Interreg Estonia-Latvia project No.Est-Lat155
“Joint actions for more efficient management of common groundwater resources (WaterAct)”

JOINT REPORT

on WP2 activities AT.2.2 “Assessment of the status of transboundary groundwater bodies according to harmonized principles”, AT.2.3 “Development of transboundary monitoring strategy” and AT.2.4 “Spring monitoring optimization and watershed modeling”

2022

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ABBREVIATIONS

CIS – Common Implementation Strategy

DEM – Digital Elevation Model

EC – European Commission

EEA – Estonian Environment Agency

EQs – Environmental Quality Standard

EU – European Union

GDTE – Groundwater dependent terrestrial ecosystem

GWB – Groundwater body

GWL – Groundwater level

JSC – Joint Stock Company

LEGMC – Latvian Environment, Geology and Meteorology Centre

LV – Limit value

NCA – Nature Conservation Agency

PA – Protected area

RBMP – River Basin Management Plan

RBD – River Basin District

TV – Threshold value

UN-ECE - United Nations Economic Commission for Europe

WP – Work Package

WFD – Water Framework Directive

INTRODUCTION

Groundwater is not limited to national borders, and therefore requires common action and management to improve and preserve water quality and conservation across the borders. According to the EU Water Framework Directive (2000/60/EC), member states should cooperate to ensure a sustainable management of the shared groundwater resources.

Estonia and Latvia started the first joint activities in the management of common groundwater resources in 2018, within the framework of the GroundEco project[1], where a methodology for the identification and asssessment of groundwater-dependent terrestrial ecosystems was developed and implemented in the Gauja/Koiva river basin. However, project “Joint actions for more efficient management of common groundwater resources (WaterAct)” is a continuation of the successful cross-border cooperation between the Latvian and Estonian authorities. The main activity of the project is to establish joint principles for assessment of transboundary groundwater bodies in line with EU water policy and management of common groundwater resources. Agreed principles[2] were implemented in transboundary Gauja/Koiva and Salaca/Salatsi river basins, based on which the first assessment of transboundary GWBs was carried out.

This report summarizes information on the activities carried out in WP2, in connection with the assessment of transboundary GWBs (activity AT.2.2), the development of a joint transboundary monitoring program (activity AT.2.3), as well as the optimization of the monitoring network (activity AT.2.4). Report also provides recommendations for future transboundary groundwater management, which includes various aspects. All results from WP2 activities will be used for development of RBMPs, which could improve the management of transboundary groundwater resources.

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[1] Interreg Estonia-Latvia project No. Est-Lat62 “Joint management of groundwater dependent ecosystems in transboundary Gauja-Koiva river basin (GroundEco)” Available: https://www.meteo.lv/fs/CKFinderJava/userfiles/files/Par_centru/ES_projekti/GroundEco/GroundEco_final_report.pdf

[2] WaterAct project report on WP1 “Capacity building through exchange of knowledge and best management practices” activities T1.1-T1.4. Riga, 2022

1. ASSESSMENT OF THE STATUS OF TRANSBOUNDARY GROUNDWATER BODIES ACCORDING TO HARMONIZED PRINCIPLES

The main objective of this activity is to assess the status of transboundary groundwater bodies (GWBs) in Salaca/Salatsi and Gauja/Koiva river basins according to the harmonized principles developed in WP1 activity AT.1.2 (Valters et al., 2022), in the line with the requirements of European level groundwater policies.

1.1. Delineation of Latvian-Estonian transboundary GWBs

The first step before assessing transboundary groundwater resources was to understand which aquifer systems in Latvian-Estonian border area are interconnected, so the first activity was delineation of transboundary GWBs. In Estonia, so far, no transboundary GWBs have been delineated, while in Latvia, GWBs were delineated with Lithuania in 2018, within the framework of the B-solutions project[3].

There are some EC guidelines and recommendations developed for the transboundary groundwater identification and management, however, detailed, specific methodologies are not available, also each country has different geological and hydrogeological conditions, as well as different approaches to the assessment and management of their groundwater resources.

In order to gain the knowledge capacity and accumulate experience, in the Wateract project, as part of the AT.1.1 activity, case studies of the experiences and best practices of other countries in the management and assessment of common groundwater resources were studied (Valters et al., 2022). Based on the knowledge gained, the most appropriate approach was chosen for Latvian-Estonian case study.

In general, the delineation process took place in two stages: (1) data collection (exchange) and (2) identification of related GWBs by analyzing the obtained information and available data.

1.1.1. Data collection

Both countries exchanged geological and hydrogeological information, as well as the spatial data of national GWBs. To make all information easily available to all partners, all data and materials are stored in an external data storage - pCloud drive. Likewise, the countries exchanged with national groundwater assessment approaches and methodologies - GWB delineation approach, anthropogenic pressure assessment, GWB quantitative and chemical state assessment methodologies. All these methods and approaches are described in more detail in Valters et al., (2022).

Regarding GWB delineation – these methods are slightly different, because in Estonia GWBs were delineated taking into account RBD boundaries, while in Latvia GWBs were delineated taking into account hydrogeological conditions and watersheds.

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[3] 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”.

Nevertheless, after assessing all available information, it was concluded that the geological stratigraphy in both countries are quite similar. The bedrock of the Devonian aquifer system is mainly distributed on the Latvian-Estonian border, which is also the main source of drinking water in the border area.

1.1.2. Identification of transboundary groundwater bodies in Latvian-Estonian border area

After all necessary information was collected, the next step was the identification of transboundary GWBs. A total of 10 GWBs have been identified on the Latvian-Estonian cross-border area – 6 GWBs on the Estonian side and 4 on Latvian side (Figure 1).

In Latvia and Estonia, GWBs are also delineated in vertical scale, so in order to assess similar GWBs, they were grouped into 3 groups according to their geological affiliation: GWBs in (1) Lower-Middle Devonian aquifer system, (2) Middle-Upper Devonian aquifer system, (3) Upper Devonian system (Figure 2).

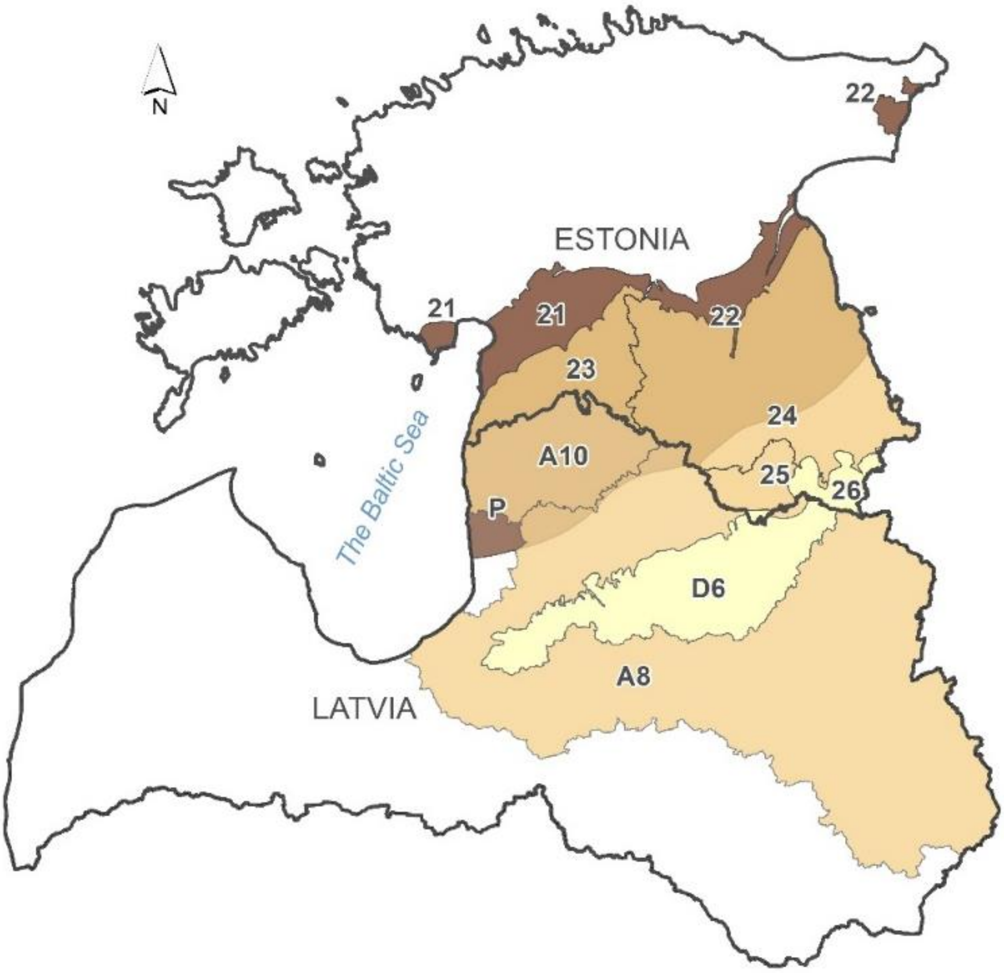


Figure 1. **Groundwater bodies in Latvian-Estonian border area**

The hydrogeological model for Baltic artesian basin (PUMA model) was used to determine the Latvian-Estonian cross-border hydrogeological conditions and hydrodynamic processes. The model was used for developing geological cross-sections, detecting groundwater flows and watersheds, which are important to understand the transboundary groundwater situation in total.

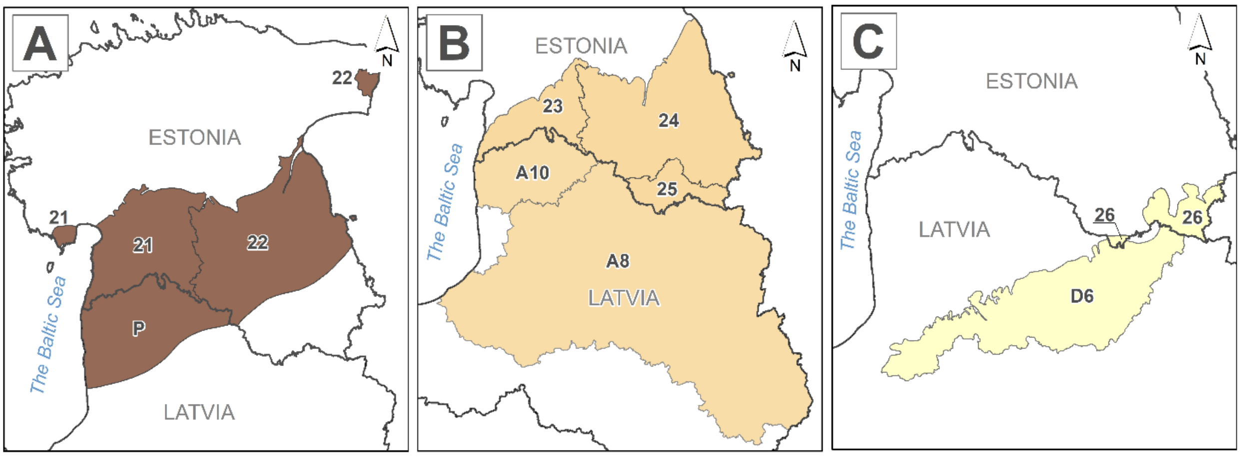


Figure 2. **Latvian-Estonian GWBs in: A – Lower-Middle Devonian aquifer system; B – Middle-Upper Devonian aquifer system; C – Upper Devonian aquifer system**

1.1.2.1. GWBs in Lower-Middle Devonian aquifer system

On the Latvian-Estonian border, 3 GWBs have been identified in the Lower-Middle Devonian aquifer system (Estonian GWBs 21, 22, Latvian GWB P) (Figure 3). All three GWBs are located in different RBD. In these deeper geological layers, the hydrogeological conditions are relatively homogeneous and the groundwater flows do not coincide with the boundaries of the RBD. In Estonia, Lower-Middle Devonian GWBs have been delineated, including the Tilže-Pärnu (D_{1-2}*tl-pr*) aquifers, in Latvia - Ķemeri-Pernava (D_{1-2}*km-pr*). The main deposits that form the aquifer layers is sandstone. Local aquitards are formed by siltstone clay interlayers and dolomitic marl.

According to the PUMA model data, the recharge zone of this aquifer system is located in the south-eastern part of Estonia, but discharge zone is located in the Gulf of Riga and the the Baltic Sea. The modeled watershed shows that the groundwater flow of GWB 21 and P is directed to the Gulf of Riga and the Baltic Sea, while in the GWB No. 24 the groundwater flow mainly is directed in the opposite direction - to Lake Peipus.

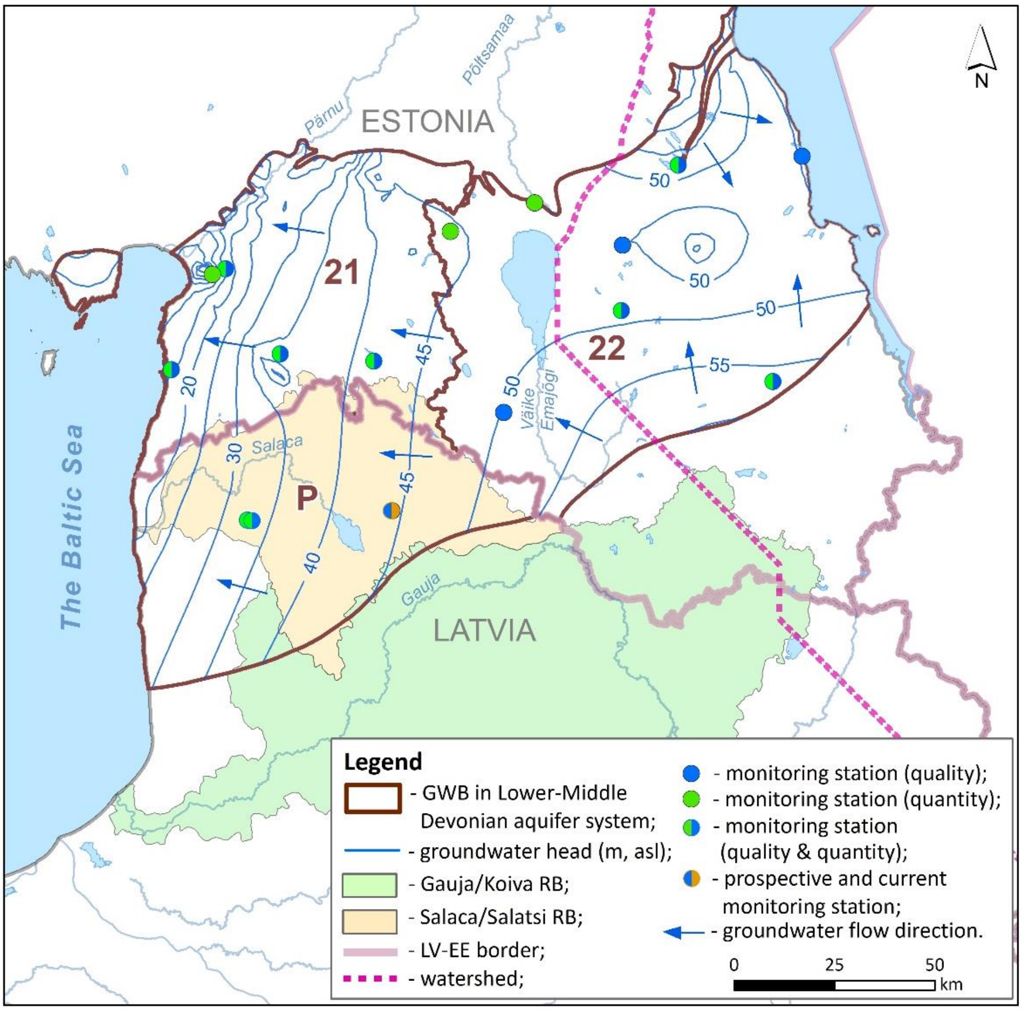


Figure 3. **Groundwater bodies in Lower-Middle Devonian aquifer system**

1.1.2.2. GWBs in Upper-Middle Devonian aquifer system

In the Upper-Middle Devonian aquifer system 5 GWBs have been delineated - Estonian GWBs 23, 24, 25 and Latvian GWB A10 and A8 (Figure 4). In both countries, GWBs in the Upper-Middle Devonian aquifer system consist of Aruküla-Amata (D$_{2\text{-}3}$*ar-am*) aquifers. The main rock that forms the aquifer layers is sandstone. Local aquitards are formed by siltstone, clay and dolomite marl. In these GWBs, groundwater flows more correlate with RBD boundaries.

Groundwater flows and watersheds from the hydrogeological model shows that GWBs 23 with A10 and 25 with A8 could be assumed as transboundary GWBs. GWB 24 watershed coincides with the Estonian-Latvian border line (also RBD boundary) and according to the model information and existing data, groundwater does not flow across the state border (no significant transboundary groundwater flow).

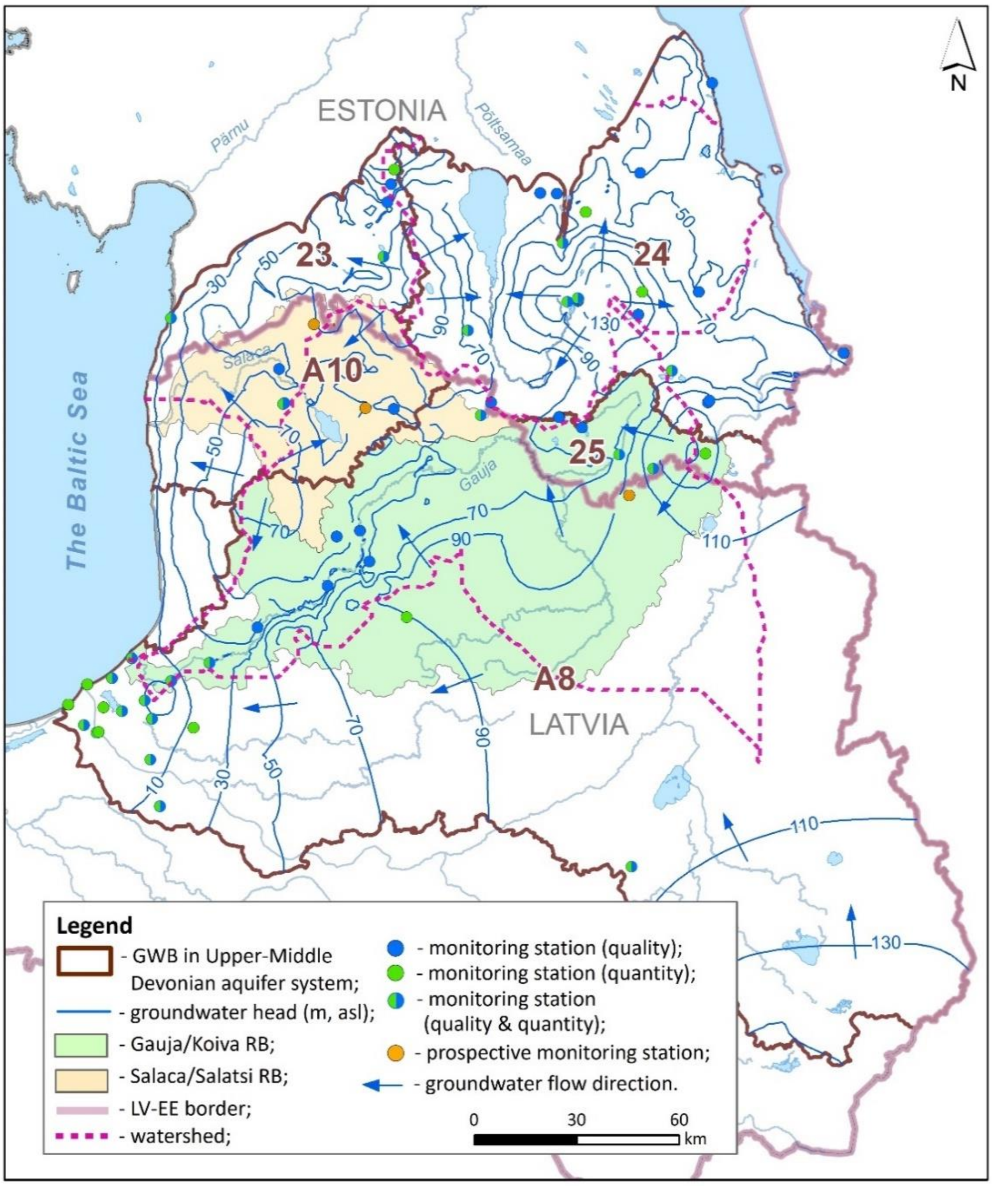


Figure 4. **Groundwater bodies in Upper-Middle Devonian aquifer system**

1.1.2.3. GWBs in Upper Devonian aquifer system

In the Upper Devonian aquifer system, two GWBs have been identified - GWB 26 (in Estonia) and D6 (in Latvia) (Figure 5). Both GWBs are located in the Gauja/Koiva RBD. GWBs consist of the Pļaviņas-Amula (D_3*pl-aml*) aquifers system. The main sediments that form the bedrock are sandstone, dolomite, and also limestone on the Estonian side. The local aquitards are mainly composed of dolomite marl, marl, siltstone, clay and gypsum.

Considering that these are uppermost GWBs, groundwater flows coincide with the boundaries of the Gauja catchment area. According to the modeled groundwater flows, GWB 26 flows across the state border, into the territory of Latvia.

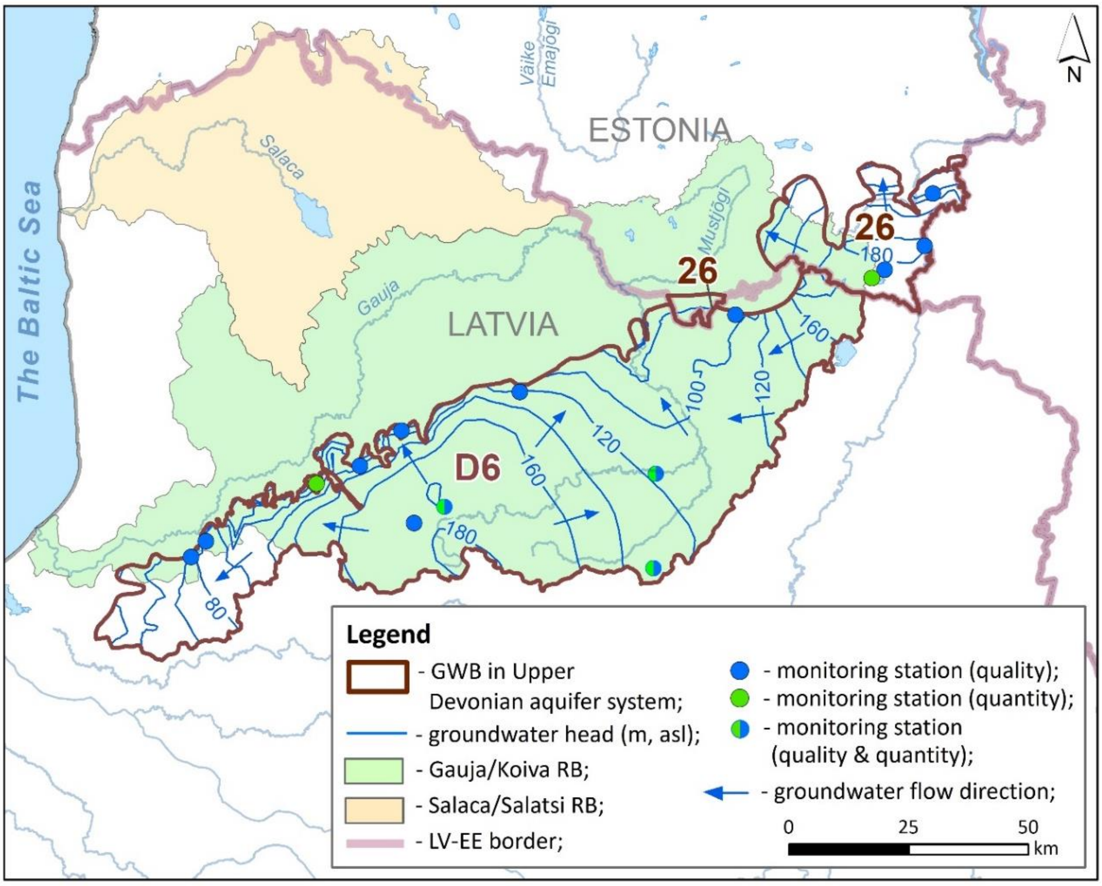


Figure 5. **Groundwater bodies in Upper Devonian aquifer system**

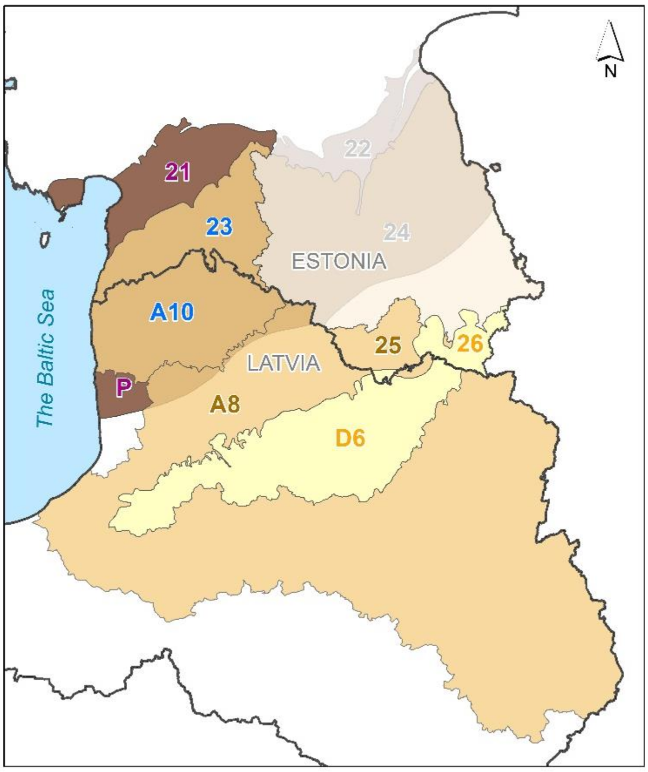
1.1.3. The results on the delineation of Latvian-Estonian transboundary GWBs

In the Lower-Middle Devonian aquifer system, the hydrogeological situation is homogeneous and does not follow the river basin boundaries. Thus, although the water body in Estonia GWB 22 territory borders the border of Latvia, it is located in another river basin (East Estonia RBD) and is outside the framework of this project tasks. For these reasons, GWBs No.21, and P were considered to be hydrogeological related and it was proposed to include these two bodies in the transboundary GWB list.

In the Upper-Middle Devonian system, according to hydrogeological model groundwater flows and watersheds, interconnected transboundary GWBs could be No.23 with A10 and A8 with No.25. Due to the fact that the Estonian GWB 24 is completely located in the East Estonia RBD (not international RBD), it is not delineated as a transboundary groundwater body within the framework of this project.

In the Upper Devonian aquifer system, two GWB 26 and D6 have been identified at the Latvian - Estonian border area and both are located in the Gauja/Koiva RBD. According to the collected data and available model information, these GWBs are connected and should be included in the transboundary GWBs list.

As a result, both parties agreed that a total of 8 GWBs in the Gauja/Koiva and Salaca/Salatsi river basins are considered as transboundary (see Figure 6).



List of transboundary GWBs in Gauja/Koiva & Salaca/Salatsi RBs

Latvian GWBs	Estonian GWBs
Upper Devonian aquifer system	
D6	**26**
Middle - Upper Devonian aquifer system	
A8 A10	**25 23**
Lower - Middle Devonian aquifer system	
P	**21**

Figure 6. **Agreed transboundary groundwater bodies in Latvian-Estonian border area**

1.2. Initial characterization of Latvian-Estonian transboundary GWBs

In order to fulfill the requirements of WFD, the next step after GWB delineation is the characterization of the transboundary GWBs by combining the available information on the characteristic parameters for the inter-connected GWBs of both states. In Table 1, the joint Latvian-Estonian GWBs were grouped together, and the table indicates the general characteristics of these bodies. Also, descriptions of these GWBs are provided in the following subchapters 1.2.1 - 1.2.4. More detailed information for each GWB is provided in GWB conceptual models (see Annex 1).

TABLE 1

Initial characterization of joint Latvian-Estonian GWBs

Transboundary GWBs	National GWB	Area (km²)	Total Area (km²)	Aquifer characterization		Main use	Overlying strata (m)	Criteria for importance
				Aquifer Type	Confined			
GWB-1 Upper Devonian	D6	4891	5617.1	F, P	Yes	DRW, IND	0-180	GW resources; GW use
	26	726.1						
GWB-2 Upper-Middle Devonian	A8	27349	28 671	P	Yes	DRW, IND	0-200	GW resources; GW use
	25	1322						
GWB-3 Upper-Middle Devonian	A10	3321	5662	P	Yes	DRW, IND	0-155	GW resources; GW use
	23	2341						
GWB-4 Lower-Middle Devonian	P	4394	8844	P	Yes	DRW, IND	0-280	GW resources; GW use
	21	4450						

Aquifer Type – P- Porous, K - Karstic, F - Fissured
Main use - DRW = Drinking water / AGR = Agriculture / IRR = Irrigation / IND = Industry / GW resources, DRW protection, dependent ecosystems; > 4000 km², GW use, GW resources
SPA = Balneology / CAL = Caloric energy / OTH = Other. Multiple selections possible.
Overlying strata Indicates a range of thickness (minimum and maximum in meters)

1.2.1. GWB-1 in Upper Devonian aquifer system

The Upper Devonian transboundary GWBs are located mainly in the Gauja/Koiva river basin. The total area is about 5617 km^2, most of which or 4891 km^2 is on the Latvian side, while on the Estonian side is about 726 km^2. A small part of the Latvian GWB D6 is also located in the Daugava RBD, while the territory of the Estonian GWB 26 partly belongs to the East Estonian RBD.

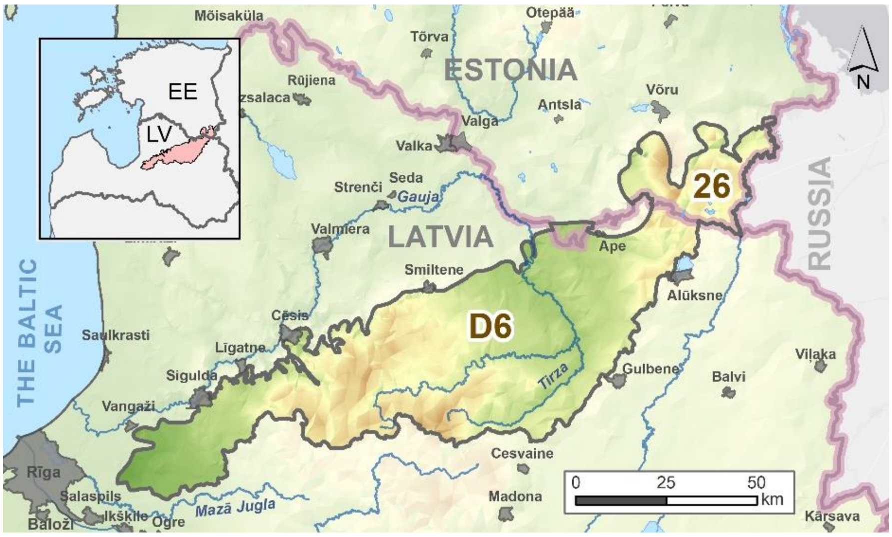


Figure 7. **Transboundary GWBs in Upper Devonian aquifer system**

Geology. The bedrock consists mainly of dolomites and sandstones on the Latvian side, while limestones and dolomitized limestones are more common closer to the Estonian border and on the Estonian side. The average thickness of the bedrock is about 30 - 40 m, reaching up to 100 m locally in the highlands. Overlying strata consist of Quaternary sediments: loam, loamy till, sand and clay. Average thickness of quaternary sediments is about 30-50 m in plains and valleys, reaching up to 75-135 m in the Vidzeme and Haanja upland.

Recharge-discharge. Main recharge areas are located in Vidzeme upland (central part of Latvia) and at the border area – *Alūksne* (Latvia) and *Haanja* (Estonia) uplands, while the discharge occurs in topographically lower regions – *Tālava* lowland in Latvia and *Hargla* depression in Estonia.

Groundwater quality, water abstraction. Aquifer system consists mainly of Ca-Mg-HCO_3 type freshwaters with mineralization up to 1 g/l. Elevated concentrations of sulphate ions (SO_4^{2-}) above 250 mg/l have been observed locally at the north-east part of Latvia (at the Estonian border area), where layers of gypsum are distributed.

Groundwater from this aquifer system is mainly used for drinking water supply. In Latvia, these aquifers are widely used for the drinking water abstraction of both individual households and for the centralized water supply of cities, as well as for industrial needs. In Estonia, these aquifers are mainly used for drinking water by individual households, because the extent and the thickness of the aquifer is limited.

On the Estonian side, water abstraction in 2018 was approximately 85 m^3/d, while total natural groundwater reserves were estimated at 221586 m^3/d. In Latvia, groundwater abstraction from well-fields in 2019 was 1147.69 m^3/d, but the approved resources from well-fields is 3884 m^3/d. The available groundwater resources or approved resources in the Upper Devonian aquifers in both Latvia and Estonia are significantly larger than water abstraction and do not pose a threat to the quantitative status of transboundary groundwater bodies.

Anthropogenic pressure. Although the pressure assessment methodologies are very different in both countries (Valters et al., 2022) in the Upper Devonian aquifer system, significant point, diffuse and water abstraction pressure in the transboundary GWBs on the Latvian and Estonian sides have not been identified according to the pressure assessment methodologies (Valters et al., 2022).

