/files/nodes/documents/groundwater_guidance.pdf

Latvian State Geological Fund, (2021). Latvian State Geological Fund archive materials on groundwater chemical monitoring and pollution assessment. Archive inventory No. 22958, 15376, 19694, 15256, 28599, 28374, 12317

Ministry of the Environment, (2021a). Eastern Estonian River Basin Management Plan 2021–2027. https://envir.ee/keskkonnakasutus/vesi/veemajanduskavad

Ministry of the Environment, (2021b). Western Estonian River Basin Management Plan 2021–2027. https://envir.ee/keskkonnakasutus/vesi/veemajanduskavad

Nałęcz, T. (Ed.). (2012). *Transboundary Aquifers in the Eastern Borders of The European Union*. NATO Science for Peace and Security Series C: Environmental Security, DOI 10.1007/978-94-007-3949-9_14, Springer Science+Business Media Dordrecht 2012

RBMPs, (2021). River Basin Management Plans. Latvian Environment, Geology and Meteorology Centre. https://videscentrs.lvgmc.lv/lapas/udens-apsaimniekosana-un-pludu-parvaldiba#58821703

Sadurzki, A. (2005). Transboundary groundwater bodies as a task of the Polish state hydrogeological survey. Polish Geological Institute Special Papers, 18 (2005): 79–85. https://www.pgi.gov.pl/en/docman-tree-all/publikacje-2/special-papers/87-sadurski/file.html

SIA "Firma L4", (2006). Izstrādes un rekultivācijas tehniskais projekts "Dolomīta ieguve atradnē "Ape" (Quarrying and recultivation technical project "Dolomite mining at the "Ape" quarry"). SIA "Firma L4", Riga, 2006. State Geological Fund archive inventory No.16452

SIA "Zemes Puse, (2015). *Pārskats par atlikuši dolomītu krājumu aprēķinu atradnē "Ape-1966.g.", ieguves licences Nr.8/291 laukumā* (Overview of the calculation of the remaining dolomite reserves in the quarry "Ape-1966", mining license No.8/291 area). SIA "Zemes Puse", Riga, 2015. State Geological Fund archive inventory No.24633

Solovey, T., Rafał, J., Małgorzata, P., [...] M., Piasecka, A. (2021). Assessment of the resources of transboundary groundwater reservoirs for the 2 pilot areas. EU-WATERRES project WP3-Harmonization of transboundary groundwater monitoring, pp 97. http://eu-waterres.eu/news-resources/resources/

Uil, H., van Geer, F.C, Gehrels, J.C., Kloosterman, F.H. (1999). UN/ECE Task Force on Monitoring and Assessment. State of the art monitoring and assessment of groundwaters.

UNECE, (2000) UNECE Task Force on Monitoring and Assessment: Guidelines on Monitoring and Assessment of Transboundary Groundwater

UNESCO, (2020). Guidelines for Monitoring Strategies in Transboundary Aquifers: Goals, Methods and Tools. The Case of the DRIN project (ALB-MTN)

Water Convention, (1992). Convention on the Protection and Use of Transboundary Watercourses and International Lakes. United Nations Economic Commission for Europe (UNECE). February 1992, https://unece.org/fileadmin/DAM/env/water/pdf/watercon.pdf

WFD, (2000). Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy

Annex I. **Required information of transboundary monitoring points**

| **Factor** | **Chemical monitoring points** | **Quantitative monitoring points** |
|---|---|---|
| GW station name | E | E |
| International code for the GW station | E | E |
| National code for the GW station | E | E |
| Location – longitude and latitude | E | E |
| Groundwater body | E | E |
| Monitored aquifer(s) | E | E |
| Filter interval, m | E | E |
| Site type – well or spring | E | E |
| Type of monitoring point – national monitoring, additional monitoring, drinking water supply monitoring and any other usage | E | E |
| Purpose (s) of monitoring site – surveillance, operational or any other | E | E |
| Vulnerability | E | D |
| Visual materials (including land use and pressures, potential sources or point pressures) | E | D |
| Start of observation | D | D |
| Construction details | D | D |