TABLE 2

Summary of the pressures in Latvian-Estonian transboundary GWBs in Upper Devonian aquifer system (Marandi et al., 2020; LEGMC, 2021)

Aquifer system	GWB	Point source pressure	Diffuse source pressure	GW abstraction
1. Upper Devonian	26	*Not significant*	*Not significant*	*Not significant*
	D6	*Not significant*	*Not significant*	*Not significant*

1.2.2. GWB-2 in Upper-Middle Devonian aquifer system

Terrain is diverse because of its wide area. West part is covered by plains and wavy plains, in north and east - plains and wavy plains alternate with small hills, medium high and high hillsides, while the central and south-eastern part basically consists of small hills, as well as medium and high hills. The absolute height of the terrain varies up to 311.5 m a.s.l.

The total area is about 28671km^2, most of which or 27349 km^2 (GWB A8) is on the Latvian side, while on the Estonian side is about 1322 km^2 (GWB 25). Largest part of the Latvian GWB A8 is located also in the Daugava RBD.

Figure 8. **Transboundary GWBs in Upper-Middle Devonian aquifer system**

Geology. Geological structure that forms the Upper-Middle Devonian aquifer system is composed of porous rocks - sandstones with siltstone and clay interlayers. The thickness of the bedrock aquifers is in the range of 115-300 m. Most of the territory (about 80%) is covered by the geological strata (dolomites, limestones) of the Upper Devonian system (incl. GWBs D6 and 26). Overlapping quaternary layer consists mainly of glaciofluvial sand, gravel, loam and clay sediments. The thickness of the Quaternary sediments is mostly from 5-25 m up to 55-190 m (60-80 m average).

Recharge-discharge. In Latvia, the recharge zones of GWB A8 are mainly located in the uplands (Vidzeme, Alūksne and Latgale uplands), while the discharge zone is located in lower relief areas, the Gulf of Riga and the cross-border area. In Estonia, groundwater flows from the recharge areas in the *Karula* and *Haanja* Uplands to discharge areas in the lower lying regions. The amount of recharge is dependent on the thickness and composition of the Quaternary sediments.

Groundwater quality, water abstraction. Aquifer system consists mainly of Ca-Mg-HCO_3 type freshwaters with mineralization up to 1 g/l. Groundwater has a naturally high iron (Fe) content. Na-Cl type brackish waters (mineralization > 1g/l) may be found in the vicinity of the city of Riga (Great Riga Depression cone). Groundwater with increased mineralization is not present in the Latvian-Estonian cross-border area.

This aquifer system contains abundant groundwater resources. These aquifers are widely used for the drinking water abstraction of both individual households and for the centralized water supply of cities, as well as for industrial needs. On the Latvian side (GWB A8) according to data, in 2019 there were 100 active well fields. In Estonia, the Upper-Middle Devonian aquifer system (GWB 25) is used mainly for the water supply for households, because it is much less distributed compared to Latvian part (GWB A8).

On the Estonian side, water abstraction in 2018 was approximately 164 m^3/d, while total natural groundwater reserves were estimated at 536689 m^3/d. In Latvia, the groundwater abstraction from well-fields in 2019 was 49 722.45 m^3/d, but the approved resources from well-fields is 180 680 m^3/d. The available groundwater resources or approved resources in the Upper-Middle Devonian aquifers in both Latvia and Estonia are significantly larger than water abstraction and do not pose a threat to the quantitative status of transboundary groundwater bodies.

Anthropogenic pressure. No significant anthropogenic pressure has been identified in the transboundary groundwater bodies of the Upper and Middle Devonian aquifers on the Estonian side according to the national pressure assessment methodology. Significant anthropogenic pressure in Latvia has been identified in GWB A8 (see Table 3).

TABLE 3

Summary of the pressures in Latvian-Estonian transboundary GWBs in Upper-Middle Devonian aquifer system (Marandi et al., 2020; LEGMC, 2021)

Aquifer system	GWB	Point source pressure	Diffuse source pressure	GW abstraction
2. Upper-Middle Devonian	25	*Not significant*	*Not significant*	*Not significant*
	A8	*Significant*	*Not significant*	*Not significant*

In the Latvian GWB A8 a significant point pressure has been identified. In this case, it has been done on a precautionary basis, taking into account the concentration of contaminating sites and the presence of regional as well as local depression cones and the potential risk to water abstraction sites. (LEGMC, 2021). The territory of the risk zone “Riga territory from the Gulf of Riga to the “Getliņi” landfill”, where only shallow groundwater pollution was observed, was identified as a significant point pollution pressure in the surface exposed part of GWB A8 (LEGMC, 2021). GWB A8 covers a large part of the territory of Latvia (see Figure 8) and a significant point-pressure is detected in the territory of Riga and its surroundings. In the border area (with Estonia), point-pressure is insignificant and does not potentially pose a threat to transboundary groundwater resources.

1.2.3. GWB-3 in Upper-Middle Devonian aquifer system

The Upper-Middle Devonian transboundary GWBs are located mainly in the Salaca/Salatsi river basin and West Estonian RBD. The total area is about 5662 km^2, most of which or 3321 km^2 is on the Latvian side, while on the Estonian side is about 2341 km^2.

Sakala upland is widespread in the eastern part of the territory, where the height of the relief reaches about 130 m above sea level. The terrain is declining towards the Baltic Sea, which borders on the west. In the western part, there is the *Piejūra* Lowland (Latvian side) and the *Pärnu* Lowland (Estonian side).

Figure 9. **Transboundary GWBs in Upper-Middle Devonian aquifer system**

Geology. Geological structure that forms the aquifer system is composed of sandstone. The local aquitards consist mainly of siltstone and clay. The thickness of the bedrock increases to the south, reaching 170 m in GWB A10, while average thickness of the bedrock is about 60-80 m. Domerite, marl and clay of the Narva regional aquitard are embedded under the aquifer system. Moraine loam, sand and clay are common in the overlapping Quaternary sediments. Average thickness of quaternary sediments are about 30-40 m in plains and lowlands, reaching up to to 100 m in the *Sakala* and *Idumeja* upland.

Recharge-discharge. The main groundwater flows are from the *Idumeja* and *Sakala* uplands (recharge areas) to the lower areas - the Salaca river valley and the adjacent plains. Groundwater mainly discharges in Gulf of Riga.

Groundwater quality, water abstraction. Aquifer system consists mainly of Ca-Mg-HCO_3 type freshwaters with mineralization up to 1 g/l. These aquifers are used for the drinking water abstraction of both individual households and for the centralized water supply of cities. On the Latvian side (GWB A10) there are 5 active well fields. In Estonia, Lower-Middle Devonian aquifer system (GWB 23) is used mainly for the water supply for households.

On the Estonian side, water abstraction in 2018 was approximately 459 m^3/d, while total natural groundwater reserves were estimated at 460246 m^3/d. In Latvia, the groundwater abstraction from well-fields in 2019 was 325.14 m^3/d, but the approved resources from well-fields is 1544 m^3/d. The available groundwater resources or approved resources in the Upper-Middle Devonian aquifers in both Latvia and Estonia are significantly larger than water abstraction and do not pose a threat to the quantitative status of transboundary groundwater bodies.

Anthropogenic pressure. No significant anthropogenic pressure has been identified in the transboundary groundwater bodies of the Upper and Middle Devonian aquifers on the Estonian side according to the national pressure assessment methodology (see Table 4).

TABLE 4

Summary of the pressures in Latvian-Estonian transboundary GWBs in Upper-Middle Devonian aquifer system (Marandi et al., 2020; LEGMC, 2021)

Aquifer system	GWB	Point source pressure	Diffuse source pressure	GW abstraction
3. Upper-Middle Devonian	23	*Not significant*	*Not significant*	*Not significant*
	A10	*Not significant*	*Not significant*	*Not significant*

1.2.4. GWB-4 Lower-Middle Devonian aquifer system

The Lower-Middle Devonian transboundary aquifer system consists of GWB P (Latvian side) and GWB 21 (Estonian side). The total area is 8844 km^2. Most of the area (76%) is covered by bedrocks of the Upper-Middle Devonian aquifer system (GWBs A10 and 23). Other part (with no overlying layers) is located on the Estonian side and is more exposed to surface pressure. The relief in this part is mostly flat – most of the territory is located in the *Pärnu* lowland. Further from the sea coast - on the eastern side, the relief is more wavy and uneven (*Sakala* upland).

Figure 10. **Transboundary GWBs in Lower-Middle Devonian aquifer system**

Geology. Geological structure that forms the aquifer system is composed of sandstone. The local aquitards consist mainly of siltstone and clay. The thickness of the bedrock increases from north to south, reaching a maximum thickness of about 114 m in Latvian GWB P. The average thickness is about 40 m. Domerite, marl and clay sediments of the Narva regional aquitard covers the Lower-Middle Devonian aquifer system and separates it from the active water exchange zone, i.e. the overlapping Upper-Middle Devonian aquifer system (GWBs A10 and 23).

Recharge-discharge. Main recharge areas are located in Estonian uplands. Groundwater mainly discharges in the Baltic Sea.

Groundwater quality, water abstraction. Aquifer system consists mainly of Ca-Mg-HCO_3 type freshwaters with mineralization up to 1 g/l. These aquifers are used for the drinking water abstraction, centralized water supply of cities and industrial use.

On the Estonian side, water abstraction in 2018 was approximately 757 m^3/d, while total natural groundwater reserves were estimated at 536689 m^3/d. In Latvia, the groundwater abstraction from well-fields in 2019 was 702.44 m^3/d, but the approved resources from well-fields is 3651 m^3/d. The available groundwater resources or approved resources in the Lower-Middle Devonian aquifers in both Latvia and Estonia are significantly larger than water abstraction and do not pose a threat to the quantitative status of transboundary GWBs.

Anthropogenic pressure. No significant anthropogenic pressure has been identified in the transboundary groundwater bodies of the Lower-Middle Devonian aquifers on the Estonian side according to the national pressure assessment methodology (see Table 5).

TABLE 5

Summary of the pressures in Latvian-Estonian transboundary GWBs in Lower-Middle Devonian aquifer system (Marandi et al., 2020; LEGMC, 2021)

Aquifer system	GWB	Point source pressure	Diffuse source pressure	GW abstraction
4. Lower-Middle Devonian	21	*Not significant*	*Not significant*	*Not significant*
	P	*Not significant*	*Not significant*	*Not significant*

1.3. Overall status assessment of Latvian-Estonian transboundary GWBs

In accordance with the requirements of the WFD, Member States should carry out joint or coordinated assessments of the conditions of transboundary waters and the effectiveness of measures taken to prevent, control and reduce transboundary impact. The assessment of Latvian-Estonian transboundary GWBs was carried out based on the harmonized methodologies, developed in WP1 Activity T.1.1 "Exchange of good practices and development of harmonized principles for groundwater assessment" (Valters et al., 2022). For the chemical and quantitative status assessment of Latvian–Estonian transboundary GWBs, a nine characterization tests were carried out (based on CIS Guidance Document No.18[4]).

1.3.1. Chemical status assessment of transboundary groundwater bodies

For the assessment of the chemical condition, five tests should be performed in general: general quality assessment (GQA) test, saline or other intrusion, groundwater-associated aquatic ecosystems, groundwater-dependent terrestrial ecosystems, as well as drinking water protected area test.

1.3.1.1. General quality assessment test

For the GQA test, in both countries the first step was to assess the exceedances of the relevant parameters/pollutants in each GWB to determine whether the exceedances affect more than 20% of the total GWB area, using the Thiessen method to determine the significance fraction (Valters et al., 2022).

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[4] Guidance document No.18, 2009. Guidance on groundwater status and trend assessment, European Communities, 2009, Common Implementation Strategy for the Water Framework Directive (2000/60/EC)

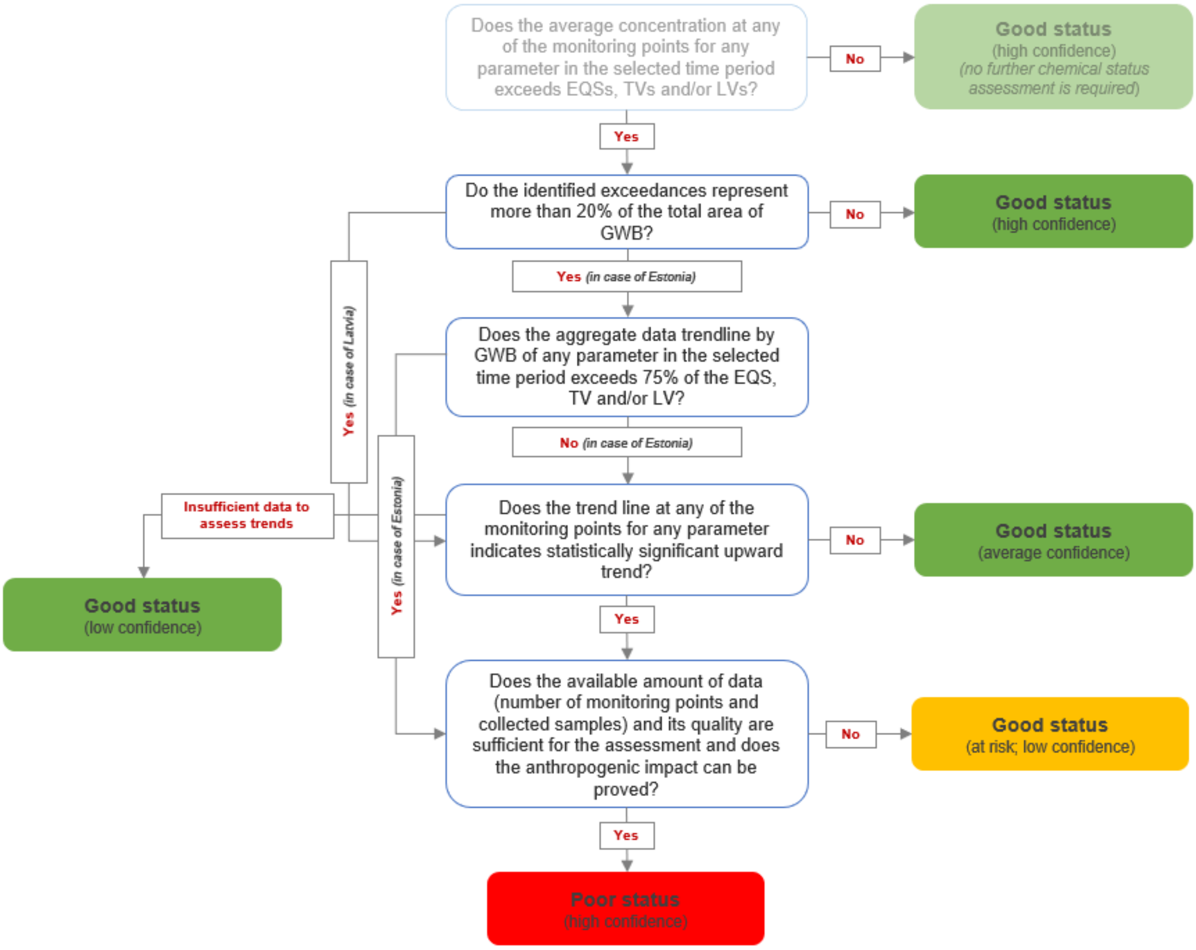

Figure 11. **Flow chart diagram of the harmonized Estonian-Latvian approach of the general quality assessment test** (Valters et al., 2022)

***Step 1**. Does the average concentration at any of the monitoring points for any parameter in the selected time period exceed EQSs, TVs and/or LVs?*

During the time period 2015-2019, an exceedance of the average concentration of bentazon was identified in the GWB D6 (1 monitoring point - *Dāvida dzirnavu* springs) and GWB A8 (1 monitoring point – *Lielā Ellīte* spring), which is related to point pollution - intensive agricultural activity near the springs (LEGMC, 2021). According to this general quality assessment (GQA) test, the next step of the scheme for GWB D6 should be carried out.

In Estonian GWB 23, the average concentrations of ammonium ions (NH_4^+) (in the period 2014-2019) have exceeded the TVs in the monitoring well No. 7592, while in the GWB 21, the chemical oxygen demand (COD) exceeds the TV in monitoring in the monitoring well No. 7568 (average concentration – 8.60 mgO/l; TV – 5 mgO/l) (Marandi et al., 2019). According to this GQA test, the next step of the scheme for GWB 23 and GWB 21 should be carried out.

In GWBs A10, P, 25 and 26, the average values of the quality indicators did not exceed the TVs in the given time period, therefore, according to the assessment procedure scheme, it is assumed that these

GWBs is in good chemical status and no further assessment tests of the chemical status should be performed.

Step 2. *Do the identified exceedances represent more than 20% of the total area of GWB?*

In the case of Latvia, both monitoring springs (*Dāvida dzirnavu* spring and *Lielās Ellītes* spring) represent less than 20% of the total territory of the GWB and do not affect the general chemical state of GWBs D6 and A8 (LEGMC, 2021). Likewise, the existing monitoring well No. 7568 in GWB 21, where the chemical oxygen demand (COD) indicator excesses were detected during the reporting period, does not represent more than 20% of the entire area of GWB 21. (Marandi et al., 2020). According to the general quality assessment scheme, if the exceedances do not affect more than 20% of the total area of GWB, it is considered to be in good status with high confidence. Accordingly, GWB D6, A8 and 21 are assumed to be in good chemical status with high confidence.

In the Estonian GWB 23 – monitoring well No. 7592, in which the average ammonium concentrations exceeded the TV/LV, represents more than 20% of the total area of GWB, or 46.9% of the total area of GWB 23 (Marandi, et al., 2019). According to the procedure of this test, it is necessary to move to the next step.

Step 3. *Does the aggregate data trendline by GWB of any parameter in the selected time period exceeds 75% of the EQS, TV and/or LV?*

The trendline of the average values of ammonium ions (NH_4^+) in the monitoring well No. 7592 (GWB 23) does not exceed 75% of the TV in the selected period (2014-2019) (see Figure 12). According to the test assessment test scheme, in the case of Estonia, it is required to move to the next step.

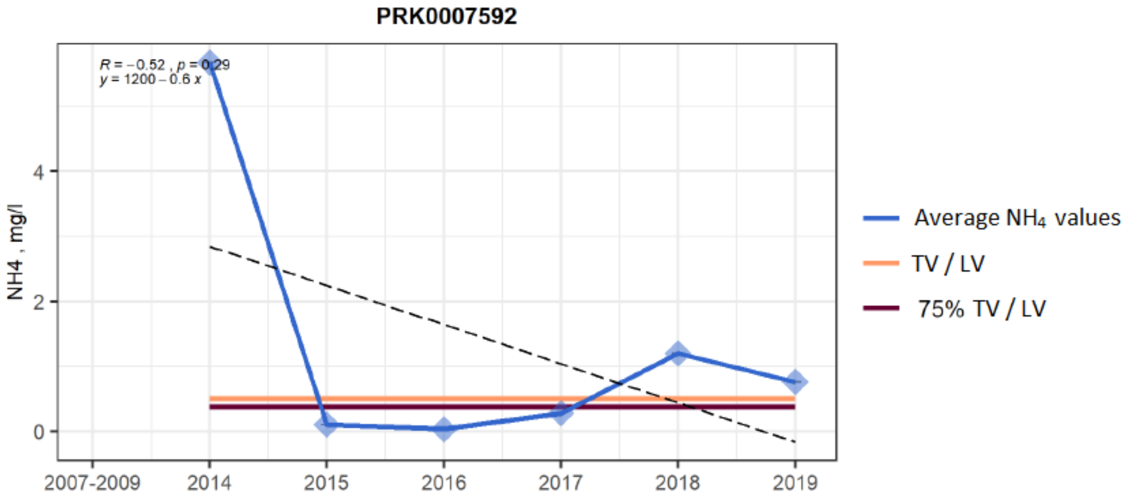

Figure 12. **Ammonium (NH_4^+) concentrations in monitoring well No. PRK0007592 (GWB 23) in the period 2014-2019** (Marandi, et al., 2019)

Step 4. *Does the trend line at any of the monitoring points for any parameter indicates statistically significant upward trend?*

In the GWB 23, the ammonium (NH_4) values in the monitoring well No. 7592 do not indicate a statistically significant upward trend. According to the assessment test, no further steps need to be carried out and the chemical status of GWB 23 is considered as good (with average confidence).

1.3.1.2. Saline or other intrusions

The assessment methods for saline water or other intrusion tests are different in Latvia and Estonia, but this project reviewed the approaches of both countries and agreed on a harmonized Estonian-Latvian approach of the saline or other intrusions test for chemical status assessment. The scheme of the common approach step-by-step is described in report Valters et al. (2022).

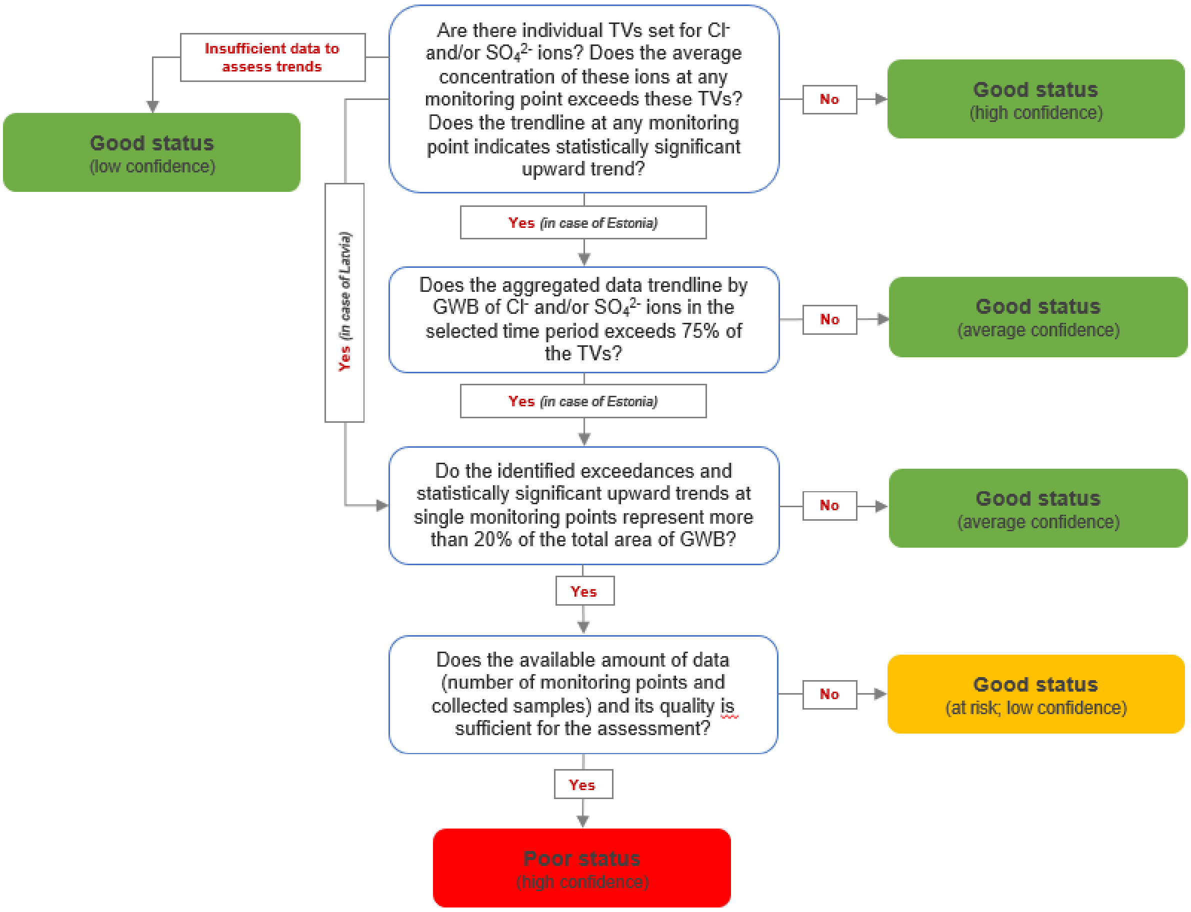

Figure 13. **Flow chart diagram of the harmonized Estonian-Latvian approach of the saline or other intrusions assessment test** (Valters et al., 2022)

***Step 1**. Are there individual TVs set for Cl^- and/or SO_4^{2-} ions? Does the average concentration of these ions at any monitoring point exceed these TVs? Does the trendline at any monitoring point indicate a statistically significant upward trend??*

The first step in the intrusion assessment procedure is the most significant in the case of Latvia and Estonia. No TVs have been set for Estonian transboundary GWBs for intrusion process indicators (Cl^- and SO_4^{2-} ions) as there is no risk of saline water or other intrusions, so no further test steps are required (Marandi et al., 2020). According to the saline or other intrusion test, all GWBs are in a good status with high confidence.

In the case of Latvia, TVs for the parameters characterizing the intrusion process (Cl^- and SO_4^{2-}) are set for each GWB.

Exceedances of the TVs were determined in GWB A8 - in several monitoring wells the average concentrations of the chloride (Cl^-) ions exceed the TV (in the case of GWB A8, the TV for Cl^- is 134 mg/l). It should be noted that GWB A8 covers a large area of Latvia and no exceedances of concentrations have been detected at the Latvian-Estonian border area, thus there is no risk of intrusion process on transboundary groundwater resources in the current situation.

Although exceedances have been detected in several monitoring points, the last criteria of the first step is about statistically significant upward trend at any monitoring point. In the case of Latvia, the available quality monitoring data set is insufficient to perform trends, so, according to the scheme, it is not necessary to perform further steps for intrusion test and the chemical status of GWB A8 is considered to be good with low confidence. In all other transboundary GWBs, the chemical status is good with high confidence.

1.3.1.3. Groundwater associated aquatic ecosystems

In Estonia, the groundwater associated aquatic ecosystem (GAAE) assessment methodology was developed and implemented already in 2015 (Terasmaa et al., 2015), while in Latvia, the development and assessment of the methodology for identifying groundwater associated aquatic ecosystems was carried out in 2021 within the project "Identification and assessment of groundwater dependent ecosystems at the level of Latvian groundwater bodies" (financed by Latvian Environmental Protection Fund) and in total in all four RBDs (including Gauja and Salaca river basins) 169 associated aquatic ecosystems (rivers, lakes, karstic features) were identified. In total, 18 ecosystems are located in the territory of Latvian-Estonian transboundary GWBs: A8 – 12; D6 - 6. (Uzule et al., 2021).

Based on the identified ecosystems and their initial assessment at the national level, a harmonized assessment scheme for these ecosystems was developed within the framework of the Wateract project. It is described in more detail in the Valters et al. (2022) report .

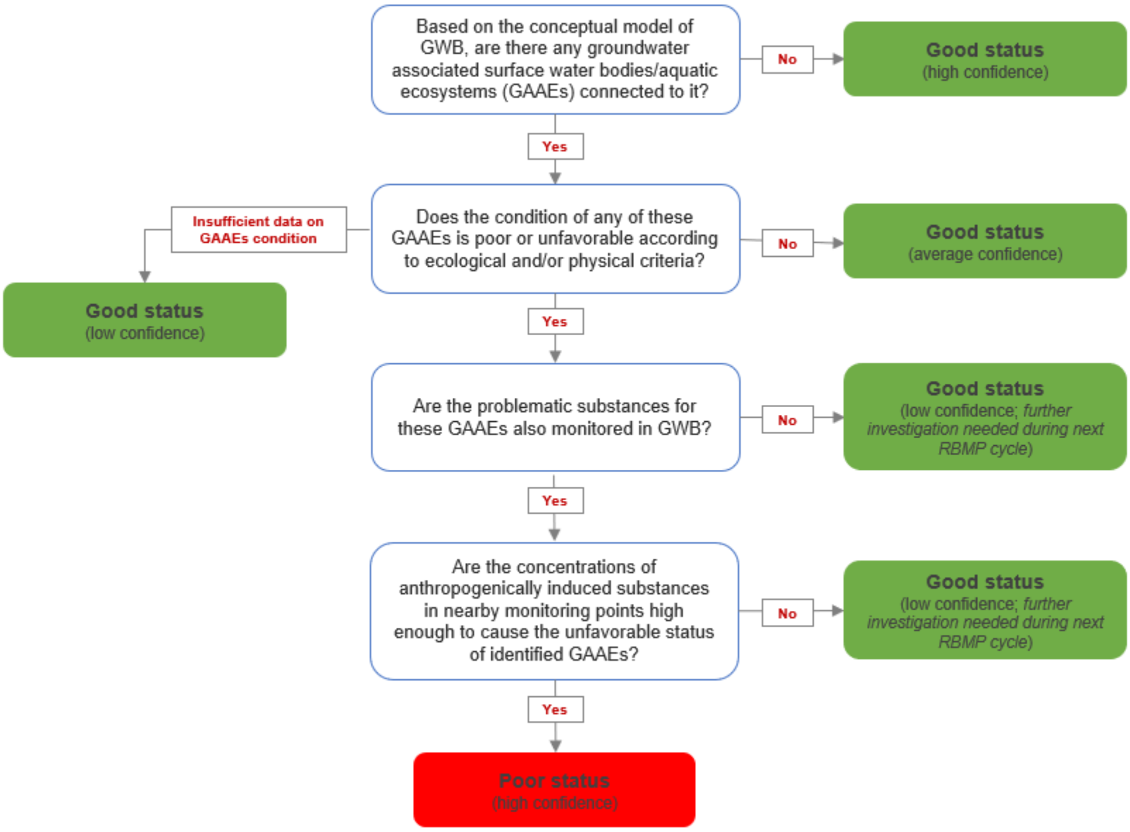

Figure 14. **Flow chart diagram of the harmonized Estonian-Latvian approach of the associated surface water bodies assessment test** (Valters et al., 2022)

Step 1. *Based on the conceptual model of GWB, are there any groundwater-associated surface water bodies/aquatic ecosystems (GAAEs) connected to it?*

According to the information specified in the conceptual models of Latvian-Estonian transboundary GWBs, a total of 30 aquatic ecosystems have been identified in transboundary GWBs: Latvian A8 -12; D6 – 6, while in Estonian GWBs 21 – 1; 23 – 3; 25 – 3; 26 – 4 (see Annex 1).

According to the results of the general quality assessment test, the other tests for GWB A10, 25 and 26 (including the groundwater dependent terrestrial ecosystems test) do not need to be performed for the assessment of the GWB chemical status

Step 2. *Does the condition of any of these GAAEs is poor or unfavorable according to ecological and/or physical criteria?*

In the GWB D6, one associated river ecosystem (*Līgatne* river) was identified, which has previously been assessed as being in good ecological status. Also, one lake ecosystem has been identified as GAAE with a good ecological condition, as well as 4 sinkholes, the condition of which is unknown. According to this test procedure, no further steps are required and the GWB D6 is assumed in good ecological status with low confidence.

A total of 12 GAAE ecosystems were identified in the territory of GWB A8, of which the status of poor ecological condition was initially assigned to a total of 4 ecosystems: 3 river water bodies (*Rauna_1, Brasla_3, Amata_2*) and 1 lake ecosystem (*Lielais Bauzis* lake).

Based on the expert's judgment, the poor ecological quality of GWB A8 ecosystems is not related to groundwaters, and there is no information that changes in the quality status of GWB would negatively affect the GAAEs (Uzule et al., 2021). According to the surface water assessment test, GWB A8 is in good chemical status with low confidence.

In the GWB 21, the river body *Pärnu_3* is assessed as having a poor quality status. According to the assessment test procedure, the next step should be carried out for further GWB 21 assessment.

In the GWB 23, the condition of the three GAAEs (*Sinialliku vooleekogum (water body code 1139900_1, Viljandi* lake *(water body code 2082800_1*) and *Õisu* lake (water body code 2089700_1)) was assessed as poor, however, according to experts' judgment, the reason for this is not the quality of groundwater (Marandi et al., 2020). Accordingly, it is not necessary to carry out further steps in this test and GWB 23 is assumed to be in good chemical status with average confidence.

***Step 3.** Are the problematic substances for these GAAEs also monitored in GWB?*

Excesses of mercury (Hg) and zinc (Zn) have been detected in the surface water ecosystem *Pärnu_3* associated with GWB 21, which, theoretically, could originate from groundwater. However, there is no available information and sufficient data to assess the situation (Marandi et al., 2020). In the future, it is planned to add mercury (Hg) and zinc (Zn) indicators to the list of monitored substances in the nearest monitoring well (Marandi et al., 2020). According to the surface water assessment test procedure, the condition of GWB 21 is assessed as good with low confidence and further investigation needed during the next river basin management planning cycle.

1.3.1.4. Groundwater dependent terrestrial ecosystems

Within the framework of the Wateract project, groundwater dependent terrestrial ecosystems were identified in the Salaca/Salatsi river basin, as well as those ecosystems that were previously identified in the Gauja river basin (during GroundEco project) were reviewed. An initial assessment of these ecosystems was also carried out using the methodology developed by the GroundEco project (Retike et al., 2020). More information on identifying the ecosystems in Salaca/Salatsi river basin is described in Chapter 1.4.

For the assessment of the status of transboundary groundwater bodies, a harmonized approach was established within the framework of the Wateract project (Valters et al., 2022) to determine whether groundwater affects the ecological status of terrestrial ecosystems.

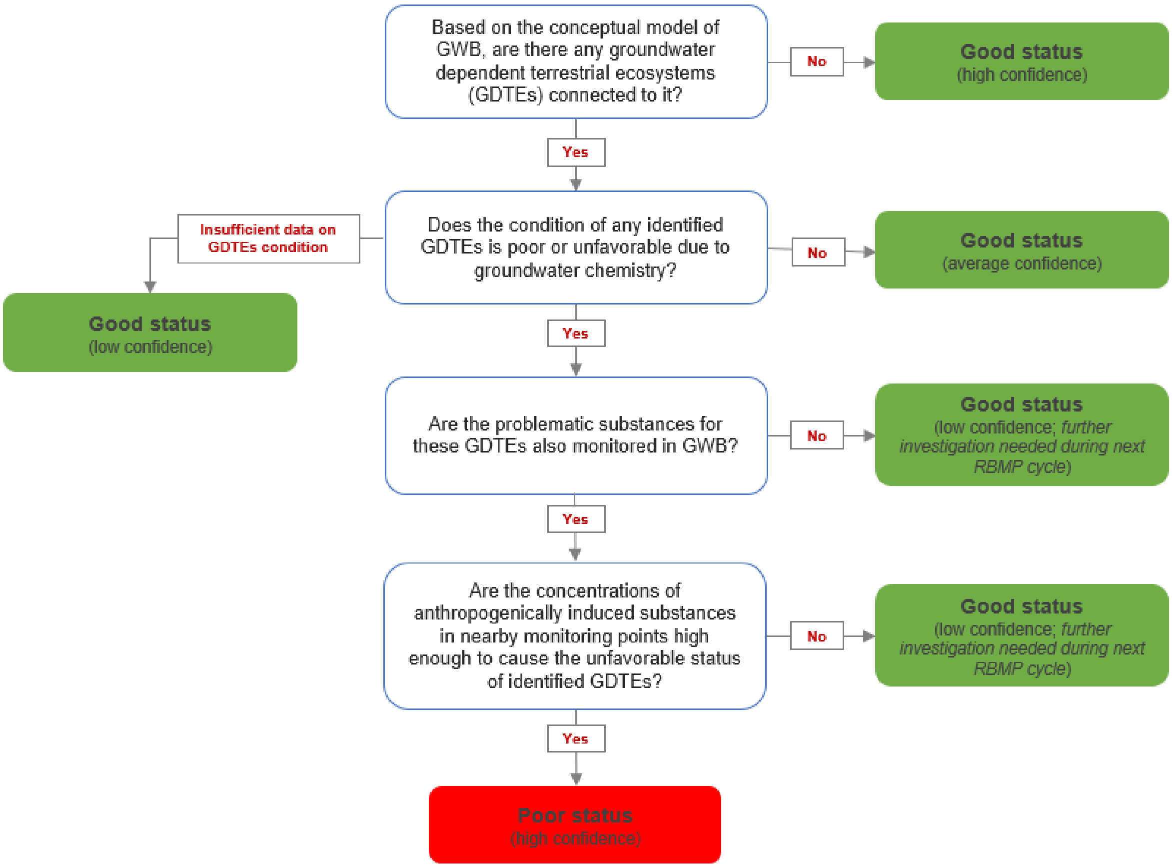

Figure 14. **Flow chart diagram of the harmonized Estonian-Latvian approach of the groundwater dependent terrestrial assessment test** (Valters et al., 2022)

***Step 1**. Based on the conceptual model of GWB, are there any groundwater dependent terrestrial ecosystems (GDTEs) connected to it?*

GDTEs have been identified in a total of 6 transboundary groundwater bodies – D6, A8, A10, 23, 25 and 26. Following the GDTE test procedure scheme, GWB D6, A8 and 23 need to proceed to the next step in this test for further assessment.

According to the results of the general quality assessment test, the other tests for GWB A10, 25 and 26 (including the groundwater dependent terrestrial ecosystems test) do not need to be performed for the assessment of the GWB chemical status.

No GDTEs have been identified in the Lower-Middle Devonian GWBs P and 21, because these GWBs are completely or partially covered by the overlying GWBs (A10 and 23) in the Upper-Middle Devonian aquifer system. According to this test scheme, no further steps are necessary for these two GWBs, and it can be assumed that according to this test, GWB P and 21 are in good chemical condition (with high confidence).

***Step 2.** Does the condition of any identified GDTEs is poor or unfavorable due to groundwater chemistry?*

In case of Latvia, the most common reasons for the deterioration of the ecosystem state are the activity of beavers, digging by wild boars, trampling and the consequences of forest machinery, however, there is no information about the quality impact directly due to groundwaters (data from Nature Census project[5]). Since no information is available on the chemical status of groundwater in the territory, as well as the chemical status of the terrestrial ecosystems, it is not possible to assess the impact of changes in the groundwater chemical status on the associated ecosystem. According to the GDTE test procedure, no further steps are required and it is assumed that due to lack of data, all GWBs (LV GWB D6, A8,) can be considered in good chemical condition (with low confidence).

In Estonian GWB 23, no terrestrial ecosystems have been identified that are in worse than good ecological condition, so based on the assessment procedure, no further steps are required and the GWB 23 is assumed to be in good chemical condition according to this test (with average confidence).

1.3.1.5. Drinking water protected areas

Latvia and Estonia have different approaches to determining groundwater well fields at the national level. In Latvia, a well field is considered a water abstraction site where the water abstraction exceeds 100 m^3/d, while in Estonia – over 500 m^3/d.

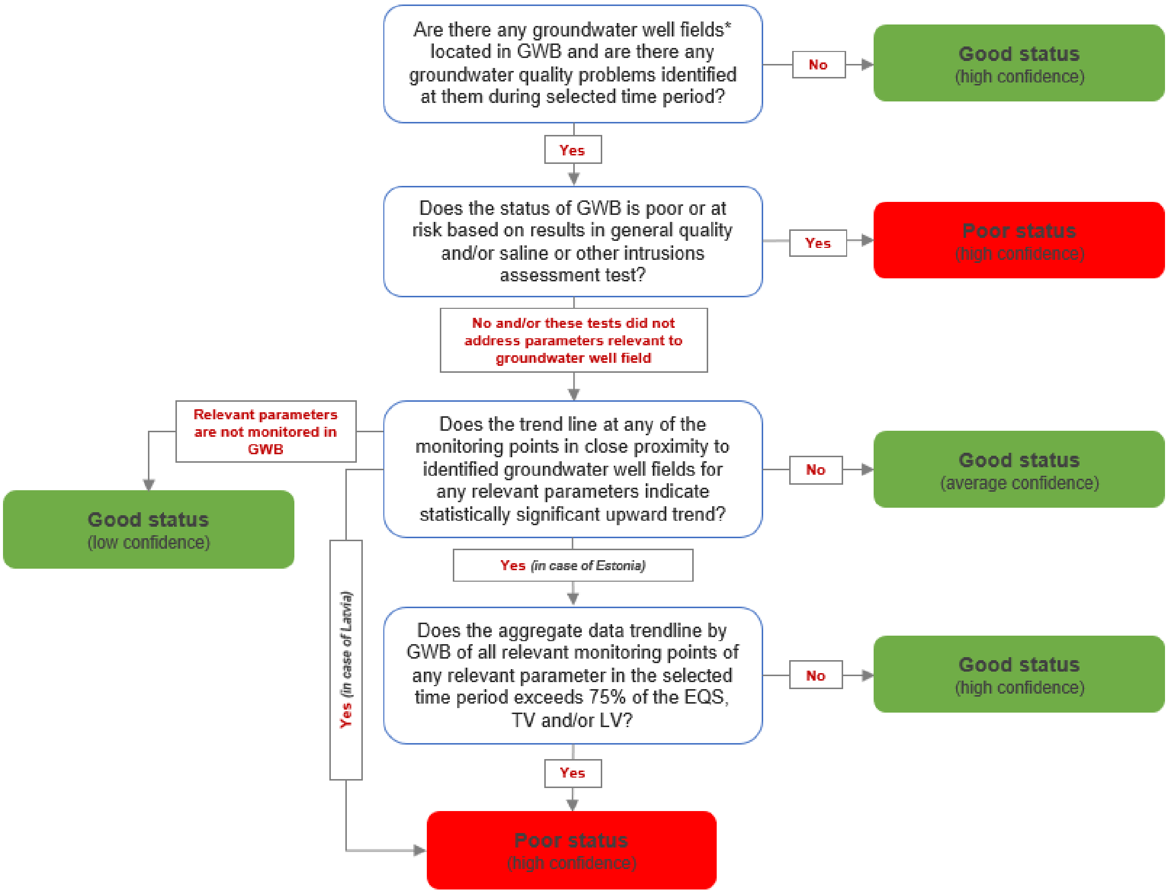

Figure 15. **Flow chart diagram of the harmonized Estonian-Latvian approach of the drinking water protected areas assessment test** (Valters et al., 2022)

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[5] https://www.skaitamdabu.gov.lv/public/eng/about_the_nature_census/

__Step 1__. Are there any groundwater well fields located in GWB and are there any groundwater quality problems identified at them during selected time period?*

There are a total of 111 well fields in Latvian transboundary GWBs: D6 – 5, A10 – 4, P – 5 and A8 – 97 (Gauja/Koiva – 29, other located in Daugava river basin district). In Estonia, groundwater well fields are located in GWB 21 and 23. According to the results of the general quality assessment test, a drinking water protected areas test for the chemical quality for GWBs A10, P, 25 and 26 does not need to be performed.

No groundwater quality problems have been detected in groundwater well fields in Latvia or Estonia during the reporting period (2014-2019) (Marandi et al., 2020; LEGMC, 2021). According to the drinking water protected areas test, no further steps need to be taken and it is assumed that the transboundary GWBs are in good chemical status with high confidence.

1.3.2. Quantitative status assessment of transboundary groundwater bodies

In order to assess the quantitative status of Latvian-Estonian transboundary GWBs, four condition assessment tests were harmonized and applied within the framework of the Wateract project: water balance test, seawater or other intrusion test, groundwater associated aquatic ecosystem (GAAE) and groundwater dependent terrestrial ecosystem (GDTE) test.

1.3.2.1. Water balance assessment test

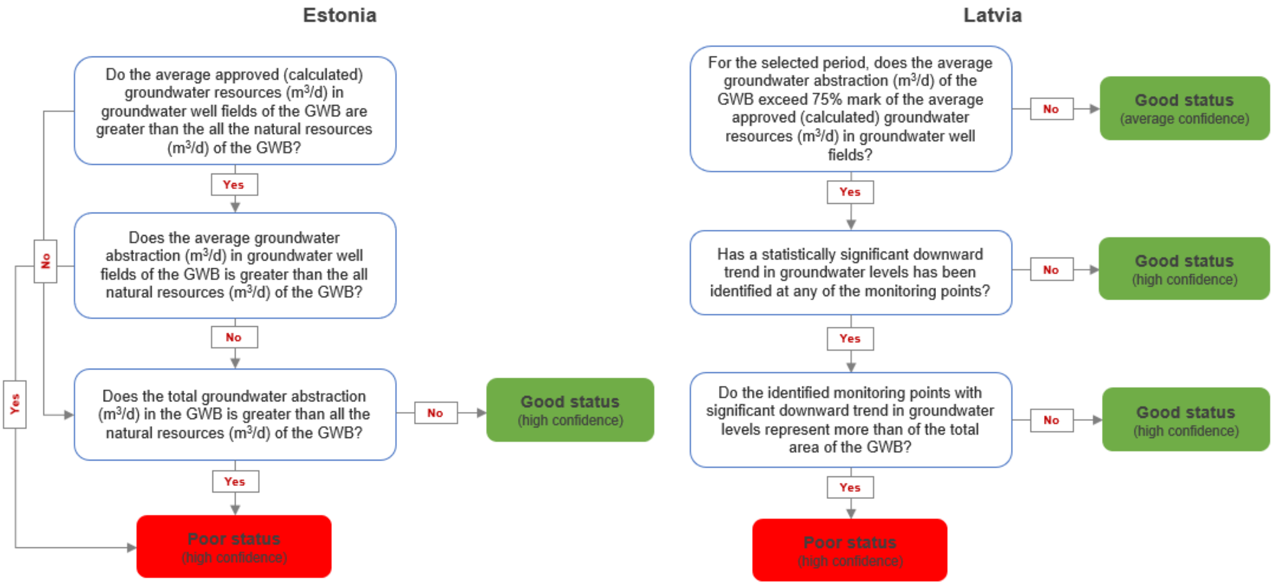

Figure 16. **Flow chart diagram of the harmonized Estonian-Latvian approach of the water balance assessment test** (Valters et al., 2022)

According to the approach, the average water abstraction (m^3/d) data for 2018 were used to perform the water balance test in Latvia and Estonia and compared with the available natural groundwater resources (in the case of Estonia) or approved stocks (in the case of Latvia) in the respective GWB.

For the Latvian approach, in the first step of the water balance test, it must be determined whether the average water abstraction in the selected time period exceeds the 75 % mark of the average approved (calculated) groundwater resources (m^3/d) in groundwater well fields. The average water abstraction rates of transboundary GWBs A10, A8, D6 and P do not exceed the permissible amount (LEGMC, 2021), and according to the balance test, all transboundary GWBs are in good quantitative status with high confidence.

In the Estonian test procedure, in the first step, it is necessary to assess whether the average approved (calculated) groundwater resources (m^3/d) in well fields exceed all natural groundwater resources (m^3/d) in the relevant GWB. These resources are not exceeded in any GWB during the selected time period. According to the methodology, it is necessary to move to the last step of the test, where to assess whether the average total groundwater abstraction (m^3/d) in the GWB (in the selected time period) is greater than all the natural resources of the GWB (m^3/d).

Based on available information, groundwater abstraction volumes of Estonian transboundary GWBs do not exceed all natural resources, and according to the water balance test, all transboundary GWBs are in good quantitative status with high confidence (Marandi et al., 2020).

1.3.2.2. Saline or other intrusions

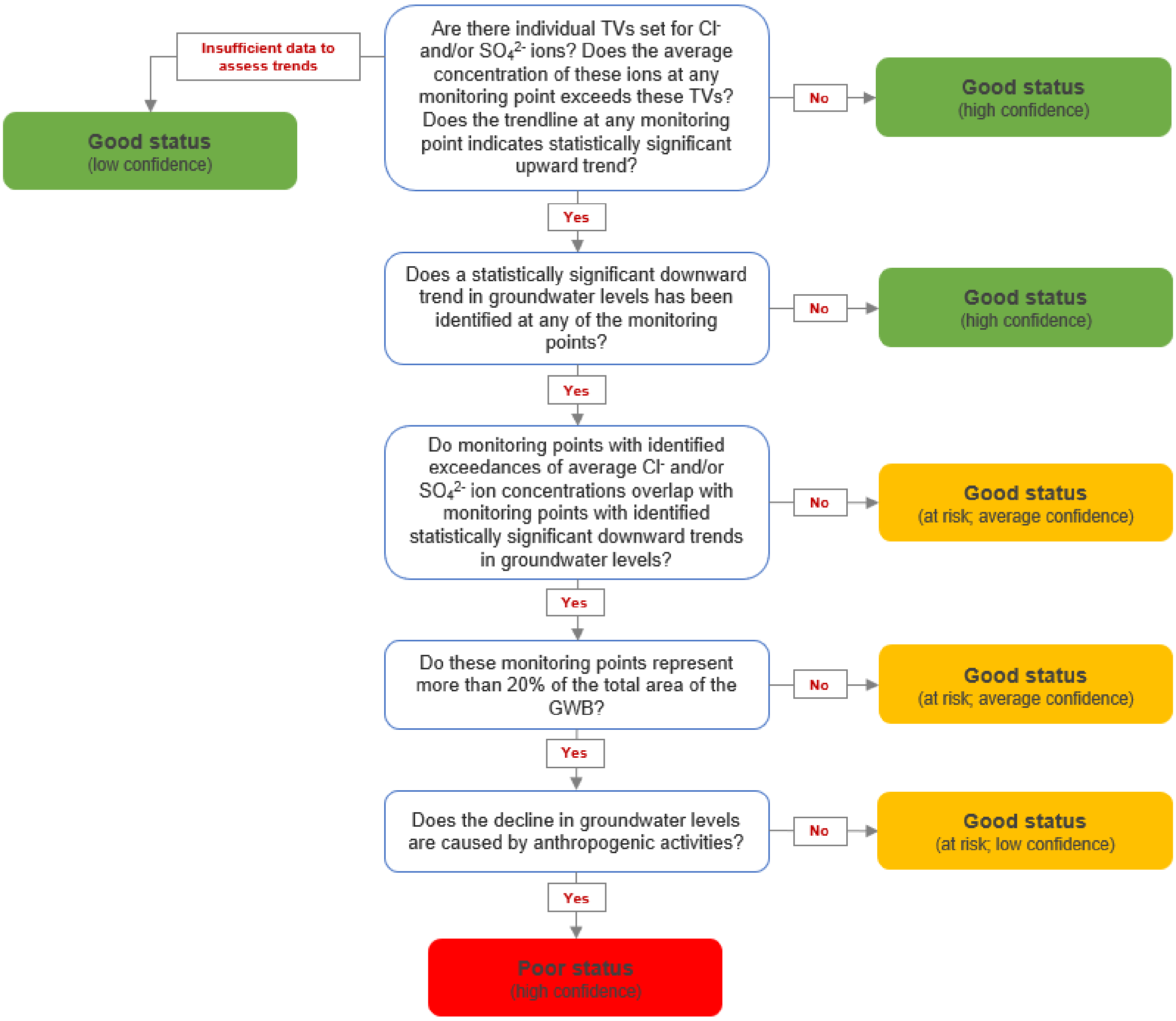

Figure 17. **Flow chart diagram of the harmonized Estonian-Latvian approach of the saline or other intrusions assessment test** (Valters et al., 2022)

***Step 1**. Are there individual TVs set for Cl^- and/or SO_4^{2-} ions? Does the average concentration of these ions at any monitoring point exceed these TVs? Does the trendline at any monitoring point indicate a statistically significant upward trend??*

The first step in the intrusion assessment procedure is the most significant in the case of Latvia and Estonia. No TVs have been set for Estonian transboundary GWBs for intrusion process indicators (Cl^- and SO_4^{2-} ions) as there is no risk of saline water or other intrusions, so no further test steps are required (Marandi et al., 2020). According to the saline or other intrusion test, all GWBs are in a good status with high confidence.

In the case of Latvia, TVs for the parameters characterizing the intrusion process (Cl^- and SO_4^{2-}) are set for each GWB. Exceedances of the TVs were determined in GWB A8 - in several monitoring wells the average concentrations of the chloride (Cl^-) ions exceed the TV (in the case of GWB A8, the TV for Cl^- is 134 mg/l). It should be noted that GWB A8 covers a large area of Latvia and no exceedances of concentrations have been detected close to Latvian-Estonian border area, thus there is no risk of intrusion process on transboundary groundwater resources in the current situation.

Although exceedances have been found in some monitoring points, the last criteria of the first step is about statistically significant upward trend at any monitoring point. In the case of Latvia, the available quality monitoring data set is insufficient to perform trends, so, according to the scheme, it is not necessary to perform further steps for intrusion test and the chemical status of GWB A8 is considered to be good with low confidence. In all other transboundary GWBs, the chemical status is good with high confidence.

1.3.2.3. Groundwater associated aquatic ecosystems

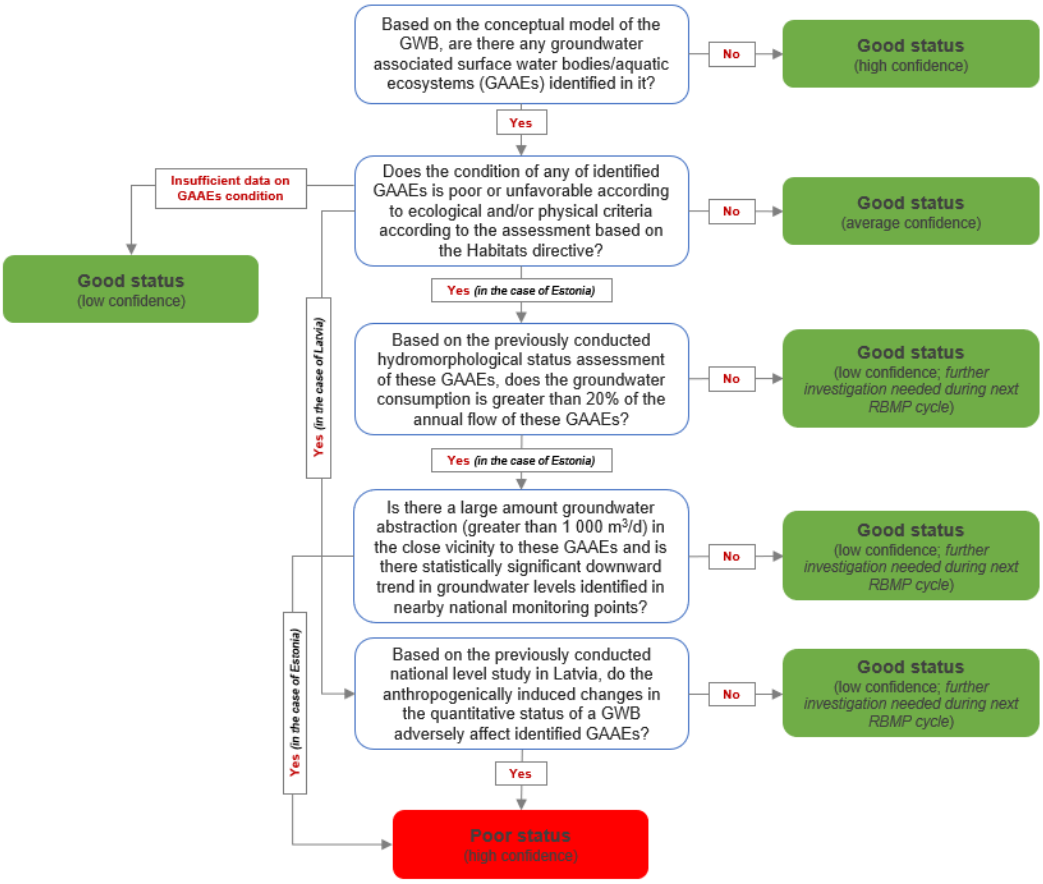

Figure 18. **Flow chart diagram of the harmonized Estonian-Latvian approach of the associated surface water bodies assessment test** (Valters et al., 2022)

Step 1. *Based on the conceptual model of GWB, are there any groundwater associated surface water bodies/aquatic ecosystems (GAAEs) connected to it?*

According to the information specified in the Latvian-Estonian transboundary GWBs conceptual models, a total of 30 surface water ecosystems have been identified in transboundary GWBs. In the Latvian GWBs: A8 -12, D6 – 6, while Estonian GWBs 21 – 1, 23 – 3, 25 – 3 and 26 – 5 GAAEs (see Annex 1).

Groundwater associated aquatic ecosystems (GAAEs) were not identified in the territory of the Latvian GWB A10, and P. In case of Lower-Middle Devonian GWB P, such ecosystems are not applicable, because the object is embedded below the Upper-Middle Devonian GWB A10 and A8, and the groundwater in this GWB are not hydrologically connected with surface waters and related ecosystems. As a result, after the assessment test, the next steps in the assessment procedure for GWBs A10 and P are not required, and according to the surface water ecosystem assessment test, both GWBs are in good quantitative status with high confidence.

Step 2. *Does the condition of any of these GAAEs is poor or unfavorable according to ecological and/or physical criteria?*

GWB D6. 1 river GAAE (*Līgatne* river) and 1 lake ecosystem (*Sudala* lake) was identified with good ecological status, as well as 4 sinkholes, the status of which is unknown. According to the test step procedure, no further steps are required, and GWB D6 is in good quantitative status with average confidence.

GWB A8. A total of 12 ecosystems were identified in the territory of GWB, of which the status of poor ecological quality was initially assigned to a total of 4 ecosystems: 3 river water bodies (*Rauna_1, Brasla_3, Amata_2*) and 1 lake (*Lielais Bauzis* lake). Based on the expert's judgment (Uzule et al., 2021), poor ecological quality of the GAAEs in GWB A8 is not related to groundwater, and there is no information that changes in the quantitative status of the GWB would negatively affect the associated GAAE. According to the surface water assessment test, GWB A8 is in good quantitative status with low confidence.

GWB 21. GAAE *Pärnu_3* is in poor quality status. According to the surface water test procedure, it is required to proceed assessment of this GWB to the next step.

GWB 23. The status of the 3 GAAEs (*Sinialliku vooleekogum*, *Viljandi* lake and *Õisu* lake) was poor, however, according to experts' judgment, the reason for this is not the quality of groundwater (Marandi et al., 2020). Accordingly, further steps in this test are not necessary and GWB 23 is assumed to be in good condition with average confidence.

GWB 25. 3 GAAEs (*Mustjõgi* river to the *Antsla-Litsmetsa* road, *Kolga* river, *Pärlijõgi* river from the *Saarlas* dam to the river mouth) were identified in the GWB 25. All ecosystems are of good ecological quality. According to the surface water assessment test GWB 25 is in a good quantitative status with average confidence.

GWB 26. 5 groundwater-associated surface water ecosystems have been identified in the territory of GWB - *Obinitsa* river, *Piusa* river up to *Kivioja* creek, *Piusa* river from *Kivioja* creek to the river mouth, *Rõuge* river, *Pärlijõgi* river from *Saarlase* dam to the river mouth. Likewise, 6 lake ecosystems have been identified in the GWB (*Kaussjärv* lake, *Liinjärv* lake, *Ratasjärv* lake, *Suurjärv* lake, *Tõugjärv* lake, *Valgjärv* lake). All associated lake water bodies are in good status. Also, there are 3 karst features: *Tsiistre* dolines, *Poksa* ponor, *Palosland* karst lake. In one associated surface water ecosystem - *Piusa* river from *Kivioja* creek to the river mouth, the quality status is marked as poor. According to the surface water test procedure, it is required to continue the assessment of GWB 26 in the next step.

Step 3. *Based on the previously conducted hydromorphological status assessment of these GAAEs, does the groundwater consumption is greater than 20% of the annual flow of these GAAEs?*

According to the assessment of the hydromorphological status of the Estonian watercourse, water abstraction in none of the watercourses in GWB 21 and 26 does not exceed 20% of the river's annual flow, while water abstraction has not been assessed for lake ecosystems. According to the surface water assessment test, these GWBs are in good quantitative status with low confidence and need further investigation in the next RBMP planning period.

1.3.2.4. Groundwater dependent terrestrial ecosystems

Within the framework of the Wateract project, groundwater dependent terrestrial ecosystems were identified in the Salaca/Salatsi river basin, as well as those ecosystems that were previously identified in the Gauja river basin (during GroundEco project) were reviewed. An initial assessment of these ecosystems was also carried out using the methodology developed by the GroundEco project (Retike et al., 2020). More information on identifying the ecosystems in Salaca/Salatsi river basin is described in Chapter 1.4.

For the assessment of the status of transboundary groundwater bodies, a harmonized approach was established within the framework of the Wateract project (Valters et al., 2022) to determine whether groundwater affects the ecological status of terrestrial ecosystems.

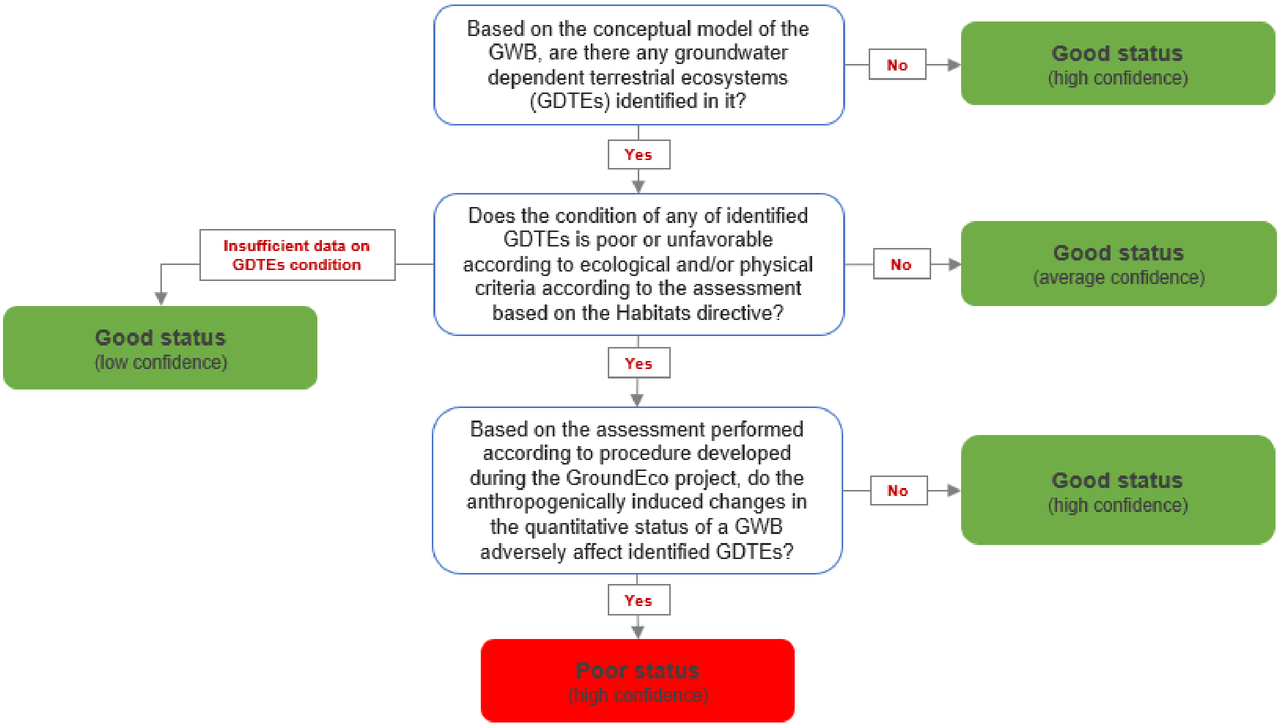

Figure 19. **Flow chart diagram of the harmonized Estonian-Latvian approach of the groundwater dependent terrestrial ecosystems assessment test** (Valters et al., 2022)

Step 1. *Based on the conceptual model of GWB, are there any groundwater dependent terrestrial ecosystems (GDTEs) identified in it?*

Groundwater dependent terrestrial ecosystems (GDTEs) have been identified in a total of 6 transboundary GWBs – Latvian GWBs D6, A8, A10, as well as Estonian GWBs 23, 25 and 26. According to the quantitative status assessment procedure, further assessment of these GWBs requires moving to the next step in this test.

No GDTEs have been identified in the Lower-Middle Devonian water bodies (GWB P and 21), because these objects are completely or partially covered by the overlying GWBs A10 and 23 of the Upper-Devonian aquifer system. According to the assessment scheme, no further step procedure is necessary for these GWBs, and it can be assumed that according to this test, GWB P and 21 are in good quantitative status (with high confidence).

Step 2. *Does the condition of any identified GDTEs is poor or unfavorable according to ecological and/or physical criteria according to the assessment based on the Habitats directive?*

According to the available information, there are no ecosystems identified in Estonian GWBs 23, 25 and 26 with a status worse than good, therefore, based on the GDTEs test procedure, further steps are not necessary and the GWBs are assumed to be in good quantitative status according to this test (with average confidence).

The status of the GDTEs identified in Latvian transboundary GWBs D6, A8 and A10, is worse than good (data from Nature Census project[6]). According to the GDTEs test procedure, the assessment of these GWBs should be continued in the next step.

Step 3. *Based on the assessment performed according to procedure developed during the GroundEco project, do the anthropogenically induced changes in the quantitative status of a GWB adversely affect identified GDTEs?*

In case of Latvia, the most common reasons for the deterioration of the ecosystem state are the activity of beavers, digging by wild boars, trampling and the consequences of forest machinery, however, according to the initial assessment of GDTEs (GroundEco methodology), there is no information on anthropogenically caused quantitative changes in the water body, which could negatively affect the state of the identified ecosystem. According to the GDTE test procedure, further no further steps are required and it is assumed that due to lack of data, GWBs D6, A8 and A10 can be considered in good chemical condition (with low confidence) and further investigation is required in the next RBMP development cycle.

1.4. Identification and assessment of groundwater-dependent terrestrial ecosystems in Gauja/Koiva and Salaca/Salatsi river basins

1.4.1. Identification of GDTEs

Within the Wateract project, groundwater-dependent terrestrial ecosystems were identified in the Salaca/Salatsi river basin. As the quality and quantity data of habitats has periodically improved, in the case of Latvia, also a review of GDTEs identified in the Latvian part of Gauja/Koiva river basin during the GroundEco project (Retike et al., 2020) was done. In the Estonian part of the Gauja/Koiva river basin, no new habitat inventories have been performed since November 2019 (data used in GroundEco). Therefore, during the WaterAct project, the identification of GDTEs was carried out only in Salaca/Salatsi river basin, while in Gauja/Koiva river basin GDTEs identified in the previous GroundEco project. The overall situation of GDTEs identified in Salaca/Salatsi and Gauja/Koiva river basins is shown in Figure 20.