E - Essential, D - Desirable

## Annex II. **Groundwater monitoring points in Latvian-Estonian transboundary pilot area**

| Nr. | Country | Station name | National code | Database | International code | GWB | Y | X | Type | Monitoring type | Aquifer | Screen interval, from | Screen interval, to | Start of monitoring | Quality | Quantity | Purpose | Location type** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | EST | Tõrva pk | SJA9243000 | 7588 | EESJA9243000 | 24 | 614650 | 428657 | well | National | $D_2$ar+br | 48.3 | 133.5 | 1995 | YES | YES | Surveillance | Forest and seminatural areas |
| 2. | EST | Misso suurfarm | SJA6773000 | 10722 | EESJA6773000 | 26 | 693403 | 389028 | well | National | $D_3$ | 44 | 70 | 2008 | YES | NO | Surveillance | Forest and seminatural areas |
| 3. | EST | Õisu | SJA7121000 | 7592 | EESJA7121000 | 23 | 589928 | 450231 | well | National | $D_2$ | 16.6 | 18.5 | 1995 | YES | YES | Surveillance | Agricultural areas |
| 4. | EST | Valga, Transporditn 1 | SJA2670000 | 8485 | EESJA2670000 | 24 | 621469 | 407529 | well | National | $D_2$ar+br | 50 | 80 | 2007 | YES | NO | Surveillance | Artificial surfaces |
| 5. | EST | Varstu alevik | SJA9725000 | 10890 | EESJA9725000 | 25 | 658874 | 392320 | well | National | $D_2$ | 83 | 123 | 2008 | YES | NO | Surveillance | Artificial surfaces |
| 6. | EST | Lüllemäe | SJB3122000 | 11890 | EESJB3122000 | 25 | 641363 | 403306 | well | National | $D_2$tr | 74.2 | 90 | 2018 | YES | NO | Surveillance | Artificial surfaces |
| 7. | EST | Krabi põhikooli puurkaev | SJA8742000 | 13376 | EESJA8742000 | 25 | 668863 | 388200 | well | National | $D_2$; gQIII | 9.6 | 15.5 | 2014 | YES | YES | Surveillance | Agricultural areas |
| 8. | EST | not applicable | SJB1928000 | 10656 | EESJB1928000 | 25 | 684137 | 392623 | well | National | $D_2$ | 153.1 | 189.3 | 2018 | NO | YES | - | Agricultural areas |
| 9. | EST | Misso vald, Kaubi küla, Vetevana kinnistu | SJB1843000 | 24521 | EESJB1843000 | 26 | 690736 | 387283 | well | National | $D_3$ | 42 | 70 | 2018 | NO | YES | - | Forest and seminatural areas |
| 10 | EST | Lillemäe | SJA7579000 | 11495 | EESJA7579000 | 25 | 641226 | 403275 | well | National | $D_2$tr | 75.5 | 100 | 2014 | YES | NO | Surveillance | Artificial surfaces |
| 11. | EST | Ahero-Alakonnu talu, Mähkli küla, Antsla vald, Võrumaa | SJA9623000 | - | EESJA9623000 | 25 | 647952 | 400223 | well | National | $D_2$ | - | - | 2014 | YES | NO | Surveillance | Agricultural areas |
| 12. | EST | Paanikse kordonelamu | SJA7613000 | 15122* | EESJA7613000 | - | 600085 | 437668 | well | National | Q | 10.3 | 30.8 | 2013 | YES | NO | Surveillance | Agricultural areas |
| 13. | EST | Reemniku | SJA1400000 | 7598 | EESJA1400000 | 24 | 626876 | 408539 | well | National | $D_2$ar | 24.53 | 40.06 | 1995 | YES | YES | Surveillance | Agricultural areas |
| 14. | LAT | Zīļu avots | 914 | 24563 | LV914D6_24563 | D6 | 662194 | 379621 | spring | National | $D_3$pl | - | - | 2006 | YES | NO | Surveillance | Forest and seminatural areas |
| 15. | LAT | Spiģu avots | 912 | 24554 | LV912A10_24561 | A10 | 559401 | 417349 | spring | National | $D_2$br | - | - | 2004 | YES | NO | Surveillance | Forest and seminatural areas |
| 16. | LAT | Govs avots | 905 | 24561 | LV905A10_24554 | A10 | 592941 | 405687 | spring | National | $D_2$br | - | - | 2005 | YES | NO | Surveillance | Forest and seminatural areas |
| 17. | LAT | Rimeikas | 391RIM | 22652 | LV391RIMA10_22652 | A10 | 560544 | 407112 | well | National | g$Q_3$ltv | 3.7 | 5.7 | 2010 | YES | YES | Surveillance | Agricultural areas |
| 18. | LAT | Rimeikas | 391RIM | 9601 | LV391RIMA10_9601 | A10 | 560984 | 407442 | well | National | g$Q_3$ltv | 3.2 | 5.6 | 1973 | YES | YES | Surveillance | Forest and seminatural areas |
| 19. | LAT | Rimeikas | 391RIM | 9600 | LV391RIMA10_9600 | A10 | 560985 | 407436 | well | National | $D_2$br | 35.8 | 40.2 | 1973 | YES | YES | Surveillance | Forest and seminatural areas |
| 20. | LAT | Rimeikas | 391RIM | 9602 | LV391RIMA10_9602 | A10 | 560544 | 407111 | well | National | $D_2$br | 23.3 | 28.2 | 1973 | NO | YES | - | Agricultural areas |
| 21. | LAT | Rimeikas | 391RIM | 22653 | LV391RIMA10_22653 | A10 | 560818 | 407312 | well | National | g$Q_3$ltv | 3.5 | 5.8 | 2008 | NO | YES | - | Agricultural areas |
| 22. | LAT | Valka | 240SED | 9637 | LV290VLKD5_9637 | A8 | 618372 | 403774 | well | National | $D_2$ar | 97.5 | 122 | 1980 | YES | YES | Surveillance | Artificial surfaces |

**Annotations:**

* The monitoring point is linked to GWB 23

** Based on CORINE Land Cover 2018 data

(grey shading) No active monitoring point