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[6] https://www.skaitamdabu.gov.lv/public/eng/about_the_nature_census/

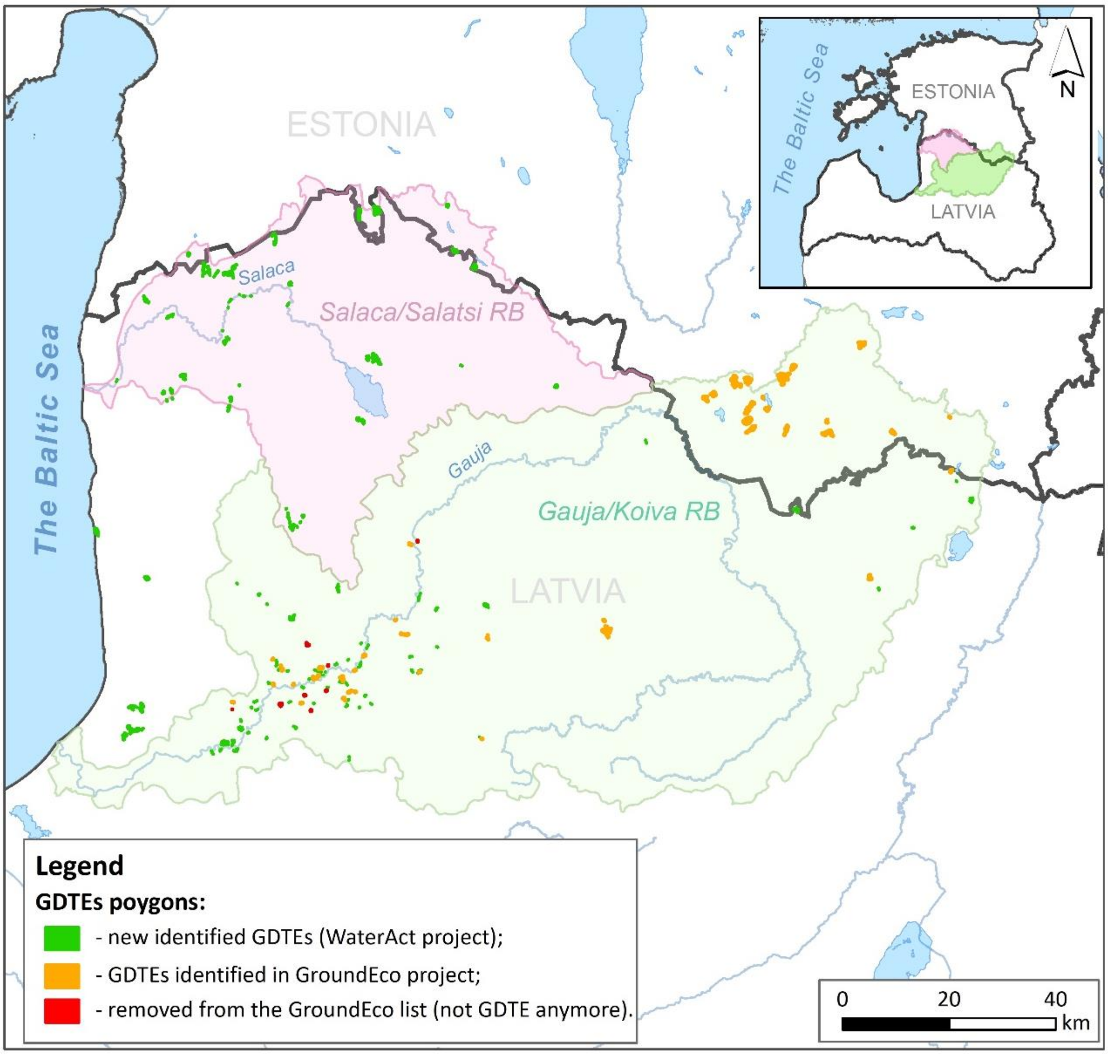


Figure 20. **The overall situation of identified GDTEs in Salaca/Salatsi and Gauja/Koiva river basins**

GDTEs were identified using the methodology described in Retike et al. (2021). In general, to identify GDTE locations in Estonia and Latvia, those critically dependent on groundwater input were selected from the list of terrestrial Annex I habitat types. Habitat types that can automatically be considered GDTE in both countries are:

- Humid dune slacks (2190), Fennoscandian mineral-rich springs and springfens (7160), and Petrifying springs with tufa formation (*Cratoneurion*) (7220*) – but only if the total area of a single polygon reaches at least 1 ha (here and below - if a polygon is smaller than the minimum area threshold, it can still be considered a GDTE if, <u>together with other polygons from the same habitat complex</u>, it occupies at least the minimum area threshold);
- Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae* (7210*), and Alkaline fens (7230) – but only if the total area of a single polygon or habitat complex reaches at least 10 ha in Estonia and 20 ha in Latvia;

  - *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*) (6410), and Fennoscandian deciduous swamp woods (9080*) – but only if the total area of a single polygon or habitat complex reaches at least 20 ha;

Some habitat types were considered GDTEs only in exceptional cases either in both countries or only in Estonia:

- Bog woodland (91D0*) – in both countries if it is a coniferous fen woodland, and if the total area of a single polygon or habitat complex reaches at least 20 ha;
- Hydrophilous tall herb fringe communities of plain and of montane to alpine levels (6430), Active raised bogs (7110*), Degraded raised bogs still capable of natural regeneration (7120), Transition mires and quaking bogs (7140), and Bog woodlands (91D0*) – only in Estonia in oil-shale mining region or if the habitat includes poor fens and poor paludified grasslands (for habitat type 6430), and only if the total area of a single polygon or habitat complex reaches at least 20 ha.

An additional criterion is the presence of GDTE-related species that include species of the protection categories I and II in Estonia (according to Paal & Leibak (eds.) 2011) (like *Dactylorhiza russowii, Hammarbya paludosa, Ophrys insectifera, Rhynchospora fusca*) and species that rely on GW-fed habitats listed in Annex I of the Habitats Directive in Latvia (e.g., *Liparis loeselii*, *Saxifraga hirculus*, whorl snails *Vertigo* spp.). The presence of such species makes the site a significant GDTE, even if it does not meet the threshold of the minimum area.

Identification in Estonia

For the Estonian part of the Salaca/Salatsi river basin, habitat polygons and their attributes were taken from the Estonian Nature Information System (EELIS). The data represents 25th February 2021.

As the part of Salaca/Salatsi basin in Estonia is small, only six significant GDTEs were identified (Figure 21, Table 6) covering an area of 266 ha. Their areas range from 20 ha to 91 ha. In five of these the main habitat type was 9080* and in one 6430. The conservation status of these GDTEs was mostly "very good", "good" or not determined. Some habitat polygons in GDTEs no. 4 and 6 had "average" conservation status. Polygons having "average" conservation status formed the areal majority only in GDTE no. 6. Therefore, it can be concluded that only GDTE no. 6 is in an unfavorable status. All significant GDTEs are dependent on the Middle-Devonian groundwater body in the West-Estonian basin. The dependence on GWBs was determined only based on spatial information. The uppermost GWB below the GDTE was considered to be the one that the GDTE depends on.

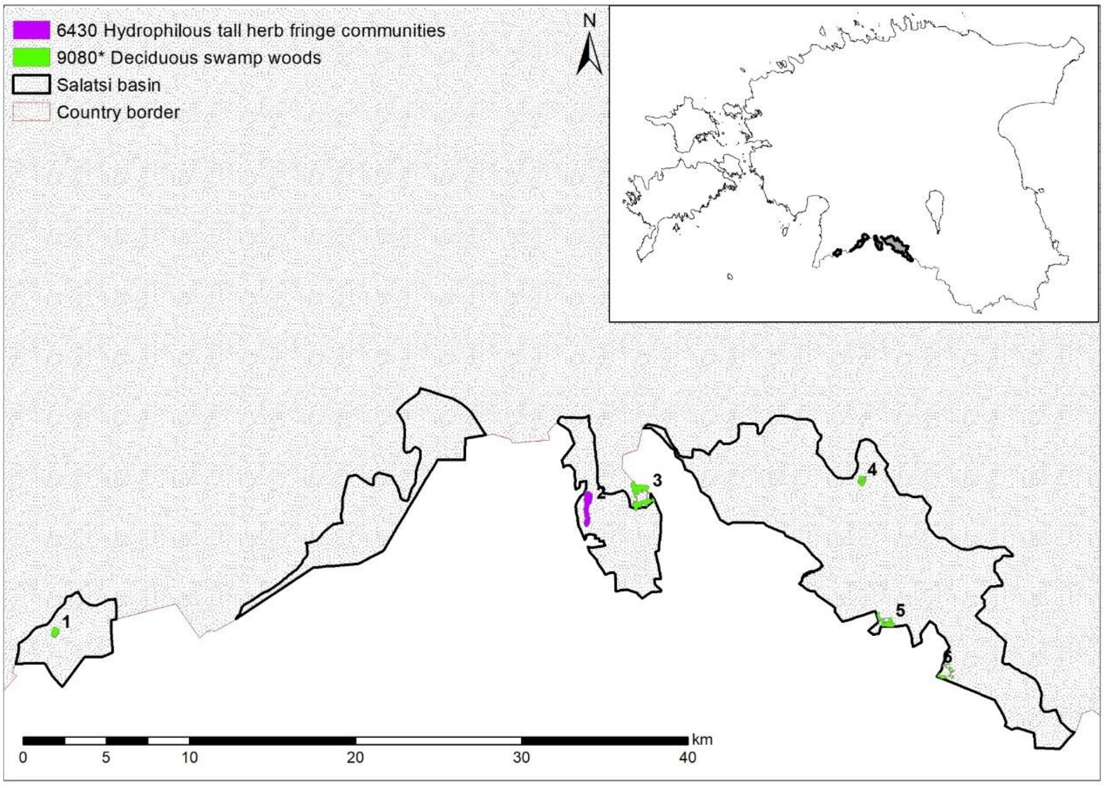


Figure 21. **Significant GDTEs identified in the Salaca/Salatsi river basin in Estonia** (as of 25th February 2021). The colors of the polygons indicate the largest habitat type in the GDTE polygons. Numbers of the polygons overlap with the order numbers in Table 6.

TABLE 6

Attributes of the significant GDTEs identified in the Salatsi river basin

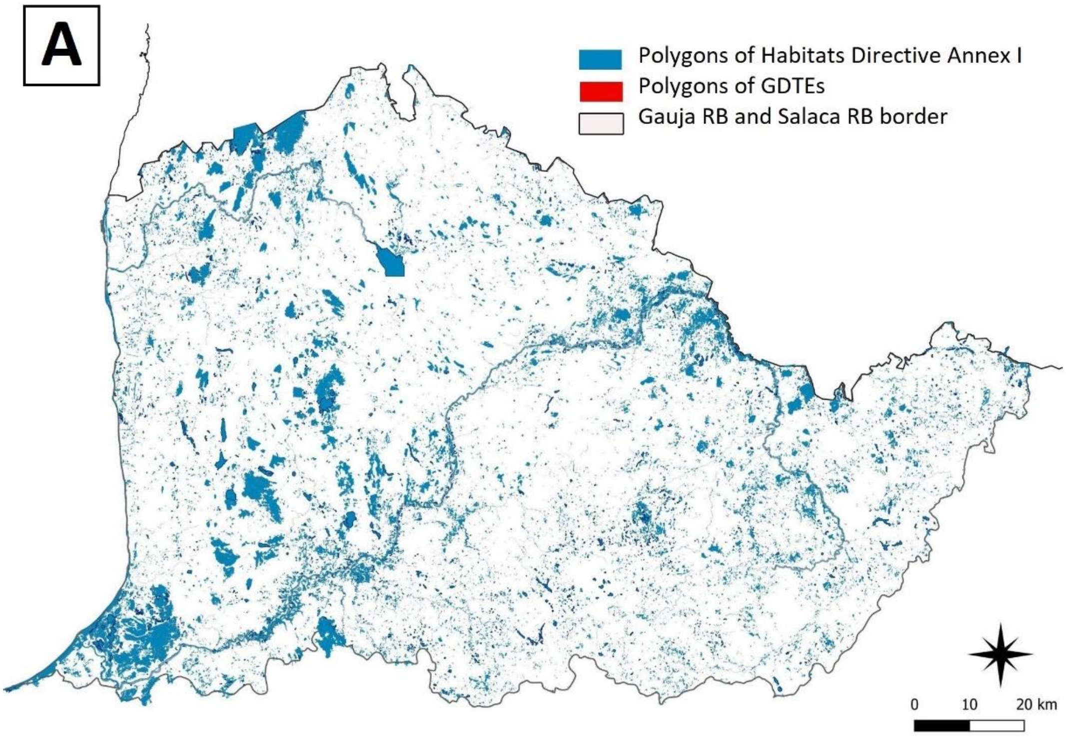
No	Main habitat type	Secondary habitat types	Rare species	Natura 2000/ National PA	Conserv. status	Area (ha)	GWB
1	Fennoscandian deciduous swamp woods (9080*)	Hydrophilous tall herb fringe communities (6430)	0	Yes/Yes	B	21.1	23
2	Hydrophilous tall herb fringe communities (6430)		0	No/No	A	73.8	23
3	Fennoscandian deciduous swamp woods (9080*)		0	No/No	NA	91.2	23
4	Fennoscandian deciduous swamp woods (9080*)	Alkaline fens (7230)	0	No/No	A, C, NA	20.0	23
5	Fennoscandian deciduous swamp woods (9080*)		0	No/Yes	NA	37.8	23
6	Fennoscandian deciduous swamp woods (9080*)		0	Yes/Yes	B, C	21.9	23

Note: PA – protected area
Conserv. status – conservation status values according to the Annex I habitat status assessment;
GWB – number of the groundwater body the ecosystem is dependent on;
NA – status not available;
As the GDTEs may consist of several habitat polygons of the same or different types, there may be several conservation statuses values for a single GDTE.

Identification in Latvia

For Latvia, the latest available information habitat inventory data (data until 2021) was used from the Nature Conservation Agency Nature Data System "OAK" and EU Cohesion Fund project "Preconditions for better biodiversity preservation and ecosystem protection in Latvia" (or in short "Nature Census") results.

In Gauja and Salaca river basins on Latvian side, the total amount of every EU habitat used in data selection were 43 481 polygons (Figure 22-A). In the next step, the EU habitats related to GDTEs were sifted, leaving 10 496 polygons (Figure 22-B). These were used in the final step, which applied an area threshold filter (per polygon or habitat complex) and analyzed the presence of GDTE-related species. As a result, in Latvia, 116 GDTEs were identified that are composed of 504 single patches or multipart polygons (Figure 22-C). Higher number of GDTEs was identified in Gauja river basin – 89 GDTEs or 316 polygons in total. In Salaca RB, the total number was much smaller, i.e. 27 GDTEs or 188 polygons.



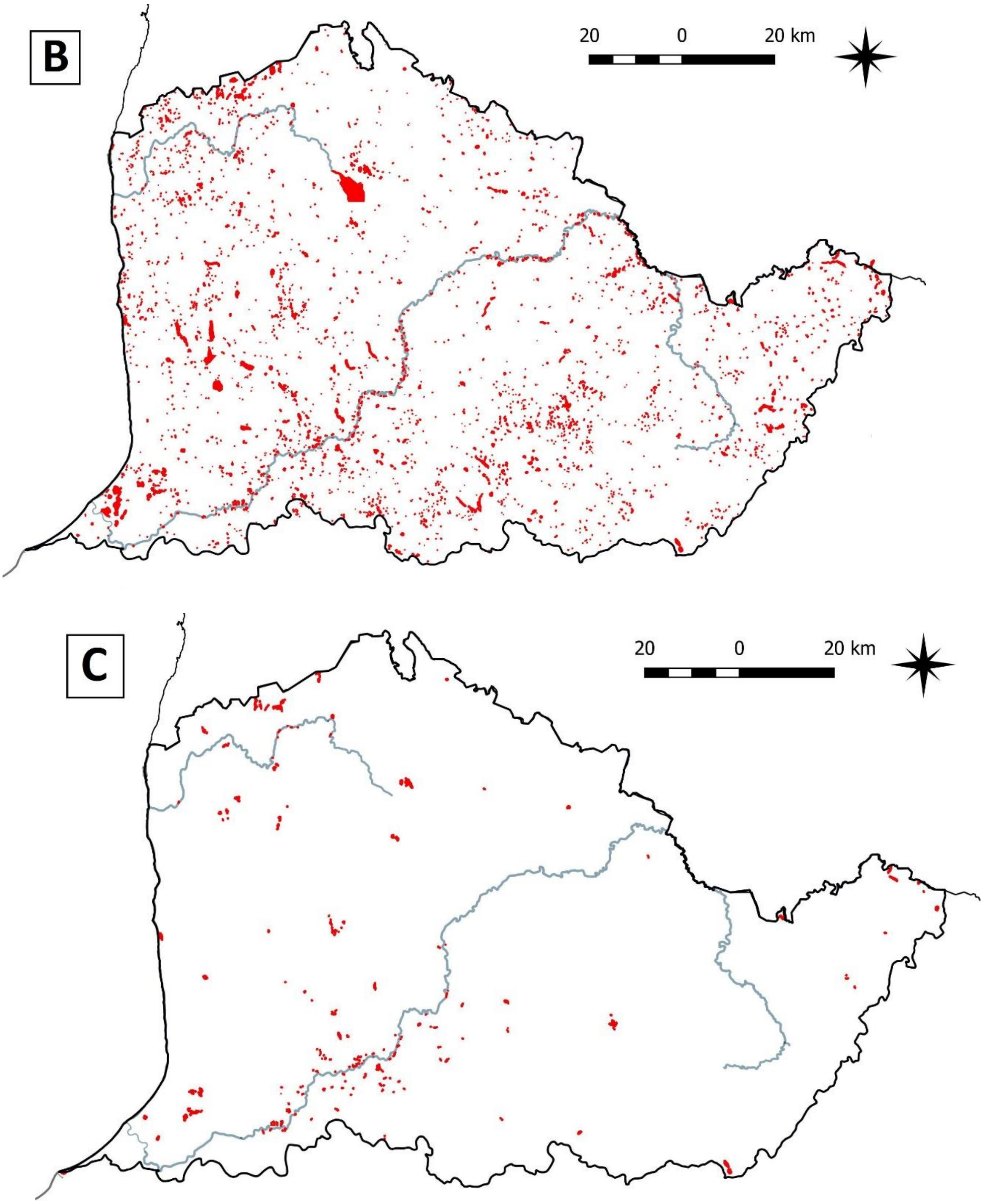


Figure 22. **Data selection steps for GDTE identification in Gauja RB and Salaca RB.**

Detailed analysis was made at the habitat level, as the total number of polygons is relatively high. In total, four habitat types are represented in the identified GDTEs in Latvia: 7160, 7230, 7220*, and 9080*. The most common types are 7160 and 9080* (Figure 23, Table 7).

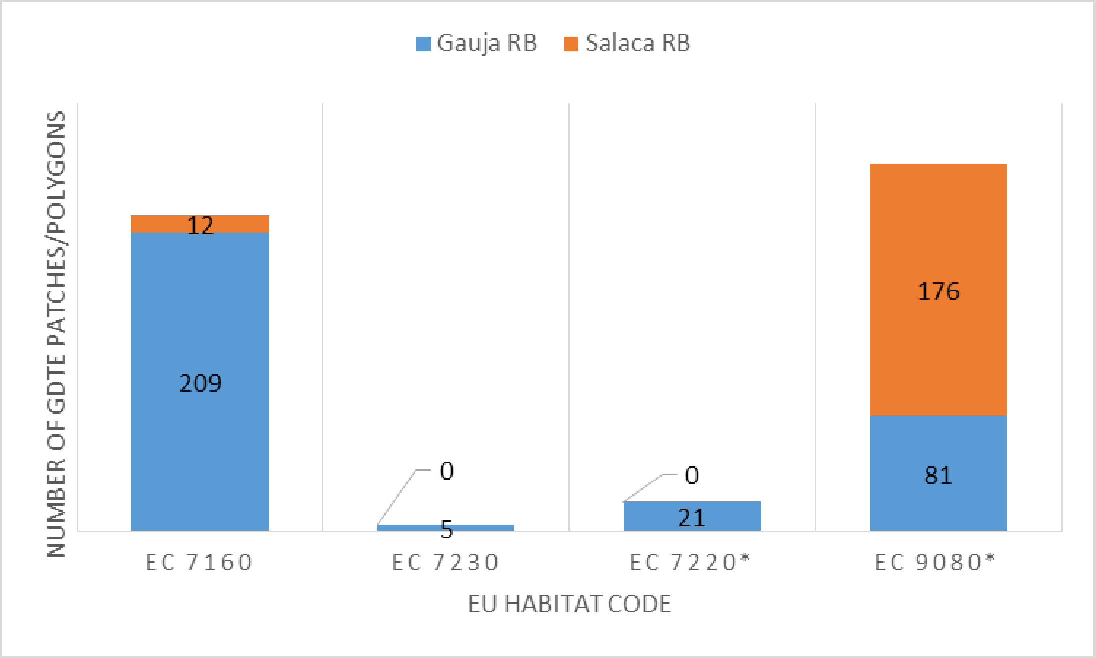


Figure 23. **Total number of identified GDTEs in Gauja and Salaca river basins in Latvia according to habitat type of Directive Annex I.**

All of the identified GDTEs are located within protected areas of national or European scale (Table 7).

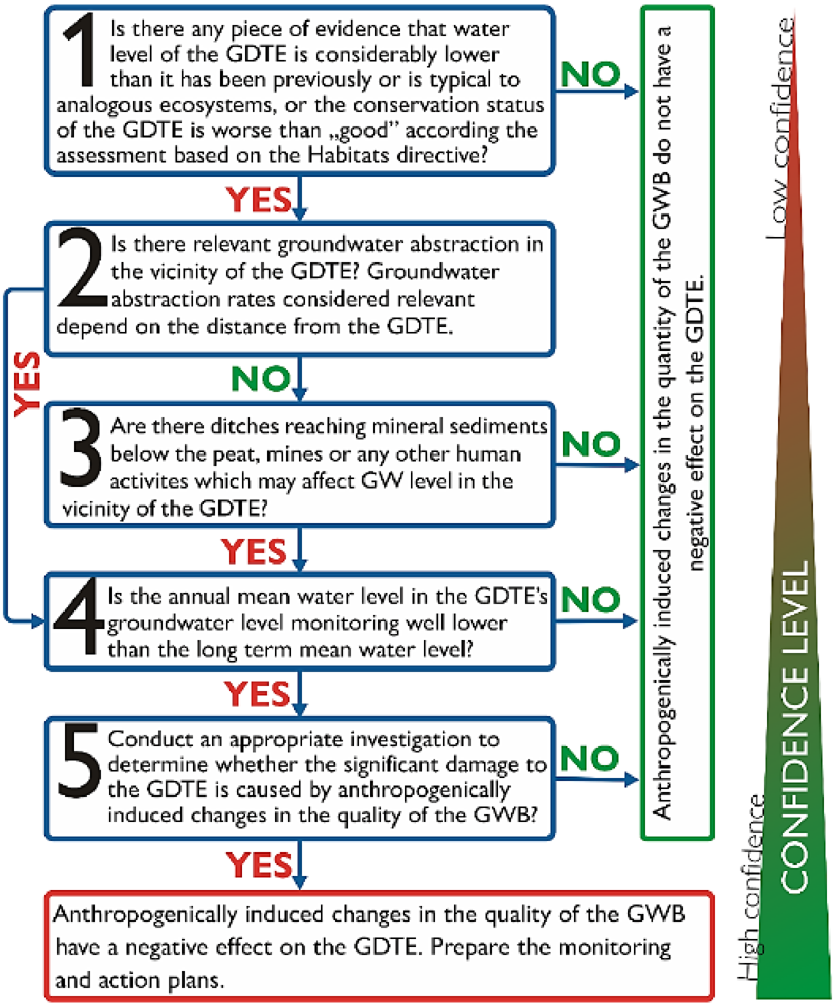
TABLE 7

Attributes of the significant GDTEs identified in the Salaca/Salatsi and Gauja/Koiva RB

Habitat type	Rare species	Natura 2000/National PA	Conserv. status	Area	No. of polygons
		Gauja RB			
7160	2	Yes/Yes	B, C	265.8	209
7230	4	Yes/Yes	B, C	6.9	5
7220*	0	Yes/Yes	B, C	5.2	21
9080*	0	Yes/Yes	B, C	382.3	81
		Salaca RB			
7160	0	Yes/Yes	C	18.5	12
9080*	0	Yes/Yes	B, C	554.1	176

1.4.2. Assessment of identified GDTEs

The next step after identifying GDTEs, is to assess whether GWB could cause a negative impact to GDTE. Habitat inventory data, maps, as well as information collected for the RBMPs were used for the assessment. As part of the GroundEco project, a joint methodology for Latvia and Estonia was developed and implemented for the identification and assessment of GDTEs in the Gauja/Koiva river basin. Quantitative and qualitative impact assessment schemes developed, including a five-step procedure (Figure 24, Figure 25). The schemes were based on the preliminary Estonian assessment scheme (Terasmaa et al., 2015) and the procedure suggested by the European Commission (EC, 2009) for the assessment of significant damage to GDTEs caused by quantitative pressures in GWB.



1 Is there any piece of evidence that water level of the GDTE is considerably lower than it has been previously or is typical to analogous ecosystems, or the conservation status of the GDTE is worse than „good" according the assessment based on the Habitats directive?

2 Is there relevant groundwater abstraction in the vicinity of the GDTE? Groundwater abstraction rates considered relevant depend on the distance from the GDTE.

3 Are there ditches reaching mineral sediments below the peat, mines or any other human activites which may affect GW level in the vicinity of the GDTE?

4 Is the annual mean water level in the GDTE's groundwater level monitoring well lower than the long term mean water level?

5 Conduct an appropriate investigation to determine whether the significant damage to the GDTE is caused by anthropogenically induced changes in the quality of the GWB?

Anthropogenically induced changes in the quality of the GWB have a negative effect on the GDTE. Prepare the monitoring and action plans.

Anthropogenically induced changes in the quantity of the GWB do not have a negative effect on the GDTE.

Figure 24. **Scheme for assessment of significant damage to GDTE caused by quantitative pressures in GWB** (Retike et al., 2020)

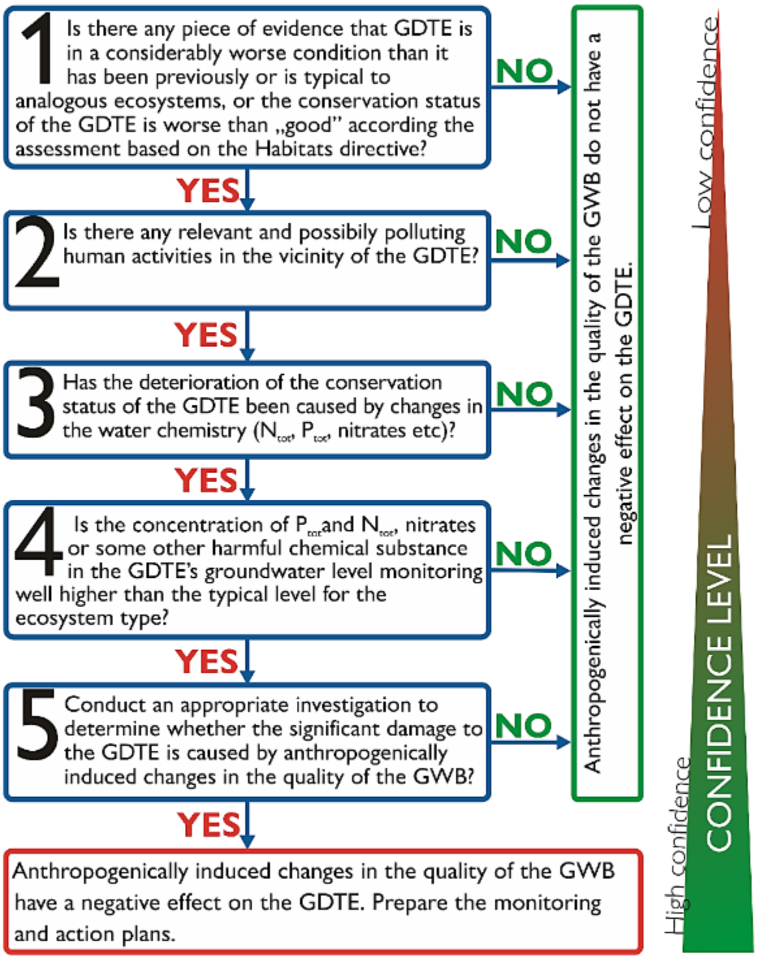


Figure 25. **Scheme for assessment of significant damage to GDTE caused by qualitative (chemical) pressures in GWB** (Retike et al., 2020)

1.4.2.1. Quantitative effect of GWBs to GDTEs on the Latvian side

Step 1. *Is there any piece of evidence that water level of the GDTE is considerably lower than it has been previously or is typical to analogous ecosystems, or the conservation status of the GDTE is worse than "good" according to the assessment based on the Habitats directive?*

In total, 116 GDTEs (504 single patches) have been delineated on the Latvian side of the border in the Gauja/Koiva and the Salaca/Salatsi River Basin (27 GDTEs identified in the Salaca river basin). According to the assessment based on the Habitats directive, 81 GDTEs (65 single patches and 17 multipart polygons) were identified with ecological quality status lower than "good" (average - 71; poor - 10). In accordance with the quantitative status assessment procedure, it is necessary to move to the next step of the assessment scheme to assess these 81 GDTEs.

Step 2. *Is there relevant groundwater abstraction in the vicinity of the GDTE? Groundwater abstraction rates considered relevant depend on the distance from the GDTE.*

In this step, it is proposed to assess the impact of the groundwater abstraction site near the GDTE. For this assessment, the information from State statistics report system “2-Ūdens”. Review on the use of water resources” on groundwater abstraction for the year 2020 was used.

For the assessment of potential groundwater abstraction pressure on GDTE, the same approach as in the GroundEco project was used (Retike et al., 2020). The amount of groundwater abstraction that is considered significant, depends on the distance from the GDTE according to the following equation:

$$x = \sqrt{\frac{Qyear}{\pi * R_{year}}}, \text{ where}$$

X – distance from groundwater abstraction site (m),
Q_{year} – groundwater abstraction in GWB (m^3/year),
R_{year} – mean groundwater recharge (m^3 m^{-2} $year^{-1}$).

The mean groundwater recharge (R_{year}) was determined based on the information available in the report “Characterization of delineated groundwater bodies in Latvia (LEGMC, 2020) on the groundwater recharge (m^3/d), for a whole territory of GWB. The equation predicts that the GDTEs located within the groundwater abstraction site affected area (distance from GDTE to GW abstraction site < x), then groundwater abstraction site might cause a pressure on the GDTE.

As a result of determining the potential impact zones of the groundwater abstraction sites, 3 GDTEs (Fennoscandian mineral-rich springs and springfens (7160) - 19JZ1209_151_2, 20JZ109_60_1 and 20JZ109_60_1) are located in the water abstraction site impact zone, or 750 m away from the groundwater well field *Pacеplīši* (see Figure 26).

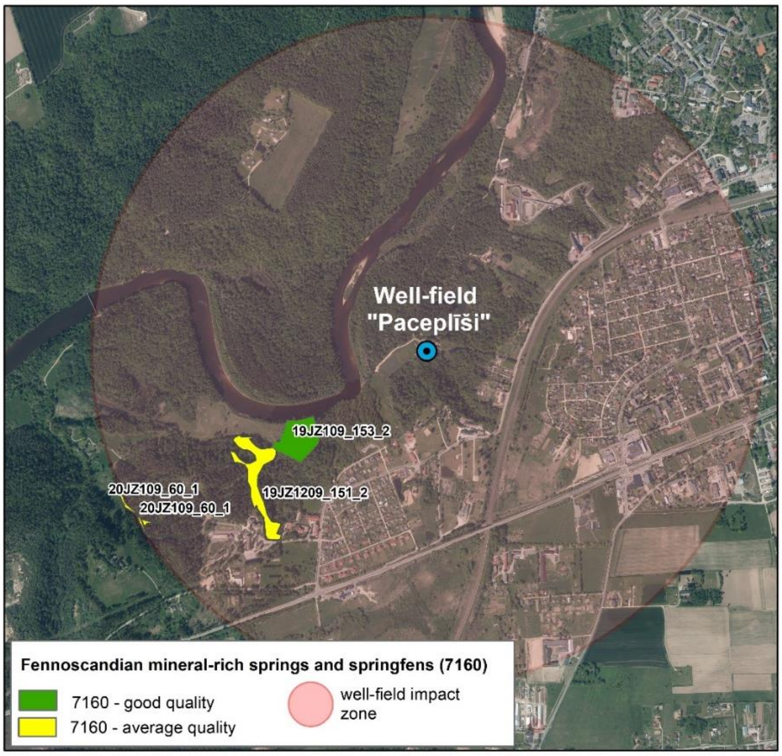


Figure 26. **Groundwater abstraction impact zone for the well-field “*Pacеplīši*”**

This well field *Paceplīši* was established to ensure the centralized water supply of the city of Sigulda. In this well field, groundwater is abstracted from the Aruküla-Gauja ($D_{2\text{-}3}$*ar-gj*) aquifers at a depth of 51-184 m. Current groundwater abstraction rates in this well field does not exceed the approved resources, thus excluding the possible impact on the quantitative status of the surrounding groundwater resources and groundwater levels. There is no information available on other water abstraction sites that could affect the quantitative status of this GDTEs, so it can be considered that the anthropogenic changes in the quantitative status of the GWB do not negatively affect the ecosystem and according to the procedure, assessment of these GDTEs should proceed to step 4.

In the vicinity of the remaining ecosystems, no significant groundwater abstraction is performed, therefore, according to the quantitative status assessment procedure, it is necessary to proceed the assessment of these ecosystems to step 3.

***Step 3**. Are there ditches reaching mineral sediments below the peat, mines or any other human activities which may affect GW level in the vicinity of the GDTE?*

In the vicinity of 77 ecosystems, no anthropogenic activities have been detected, which affect or could affect the quantitative status of GDTEs, therefore, further assessment of the quantitative status is not necessary, and it can be assumed that anthropogenically induced changes in the quantitative status of the GWBs do not negatively affect GDTEs.

Some anthropogenic activities were identified in the vicinity of 4 GDTEs, which might potentially affect groundwater levels. The situation in these GDTEs is described in more detail below.

Multipart GDTE No.14 (Fennoscandian mineral-rich springs and springfens (7160) was identified in GWB D6. The territory of GDTE is located in the "Mežole" nature reserve.

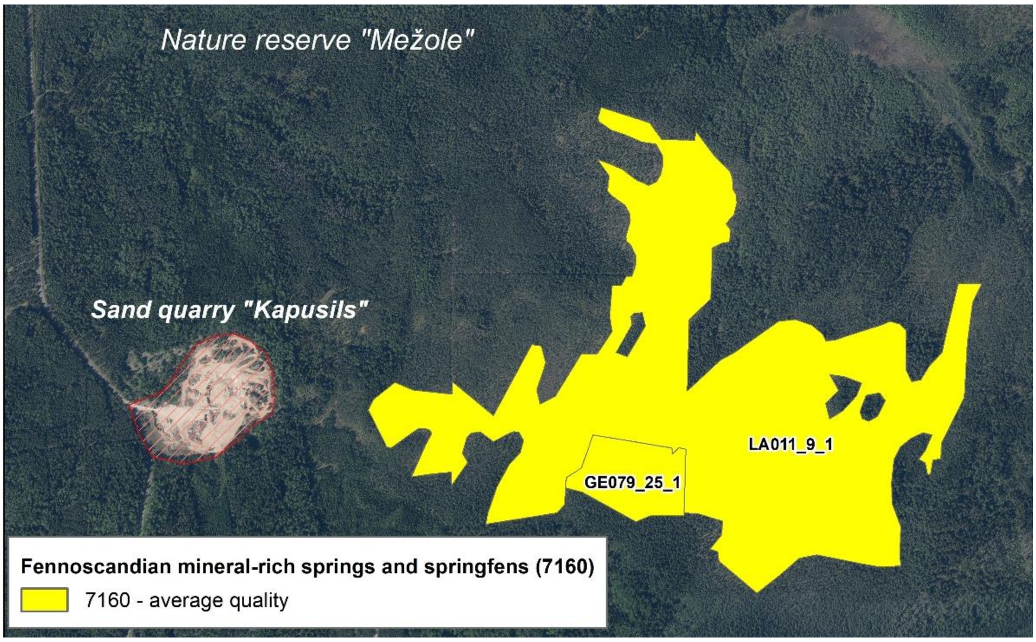


Figure 27. **Quarrying activities near the multipart GDTE No. 14** (Fennoscandian mineral-rich springs and springfens (7160))

About 250 m on the west of this GDTE (Fennoscandian mineral-rich springs and springfens (7160)) is the sand quarry "Kapusils" located. According to available information, lowering of groundwater levels is not performed in the quarry. Also, no groundwater level alterations mentioned in GDTE habitat inventory data (Nature Census project[7]).

There is no available data on groundwater level in the GDTE, as well as there are no representative monitoring wells nearby, where GW levels are measured. Based on previous information and available data, it can be assumed that anthropogenically induced changes in the quantity of the GWB D6 do not have a negative effect on the GDTE.

Multipart GDTE No.3. (Fennoscandian mineral-rich springs and springfens (7160). GDTE is delineated in GWB A8. GDTE area is surrounded by agricultural land and drainage ditches (Figure 28).

Figure 28 **Agricultural land drainage ditches around the multipart GDTE No. 3** (Fennoscandian mineral-rich springs and springfens (7160))

According to habitat inventory data, humidity conditions are adequate. There is no available data on groundwater level in the GDTE, as well as there are no representative monitoring wells nearby, where GW levels are measured. Based on previous information and available data, it can be assumed that anthropogenically induced changes in the quantity of the GWB A8 do not have a negative effect on the GDTE.

Multipart GDTE No.18 (Fennoscandian deciduous swamp woods (9080)) and GDTE No. 18LS674_956_1 (Alkaline fens (7230)). Multipart GDTE No. 18 is delineated in GWB A10, but GDTE No. 18LS674_956_1 – in GWB A8. GDTE is delineated in GWB A10. According to habitat inventory data, historical effects

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[7] https://www.skaitamdabu.gov.lv/public/eng/about_the_nature_census/

of drainage have been noted in both GDTEs, however, it is indicated that drainage systems are no longer functional and the forest is recovering, or naturally regenerating (Figure 29).

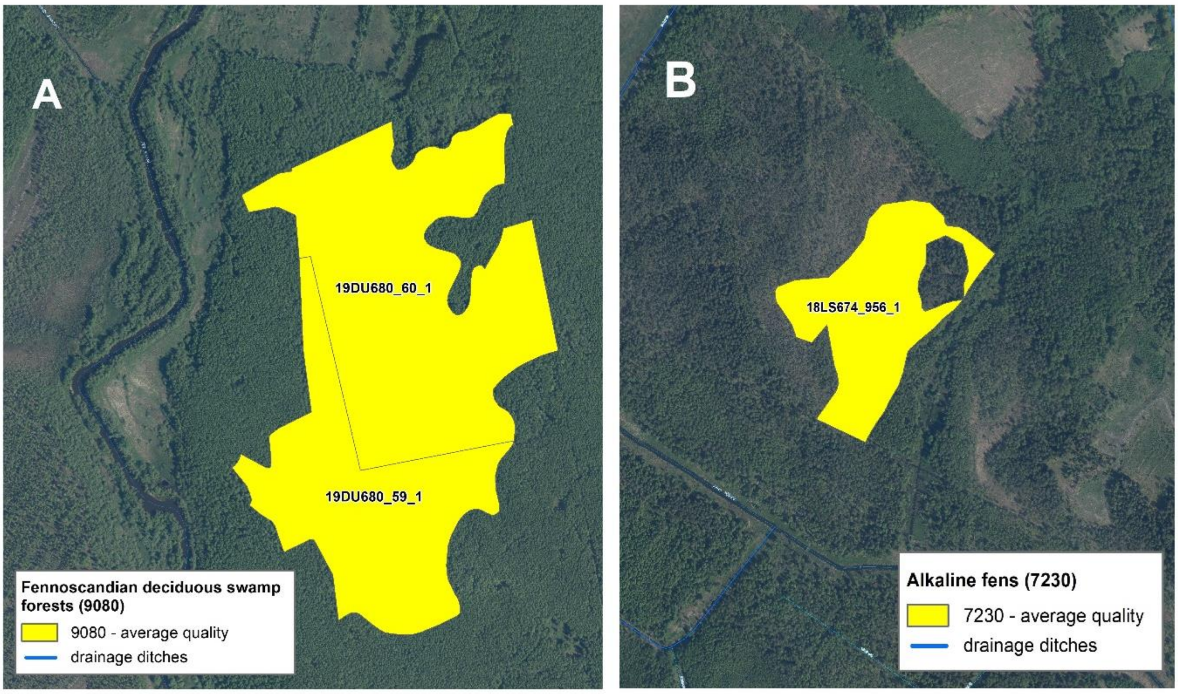

Figure 29. **Historical effects of drainage in 2 GDTEs: A - multipart GDTE No. 18** (Fennoscandian deciduous swamp woods (9080)); B - Alkaline fens (7230)

According to the assessment procedure of the quantitative status of ecosystems, the assessment of these above-mentioned four GDTEs should proceed to step 4.

Step 4. *Is the annual mean water level in the GDTEs groundwater monitoring well lower than the long-term mean water level?*

In this step, it is intended to assess the changes in groundwater levels in the vicinity of those GDTEs, of which some anthropogenic activity was detected (quarry, agricultural and forest drainage ditches, etc.). Such activities were detected in the vicinity of a total of seven GDTEs (19JZ1209_151_2, 20JZ109_60_1, 20JZ109_60_1, Multipart-14, Multipart-3 Multipart-18, 18LS674_956_1), however, no changes in groundwater levels were marked in the habitat inventory data. There is no available data on groundwater levels in GDTEs, nor are there any representative groundwater level observation wells. Accordingly, it is not necessary to carry out the following steps for the quantitative status assessment of GDTE and it can be assumed that anthropogenically caused changes in the quantitative status of the GWB do not negatively affect GDTEs.

1.4.2.2. Qualitative effect of GWBs to GDTEs on the Latvian side

Step 1. *Is there any piece of evidence that water level of the GDTE is considerably lower than it has been previously or is typical to analogous ecosystems, or the conservation status of the GDTE is worse than "good" according to the assessment based on the Habitats directive?*

In total, 116 GDTEs (504 single patches) have been delineated on the Latvian side of the border in the Gauja/Koiva and the Salaca/Salatsi River Basin (27 GDTEs identified in the Salaca river basin). According to the assessment based on the Habitats directive, 81 GDTEs (65 single patches and 17 multipart polygons) were identified with ecological quality status lower than "good" (average - 71; poor - 10). In accordance with the quality state assessment methodology, it is necessary to move to the next step of the assessment scheme to assess these 81 GDTEs.

Step 2. *Is there any relevant and possibly polluting human activities in the vicinity of the GDTE?*

After assessing the available data and cartographic materials, it was concluded that in the vicinity of 62 ecosystems, no significant and potentially polluting anthropogenic activities are performed. Accordingly, it can be considered that the anthropogenically induced changes in the qualitative state of the GWB do not have a negative effect on these GDTEs, and further steps for the assessment of the quality state do not need to be performed.

Potentially polluting anthropogenic activities are detected around the 19 GDTEs. In most cases, agricultural activities are performed near the GDTE (15 GDTEs); 3 ecosystems (19JZ1209_151_2; 20JZ109_60_1; 20JZ109_60_1) are located about 700 m from wastewater treatment plants, while 1 GDTE (20JZ109_68_1) is located about 600 m from a wood processing plant.

According to the quality assessment procedure, these 19 ecosystems should continue to be assessed and need to move to the next step of the assessment scheme.

Step 3. *Has the deterioration of the conservation status of the GDTE been caused by changes in the water chemistry (*N_{tot}*,* P_{tot}*, nitrates etc)?*

In the habitat inventory data, the most common reasons for the deterioration of the GDTE status are the activity of beavers, digging by wild boars, trampling and the consequences of forest machinery, however, there is no information about the quality impact directly due to groundwater. As no information is available on the groundwater chemical status in the territory, as well as the chemical status of the dependent ecosystem itself, it is not possible to assess the impact of changes in the groundwater chemical status on GDTE. According to the assessment scheme procedure, the following steps do not need to be performed.

Taking into account the above, it can be considered that the anthropogenically induced changes in the groundwater qualitative status of the GWB do not have a negative impact on GDTEs.

1.4.2.3. Quantitative effect of GWBs to GDTEs on the Estonian side

Step 1. *Is there any piece of evidence that water level of the GDTE is considerably lower than it has been previously or is typical to analogous ecosystems, or the conservation status of the GDTE is worse than "good" according to the assessment based on the Habitats directive?*

In one of the identified GDTEs (No. 6 in Figure 21) in the Estonian part of the Salaca/Salatsi basin the areal majority of it (a multipart polygon consisting of several habitat polygons) had a worse than "good" conservation status. In accordance with the quantitative status assessment procedure, it is necessary to move to the next step of the assessment scheme to assess that GDTE.

***Step 2.** Is there relevant groundwater abstraction in the vicinity of the GDTE? Groundwater abstraction rates considered relevant depend on the distance from the GDTE.*

In this step, it is proposed to assess the impact of the groundwater abstraction site near the GDTE. For this assessment, the information from the Estonian Nature Information Database was used.

For the assessment of potential groundwater abstraction pressure on GDTE, the same approach as in the GroundEco project was used (Retike et al., 2020). The amount of groundwater abstraction that is considered significant, depends on the distance from the GDTE according to the following equation:

$$x = \sqrt{\frac{Qyear}{\pi * R_{year}}}, \text{ where}$$

X – distance from groundwater abstraction site (m),
Q_{year} – groundwater abstraction in GWB (m^3/year),
R_{year} – mean groundwater recharge ($m^3\ m^{-2}\ year^{-1}$).

In case of the single GDTE that moved to that step, there is no registered groundwater abstraction tens of kilometers from the GDTE therefore the potential effect of groundwater abstraction was considered nonexistent and the GDTE moved to the next step.

***Step 3.** Are there ditches reaching mineral sediments below the peat, mines or any other human activities which may affect GW level in the vicinity of the GDTE?*

There is a ditch going through the GDTE (Figure 30) and no other anthropogenic activities that could affect groundwater level in the vicinity of the GDTE. The ditch has most likely been dug to lower the water level in the wetlands upstream of the GDTE and therefore has likely not caused a noteworthy drop in the groundwater level feeding the GDTE. It probably has caused faster water runoff from the GDTE and lower water level in the peat layer and deteriorated the conservation status of the GDTE that way. Accordingly, it is not necessary to carry out the following steps for the quantitative status assessment of GDTE.

It can be assumed that possible anthropogenically caused changes in the quantitative status of GWB no. 23 have no negative effect on the GDTEs in the Estonian part of the Salaca/Salatsi river basin.

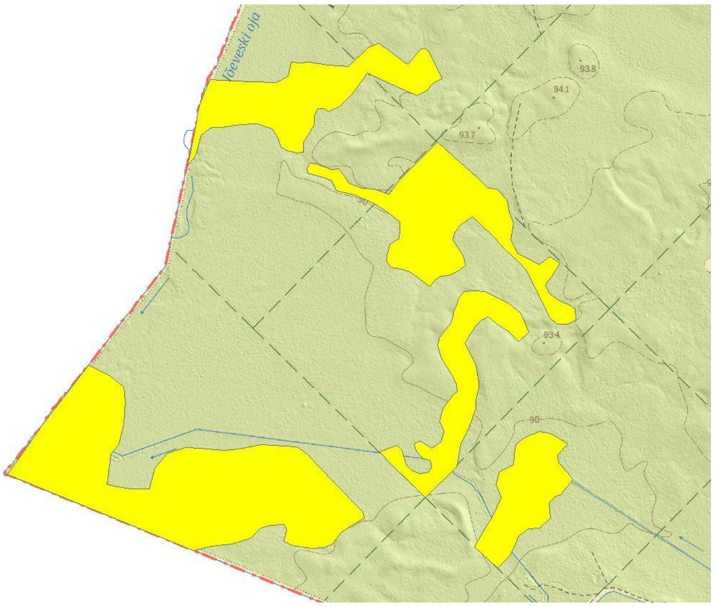

Figure 30. **A ditch going through the GDTE no. 6 (Fennoscandian deciduous swamp woods (9080*)).**

1.4.2.4. Qualitative effect of GWBs to GDTEs on the Estonian side

Step 1. *Is there any piece of evidence that water level of the GDTE is considerably lower than it has been previously or is typical to analogous ecosystems, or the conservation status of the GDTE is worse than "good" according to the assessment based on the Habitats directive?*

In one of the identified GDTEs (No. 6 in Figure 21– in chp.1.4.1.) in the Estonian part of the Salaca/Salatsi basin the areal majority of it (a multipart polygon consisting of several habitat polygons) had a worse than "good" conservation status. In accordance with the quantitative status assessment procedure, it is necessary to move to the next step of the assessment scheme to assess that GDTE.

Step 2. *Is there any relevant and possibly polluting human activities in the vicinity of the GDTE?*

The GDTE is located in a remote and mostly forested area. There is an agricultural grassland 300 m south of the southern part of the GDTE in the territory of Latvia, but no fields in the vicinity. Therefore, it can be concluded that there are no relevant and possibly polluting human activities in the vicinity of the GDTE and the following steps of the assessment scheme do not need to be performed.

Taking into account the above, it can be considered that possible anthropogenically induced changes in the groundwater quality of GWB no. 23 have no negative effect on the GDTEs in the Estonian part of the Salaca/Salatsi river basin.

2. DEVELOPMENT OF TRANSBOUNDARY MONITORING STRATEGY

2.1. Groundwater monitoring principles in Estonia and Latvia

The need for groundwater monitoring and its system in countries was mainly determined by three higher-level EU normative documents: The Water Framework Directive (2000/60/EC), the Groundwater Directive (2006/118/EC) and the Nitrates Directive (91/676/EC); as well as the relevant laws and regulations of each country[8]. In addition, there are EC recommended guidelines – Guidance Document No.15 "Guidance on Groundwater Monitoring", Guidance Document No.26 "Guidance on Risk Assessment and the Use of Conceptual Models for Groundwater" and Guidance Document No.16 "Guidance on Groundwater in Drinking Water Protected Areas".

The main purpose of groundwater monitoring in both countries is to monitor the chemical and quantitative status of groundwater bodies (changes and trends in quality indicators) in order to obtain a comprehensive overview of the status of groundwater bodies in each river basin district. Groundwater monitoring in Latvia and Estonia 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. Long-term groundwater monitoring programs developed in each country with a 6-year cycle help 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.

It should be noted that new groundwater monitoring programs[9][10] have now been developed in both countries, which will help to assess the status of groundwater resources in the future and their possible changes over the period. It should be noted that in order to describe the current state of groundwater resources, the results of previous monitoring programs implemented until 2021 were used to prepare the 3rd Cycle RBMPs - in the case of Estonia the program was fully implemented in the period from 2016 to 2021[11], but in the case of Latvia - in the period from 2015 to 2020[12].

2.1.1. Groundwater monitoring network in Latvia and Estonia

Groundwater monitoring networks in the countries were described in the framework of the GroundEco project, which can be found in the final report on the results of the project[13]. This section examines

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[8] In Estonia, these requirements are set out in the Water Act and Regulation No.49 of the Ministry of the Environment "Sampling Methods"; in Latvia, these requirements are determined by the Water Management Law and Cabinet Regulation No.92 "Requirements for Monitoring of Surface Waters, Groundwater and Protected Areas and Development of Monitoring Programs" (adopted on 17 February, 2004)

[9] https://envir.ee/veemajanduskavad-2022-2027-eelnou#veemajanduskavade-do

[10] https://www.varam.gov.lv/lv/search?q=2021.-2026.

[11] https://envir.ee/veemajanduskavad-2015-2021

[12] https://www.meteo.lv/lapas/noverojumi/vides-monitoringa-pamatnostadnes-un-programma/vides-monitoringa-programma-2015-2020-gadam/vides-monitoringa-programma-2015-2020-gadam?id=2002&nid=968

[13] https://www.meteo.lv/fs/CKFinderJava/userfiles/files/Par_centru/ES_projekti/GroundEco/GroundEco_final_report.pdf

and compares in more detail the national approaches to the implementation and enforcement of groundwater monitoring, as well as described in more detail the principles of monitoring networks.

Groundwater monitoring in both Latvia and Estonia is mainly provided by the National Monitoring Networks with existing monitoring points (wells[14] and springs), which basically allow to assess regional groundwater changes and provide background data on groundwater chemical and quantitative status at GWB level. In addition, monitoring in both countries is provided in nitrate vulnerable zones, which are integrated with other monitoring programs and implemented by other organizations. The current National Monitoring Network in Latvia and Estonia does not provide adequate monitoring in all protected areas identified in Annex 4 of the WFD (drinking water abstraction areas, specially protected nature areas - associated freshwater ecosystems). In the case of Latvia, additional monitoring is provided in drinking water protected areas (sites with groundwater abstraction above 100 m^3/d), which is integrated with other monitoring programs and provided by the water user in accordance with the requirements specified in the groundwater well field passport. Information on the above types of monitoring (national and nitrate or additional monitoring) and the number of observed monitoring points is summarized below, taken into account newly developed monitoring programs in each country - in Latvia case based on the 2021-2026 plan, in Estonian case based on the 2022-2027 plan (see Table 8). It should be noted that in Latvia the maximum number of monitoring points can be reached only after checking the technical condition of individual old monitoring wells and including them in the existing monitoring network after improving or restoring these wells.

TABLE 8

Types of groundwater monitoring in Latvia and Estonia

Country	Point type	Quality			Quantity	Additional monitoring	Aquifer complex or aquifer
		S*	O*	Total			
Latvia	Well	186	37	223	313	20	Quaternary, Famennian, Pļaviņas-Amula, Aruküla-Amata, Pärnu
	Spring	30	-	30	-	-	
Estonia	Well	248	171	248	256	93	Quaternary, Ordovician-Cambrian, Silurian-Ordovician, Cambrian-Vendian, Devonian
	Spring	3	3	3	-	32	

** S – surveillance monitoring, O – operational monitoring. Operational monitoring is carried out within the boundaries of groundwater bodies at risk, while surveillance monitoring is provided in other groundwater bodies. Operational monitoring wells overlap with surveillance monitoring wells.*

The location of monitoring points is visually shown in Figure 31, where it can be seen that monitoring points are unevenly distributed in national territories. The density of monitoring points in countries mainly depends on the intensity of anthropogenic load (water abstraction, intensity and nature of industrial activity, including mining and agriculture), monitoring tasks and hydrogeological conditions in countries.

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[14] In Latvia, groundwater monitoring stations consist of several wells, which are installed in one set and provide GWB vertical coverage. Some wells are equipped with filters at different depths, but in some stations fluctuations in groundwater levels and their chemical quality are observed in shallow groundwater. In Estonia, on the other hand, the concept of a station is not used, as monitoring is provided mainly in individual monitoring wells. The vertical coverage of groundwater bodies is ensured with groups of monitoring wells with different open intervals.

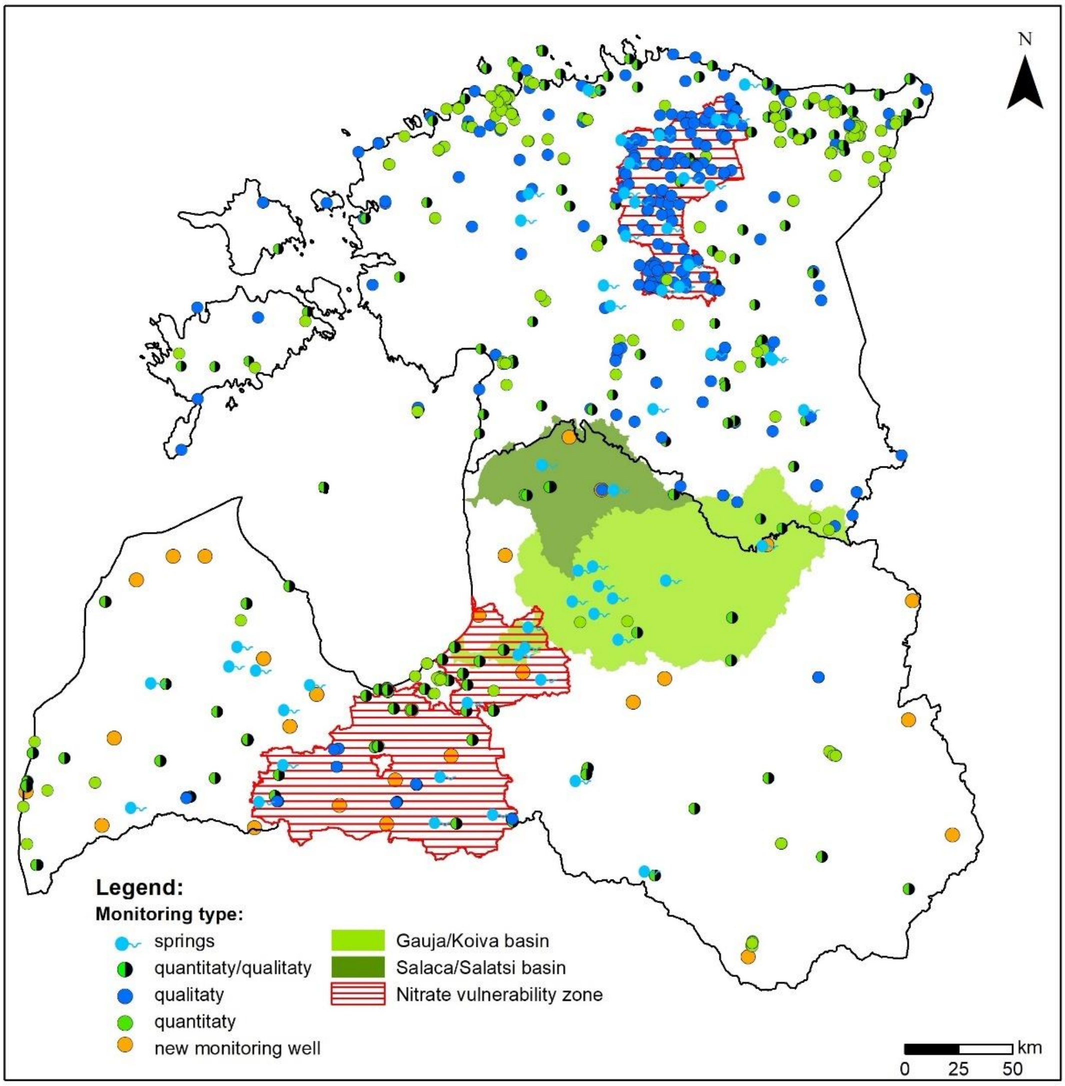

Figure 31. **Groundwater monitoring points in Latvia and Estonia**

In Latvia, the monitoring network provides observations in basically all aquifers of the active water exchange zone[15], focusing on the aquifers used in water supply. The highest density of the network is in Rīga, Jūrmala and Liepāja, where there is a higher consumption of groundwater, as well as the number of potential sources of pollution. In Estonia, on the other hand, the highest network density is noted in the nitrate vulnerable zone, where additional quality monitoring and a denser network of groundwater monitoring wells have been designated for the Ordovician Ida-Viru and the Ordovician Ida-Viru oil-shale basin groundwater bodies, where the pressure on groundwater is the highest due to oil shale mining. A relatively dense monitoring network is also designated for the Cambrian-Vendian type GWBs, as these are subject to the most intense consumption of groundwater which has caused the formation of extensive cones of depression in groundwater.

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[15] The exception is GWB P (distributed in the vicinity of Salacgrīva and Aloja near the Estonian border), where observations are also made in the deepest Pärnu aquifer, because in this area the Pärnu aquifer contains freshwater. In the rest of Latvia, this aquifer contains highly mineralized waters or saline waters.

In the new planning period, it is planned to improve the existing groundwater monitoring network[16] 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 sediment boreholes) and the deepest groundwater aquifers or pre-Quaternary sedimentary wells. As far as possible, it is planned to improve the technical condition of the existing wells and include them in the current monitoring network.

2.1.2. Principles of groundwater quality monitoring

This section summarizes information on groundwater quality monitoring indicators, principles of water sampling and analysis in the framework of national monitoring, focusing on the coincidence and differences of groundwater monitoring approaches. Mainly focusing on the newly developed monitoring programs.

2.1.2.1. Sampling and analysis

Groundwater samples in both countries are taken, transferred and analyzed in accordance with national methods, which are standardized and in accordance with the requirements of Article 8, Paragraph three of the WFD. Under field conditions, the Ph, temperature, dissolved oxygen concentrations and electrical conductivity of water are determined (the total iron and oxidation-reduction potential is also determined at Latvian monitoring points)[17]. After stabilization of the above field parameters, a water sample is taken, placed in a closed cold box and delivered to the laboratory. Groundwater sampling is provided by well-trained specialists – in Latvia, sampling specialists are authorized to take samples, and the head of the laboratory quality system inspects sampling at least once a year, while in Estonia sampling is provided by a certified specialist, who must renew certification every four years by completing training. The summarized information on groundwater field analysis methods in Latvia and Estonia is provided in Table 9, but the information on the used devices and the applied procedure for taking groundwater samples is summarized in Annex 2.

TABLE 9

Groundwater field analysis methods in Latvia and Estonia

Parameter	Latvian method	Estonian method
pH, determined at 20°C	LVS EN ISO 10523:2012	ISO 10523
Temperature, °C	LVS EN ISO 10523:2012	ISO 5667-11
Total iron, mg/l	ISO 6332	Determined in the laboratory
Dissolved oxygen, mg/l	LVS EN ISO 5814:2013	EVS-EN 5814
Electrical conductivity (20°C), µS/cm	LVS EN ISO 27888:1993	EN 27888
Oxidation-reduction potential, mV	-	Not determined

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[16] The existing groundwater monitoring network is planned to be improved in accordance with the specific support objective 5.4.2 of the European Union Cohesion Fund "Ensure the development of the environmental monitoring and control system and timely prevention of environmental risks, as well as public participation in environmental management" of measure 5.4.2.2 "Environmental monitoring and control systems development and promotion of public participation in environmental management" of the third selection round project "Development of water monitoring and control system".

[17] It should be noted that stabilization of field parameters and proper pumping of wells (pumping of at least 3-6 well volumes from the observation well) ensures that the water sample is taken from the required aquifer and not from the water standing in the well casing.

In both countries, the analysis of water samples is performed in accredited laboratories in accordance with the requirements of EN ISO / IEC 17025, which guarantees the reliability of the data. In Latvia, it is provided by the LEGMC (national accreditation No. LATAK-T-105-34-97), while in Estonia the analysis of water samples is performed by the Estonian Environmental Research Center (national accreditation No. L008).

In order to characterize the quality and assess the status of groundwater bodies in both countries, basic (universal) indicators are defined at all monitoring points and specific indicators - at monitoring points, which characterize the respective anthropogenic load or characterize the shallow aquifer. Universal indicators serve as a basis for many hydrogeochemical processes (caused by both anthropogenic and natural factors), incl. diffuse pollution indicators. According to the recommendations of the EC, the list of universal indicators should at least include - Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, NH_4^+, NO_2^-, NO_3^-, and field work parameters (temperature, pH, Dissolved Oxygen and Electrical Conductivity). The above main ions and field work parameters are also needed for quality control of water samples during sampling and analysis (mainly for ion balance calculation). It should also be noted that other trace ions could be also monitored and its choice is dependent on the aquifer lithology and territory hydrogeological characteristics. The trace ions may be clues to depict flow path, recharge areas, and so on. Moreover, trace ions may be directly related to some identified pressure and, therefore, they become indicative of the risks to and impacts on groundwater from identified pressures.

Annex II of the Groundwater Directive also identified the need to monitor specific indicators, including at least As, Cd, Pb, Hg, as well as trichlorethylene, tetrachloroethylene and other synthetic substances (monitoring these parameters at least once during the water management period), as well as parameters such as PO_4^{3-} or P_{tot}. However, Annex I of the Groundwater Directive stipulates the requirement to control not only nitrate pollution in groundwater, but also to monitor pesticide pollution. Table 10 below summarizes the information on the list of analyzed indicators and their coincidence in both countries.

TABLE 10

Observed indicators of groundwater quality in Latvia and Estonia

Parameters	Latvia	Estonia
Major ions	Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, total hardness (calculated), PO_4^{3-}, P_{tot}, Fe_{tot}*, Mn	Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, total hardness, PO_4^{3-}, P_{tot}*, Fe_{tot}, Dry residue
Nitrogen compounds and their ionic forms	NH_4^+, NO_2^-, NO_3^-, N_{tot}, DOC, TOC, UV absorption, permanganate index	NH_4^+, NO_2^-, NO_3^-, N_{tot}*, DOC, CO2 (calculated)
Heavy metals	Cd, Pb, Hg, As, Ni	Cd, Pb, Hg, As, Ba, Zn*, Cu*, Ni*
Chemical pollutants	Trichlorethylene, tetrachloroethylene, 1,2-dichloroethane, trichloromethane, BTEX + *other parameters* (more information in Annex 3)	Trichlorethylene, tetrachloroethylene, 1,2-dichloroethane + *other parameters* (more information in Annex 3)

Parameters	Latvia	Estonia
Pesticides	Atrazine, simazine, bentazone, MCPA, promethrin, propazine, 2,4-D, isoproturon, aclonifen, bifenox, aldrin, dieldrin, heptachlor, dimethoate, cypermethrin, trifluralin, tebuconazole*, epoxiconazole*, diflufenican*, metribazuzan*, metribazuran*, MCPB, heptachlor epoxy, alpha-cypermethrin, pendimethalin*, azoxystrobin*, prochloraz*	Atrazine, simazine, bentazone, MCPA, promethrin, propazine, 2,4-D, isoproturon, aclonifen, bifenox, aldrin, dieldrin, heptachlor, dimethoate, cypermethrin, trifluralin, tebuconazole, epoxiconazole, diflufenican, metribuzin, metazachlor + *other parameters* (more information in Annex 3)

*Notes: Basic parameters, Additional parameters, Mn – a parameter measured in only one country. * Components are included in the new monitoring program.*

According to the collected data, it can be seen that the monitoring of groundwater quality in both Latvia and Estonia takes into account the recommendations of the European Commission, as well as the requirements of the Groundwater Directive. Accordingly, a minimum list of universal and specific indicators has been observed in both countries. However, discrepancies have also been noted, mainly related to the characteristics of each country's monitoring, as well as to observed anthropogenic pressures and other factors. For example, in Latvian monitoring to check the reliability of data, to correct the obtained data and increase the accuracy, which is very important in typically low concentrations or, conversely, very high mineralization amplitude, the list of water quality indicators includes control indicators: total hardness, UV absorption or permanganate index and N_{tot} (also allows the identification of groundwater impacts on surface water bodies and terrestrial ecosystems). As manganese (Mn) is characterized by high migration capacity in groundwater and Latvian conditions are also characterized by natural excesses of manganese concentration, this parameter is included in the universal list of indicators.

In Estonia, no control indicators are currently measured beside the main water quality indicators. During the next six-year cycle, N_{tot}, P_{tot}, PO_4, Zu, Cu, Ni and increase the determination of Ba are included in the Estonian monitoring program in order to identify groundwater impacts on surface water bodies and terrestrial ecosystems. Estonia has established a list of terrestrial and aquatic ecosystems that are directly dependent on groundwater bodies. From here, the status of groundwater bodies are assessed to determine whether groundwater chemical quality indicators can lead to unfavorable status for surface water bodies or terrestrial ecosystems feeding on groundwater. N_{tot} and P_{tot} measurements from groundwater make it possible to compare monitoring data between surface water and groundwater, as it is also measured from surface water. Heavy metals Ni, Cu, Zn will also be added as they were standardized in drinking water and will need to be monitored under the new Drinking Water Directive. Also have been added the Watch-list indicators – Pharmaceuticals (drug residues) and perfluor (PFAS) substances, which are planned to monitor in 17 different Estonian GWBs in Ordovician, Silurian and Quaternary complexes.

Laboratories in both countries provide testing results in quality control procedures: at least the percentage of total concentrations of cation and anion equivalents tested, as well as simple correlations between parameters ($P/PO_4 < P_{tot}$, $N/NO_3 + N/NH_4 + N/NO_2 < N_{tot}$ mg/l). In turn, the used groundwater laboratory analysis methods in Latvia and Estonia are summarized in Table 11, trying to find an opportunity to jointly analyze the obtained results (data are summarized for common indicators and identifying similar methods). In turn, more detailed information on the methods used in each country for each parameter and their diversity is provided in Annex 3.

TABLE 11

Groundwater laboratory analysis methods in Latvia and Estonia*

Parameter	Latvian method	Estonian method
Calcium (Ca)	LVS EN ISO 11885:2009	EVS-EN ISO 11885
	LVS EN ISO 7980:2000	ISO 6058
	-	SFS 3003
	-	EN ISO 14911
Magnesium (Mg)	LVS EN ISO 11885:2009	EVS-EN ISO 11885
	LVS EN ISO 7980:2000	ISO 6059
	-	EN ISO 14911
Sodium (Na)	LVS ISO 9964-3:1993	EVS-ISO 9964-3
	LVS EN ISO 11885:2009	EN ISO 14911
Potassium (K)	LVS ISO 9964-3:1993	EVS-ISO 9964-3
	LVS EN ISO 11885:2009	EN ISO 14911
Bicarbonates (HCO_3)	SM 2320 B:2017	EVS-EN ISO 9963-1
Sulphates (SO_4)	LVS EN ISO 10304-1:2009	EVS-EN ISO 10304-1
Chlorides (Cl)	LVS EN ISO 10304-1:2009	EVS-EN ISO 10304-1
Phosphate phosphorus and phosphates (PO_4)	LVS EN ISO 6878:2005, 4.nod	EVS-EN ISO 6878
	-	ISO 15681-2
Total phosphorus (P_{tot})	LVS EN ISO 6878:2005, 7.nod.	ISO 15681-2
Total nitrogen (N_{tot})	LVS EN ISO 11905-1:1998	ISO 11905
	LVS EN 12260:2004	-
Ammonium (NH_4)	LVS EN ISO 11732:2005	EVS-EN ISO 11732
	QuAAtro Method no. Q-080-06 Rev.2:2008	SFS 3032
Nitrites (NO_2)	LVS ISO 6777:1984	EVS-EN ISO 13395
Nitrates (NO_3)	LVS EN ISO 13395:2004	EVS-EN ISO 13395
	-	EVS-EN ISO 10304-1
Total hardness	SM 2340 C:2017	SM 2340 C:2017
	-	ISO 6059
	-	SFS 3003
Total iron (Fe_{tot})	LVS EN ISO 11885:2009	ISO 6332
Lead (Pb)	LVS EN ISO 11885:2009	EVS-EN ISO 11885
	-	EVS-EN ISO 17294-2
Nickel (Ni)	LVS EN ISO 11885:2009	EVS-EN ISO 11885
	-	EVS-EN ISO 17294-2
Cadmium (Cd)	LVS EN ISO 15586:2003	EVS-EN ISO 17294-2
	LVS EN ISO 11885:2009	EVS-EN ISO 11885
Mercury (Hg)	LVS EN ISO 17852:2008	EVS-EN ISO 17852
	-	EVS-EN ISO 12846
Arsenic (As)	LVS EN ISO 15586:2003	EVS-EN ISO 17294-2

Parameter	Latvian method	Estonian method
	-	EVS-EN ISO 11885
Atrazine	EN ISO 10695:2000*	STJnrU63
Simazine	EN ISO 10695:2000*	STJnrU92
Propazine	EN ISO 10695:2000*	STJnrU63
Bentazone	US EPA Method 8151A:1996*	STJnrU92
MCPA	US EPA Method 8151A:1996*	STJnrU92
Aldrin	ISO 6468:1996	STJnrU63
Dieldrin	ISO 6468:1996	STJnrU63
Heptachlor	ISO 6468:1996	STJnrU63
2,4-D	BIOR-T-012-162-2015	STJnrU92
Isoproturon	BIOR-T-012-162-2015	STJnrU92
Aclonifen	BIOR-T-012-162-2015	STJnrU63
Biphenox	BIOR-T-012-162-2015	STJnrU63
Promethrin	BIOR-T-012-162-2015	STJnrU63
Dimethoate	BIOR-T-012-162-2015	STJnrU92
Cypermethrin	BIOR-T-012-162-2015	STJnrU63
Trifluralin	BIOR-T-012-162-2015	STJnrU63
Tebuconazole	BIOR-T-012-162-2015	STJnrU92
Epoxiconazole	BIOR-T-012-162-2015	STJnrU63
Diflufenican	BIOR-T-012-162-2015	STJnrU92
Metribuzin	BIOR-T-012-162-2015	STJnrU63
Metazachlor	BIOR-T-012-162-2015	STJnrU92
Trichlorethylene	ISO 10301:1997	ISO 20595
Tetrachlorethylene	ISO 10301:1997	ISO 20595
1,2-dichloroethane	ISO 10301:1997	ISO 20595

Notes: Methods are not comparable, Methods are comparable
** The data is for a specific date; data can be updated as needed*

The methods of analysis used in the countries are standardized and, in many cases, the same. Differences in the methods are mainly noted for the detection of pesticides and other chemical pollutants. Also in the previous period, in Latvia the assessment of the total iron concentration was performed at the time of sampling, but in Estonia the sample is delivered to the laboratory. At present, the methods are not comparable, because during the transfer of the sample, the iron in the water precipitates at the bottom of the vessel. However, it should be noted that, according to the new monitoring program, the iron content in the water in the case of Latvia will also be determined under laboratory conditions.

In general, the quality system in place in both countries can be considered to guarantee the reliability of monitoring data from the moment of sampling to the results of data analysis, as the certification and accreditation system guarantees control and monitoring throughout the data supply chain. Consequently, the existing monitoring system in Latvia and Estonia provides an opportunity to jointly assess the quality of transboundary groundwater bodies, as the underlying analysis methods are in many cases comparable.

2.1.2.2. Frequency of groundwater quality monitoring and sampling

The frequency of monitoring inspections is not defined in national legislation; as well as the Water Framework Directive, the Groundwater Directive and the Nitrates Directive do not set specific requirements for the frequency of groundwater monitoring observations (except for operational monitoring of groundwater bodies at risk – to be performed at least once a year), but only the frequency (cyclicality).

According to the recommendations of the EC (Guidance Document No.15, Guidance on Groundwater Monitoring (EC, 2007)), the recommended sampling frequency for surveillance monitoring can vary from twice a year in shallow wells with the highest risk of contamination to once in 6 years in deeper wells with the lowest the risk of contamination (the frequency of the initial assessment may vary from 4 to 2 times a year, respectively).

After data collection, it can be seen that in Latvia and Estonia there are no coincidences related to the frequency of groundwater quality surveys[18] and the frequency of water sampling (see Table 12).

TABLE 12

Frequency of groundwater quality monitoring at monitoring points in Latvia and Estonia

Country	Parameter	Survey frequency (from-to)	Sampling frequency (from-to)	Sampling points
Latvia	Basic	Once a year - once every 6 years	Once a year – 4 times a year	all points
	Additional*	Once a year – 2 times in 6 years	Once a year – 4 times a year	only at points with the lowest protection or GWBs at risk
Estonia	Basic	Once a year – 3 times in 6 years	Once a year – 4 times a year**	all points
	Additional*	Once a year – 1 time in 6 years	Once a year	depending on the compound: only at points with GWB at risk, connected with GDTEs, have specific pressure load or by additional random sampling

** In Latvia, sampling of specific indicators in deeper aquifers is envisaged only if excesses of these parameters have been detected in the upper layer. In Estonia, on the other hand, they are monitored in shallow wells once or twice during a 6 year period, and in the deepest wells once during a 6 year period.*

*** In Estonia, the sampling frequency for NO_3 in the nitrate vulnerable zone in 4 times a year for some monitoring stations.*

In Latvia, the frequency of surveys at monitoring points mainly decreases with the increase of the depth of the aquifer, as well as with the decrease of the degree of risk of surface pollution infiltration. The frequency of inspections at monitoring points can vary from once a year to once every 6 years. Accordingly, at monitoring points that are not protected or are relatively protected, the frequency of inspections varies from 1 time per year[19] to 1 time in 2 years, while at monitoring points with the best

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[18] The monitoring cycle or inspection frequency is the period when monitoring is performed in a 6-year planning period. For example, a water sample is taken from the monitoring point every year (once a year) or every two years (once every 2 years), or every third year (twice every 6 years), and so on.

[19] Monitoring points where changes in the chemical composition of groundwater or exceedances of certain parameters have been detected in the previous 6-year period (permanent exceedances of heavy metals or nitrate content above 25 mg/l), as well as permanent presence of pesticides. Ideally, it is necessary to maintain the same frequency of inspections in springs where single exceedances of heavy metals and pesticides have been detected or the presence of pesticides has been observed, as the springs are more exposed to pollution (NITRA).

level of protection the frequency of inspections can vary from 1 time in 2 years to 1 time in 6 years. The frequency of inspections of groundwater bodies at risk is at least once a year, which is determined by the regulatory enactments of the Republic of Latvia, as well as the requirements set out in the WFD.

In Estonia also the frequency of surveys at monitoring points mainly decreases with the increase of the depth of the aquifer, as well as with the decrease of the degree of risk of surface pollution infiltration. The frequency of monitoring basic parameters can vary from once a year to three times in 6 years and for additional parameters the frequency can vary from once to twice in 6 years. In general monitoring points that are not protected or are relatively protected, the frequency of monitoring varies from 1 time per year to 3 times in 6 years, while at monitoring points with the best level of protection the frequency of inspections can vary from 1 time in 6 years. In wells where the limit value is exceeded, annually. In the previous period the frequency of monitoring basic parameters varied from once a year to two times in 6 years and for additional parameters the frequency can vary from once to twice in 6 years and in well protected areas the frequency was 1 time in 18 years.

In Estonia, the frequency of water sampling at all monitoring points (exemption, monitoring points in nitrate vulnerable zone) takes place once a year, usually during the summer period, while in Latvia the frequency of water sampling at monitoring points varies from 4 times a year to 1 time per year (frequency mainly depends on the monitoring point's degree of protection, seasonality and monitoring objectives). Accordingly, in Estonia, the frequency of water sampling in nitrate vulnerable zone at all monitoring wells varies from 4 times a year to 1 time per year. In main monitoring wells (53 wells) water sampling frequency is 4 times per year and in support network monitoring wells (71 wells) it is 1 time per year.

2.1.3. Principles of groundwater quantity monitoring

The main indicator of groundwater quantitative monitoring in both countries is the groundwater level. In Estonia, if necessary, quantitative monitoring also includes measuring the amount of water flow in springs and watercourses, while in Latvia it is only planned to consider the possibility of including spring flow measurement (at least for falling springs) in groundwater quantitative monitoring[20].

Manual and automatic water level measurements are performed in the observation wells. Most of the wells in the countries are equipped with automatic water level meters, which provide water level data collection with a frequency of 2-8 times a day (see Table 13).

TABLE 13

Frequency of groundwater quantity observations at monitoring points in Latvia and Estonia

Type/frequency of measurements		Number of Latvian monitoring points	Number of Estonian monitoring points
Manual measurements	Once a year	-	-
	4 times a year	7	-
	Once a month	70	105
	Twice a month	35	-
Automatic measurements	Twice a day	201	-
	8 times a day	-	151
	Total:	**313**	**256**

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[20] Spring flow measurement is used by many countries to monitor climate change and is one of the recommendations in the EC guidelines.

In Latvia, the frequency of observations in monitoring wells currently varies from twice a day to four times a year. In the future, it is planned to consider increasing the frequency of automatic level measurements at least up to 12 times a day (ideally up to once an hour) in groundwater monitoring wells where potential groundwater-surface linkages have been identified or the risk of marine and other saline intrusion has been noted. In Estonia, on the other hand, the frequency of observations in monitoring wells varies from once a year to 8 times a day. Automatic level meters are set every three hours so that the level data obtained is comparable with meteorological measurements.

Table 14 summarizes the information on the measuring devices currently used for automatic water level measurements in both countries, their types and characteristics. It should be noted that in the near future it is already planned to equip new wells in Latvia with more modern water level data loggers, which will ensure reading and loading of levels online (currently data is read only once a quarter).

TABLE 14

Characteristics of automatic water level data loggers

Measuring device type (manufacturer)	Measurement interval, m	Measuring device accuracy/resolution	Country
Mini-Diver DI501; Mini-Diver DI502 (VanEssen)	10, 20	±0,5 / 0,2 cm H2O; ±2 / 0,4 cm H2O	Latvia
Micro-Diver DI601; Mini-Diver DI602 (VanEssen)	10, 20	±1,0 / 0,2 cmH2O; ±2 / 0,4 cm H2O	Latvia
Cera-Diver DI701 (VanEssen)	10	±0.05%/ ±0,2 cmH2O	Latvia
TD-Diver DI801; TD-Diver DI802 (VanEssen)	10, 20	±0,5/0,2 cm H2O; ±1,0/0,4 cmH2O	Latvia
Baro-Diver DI500; Baro-Diver DI800	1,5, 1,5	±0,5 / 0,1 cm H2O; ±0,5 / 0,1 cm H2O;	Latvia
CTD-DIVER (Eijkelkamp)	50, 100	±2,5 / 1,0 cm H2O; ±5,0 / 2,0 cm H2O	Estonia
Mini-DIVER (Eijkelkamp)	20, 50, 100	-	Estonia
Baro-DIVER (Eijkelkamp)	1,5	±0,5 / 0,03 cm H2O	Estonia

It should be noted that the Mini-Diver, Micro-Diver, TD-Diver differ from each other only in size and memory capacity (for example, the Micro-Diver is specifically designed for monitoring wells or drive-points too small to accommodate larger data loggers). Cera-Diver, on the other hand, is used for monitoring groundwater under potentially corrosive conditions, such as brackish water and seawater. All automatic water level data loggers also measure pressure and temperature, so there is one Baro-Diver per monitoring station in Latvia, which records changes in atmospheric pressure and which are compensated during the data processing process. Figure 32 illustrates the automatic and manual measuring devices used in Latvia.

Figure 32. **Groundwater level measuring devices in Latvia** (on the left - automatic water level datalogger; on the right - manual water level meter)

2.2. National Natura 2000 monitoring program principles in Latvia and Estonia

2.2.1. Natura 2000 monitoring program principles in Latvia

In Latvia, several monitorings are carried out to determine the status of biological diversity:

1) Monitoring of Natura 2000 sites in 333 areas that are included in the European N2000 Network. The main objective of this monitoring is to evaluate the status and changes of species populations and habitats of European Union importance in Natura 2000 sites in the country as a whole in order to pay attention to all Annex I species, Annex I habitats and Annexes II and V species identified in Latvia. Protected species outside Natura 2000 sites are sometimes assessed as part of this monitoring, such as the monitoring of vascular plant and bryophyte species covered by the Habitats Directives.
2) So-called 'base monitoring' carried out throughout the country outside protected areas in order to follow trends in the size of species populations and habitats. Until now, a detailed assessment of such species and groups of species as the brown bear, moths and butterflies, dragonflies, amphibians, reptiles, waterfowl, birds of prey and nesting birds, bats, otter, fish, lampreys, etc. has been carried out in Latvia.
3) So-called 'special monitoring', which provides information on the ecological processes that take place in ecosystems and the relationships between organisms. The monitoring selects protected species that have important populations in Latvia in the European context and that also indicate the status of other species groups or habitats, such as large carnivores (wolf and lynx), migratory bats, forest and small grebes, migratory birds, and black stork. The special

monitoring program also includes the monitoring of mire restoration and management measures.

4) Monitoring of invasive species to assess the growth of alien species and the invasion of species not typical of native ecosystems.

Each monitoring has clearly defined goals and objectives, they do not overlap, and each has a methodology with the necessary field data forms. The results obtained in monitoring, for example, new species localities or updated boundaries of populations or habitats are stored in the Nature Data Management System "Ozols" ("OAK") of the Nature Conservation Agency[21]. Not only species and habitats experts of the NCA, but also scientific institutions and non-governmental organizations operating in the field of nature protection and habitat management, such as the Latvian Fund for Nature, the Latvian State Forest Research Institute "Silava", JSC "Latvian State Forests", University of Latvia, Daugavpils University, Latvian Botanical Society, Latvian Ornithological Society, etc. are involved in monitoring.

In Latvia, the need for Natura 2000 monitoring became relevant in 2006 after the reassessment and specification of Natura 2000 sites. This was followed by the development of a Monitoring Methodology (SIA Estonian, Latvian & Lithuanian Environment, 2007), which was used for the first time to prepare a report to the European Commission for the 6-year period 2007-2012, but was actually carried out in the period 2009-2012 (Dabas aizsardzības pārvalde, 2012). Subsequently, in 2013, the monitoring methodology was updated, a more detailed assessment of the condition of Natura 2000 sites was carried out, as well as the improvement of experts' knowledge and competence in training. This was followed by the preparation of the next major report for the period 2014-2020. During this period of Natura 2000 sites monitoring, 8 detailed sub-programs were developed for the following species groups: pond bat, otter, brown bear, birds, combined amphibia and reptiles, combined fish, lampreys and crayfish, invertebrates, and joint plant monitoring involving bryophytes and vascular plants.

It should be noted that the monitoring carried out for the last report (until 2020) was mainly related to the assessment of the populations of protected species (species-site), while the habitats or ecosystems (habitat-site) were not directly monitored. However, the condition of habitats has been assessed indirectly, because in the species monitoring field data form it is necessary to make notes on the quality, impacts and risks of their inhabited habitats and Natura 2000 sites.

As an additional tool for assessing the condition of habitats, a methodology for monitoring the area of habitats using remote sensing data and state registers has been developed (Auniņš & Lārmanis, 2013). It is defined that the condition of a habitat is considered favorable only if its area is stable or increasing. Following the changes in area, conclusions can be drawn about the quality of habitats. However, it is understood that this methodology is not suitable for groundwater dependent ecosystem (hereinafter – GDE) monitoring, as the area indicators do not directly indicate GW quality. For example, changes in the area of the lake may be related not only to the changed inflow of GW, but also to the establishment of new drainage systems or, conversely, the blocking of ditches.

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[21] https://ozols.gov.lv/pub/

In total, the Natura 2000 monitoring methodology describes 12 monitoring methods for different habitat groups, all of which are related to GDEs, except for BIO1, BIO8, BIO11 and BIO12 (SIA Estonian, Latvian & Lithuanian Environment, 2008) (Table 15).

TABLE 15

List of methods used in Natura 2000 site habitat monitoring in Latvia (SIA Estonian, Latvian & Lithuanian Environment, 2008).

Method	Title	No. of habitats on which applicable	No. of Natura 2000 sites were planned to use	EU habitats related to GDEs
BIO1	Description of coastal habitats in monitoring points	1	3	-
BIO2	Complex transect monitoring of coastal habitats	10	62	2190
BIO3	Inspection of lake habitats	4	62	3130, 3140, 3150
BIO4	Monitoring of river habitats	2	14	3260, 3270
BIO5	Monitoring of karst lakes	1	2	3190*
BIO6	Monitoring of grasslands and heaths	14	128	6410, 6430
BIO7	Spring monitoring	2	20	7160, 7220*
BIO8	Outcrop and cave monitoring	4	26	-
BIO9	Monitoring of heaths and mires	7	103	7210*, 7230
BIO10	Forest inspection	10	197	9080*
BIO11	Aerial survey of coastal shallow habitats	1	7	-
BIO12	Inspection of coastal shallow habitats from a boat	1	2	-

Abbreviation: 2190—Humid dune slacks, 3130—Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto-Nanojuncetea, 3140—Hard oligo-mesotrophic waters with benthic vegetation of Chara spp., 3150—Natural eutrophic lakes with Magnopotamion or Hydrocharition -type vegetation, 3260—Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho – Batrachion vegetation, 3270—Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation, 3190—Lakes of gypsum karst, 6410—Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae), 6430—Hydrophilous tall herb fringe communities of plain and of the montane to alpine levels, 7160—Fennoscandian mineral-rich springs and springfens, 7220*—Petrifying springs with tufa formation (Cratoneurion), 7210*—Calcareous fens with Cladium mariscus and species of the Caricion davallianae, 7230—Alkaline fens, 9080*—Fennoscandian deciduous swamp woods.*

Description of each GDE-related method is given:

BIO2 (includes habitat 2190) - Due to the fact that beach and dune habitats form a single complex and are located in bands along the sea shore, it is recommended to unify their monitoring using the combined route transect method. Based on habitat and orthophoto maps, as well as other materials, a route along the coast is created in the Natura 2000 site. Before going to the site, approximately 10 stopping points are randomly marked on the route map (the number of points depends on the length of the route, the area of the habitat landfills, the environmental conditions and the diversity of plant communities). At these points, the expert describes the features mentioned in the field data form - in the sample plots or by marking the features without the installation of the sample plots. Individual habitat structures and impacts are assessed along the entire route or between sections. The optimal time for monitoring is August, but it is possible to perform from July to September. During the monitoring, if necessary, the boundaries of the landfills are also specified in the habitat map, obtained after new orthophotos.

BIO3 (includes habitats 3130, 3140, 3150) - One lake or, in very large lakes, a separate part of the lake delimited by configuration, with different vegetation or area (~ 300 ha) is considered as one polygon. If the area is slightly affected, it is recommended to inspect at least 20-30% of the polygon in the area. If the site is affected or known to be potentially affected, it is recommended to survey 50-70% of the polygon in the site, selecting both unaffected and affected polygons. The route is carried out by boat crossing the landfill in a zigzag manner, except in some cases for habitat 3130, which can also be surveyed during spawning. Polygons and routes are selected and displayed on the map before going to the site. The route shall be chosen so as to cross the sites where the largest populations of habitat-specific species have been identified. The optimal time for monitoring is July and August. At each polygon, the expert keeps records of the features mentioned in the field data form. Impacts are also being assessed on the embankment adjacent to the polygon.

BIO4 (includes habitats 3260, 3270) - If the habitat is site-specific (more than 1 km in length), the characteristics listed in the field data form shall be listed at a minimum of 10 randomly selected points evenly spaced in the site. It is recommended to increase the number of inventory points if there are several river sections longer than 1 km in the territory or if significantly different impacts are identified in separate parts of the territory (river sections). If the habitat is rare in the area and is not characteristic of the area, it is recommended to survey at least 20-30% of the identified habitats, selecting one inventory point at each stage. Routes and locations are selected and displayed on the map before heading to the site. The optimal time for monitoring is July and August. The expert shall keep records of the features mentioned in the field data form at the selected locations. The features shall be counted without the establishment of plots by surveying and assessing a 100 m long section of the river or its bank. Impacts on streams are also assessed on the embankment adjacent to the site.

BIO5 (includes habitat 3190*) - Surveys all known and potential karst lakes in the area. Bypass the shoreline around the perimeter to record habitat features.

BIO6 (includes habitats 6410, 6430) - The time of work is 1.06-10.07, because on this date the mowing of biologically valuable grasslands starts, if the lawn is not mowed, then until 1.09. For the assessment of the conservation status and representativeness of the habitat, each polygon shall be selected at random in such a way that there are at least 10 plots for species inventories and 10 replicates for structure inventories in one Natura 2000 site. Impacts are assessed for the polygon as a whole by walking around them and visually identifying impacts. Transects shall be established for the structure and species inventory. The surveys are performed at the metering points located on the transect (within a radius of ~ 2 m) according to the given methodology. Species counts are usually limited to one plot. The species plot for the inventory of species (5 m^2) shall be arranged by placing the lower left corner of the plot in the middle of the transect, the coordinates shall be determined and recorded in the field data form. If the polygon is homogeneous, then one plot is established, but if there are significant differences in the condition of the habitat, then another plot is also located in the worst / different part of the polygon. The occurrence of typical species in the polygon is determined both visually by the expert passing the polygon along the longest axis and according to the total species composition in the sample plots.

BIO7 (includes habitats 7160, 7220*) - It is recommended to include the source of the spring and a 50 - 100 m long section along the spring stream in the transect. One field data form must be filled in for one spring. A single field data form may also correspond to a spring complex if it consists of several small springs located close to each other. During the habitat assessment, the visible situation should be described without creating plots. The remarks in the field data form should indicate whether the spring is located in an open or shady habitat. Depending on this, the presence of trees and shrubs or their felling can be considered positive or negative.

BIO9 (includes habitats 7210*, 7230) - Habitat assessment is performed by selecting a transect so that the transect crosses the largest polygons with surveyed habitats in Annex I of the Habitats Directive in a given Natura 2000 site. One habitat can have several transects in one Natura 2000 site. At least 10 stopping points shall be marked at random at each polygon crossed before entering the area on the transect. At the stopping point, the expert shall keep records of the features mentioned in the field data form in accordance with the methodology (typical species, structures) in a sample plot of 20x20 m. Impacts must be assessed for the entire polygon of a given habitat. For habitat 7210, at each stop, the expert describes the current situation in a 10x10 m plot. A boat may be required to survey the habitat if the stopping points are in the shallow part of the lake. In habitat 7230 Alkaline fens, which may be long and small in configuration, the transect must cross both the narrowest and the widest part of the fen and the description points must be both at the edge and in the central part of the fen. The dominant species of bryophytes must be recorded in the notes.

BIO10 (includes habitat 9080*) - A typical plot or part of a plot showing habitat-specific structures (both species composition and structures typical of a natural forest) is selected for the habitat survey. This part of the forest is crossed by a transect, visually assessing the occurrence of the relevant indicators. Forest stand plans are needed to find the relevant habitat.

A field data form has been prepared to characterize each habitat, in which the expert must indicate various criteria, divided into three groups: (1) structures, (2) typical species, (3) impacts. Marking the relevant criterion with a quantitative or qualitative indicator (e.g. number of typical plant species: 0, 1, 2-3,> 3 or beaver activity: many, average, little, none) gives the sum of points that, compared to the maximum yield points (in the case of an excellent habitat), the surveyed polygon is classified as A (good), B (average) or C (poor) category. It was analyzed how many of the field data form criteria used are related to the quality of GDEs, the quantity of groundwater or the threats (Table 16 and Table 17).

For habitats representing groundwater associated ecosystems (hereinafter – GAAE), the total number of criteria exceeds 40, of which 6 structural criteria indicate GW quality or quantity, such as the number of Charophyta communities (stands) in habitat 3140 or exposed bed (in meters) at low water level in habitat 3270 (Table 16). Most of the typical species included in these questionnaires are important for the identification of EU habitats (e.g. *Isoëtes* sp. and *Lobelia dortmanna* for habitat 3130). A large group with impact criteria is also related to the occurrence of aquatic plants, which indirectly indicates whether the habitat has negative impacts (causing either extinction or expansion of plant species, respectively). Impact criteria such as artificial water level fluctuations or logging or mining in the area also have a direct impact on GW. The recommendation is to include a structural criterion on the presence of springs in the questionnaires of all habitats and an impact criterion on the beaver activity in the questionnaires of habitats 3140, 3150 and 3270.

TABLE 16

Criteria used for Natura 2000 sites monitoring of habitats related to groundwater associated aquatic ecosystems in Latvia.

Criterion	EU habitat code					
	3130	3140	3150	3260	3270	3190*
Structures						
Total number of typical species	x		x			
Isoethide (typical species) communities (stands)	x					
Number of annual plant species					x	
Charophyta communities (stands)		x				
Rheophilic invertebrate communities				x		
Lake shore overgrowth / Shade (trees on shores)				x		x
Mineral soil / Mineral soil in the littoral (% of coastline length)	x	x	x			
Rocky, granular soil				x		
Exposed bed (width in meters) in low water conditions					x	
Water color			x			
Water transparency (m)			x			
Swirling current				x		
Number of lakes with empty or partially empty lake basin						x
Impact of springs / Number of spring outflows	🟧	🟧	🟧	🟧	🟧	🟧
Typical species						
Isoëtes sp.	x					
Lobelia dortmanna	x					
Chara spp.		x				
Bryophytes and Sphagnum on the shores of lakes						x
Water mosses						x
Impacts						
Invasive species					x	
Mixed isoethide and other aquatic plant communities	x					
Helophyte (surface plant) stands	x	x		x		
Nymphoid stands	x	x		x		
Elodeide (submerged aquatic plant) stands	x	x				
Lemnids (free-floating plants)	x	x	x	x		
Stands od Sphagnum cuspidatum and Warnstorfia exannulata	x					
Filamentous green algae	x	x	x	x		
Water blooms	x	x	x			
Lean, monodominant stands			x			
Swimming areas, etc. (artificial breaks in aquifer zones)	x	x	x			
Trampled ground cover, soil erosion on the shore	x	x	x			
Campfire places, municipal waste on the shores	x	x	x	x		
Buildings in the 10 m shoreline	x	x	x	x		
Buildings in the main pool	x	x	x	x		
Sewage outlets	x	x	x	x		
Beaver activity / Beaver dams / Dams	x	🟧	🟧	x		
Loads of logs				x		
Water level control / Artificial water level fluctuations	x	x	x	x	x	
Pollution / Municipal waste					x	x
Overgrowth with bushes (%)						x
Logging or quarrying in the area						x

Notes: gray—criterion used for habitat but not relevant to GAAE, blue—criterion used for habitat and important for GAAE, orange—criterion not used for habitat but important for GAAE.

Habitats associated with groundwater dependent terrestrial ecosystems (hereinafter – GDTE) are more numerous than GAAE, so the overall list of criteria to be used is also longer (Table 17). The structural criteria can mostly be used to characterize groundwater, however such criteria are only few or none to habitats 6410, 6450 and 7230. Therefore, it is recommended to supplement these field data forms with at least a minimum reference to GW as a number of spring outflows and spring impact. The proportion of typical species in the field data forms is richly represented, including plant species identifying the relevant habitats (e.g. *Cladium mariscus* and *Schoenus ferrugineus*), however, none of the GDTE-related plant and whorl snail species are mentioned in the field data forms as mandatory. It should be noted that the final part of each habitat field data form has a column on other protected species (Annex II of the Habitats Directive, the Red Data List of the Republic of Latvia), however, it would be optimal to introduce an additional box for the names of GDTE-related species. Recognizing that whorl snails of the genus *Vertigo* are almost invisible in the field, therefore the inclusion of their species is debatable. The impact criteria in the field data forms are sufficiently detailed and relevant to the quality characterization of the GDTE, and the inclusion of additional indicators is not necessary.

TABLE 17

Criteria used for monitoring the habitats of Natura 2000 sites related to groundwater dependent terrestrial ecosystems in Latvia.

Criterion	EU habitat code							
	2190	6410	6450	7160	7220*	7210*	7230	9080*
Structures								
Humidity	x							
Depression	x						x	
Spring debit				x	x			
Number of spring outflows		🟧	🟧	x	x		🟧	
Impact of springs		🟧	🟧				🟧	x
Connection to alkaline fens or springs		🟧	🟧					
Limestone, tuff					x			
Decaying wood								x
Dried trees, trunks or withering trees								x
Shrubs and trees, cover (%)		x	x				x	
Old grass, average layer thickness in the sample plot (cm)		x	x					
Bare ground, cover (%)		x	x					
Vascular plants, cover (%)		x	x					
Average height and total height of vascular plants in eaten / uneaten places (cm)		x	x					
Number of herbaceous / flowering & fern species		x	x				x	
Mesophytic and / or hygrophytic plants	x							
Cladium stand is in the water (%)						x		
Generative shoots of *Cladium mariscus*						x		
Habitat mosaic			x					
Typical species								
Number of flowering and fern species				x	x	x		
Bryophytes				x	x		x	
Alnus glutinosa								x
Centaurium littorale, Epipactis palustris, Equisetum variegatum, Juncus balticus, Rhinanthus sp., Sagina nodosa	x							

Criterion	EU habitat code							
	2190	6410	6450	7160	7220*	7210*	7230	9080*
Betonica officinalis, Inula salicina, Ophioglossum vulgatum, Parnassia palustris, Linum catharcticum, Scorzonera humilis, Sesleria caerulea, Succisa pratensis, Veronica longifolia		x						
Caltha palustris, Cardamine sp., Cnidium dubium, Lathyrus palustris, Peucedanum palustre, Phalaris arundinacea, Ranunculus auricomus			x					
Different *Carex* species		x	x				x	x
Galium boreale		x	x					
Molinia caerulea		x						
Cladium mariscus (%)						x		
Pinguicula vulgaris, Primula farinosa							x	
Schoenus ferrugineus							x	
Thelypteris palustris								x
Number of especially protected species				x	x		x	
Ligularia sibirica		🟧		🟧				🟧
Liparis loeselii						🟧	🟧	
Saussurea alpina ssp. esthonica		🟧		🟧			🟧	
Saxifraga hirculus				🟧		🟧		
Vertigo angustior	🟧	🟧					🟧	🟧
Vertigo genesii		🟧			🟧		🟧	
Vertigo geyeri		🟧			🟧	🟧	🟧	
Vertigo moulinsiana					🟧	🟧	🟧	🟧
Impacts								
Drainage / flooding		x	x					x
Water is being pumped				x	x			
Straightened spring bearing / extended spout				x	x			
Man-made dam				x	x			
Impact of beaver activity / dam / flood		x	x	x	x	x	x	
Water pollution / Mineral fertilizers, pesticides are used nearby / Municipal waste				x	x	x		
Trampling (people, animal feeder, etc.,%) / Destroyed, driven out, crushed, etc.	x	x	x	x	x		x	
Mowing and / or grazing		x	x				x	
Cushions		x						
Plowing (%)		x	x					
Overgrowth with trees, shrubs / Afforestation (%)	x	x	x					
Felling / Felling trees, shrubs							x	x
Cut down trees, shrubs (along the spring / shady springs / springs in the open)				x	x			
Burned							x	
Improved infrastructure / Buildings (including footbridges, other infrastructure)	x			x	x			
Proportion of plant species in adjacent habitats	x							
Expansive and invasive species, coverage (%) / Invasive species	x	x	x					
Amelanchier spicata, Heracleum sosnowskyi, Impatiens spp., Solidago canadensis				x	x			
Betula pubescens							x	

Criterion	EU habitat code							
	2190	6410	6450	7160	7220*	7210*	7230	9080*
Molinia caerulea							x	
Phragmites australis				x	x	x	x	
Pinus sylvestris							x	
Salix aurita and other high *Salix* species							x	
Thelypteris palustris, Typha angustifolia, T.latifolia						x		

Notes: gray—criterion used for habitat but not relevant to GDTE, blue—criterion used for habitat and important for GDTE, orange—criterion not used for habitat but important for GDTE.

Out of all 333 Natura 2000 sites established in Latvia, which is an average number (597 in Estonia and 562 in Lithuania), only a small part or 10% with the monitoring points and transects installed and surveyed in it are included in the GAAE and GDTE identified by the WaterAct project. These are a total of 36 ecosystems, most of which are located in the Habitat 7160 and the Gauja river catchment area (Table 18).

TABLE 18

Total number of groundwater dependent ecosystems monitored during 2008-2012 in Latvia in Natura 2000 sites in general and in the Gauja and Salaca river basins.

Year	EU habitats related to identified GDEs																	
	3130		3140		7160					7220*				7230		9080*		
	mon-t	G-t	mon-t	G-t	mon-t	mon-p	G-t	G-p	S-p	mon-t	mon-p	G-t	G-p	mon-t	G-t	mon-t	G-t	S-t
2008	7	1	2	1	1		1			2		2		1	1			
2009	1				3	8	1			1				6	2	22		
2010					1											14		
2011	1		1		5	12		3	1					10		18	2	
2012	7*	3	7		28	23	4	5		17	14	1	2	8		96	2	4
SUM	16	4	10	1	38	43	6	8	1	20	14	3	2	25	3	150	4	4

Notes: t—monitoring transect, p—monitoring point; G—Gauja river basin, S—Salaca river basin.
**Some habitat types have changed over time due to improved expert knowledge, as a result some monitoring forms completed for one habitat, e.g. 3150, are in fact linked to another habitat, e.g. 3130. If such cases were identified during the data analysis, this was taken into account. Therefore, the figures in this table may differ from the database of the Nature Conservation Agency.*

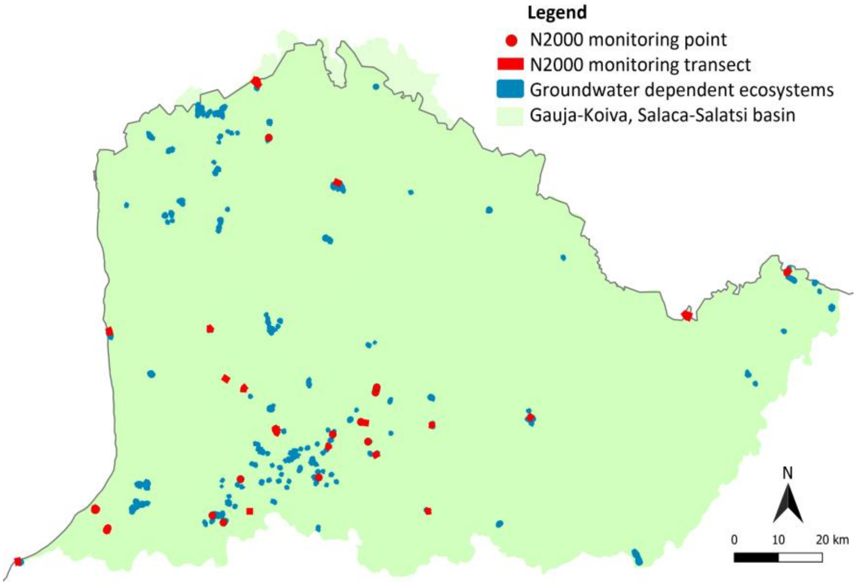

Figure 33. **Natura 2000 monitoring points and transects located in identified GDEs in Gauja and Salaca river basins in Latvia.**

In general, all GDEs that are identified in the catchment areas of both rivers in the territory of Latvia are represented, and in the future all 36 ecosystems should be included in the integrated Natura 2000 and GDE monitoring network (Figure 33).

2.2.2. Natura 2000 monitoring program principles in Estonia

In Estonia, the national environmental monitoring program consists of 12 sub-programs and the monitoring of GDE habitat types is carried out under the "Biodiversity and landscape monitoring sub-program". The objective of the "Biodiversity and landscape monitoring sub-program" is to identify and monitor changes in the abundance and distribution of species and in the landscape. The general objective of biodiversity monitoring is to provide input for the overall assessment of the state of the environment in the country. Among the other issues, it is necessary to ensure the collection and availability of high-quality data for the fulfillment of international obligations, for making decisions affecting the state of the living environment and for determining the sustainable use of natural resources. The Biodiversity and Landscape Monitoring sub-program is the most comprehensive and diverse of all national monitoring programs, covering many species, communities, habitats and landscape monitoring activities. In order to harmonize monitoring and improve the exchange of information, the Environmental Monitoring Data Information System (Keskkonnaseire infosüsteem - KESE) has been developed since 2013.

Objectives and tasks of the Biodiversity and Landscape Monitoring sub-program

According to the Environmental Monitoring Act (RT I, 18.05.2016, 1), the purpose, tasks and procedures of the national environmental monitoring sub-program (RT I, 25.01.2017, 9) for the biodiversity monitoring are:

- elucidation, monitoring and prediction of changes in the abundance and distribution of species, and analyzing their causal links with human activities and natural processes;
- explanation of the impact of land use on habitats, and identification and monitoring of the changes in landscapes and forecast of possible development directions;

- identification and forecasting of the status of populations and habitats of species referred to in EU legislation and international conventions;
- compliance with international requirements and obligations.

Under the last point, for example, Article 17 of the Habitats Directive 29/43/EEC requires Member States to draw up a report on the implementation of the directive every six years. Particular attention must be paid on the assumption that the population of a (rare) species cannot survive without its natural habitat. Consequently, this (rare) species is also an indicator of the state of the habitat in general or the existence of possible other values of biodiversity, and therefore a habitat in good natural condition is also a value itself.

Description and methodology of monitoring activities of the Biodiversity and Landscape Monitoring sub-program.

According to the Environmental Monitoring Act (RT I, 18.05.2016, 1), the requirements and methods established in the relevant legislation or international program are used in the monitoring activities of the national environmental monitoring program.

The basic methodological criteria for all monitoring work are:

- The monitoring sample must characterize the status (distribution, structural and functional quality) of the whole relevant species, habitat or landscape type in Estonia;
- The monitoring methodology must be able to capture critical changes in the distribution and qualitative status of the object/type monitored;
- The monitoring methodology must be as simple and robust as possible so that it is not sensitive to the observer/expert, the technical means used, the timing, etc.;
- The monitoring methodology must be cost-effective, including the most important principled approach being that a larger sample that better characterizes the population should be preferred to technically expensive and labor-intensive measurement methods in a small number of sample locations;
- The cost-effective planning of monitoring must find the optimal one, based on the hierarchy of information needs, starting with a general assessment and focusing on details: 1) checking whether the monitoring object continues to exist, 2) assessment of the general condition and threats;
- The monitoring methodology must be integrated between the different sub-programs, i.e., as many indicators as possible used for monitoring must overlap between the sub-programs, ensuring the optimal structure of the databases and the interoperability of data;
- Surveillance is structured into monitoring areas (defined as spatially independent units) and (temporary) measurement sites within the monitoring areas;
    - The monitoring area of the species, i.e. the basic unit for monitoring planning, is the local populations, which consist of closely spaced (sub) populations, which are probably historically connected but are now fragmented;
    - The monitoring area of communities and habitats is a local habitat or a collection of adjacent and historically connected fragments of habitat ("meta-habitat") that are currently fragmented or designated as separate units for mapping, but are still ecologically sufficiently integrated due to the extent of their characteristic species and/or suitable the existence of connecting corridors;

- Monitoring must remain an objective bystander, i.e., the monitoring must not be affected by the special status or economic/maintenance activities of the observation site (e.g., special maintenance procedure as an observation area, or additional disturbance due to a permanent observation visit, etc.) or location (e.g., harder to access);
- Monitoring must also focus on those conditions and changes in environmental conditions that are critical for the species/community/habitat/landscape to ensure that potential developments are predicted and preventive measures are implemented, as inert (delayed) reactivity to.

The specific number of monitoring areas, the total or site-specific description and the frequency of monitoring depend on the characteristics of the respective monitoring object, the number of sites and the dynamics. As a general rule, a sample of sites related to Natura reporting has been compiled/divided into 6-year monitoring periods to ensure regular updating of the basic data required for the report.

According to the objectives set for the wildlife monitoring activities, the monitoring work of the Biodiversity and Landscape Monitoring program can be divided into three groups:

- habitat monitoring;
- monitoring of different species, species groups and their communities;
- landscape monitoring.

Habitat monitoring

Habitat monitoring observes both human and non-human influenced species communities, including mainly plant-based community groups (e.g., Habitat Directive habitat types and Estonian vegetation types), as well as landscape or geological complexes (coastal, flood-meadows, bank forests, wooded meadows) or habitats based on an integrated complex of several taxonomic groups (seabed habitats).

The current national monitoring program is in use since 2019. In the previous monitoring program the sub-program "Monitoring of endangered (Natura 2000) plant communities" included separate surveys and methodologies for a) alvars and heathlands (6280*, 4030); b) alluvial and paludified meadows (6450, 7230); c) forest habitats (2180, 9010, 9020, 9050, 9060, 9070, 9080*, 9180, 91D0*, 91E0 and 91F0); d) dry meadows (6530*, 6210*, 6270*); e) coastal meadows (1630); f) mires (7110*, 7120, 7140, 7160, 7210*, 7230). In the current monitoring program Annex I habitat types are divided into five groups with specific methodologies:

- forest habitats: 2180, 9010, 9020, 9050, 9060, 9070, 9080*, 9180, 91D0*, 91E0 and 91F0;
- grassland habitats: 6280*, 6530*, 1630, 4030, 6210*, 6270*, 6450 and 7230;
- coastal habitats: 1210, 1220, 1230, 1310, 1640, 2110, 2120, 2130*, 2140*, 2190 and 2320;
- wetlands (habitat types not specified)
- marine habitats (habitat types not specified)

As seen from the lists, freshwater habitat types were not monitored in Estonia during the previous monitoring program nor are monitored during the current program. Lakes and rivers are monitored only according to the requirements of the Water Framework Directive. From the six terrestrial habitat types considered as GDTEs only four were monitored during the previous program (excluding Humid dune slacks (2190) and Petrifying springs with tufa formation (7220*)). Habitat types 7160, 7210*, 7230 were monitored as mires, habitat type 7230 also as meadows, and habitat type 9080* as forests.

According to the current program, three GDTE habitat types are monitored, 9080* as forests, 7230 as grasslands and 2190 as coastal habitats.

Several habitat types are considered GDTEs only in exceptional cases: 6410, 6430, 7110*, 7120, 7140 and 91D0* (Retike et al., 2020). Habitat types 7110*,7120 and 7140 are considered GDTEs only in Northeastern Estonia in the oil shale mining region and the dependence is only quantitative not qualitative. They are not critically dependent on groundwater under normal circumstances, but are considered GDTEs as a precautionary measure, because groundwater drawdown caused by extensive subsurface mining could lower the water level both in transitional mires or bogs. Only four habitat types out of these six were monitored in Estonia during the previous program (excluding Molinia meadows… (6410) and Hydrophilous tall herb fringe communities (6430)). Habitat types 7110*, 7120 and 7140 were monitored as mires and habitat type 91D0* as forests. According to the current monitoring program only one of these habitat types is being monitored - 91D0* as forests.

Neither under the previous nor the current version of the monitoring program, the sites chosen for monitoring were/are not limited to Natura 2000 sites, but their selection is based on all mapped polygons of the relevant habitat type. Though most of the mapped polygons are located in protected areas, which makes them regionally unevenly distributed.

In addition to the monitoring of habitat types, the Environmental Board orders and conducts habitat inventories of protected areas that often cover all the habitat types present. Opposite to the habitat monitoring, however, these inventories tend to be inconsistent in their methodology and interval.

Though listed in the monitoring program, wetland habitats have not been monitored in Estonia since 2017. In 2006-2016, a six-year cycle was applied to monitor mire habitats, with ~120 sites monitored in 2006-2011. A roughly even distribution of the sites was aimed all over the country, thus the mires were chosen intentionally, not randomly. At the beginning of that program, fens (7230) and bogs (7110*) were monitored separately, with 10 bogs and 10 fens being visited every year. Additionally, some spring fens and transitional mires were later added to the program. The monitoring methodology of mire habitats consisted of vegetation analyses on 2 x 2 m permanent plots (4 x 1 m^2) and a qualitative assessment (status, structure, functions and human impacts).

From 2017, new methodology is being applied to include more sites, but to visit them less often. Moreover, in 2008-2011 Estonian Fund for Nature (ELF) conducted a large inventory of mire habitats, where the status and vegetation of the Annex I mire habitat types were assessed on all mire sites in Estonia that exceeded 0,5 ha – that information is planned to be included to the EELIS database, which houses the official Annex I habitat data in Estonia. The next large inventory most likely takes place in 2025 and is planned to collect sufficient data to assess Annex I mire habitats. Also, in 2007-2009 Institute of Ecology at Tallinn University conducted an inventory of peatland forests outside protected areas. There, the main attention was on the qualitative and quantitative parameters of habitat type 9080* to assess their general state, quantify their area and find possible new ecologically valuable sites for the protection.

Monitored GDTE habitat types under the Biodiversity and Landscape Monitoring in Estonia

Currently, there are only four GDTE habitat types (including habitats considered GDTEs only in exceptional cases) in three habitat groups being monitored in Estonia:

- forest habitats - 9080*, 91D0*;
- grasslands - 7230;
- coastal habitats - 2190.

Monitoring the condition of forest habitats - includes habitats 9080* and 91D0*

The tasks of the forest habitat monitoring are:

- to collect data in Estonia on a regular basis in order to provide an adequate assessment of the condition and biodiversity of endangered forest habitats and their changes over time;
- provide an expert assessment of the status of the monitored forest habitats and the adequacy of conservation and management measures;
- collect data on the distribution of endangered species and the status of populations in forest habitats (through a monitoring program for protected vascular plants).

The methodological basis for the current monitoring of forest habitats is: Liira, J. 2009. Assessment of monitoring methods for existing communities and recommendations for promoting monitoring methods for the status of Natura 2000 habitats (in Estonian). The monitoring of forest habitats has been carried out according to this methodology since 2010.

The main method is to carry out an expert observation of the condition of the habitat in the monitoring area (see Table 19). The monitoring takes place in six-year cycles. In the three most common habitat types (9010*, 9080*, 91D0*), the target number of monitoring points corresponds to the area proportion of the habitat type, 240, 170 and 190 sampling points per monitoring cycle, respectively. Forest monitoring methodology does not use permanent plots, but randomly chosen points (20-40 m radius). During the fieldwork, the monitoring areas shall be described as far as possible at a given point, in individual cases the point shall be moved within a range of 20-50 m so that it does not reach a road, target, ditch or border of different habitats and is accessible to the observer. During the forest monitoring in 2013-2018, 75 sites were randomly chosen from all the forest habitat types, using the polygons of all cadastral forest areas. That set of samples is considered sufficient to conduct statistical data analysis. In 2019-2024, a new selection was made and sites are being visited.

Monitoring the condition of grassland habitats - includes habitat 7230

The tasks of monitoring grassland habitats are:

- to collect data in Estonia on a regular basis in order to provide an adequate assessment of the status and biodiversity of plant communities of valuable semi-natural habitats and their changes over time;
- provide an expert assessment of the status of the monitored grasslands, the adequacy and impact of conservation and management measures, and make recommendations for the implementation of appropriate measures to improve the condition of the habitat;
- to collect data on the distribution of endangered species and the status of populations in the habitats of natural grasslands (part of the monitoring program for protected vascular plants);

- to collect data on a regular basis for the assessment of small-scale species richness in permanent monitoring areas of wooded meadows and alluvial plains (based on square monitoring methodology).

Grassland habitats are endangered semi-natural communities (habitats) that are highly dependent on the scale and intensity of human activities (mainly grazing and forage harvesting). Before 2005, the monitoring of endangered vascular plant species was carried out using square monitoring methods, later the status monitoring has been used. The status monitoring is based on the inventory of habitats valued by the Habitats Directive, which was originally carried out to identify Natura 2000 protected areas upon accession to the European Union. Habitat type 7230 has been included in the monitoring since 2016. The sampling of monitoring areas is selected on the basis of a stratified (mainly using soil maps and aerial photographs to find grasslands) random selection method with six-year monitoring cycles. For each monitoring cycle, an approximately proportionate number of sites for a given habitat type are randomly taken from the Natura site database. The sample size of the sites to be monitored during the monitoring cycle depends on the proportion of the respective habitat type in the data of the grassland habitats. For habitat 7230 the number of monitored sites is 8 per year. The dynamics of plant communities of the habitat type, as well as other parameters to be recorded, are compared in a six-year cycle. There is no so-called 'repeat monitoring', which records the dynamics of a particular permanent plant community. Areas may be re-monitored by re-sampling. Also, from 2018, the size of the measuring of monitoring area was limited to 0.1 hectare instead of the previous 0.8 ha (circle with a radius of 50 m), which ensures a better targeting of the data collected to the habitat-specific characteristics of the specific habitat and reduces the proportion of concomitant, adjacent and marginal communities in the description.

The observations result in expert assessments (see Table 19) that characterize nature conservation value and status in accordance with the Habitats Assessment Standard are provided, based on the definition of habitat type and extent, vegetation indicators characterizing the layered and floristic composition of the community and influencing factors. In addition, the expert provides management recommendations for a specific monitoring area.

Monitoring the condition of coastal habitats - included habitat 2190

The tasks of monitoring grassland habitats are:

- to collect data in Estonia on a regular basis in order to provide an adequate assessment of the condition and diversity of endangered coastal habitats and their changes over time;
- provide an expert assessment of the status of monitored coastal habitats and the adequacy of conservation measures.

The state of coastal landscape diversity is characterized by a synthesis map of sites and vegetation, which is the basis for recording future changes. The indicators of monitoring of coastal habitats are described in Table 19. The interrelationships and species diversity of the individual components in the landscape are expressed in the landscape profile with lists of species of vascular plants, bryophytes and lichens. As a result of the processing of coastal land cover from different timesteps, the trend of changes in the landscapes of the monitoring areas is compiled. Also, the locations or distributions of valuable objects, which are evaluated on a 4-point scale, are marked on the map. The work is illustrated with photographs, which are preferably taken from the same place during the repetitive monitoring. Repeated surveys in monitoring areas are recommended at 10-year intervals, in areas that change rapidly or in the event of extreme changes the monitoring should be conducted more frequently.

A questionnaire has been prepared to characterize each habitat group, in which the expert must indicate various criteria. It was analyzed, how many of the questionnaire criteria used are related to the quality of GDEs, the quantity of groundwater or the threats (Table 19).

TABLE 19

Criteria used for monitoring Annex I habitats related to groundwater dependent terrestrial ecosystems in Estonia

Criterion	EU habitat code			
	2190	**7230**	**9080***	**91D0***
Habitat identification				
Soil profile: organic surface layer		x	x	
Land cover		x	x	
Landscape dimensions		x	x	
Presence		x	x	
Qualitative habitat management		x	x	
Land use				x
Parameters of key area/Description of the community (layers)				
Proportion of species in the forest stand %	x	x	x	
Age of the species in the I layer a.		x	x	
Ground cover %	x	x	x	
Height of I layer m		x	x	
Basal area of the stand m²/ha		x	x	
Presence and density class of II layer		x	x	
Species occurrence and abundance assessment (II layer)	x	x	x	
Height of II layer m		x	x	
Presence and density class of seedlings		x	x	
Assessment of the occurrence and abundance of the species (seedlings)		x	x	
Abundance of bush layer	x	x	x	
Assessment of the occurrence and abundance of the species (bush layer)	x	x	x	
Height of bush layer m	x	x	x	
Height of grass and shrub layer cm	x			
Abundance of specimens of the species (grass and shrub layer)	x			
The occurrence of negative changes in the grass and shrub layer	x			
Species distribution (grass and shrub layer)	x			
Abundance of moss layer	x			
Humidity conditions	x			
Type and degree of risk and impact factors: impact of drainage	x			
Type and degree of risk and impact factors: impact of mowing	x			
Type and degree of risk and impact factors: impact of grazing	x			
Grazing pressure	x			
Type and degree of risk and impact factors: impact of restoration	x			
Type and degree of risk and impact factors: impact factors	x			
Complex profile of the monitoring area				x

Criterion	EU habitat code			
	2190	7230	9080*	91D0*
Characteristics of habitat diversity				
Presence of substrate / microhabitat		x	x	
Abundance of substrate / microhabitat		x	x	
Diameter of the largest substrate unit cm		x	x	
Hollows in I layer		x	x	
Biologically old trees		x	x	
Trees grown in poor lighting conditions		x	x	
Vegetative / multi-stemmed trees		x	x	
Well-developed supporting roots		x	x	
Abundance of biologically old shrubs		x	x	
Presence of long hanging lichens		x	x	
Presence of polypore		x	x	
Presence of great foliose lichen		x	x	
Presence of species / taxon		x	x	
Abundance of specimens of the species		x	x	
Aggregate habitat assessments /Habitat status assessments				
Representativity of the habitat	x	x	x	
Degree of conservation of structure	x			
Degree of conservation of functions	x	x	x	
Restoration possibilities	x	x	x	
Global assessment of the habitat	x	x	x	
Value of community status	x			
Floristic value of the habitat	x			
Small-scale species richness of grass layer	x			
Natural values				
Geological-landscape objects/areas	x			
Protected plant communities and species, protected parks, stands	x			
Nesting sites and biotopes of animals worthy of protection, staging points for birds during migration	x			
Socio-economic values				
Archaeological and cultural values	x			
Land use value based on soil quality class, forage value of meadow vegetation, forest type and quality class	x			
Recreational values	x			
Existing and potential threats	x			

Notes: gray—criterion used for habitat but not relevant to GDTE, blue—criterion used for habitat and important for GDTE, orange—criterion not used for habitat but important for GDTE.

Monitoring of species and communities

Monitoring of species and communities must provide an overview of the status of populations of species as well as of different species groups (e.g., functional groups or communities) as well as the effectiveness of conservation and management measures (including alien species) applied to them. The main monitoring program includes all species of protection category I, in addition to a selection of species of categories II and III. From the list of internationally endangered species, an optimal selection has been made of those species that can be monitored based on the available resources (species representation, availability of skilled labor, financial resources). Alien species that affect local life must also be monitored. No permanent sites have been selected, but 12-30 sites are being visited during a six-year monitoring cycle. All monitoring results, except I and II category species, are publicly available at the KESE database. In the future, the data collected by the Environmental Board will also be included in KESE.

The monitoring of species and their groups is divided as follows:

- vascular plants and bryophytes
- species of fungi and lichens
- invertebrates
- fishes
- amphibians
- reptiles
- birds
- mammals

Output results of the Biodiversity and Landscape Monitoring

The main output of biodiversity and landscape monitoring is overviews and reports on changes in the environment as a result of human activities and natural processes. In addition, reports arising from various international and national obligations. In addition to the need to assess an individual monitoring object, an integrated approach must be taken into account when analyzing the data.

The successfully completed Biodiversity and Landscape Monitoring sub-program provides the main input for assessing the state of Estonian wildlife. The indicator of effectiveness shall be the proper fulfillment of the objectives of the sub-program, including the objective of each individual monitoring work. For species (and habitats) of international importance (species and habitats under the Habitats and Birds Directive), the number of meaningful reports is an indicator of effectiveness. For the purposes of the Habitats and Birds Directive, a meaningful report means that the necessary data have been collected under the sub-program for the quantitative assessment of all report fields indicating the status (e.g., population size, trend, distribution area, trend) and the report is based on analytical data. One of the indicators of the success of the monitoring of species and habitats is the proportion of sites (monitoring areas) inspected over the years or the corresponding number of repeated observations. At national level, long-term, consistent data series are an indicator of the success of the program, where disruptions are not due to reduced budgets and allow for long-term changes to be estimated.

Today's Biodiversity and Landscape monitoring in Estonia does not provide sufficient data for making science-based decisions and fulfilling the country's international obligations, e.g., for reporting on the conservation status of the habitat types and species under the Birds Directive and Habitats Directive, about changes in the biodiversity of managed forests, etc. Species and habitat types with data deficiencies need to be mapped and possible overlaps between different monitoring programs identified. Monitoring methodologies must be improved, including enhanced usage of remote sensing. Coherence is to be developed between biodiversity monitoring and other sub-programs of national monitoring, between different subareas of wildlife monitoring, and between national monitoring and conservation management monitoring and inventories. Proceeding from the above, it is also necessary to improve the structure and coherence of the network of monitoring stations and sites and of the set of monitored parameters, which is often not representative enough to provide information about changes at the national level.

2.2.3. Comparison of Natura 2000 monitoring parameters in Latvia and Estonia

In order to compare the monitoring methodologies and the criteria used for assessing the quality of habitats in Natura 2000 sites in Latvia and Estonia, two types of habitats related to GDTEs were chosen as an example. In Estonia, the N2000 monitoring program does not include any habitats representing GAAEs, so rivers and lakes cannot be used for comparison with Latvia. Therefore, in the text below, we focus only on terrestrial habitats (forests, peatlands). Since in Estonia only 4 types of habitats are applicable to the topic discussed, and only 3 of them are represented in Latvia, moreover 2190 is very rare, then habitats 7230 and 9080* are taken as examples for comparing the applied methodologies of both countries. In Latvia, in the time period from 2008 to 2012, the habitat 7230 Alkaline fens in **25 Natura 2000 sites**, including 3 places in the Gauja river basin, has been monitored once in each place using the transect method. In Estonia, habitat 7230 used to be part of mire habitat monitoring and 10 sites were surveyed annually using the permanent square plot methodology, but later it has been included in the grassland monitoring program and **8 sites** are surveyed annually using 0.1 ha monitoring area. Habitat 9080* Fennoscandian deciduous swamp woods are monitored in **150 Natura 2000 sites** in Latvia, incl. 4 locations in the Gauja river basin and 4 in the Salacas river basin once every 6 years, using the transect method. In Estonia, habitat 9080* was monitored as part of a forest monitoring program where **75 sites** were randomly selected and a site-specific number of random monitoring plots was used (i.e. 240, 170 and 190 sampling sites per monitoring cycle). As can already be seen from the information provided, the choice of monitoring sites and the methodologies used in both countries are very different.

TABLE 20

The list of common criteria used in monitoring field data forms of habitats 7230 and 9080* in Latvia and Estonia.

Latvia	7230	9080*	Estonia	7230	9080*
Number of herbaceous / flowering & fern species	x		Proportion of species in the forest stand %	x	x
Shrubs and trees, cover (%)	x		Assessment of the occurrence and abundance of the species (bush layer)	x	x
Drainage / flooding		x	Type and degree of risk and impact factors: impact of drainage		
Mowing and / or grazing	x		Qualitative habitat management	x	x
Depression	x		Presence of substrate / microhabitat	x	x

Notes: gray—criterion used for habitat but not relevant to GDTE, blue—criterion used for habitat and important for GDTE, orange—criterion not used for habitat but important for GDTE.

Additional analysis was performed to compare the criteria used in the field data forms to monitor both 7230 and 9080* habitat types in Latvia and Estonia. Of all the criteria used (Table 16, Table 19), only four of them were common in both countries, and one is used in Latvia, but marked as important in the future also in Estonia (Table 20). All of these common criteria are used generically and do not provide very useful information if the habitat were to be evaluated from a GDE perspective only. In both countries, the status of species communities and various physiogeographical parameters (for example, hydrological system conditions) are mainly used to assess habitat quality, but no chemical indicators are evaluated. It should be noted that the opinion of the expert may differ from the level of his/her experience and training, as well as the opinion may depend on the season of the survey. In particular, the quality of habitat 9080* can be significantly different in early spring after snow melt or in the second half of summer after a long drought. On the other hand, for the habitat 7230, the knowledge of the flora is of great importance, because the recognition of individual vascular plant and bryophyte indicator species can indicate a completely different level of habitat quality (from low to very good). Therefore, the used criteria must be critically evaluated, so that they can be applied to the GDE condition assessment at all. The main conclusion from this comparison is that each country has chosen specific criteria for its national monitoring methodology and these are useful for preparing biodiversity reports to the EC for a 6-year period. However, the methods used would have to be drastically changed to be uniform in both countries, and it is likely that all previously collected data would no longer be comparable.

2.2.4. Recommendations for linkage GDEs and GW monitoring programs

In order to ensure protection of groundwater dependent ecosystems and to provide data about ecosystem status and thus indicate the overall status of GWBS, a link to national Natura 2000 and groundwater monitoring programs must be developed. After data collection, it was concluded that currently implemented monitoring of the Natura 2000 territories in both Latvia and Estonia is mainly based on the results of the habitat type survey according to the developed methods, but was not based on actual data (water samples).

Accordingly, in order to determine the impact of groundwater on surface water bodies and terrestrial ecosystems, both monitoring programs must assess water quality both in GWs and in the ecosystem itself, establishing a single list of parameters (temperature, pH, specific conductivity of water, N_{tot}, P_{tot}, PO_4 and additional Zu, Cu, Ni and Ba). Temperature, pH and specific conductance could provide first insight into water quality and functioning of the site, which is recommended to be at least included in the initial monitoring. Although this requires equipment and training for the habitat experts who will carry out the field surveys, the costs are rather low (such equipment is easy to use and do not require large maintenance costs). On the other hand, in order to get a better idea of the impact of underground water on surface water bodies and terrestrial ecosystems, it is necessary to include the remaining parameters (at least P_{tot} and N_{tot}) in the monitoring.

It would be recommended to provide water level monitoring in GDEs where there are activities nearby that could change the groundwater level. Currently the locations of groundwater monitoring networks and GDEs do not overlap. Established state groundwater monitoring networks in Estonia and Latvia were designed to serve different purposes (e.g. to detect regional trends in groundwater quality or quantity, assess impacts of diffuse pollution) and provide valuable long-term datasets. The locations of wells cannot be moved, and current monitoring frequency must not be interrupted. However, an effort should be made to improve groundwater monitoring networks by establishment of new wells and selection of new springs for national monitoring need.

Currently temperature, pH and specific conductance of water in monitored habitat types in Estonia are not a part of habitat status assessment but could provide first insight in water quality and functioning of the site, and therefore is recommended. Although this requires equipment and training for the habitat experts who will carry out the field surveys, the costs are rather low (such equipment is easy to use and do not require large maintenance costs).

2.3. Joint monitoring program for Latvian-Estonian cross-border area

According to the WFD, the Member States which have a transboundary GWBs should carry out joint activities to monitor, share data and assess the chemical and quantitative status of joint GWBs. The conditions for the selection of transboundary monitoring points in the WFD are described very generally and points 2.2.2 and 2.4.2 of Annex V to that directive provided that 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, as well as track groundwater quality, timely identify and control transportation of potential pollutants. In turn, the European Commission Guidance Document No.15 "Guidance on Groundwater Monitoring" and UN-ECE "Guidelines on monitoring and assessment of transboundary groundwaters" set already more detailed requirements 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.

Particular attention must be paid to transboundary GWBs that have been identified as GWBs at risk, stated or objected to with intense anthropogenic pressure. In such areas the density of the transboundary monitoring network may increase, respectively in the water bodies with the lowest anthropogenic pressure it may be lower - surveillance monitoring may be provided only with the existing monitoring points located in the transboundary area.

Based on the results of the anthropogenic pressure and status assessment of GWBs, no intensive anthropogenic pressure was identified in the Estonian-Latvian transboundary area that could significantly affect the status of GWBs and no GWBs at risk were identified that do not achieve good groundwater quantitative and/or chemical status (Chapter 1.2 and 1.3). Therefore, at present, general information on the situation of transboundary GWBs can be achieved by existing monitoring points in the transboundary area. Additional monitoring points or integrated monitoring could be served by springs which represent chemical composition and features of corresponding aquifers. Such representative springs have been identified during the WaterAct project and they can help in transboundary GWBs status assessment.

2.3.1. Existing monitoring points qualification

There are a total of 53 monitoring points in the Gauja/Koiva and Salaca/Salatsi river basin districts, most of which (85%) are located in Latvia due to the distribution of the river basin districts (see Chapter 1.1). However, not all monitoring points located in the abovementioned river basins can directly characterize it and meet the requirements set out in the WFD Annex V, points 2.2.2 and 2.4.2. Therefore, in order to fully manage the cross-border GWBs and the cross-border area itself, as well as to assess the impact of only transboundary anthropogenic pressures on groundwater resources, it was decided to distinguish a 25 km buffer zone on both sides of the Estonian-Latvian border. It should be noted that the selected territory also basically covers the transboundary area identified within the EU-WATERRES project[22], during which shared groundwater resources between Latvia and Estonia were studied in more detail (with the exception that it includes the full area of Salaca/Salatsi river basin).

Accordingly, monitoring points that fall within the previously delineated buffer zone and characterize 8 previously identified transboundary GWBS (D6, A8, A10, P, 21, 23, 25 and 26) (see Chapter 1.1. for more details) may be included in the cross-border monitoring network. as an initial list of observation points, although some of the points may also be located outside the Gauja/Koiva and Salaca/Salatsi river basin districts. Such an approach allows for the full management and assessment of the Estonian-Latvian transboundary territory and common groundwater resources, as the distribution and watersheds of groundwater do not always correspond to the boundaries of surface water bodies inside the river basin districts. Therefore, it is recommended to consider in the future the possibility to include in the transboundary monitoring network also those monitoring points that characterize GWBs 22 and 24 (currently not identified as transboundary GWBs) - at least at the national level.

There is a total of 27 monitoring points in the territory under review, of which 3 monitoring points in the territory of Estonia have not been used for monitoring in recent years, as well as they have not been planned to be included in the State Monitoring Network in the future (Figure 34). More detailed information on the identified monitoring points is summarized in Annex 4, while a summary by type of monitoring at the GWB level is provided in Table 21.

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[22] EU-WATERRES ""EU-integrated management system of cross-border groundwater resources and anthropogenic hazards"" http://eu-waterres.eu/

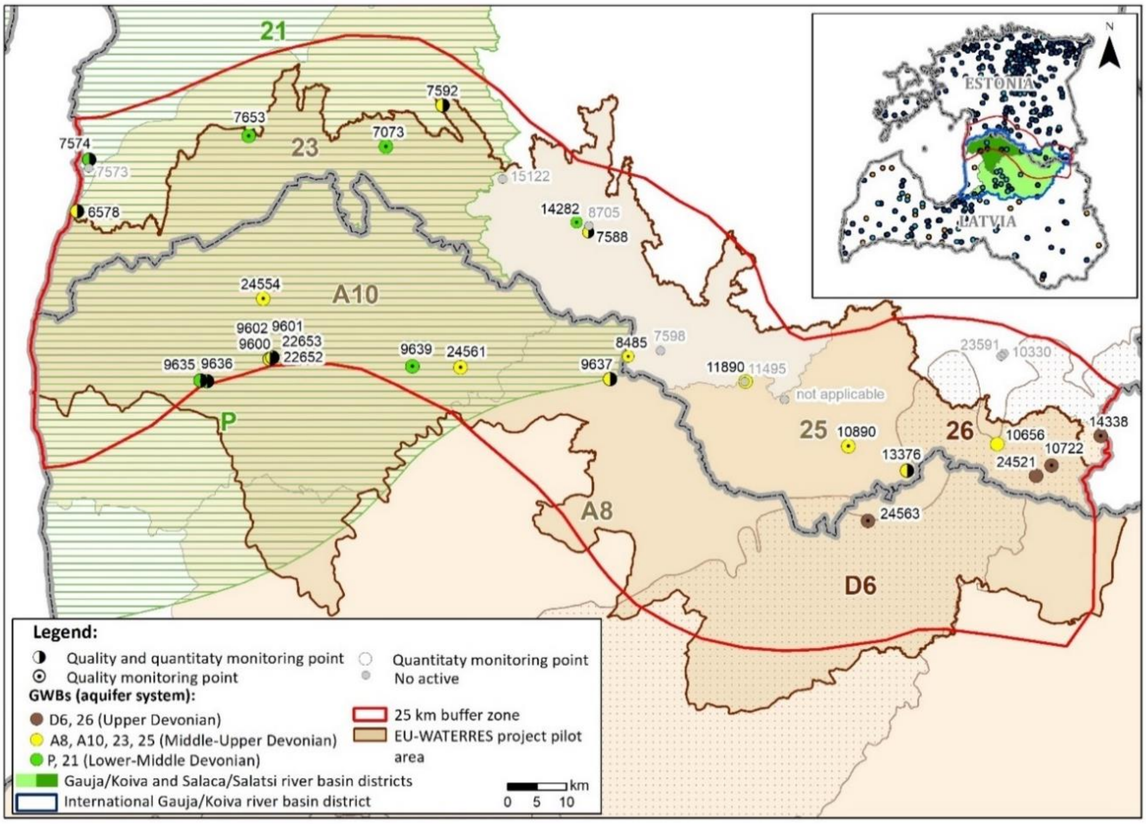


Figure 34. **Location of transboundary monitoring points**

It should be noted that the existing active monitoring points in 79% of cases provide quality monitoring and only about 58% of them provide quantitative monitoring or water level measurements. The largest number of monitoring points is located in GWB A10, because in this GWB groundwater monitoring station "Rimeikas" is located, which includes 5 observation wells.

TABLE 21

Number of transboundary monitoring points and their distribution at TGWB level

Type of monitoring and distribution of monitoring points	TGWBs								Total number of monitoring points
	26	D6	23	25	A8	A10	21	P	
Quality	2	1	2	3	1	5	2	3	19
Quantity	1	0	2	2	1	5	1	2	14
Inactive	-	-	1	2	-	-	-	-	3
Total number	3	1	3*	6	1	7	3	3	27

*Note: *A quaternary well attached to GWB 23 is currently inactive*

In general, it can be concluded that no uniform distribution of monitoring points is observed in any of the TGWBs and that the density of the monitoring network is acceptable only at low anthropogenic pressure and provided that no problems have been identified in the transboundary area. Otherwise, attention should be paid to the installation of new monitoring points and/or the integration of other monitoring points into the existing monitoring network in those areas where groundwater is more polluted and/or groundwater resources are depleted or the hydrogeological regime changes.

It should be noted that the new monitoring wells, which are planned to be installed in the near future in the territory of Latvia (see Chapter 1.1) in GWBs A8 and A10, can improve the coverage of the existing monitoring network in the above-mentioned GWBs and ensure both quality and quantity monitoring in the future. Once installed, they can also be included in the transboundary monitoring network.

However, it should be noted that no significant groundwater abstraction has been identified in the transboundary area, which could lead to changes in the hydrogeological regime and change of groundwater flows in the transboundary area, and no further increase in groundwater abstraction is planned due to low population density. Accordingly, it is recommended in the future to focus on the development and harmonization of a long-term groundwater quality monitoring program in order to obtain initial information on the natural state of the transboundary area and to develop a systematic, continuous exchange of data. The exchange of groundwater level or quantity monitoring data is currently not a priority (no harmonization required). However, as far as possible, it is necessary to exchange quantitative measurement data on an annual basis to the extent currently provided for in the existing monitoring programs in both countries.

2.3.2. Recommendation of new monitoring points (springs)

Based on the statistical analysis of spring and well water hydrochemistry, which is described in more detail in chapter 3.2., representative springs were selected that would be suitable for further integration into the cross-border monitoring network (Table 22). The selection was made based on the results of the DA analysis. The springs that were situated near the centroids of the aquifer system clusters in the discriminant space, were selected as candidates for monitoring sources. The selection was based on the assumption that the springs represent the average water quality of the groundwater body/aquifer system, and can be used for background monitoring. The results indicate that the best representativeness of GWB was found in the case of the D_2 (Upper-Middle Devonian) aquifer system springs, while D_3 (Upper Devonian) aquifer system springs featured a bit lower representativeness. On the contrary, Q (Quaternary) aquifer springs represented primarily local catchment areas and are not suited for GWB background monitoring. However, Q springs could be used as reference monitoring points that characterize local processes in particular areas - i.e. local pollution or abstraction impact, long term climate change impact on local scale. Moreover, these springs can be used as reference monitoring points to assess groundwater dependent ecosystem dependency on groundwater and vulnerability, as well as for groundwater assessment.

TABLE 22

Representative spring candidates for EE-LV transboundary groundwater body monitoring. The springs were selected based on the statistical analysis described in chapter 3.2.

Spring name	B	L	Elevation (m asl)	Quaternary cover thickness (m)*	Aquifer index	TGWB	Watershed area (m^2)	Specific conductance (µS/cm @ 25°C)
Aquifer system (Q)								
Roodsi-Mõtsakunna	57.64576	26.39533	79.3	57.5	Q	-	15905	241
Vorstimäe	57.65146	27.08879	237.1	111.4	Q	-	18299	490
Velnakmens	57.86216	25.01626	42.1	19.5	Q	-	45332	190

Spring name	B	L	Elevation (m asl)	Quaternary cover thickness (m)*	Aquifer index	TGWB	Watershed area (m^2)	Specific conductance (µS/cm @ 25°C)
Oliņu	57.62026	25.79675	42.4	29.5	Q	-	184930	127
Aquifer system (D_3)								
Viinavabriku	57.61156	27.25587	177.8	27.6	D_3pl	26	2519696	545
Veskiläte	57.68862	26.89132	129.2	27.5	D_3pl	26	1080074	481
Lauvas mutes	57.51329	26.39856	71.5	16.5	D_3pl	D6	39745605	681
Gaujienas	57.51695	26.38675	69.4	19	D_3pl	D6	9202939	655
Aquifer system (D_2)								
Laurimäe	57.59401	26.67028	73.5	12.7	D_2gj	25	960161	533
Tuurimäe	57.59298	26.73124	79	15.5	D_2gj	25	10481264	472
Pantenes	57.86807	25.21666	46	19.2	D_2br	A10	43990764	667
Zilaiskalns	57.56691	25.19345	53.2	22.4	D_2br	A8	4803322	610

2.3.3. Development of long-term quality monitoring program

In the future, it is recommended that groundwater quality monitoring data on the transboundary area be exchanged between the LEGMC and the EEA. The (initial) list of monitoring sites at least for which the exchange process should be provided is given in Table 23. Increased attention should be paid to monitoring points that fall entirely within the Gauja/Koiva river basin district, as these are the areas where the most intensive groundwater flow between the two countries has been identified; in the event of an increase in anthropogenic pressures, it is possible that changes in the status of groundwater, which may be affected by transboundary activities, could be observed at these points. The highest groundwater flow intensities in this river basin district have been identified both within GWBs 26 and D6, which characterize the Pļaviņas-Ogre groundwater aquifer complex, and within GWBs 25 and A8, which characterize the Aruküla-Amata groundwater aquifer complex and are also the main groundwater source throughout the transboundary area (Solovey et al., 2021).

TABLE 23

Agreed sampling sites for exchange of groundwater quality monitoring data in transboundary area between Latvia and Estonia

Well/ spring No. in national databases	Name of monitoring site in national language	River basin district	Coordinates		Aquifer	Country
			X (m)	Y (m)		
Wells						
10722	Misso suurfarm	Gauja/Koiva	693403	389028	D_3	EE
10890	Varstu alevik	Gauja/Koiva	658874	392320	D_2	EE
11890	Lüllemäe	Gauja/Koiva	641379	403409	D_2*tr*	EE
13376	Krabi põhikooli puurkaev	Gauja/Koiva	668863	388200	D_2; gQIII	EE
9635	Aloja	Salaca/Salatsi	548750	403489	D_2*pr*	LV
9636	Aloja	Salaca/Salatsi	549905	403409	D_2*pr*	LV
22652**	Rimeikas	Salaca/Salatsi	560544	407112	gQ_3ltv	LV
9601**	Rimeikas	Salaca/Salatsi	560984	407442	gQ_3ltv	LV
9600	Rimeikas	Salaca/Salatsi	560985	407436	D_2*br*	LV
9639	Seda	Salaca/Salatsi	584754	405850	D_2*pr*	LV

Well/ spring No. in national databases	Name of monitoring site in national language	River basin district	Coordinates		Aquifer	Country
			X (m)	Y (m)		
9637	Valka	Salaca/Salatsi	618372	403774	D_2*ar*	LV
6578	Pärnu maakond, Häädemeeste vald, Krundiküla, Jaagupi	West Estonia*	527793	432248	D_2	EE
7073	Põlde	West Estonia*	580276	443188	D_2*pr-nr*	EE
7592	Õisust 0,8 km kagus	West Estonia*	589928	450231	D_2	EE
7653	Saarde vald, Saarde küla, Saarde keskuse puurkaev	West Estonia*	556936	445007	D_2pr	EE
14338	Luhamaa piiripunkt	East Estonia*	701730	393870	D_3	EE
		Springs				
24563	Zīļu avots	Gauja/Koiva	662194	379621	D_3*pl*	LV
24561	Spiģu avots	Salaca/Salatsi	559401	417349	D_2*br*	LV
24554	Govs avots	Salaca/Salatsi	592941	405687	D_2*br*	LV

*Note: *The monitoring points are located outside the Salaca/Salatsi and Gauja/Koiva river basin districts, but they would help to assess transboundary groundwater resources, which are very important for sustainable groundwater management.*
***Given that the monitoring points characterize the same aquifer, it will be possible to choose without restriction which of the monitoring points will be exchanged in the future.*

In turn, the parameters with which the monitoring data should be exchanged and their recommended sampling frequency are given in Table 24. It should be noted that the list of parameters is mainly based on the results of the anthropogenic pressure assessment, the long-term results of groundwater quality monitoring in each country and the existing knowledge base on the hydrogeological conditions of the transboundary area. Also, the choice of parameters and frequencies did not exclude the financial aspect and the monitoring programs currently developed in both countries, which have different principles for determining the parameters to be analyzed and the frequency of their sampling (including no common vulnerability map or principles for determining vulnerability).

TABLE 24

Agreed list of parameters and frequency for exchange of groundwater quality monitoring data in transboundary area between Latvia and Estonia

Parameters		Frequency (monitoring points)
	Basic (universal) parameters	
Descriptive determinants (field parameters)	Temperature, pH, Electrical conductivity, dissolved oxygen (O_2)	3 times in 6 years (springs and wells which represent GWB 23, 25, 26, A8, A10 and D6); 2 times in 6 years (wells which represent GWB 21, P)
Major ions and nitrogen compounds	Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, total hardness, Fe_{tot}, NH_4^+, NO_2^-, NO_3^-	
	Additional parameters	
Metals	Cd, Pb, Hg, As	1 time in 6 years (in the all monitoring points)
Chemical pollutants	Trichlorethylene, Tetrachlorethylene, 1,2-dichloroethane	1 time in 6 years (only in the monitoring points, which parameters analyzed)
Pesticides	Atrazine, Simazine, Propazine, Bentazone, MCPA, Aldrin, Dieldrin, Heptachlor, 2,4-D, Isoproturon, Aclonifen, Bifenox, Promethrin, Dimethoate, Cypermethrin, Trifluralin, Tebuconazole, Epoxiconazole, Diflufenican, Metribuzin, Metazachlor	

In view of the above, it is further recommended to start exchanging data on groundwater monitoring points for at least the main parameters (field measurements, main ions, nitrate compounds). It is recommended to monitor them in springs and wells that characterize TGWBs 26, D6, A8 and A10 at least 3 times over a 6-year period, and to reduce them to 2 times over a 6-year period in deeper wells that characterize TGWBs 21 and P. If exceedances will be observed in the monitoring results, the sampling frequency may be increased to 1 time per year. However, in order to carry out the above-mentioned monitoring frequency in the case of Latvia, it will be necessary to increase the sampling frequency in certain monitoring wells (No.9600 and No.9637, which characterize GWBs A8 and A10, as well as at all monitoring points, which characterize GWB P), as it currently ranges from twice in 6 years to once in 6 years, as the observed aquifers are considered to be well or very well protected from surface pollution.

In turn, additional parameters (heavy metals, chemical pollutants, pesticides) should be exchanged at least once every 6 years - heavy metals should be collected at all monitoring points, but chemical pollutants and pesticides should be collected only at those monitoring points where they are analyzed according to the national monitoring programs of both countries (at present, at least in the case of Latvia, pesticides and chemical pollutants are not expected to be measured at all monitoring points - currently they are measured only at those monitoring points that can characterize their possible pollution and are more exposed to pollution or with the lowest degree of protection). It should be noted that additional indicators should be measured at one time when the main indicators are measured.

Despite the fact that within the framework of this project, monitoring points in the GWBs 22 and 24 are not included in transboundary monitoring, it is still recommended to exchange with the chemical data from these monitoring points. The frequency of monitoring sampling and the spectrum of observable parameters can respectively meet the requirements set forth in Table 24 (GWB 22 must be sampled 2 times in 6 years and GWB 24 must be sampled 3 times in 6 years). In the future, it is also recommended to consider the possibility of including in the transboundary monitoring network at least the springs identified in Chapter 2.3.2, which characterize GWBs 26, D6, 25, A10 and A8, and to carry out continuous quality monitoring of them (springs are shown in Figure 35).

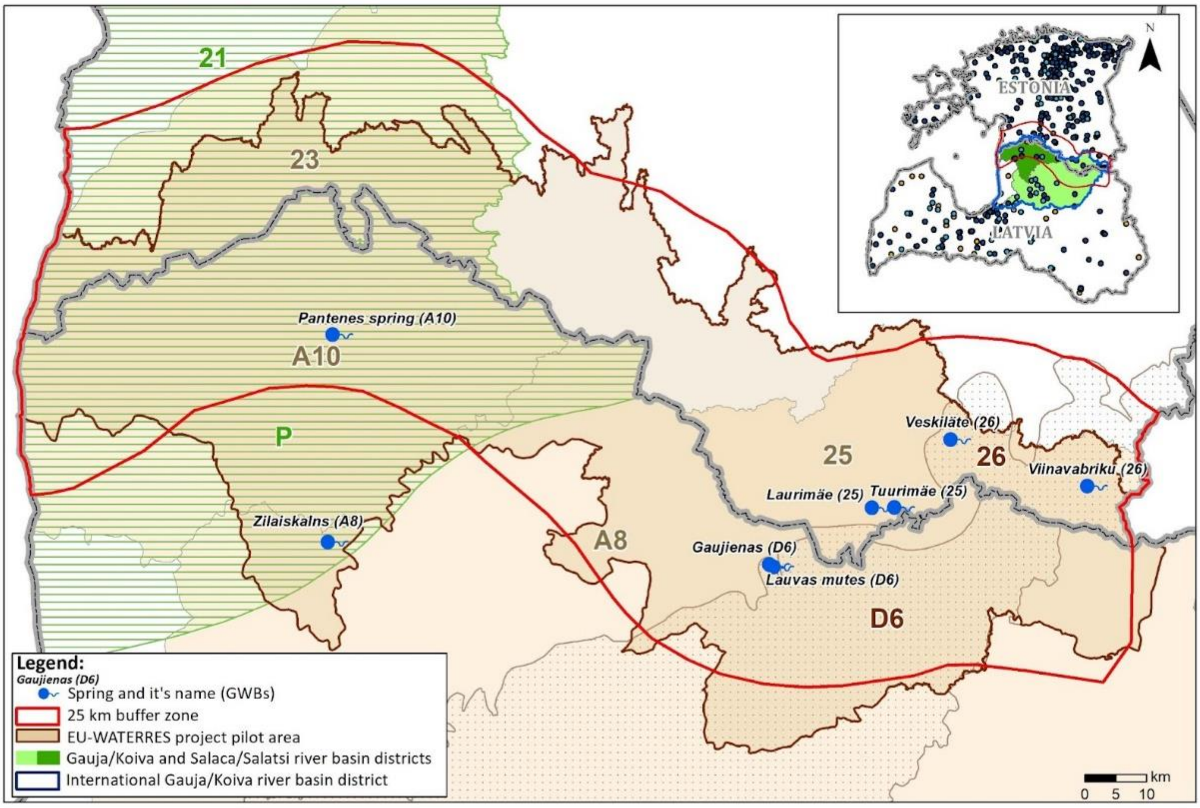


Figure 35. **Recommended springs to be included in the transboundary groundwater monitoring network**

In order to achieve a continuous data exchange process in the future, the two parties (LEGMC and EEA) should mutually conclude an agreement on the exchange of data with a view to providing each other with the relevant monitoring results on an annual basis. The list of monitoring sites to be monitored and the parameters to be exchanged, the frequency of their sampling may be specified after the acquisition of new data on pollution sources and hydrogeological conditions of the territory, as well as after the development of a harmonized vulnerability map. It should therefore be noted that this is only an initial list, mainly to improve cooperation between countries and to introduce a continuous exchange of monitoring data.

3. SPRING MONITORING OPTIMIZATION AND WATERSHED MODELING

Springs can be great sources of information on groundwater quality in a wider catchment context. There are many advantages for springs being included into national groundwater monitoring networks - there are no installation or maintenance costs and sampling does not require time-consuming water pumping compared to wells and boreholes.

Still, there are some obstacles to using springs as representative monitoring points: first, the water quality can feature a high variability/seasonality and single measurement/single sample in a year can show misleading information. Thus, springs need to be screened at optimally four times a year to identify the appropriate sampling frequency. Secondly, the corresponding aquifer system and catchment area should be determined using modeling tools and data analysis. Understanding catchment boundaries is crucial for analyzing spring water chemical composition data, especially if changes in specific parameter values occur or new compounds emerge. Delineated catchment helps to understand both natural and human impact on spring water quality through analyzing land use and point source pollutants within the catchment area. Moreover, a spring can represent a specific groundwater aquifer or a mixture of multiple aquifers. Each aquifer typically contains groundwater with a specific chemical composition and there are particular characteristics to each aquifer that define water quality, vulnerability to pollution, importance for ecosystems etc. Taking it into account, knowing the representing aquifer of a spring is essential.

Springs have been used for groundwater monitoring purposes for years in Latvia - they supplement groundwater qualitative monitoring network (chemical composition), but since no discharge measurements are performed within the monitoring, these springs are not used for quantitative monitoring needs. In total, 30 springs in Latvia are actively monitored, but their distribution is not even within the country. Moreover, their catchments are not delineated, and thus it is not known what is the territory that each spring represents. In Estonia, springs have been used primarily in the Nitrate Vulnerable Zone monitoring program with only a limited selection of parameters measured. Competence was mediated and implemented during this activity to develop a joint monitoring network in the Latvia-Estonia transboundary area.

3.1. Spring watershed delineation methodology

Spring watershed or springshed delineation consists of several subsequent steps that depend on what spatial and temporal data are available, their quantity, spatial resolution and data source being up-to-date. Borders of delineated springsheds never can be unmistakably drawn, therefore, they are considered as potential or current state springsheds. However, their estimated precision can be substantially improved by choosing the appropriate spatial delineation methods, more precise input data and more frequent variable data collection such as discharge measurements, chemical analysis etc.

Springshed borders can be mapped based only on available spatial data, if springs were not observed or sampled at all. The best practice in this case would be building the conceptual geological or hydrogeological model based on spatial, geological and hydrogeological information or/and utilizing already built hydrogeological mathematical models. In the territory of Latvia and Estonia several regional scale mathematical models are available (EC, 2010, https://www.puma.lu.lv, http://virumudel.ut.ee/avaleht/, Spalviņš et al., 2018). In the Groundwater Directive as well as in several of the CIS Guidance Documents, the use of conceptual models is mandatory or recommended (EC, 2010). Examples of hydrogeological data include the confined features of aquifers, potentiometric surfaces and groundwater flow rates. Topographic catchment is delineated based on surface features and topography without considering geological setting at all. Borders of topographic catchment will match with surface streamflow catchment. In the case of very small or intermittent/perennial springs feeding catchment won't be larger than the topographic one.

GWBs are larger than topographic borders and are delineated similarly to surface watersheds, however topography is subsurface not surface values. GWB's are horizontal subdivisions of confined aquifers or multi-aquifer systems. Delineated springsheds of the same spring based on different methods can have substantially different areas. As well, it can change between low and high recharge conditions. GIS-DEM based methods tend to calculate smaller springsheds than empirical calculations (Bystron, 2013).

The first question to be answered after a conceptual model is built or an already prepared mathematical model used is: "Are aquifers connected?". IF aquifers are not connected based on GWL difference or occurrence of thick impermeable layer between, etc., the next step is to determine which aquifer does spring discharge from. From the conceptual model, it is easy to deduce the right aquifer. IF aquifers are connected (hydrogeological window in impermeable layer or lack of aquitard, GWL difference determine possible mixing between aquifers etc.) we should consider that spring might represent both, i.e., confined and unconfined aquifers therefore, recharge area will be drawn somewhere between larger GWB and smaller topographic catchment.

In case when springs are observed and/or sampled once, additionally to spatial delineation, this data can improve our understanding about vertical connectivity of aquifers, therefore, specify recharge area and extend or vice versa decrease springshed area.

Discharge is one of the most important quantitative characteristics of springs. It not only specifies the yield of groundwater, but also reflects the water retention conditions of the aquifer. An analysis of a long-term spring discharges enables linking them to hydrogeological and meteorological conditions of their catchment area, as well as calculation of seasonal and multiannual variability parameters (Bartnik & Moniewski, 2019).

A spring's discharge itself can determine the spring recharge area from various empirical equations (Eq. 1) using the annual balance method. However, if groundwater flow path directions and spatial data are not used, discharge alone is useless as there is no known direction (both horizontal and vertical) of groundwater flow so does its shape (conceptual, mathematical models or at least hydrogeological maps can be used here to determine groundwater flow paths). It is highly beneficial to calculate the springshed area in case of semi-confined springshed.

$$A = Q/R \qquad \text{(Eq. 1.)}$$

where:
A- area of PCZ (potential catchment zone)
R - annual average recharge (calculated from Eq.2) (Valle, 2021)

Ascending/artesian springs are more complicated because there are no observable geological strata where it outflows, in case of descending/gravity springs if spring outflow is clearly visible, it is also additional information and can be detected from which geological layer spring is discharging. Otherwise, conceptual models can help to determine strata from where spring is more likely to discharge.

Usually, if spring sample is collected, as well in situ field parameters, such as electric conductivity (EC, mS), redox potential (ORP, mV), Temperature (T, C º), dissolved oxygen (DO, mg/L) and pH are measured. These parameters can give hints if groundwater discharged by springs are confined, unconfined or represent both groundwater systems. Lack of unified criteria is due to geological and hydrogeological peculiarities of the examined groundwater body, sometimes unique to the study area. Usually increased EC, T indicate groundwater of longer residence time and higher DO and ORP shorter recharge period. The more stable are measured field parameters between field campaigns, the larger is recharge area and therefore longer groundwater residence time. Once measured, chemical composition of spring water also provides fundamental input to distinguish at least between clearly confined and strictly unconfined sources. Hydro and isotope geochemistry of spring water can be used to interpret the various lithologies with which the groundwater has interacted and to determine the mean residence time of the water, ultimately enabling reconstruction of the groundwater flow path and identifying the spring's source area (Huff, et al., 2012; Jacobson & Langmuir, 1974; Langmuir, 1971; Leybourne et al., 2009).

Unconfined groundwater springs will have smaller horizontal recharge area and will be more prone to discharge diminishing due to droughts, increased abstraction rates and be more vulnerable to anthropogenic pollution and its protection zone will be larger near the spring outflow. Unconfined groundwater represents precipitation water with slightly increased dissolved solids (TDS compared to atmospheric waters), this leads to higher EC, DO and higher ORP/Eh values and noticeably lower or higher groundwater temperature, compared to mean observed temperatures in groundwater, of course, depending on recharge season.

Main chemical composition will be Ca-Mg-HCO_3. In the territory of Latvia, where gypsum deposits are more widespread, Ca-SO_4 also can be observed in unconfined groundwater springs in heavily karstified areas (Skaistkalne vicinity and Daugava River valley).

Confined groundwater source will have a larger recharge area as recharge will take place further from its outflow, recharge area can even correspond to whole GWB (groundwater body) borders for very large springs. Reaction to drought and pollution will be opposite to unconfined source, and their protection zone near spring outflow will be considerably smaller than in case of unconfined source. For a confined spring source, springs will portray physical and chemical values significant to a particular aquifer that feeds the spring, so it is beneficial to establish characteristic values and natural thresholds for specific areas and possibly involved aquifers (Retike et al., 2016) for instance mean values of groundwater wells in GWB versus groundwater depth.

Anthropogenic substances and agricultural chemicals are most widespread, and their concentrations increased in unconfined springs. Chloride ions are rare and can be present due to de-icing the highway during the cold season. pH can be variable in unconfined springs, however, tend to be less alkaline due to decreased residence time of water, therefore, lower dissolution of carbonates.

Chemical composition of confined groundwater mostly will be Ca-Mg-HCO_3, Ca-SO_4 or in rear cases Cl-Na. In contrast to unconfined springs, EC increased. Electric conductivity will increase with changing chemical types of spring in order: Ca-Mg-HCO_3 → Ca-SO_4 → Cl-Na. Confined types will have TDS > 500 mg/l. Confined groundwater sources will be free of DO, due to problematic precise measurements of DO in springs, DO values will be > 0 mg/l nevertheless DO will be smaller than for unconfined types. In pure confined groundwater, anthropogenic substances and agricultural chemicals are rare, or their concentrations are noticeably lower.

Mixed groundwater source is probably the most common type in our region as closer to major groundwater areas, their geological strata are affected by increased number of fractures, karstified rocks and increased wedging of geological layers. If the groundwater source is mixed, it represents both or more end-sources (several confined aquifers) in changing proportions for each site, and also can have temporally unstable values due to GWL fluctuations of each aquifer involved. This spring type is the most complex as springshed will be drawn somewhere between both upper described areas and it is more feasible to inaccurate delineation. This is the main task of spring monitoring and further data processing methods involved to distinguish proportion of each groundwater source to spring discharge.

3.1.1. Topography-derived spring watersheds

For topographic catchment delineation, initial tests suggest that ArcGIS Pro Watershed toolbox gives quite representative and repeatable results. As input, a water flow raster is necessary, which is calculated from depressionless DEM. An additional water accumulation raster is helpful to check if the outlet point lies within the accumulation zone. Following multiple publications, flow accumulation should be used to reposition pour points to higher accumulation zones to obtain "better" results for watershed delineation. Initial tests suggest that DEM with 10 m resolution is suitable for topographic catchment delineation. Initially tests were performed with DEM with 20 m cell size, and considering that spring catchments are rather small, obtained results almost always were too coarse for viable usage. For Latvian-Estonian transboundary area, DEM is created incorporating 5 m DEM for Estonia (derived from Land Board) and 10 m LiDAR derived DEM for Latvia. Working extent is defined, so it covers all of our sampled springs.

Despite the good quality of nowadays DEMs, they still are not always that good to perform any hydrological analysis directly. Therefore, sinks (local depressions) should be removed even from such highly detailed datasets. It was done using ArcGIS Fill tool. Flow direction file was calculated with Arcgis tool Flow direction and flow accumulation distribution was calculated with Arcgis flow accumulation tool.

3.1.2. Bedrock-derived spring watersheds

The groundwater flow model was constructed to calculate the watersheds of springs and monitoring points by MODFLOW 6 (Langevin et al., 2022). MODFLOW 6 is a widely used numerical model that solves the groundwater flow equation through a porous media in three dimensions, and can represent groundwater and surface water interactions.

The model was built by using the open-source interface ModelMuse v 4.3.0.0 (Winston, 2019). The model consists of 7 layers that discretize three main aquifers and represents an area of 45 000 km^2. The cell size of the model varies from 200 to 1000 m. The ground surface was determined by a Digital Elevation Model with a resolution of 10×10 m (Latvian Geospatial Information Agency, 2021; Estonian Land Board, 2021). In addition, the geological surfaces from a PUMA model (Virbulis et al., 2013) were used to build the model domain geometry.

The first layer represents the Quaternary aquifer system. The following two layers of Upper Devonian karstified carbonates represent the Pļaviņas-Ogre aquifer system and the subsequent two layers of Middle Devonian sandstones Aruküla-Amata aquifer system. The next layer represents the Narva regional aquitard, and the lowermost is the Lower-Middle Devonian aquifer system.

Two natural boundaries define the model limits: the coastline of the Baltic Sea to the west and Peipsi and Pihkva lakes to the northeast. The sea and lake water levels were defined with package CHD (Time Variant Specific Head). Recharge from precipitation values ranges from 0 to 0.00081 m/d. Pumping wells were defined to describe groundwater abstraction using the WEL package. The rivers in the study area were defined using the RIV package, which calculates the water exchange between the rivers and groundwater. Riverbed conductance was defined by calibration.

Hydraulic conductivity for the main geological formation was obtained from the available field pumping test measurements and previous studies (Virbulis et al., 2013, Vallner and Porman, 2016). A steady-state simulation for the year 2010 was used to conduct the first calibration of hydrogeological parameters. The model was calibrated against two sets of calibration targets- one representing the measured elevation of the groundwater table in the study area, and another corresponding to calculated rates of baseflow at stream stations.

The first bedrock aquifer water table was used to calculate watersheds to springs and monitoring points. The water table raster was processed with the SAGA-GIS tool upslope area in QGIS (Conrad, 2001). The upslope area is a tool for hydrological calculations and allows finding catchment areas based on the slope of a groundwater surface.

Raster calculation was performed with the following input parameters:

```
processing.run("saga:upslopearea", {'TARGET_PT_X': geom.asPoint().x(), 'TARGET_PT_Y':
geom.asPoint().y(), 'ELEVATION': path_DEM, 'METHOD': 2 ,'CONVERGE':1.1, 'AREA':
path_to_temp_output1.format(str(i))})
```

Watersheds, calculated by using the upslope methodology, represent the maximum area from which groundwater can reach a spring or well. These calculations, however, may overestimate the catchment area because the infiltration rate, aquifer conductivity, porosity, and thickness of the aquifer were not taken into account.

3.2. Spring sampling and water quality

During the project period (2021-2022) 53 various springs in the transboundary area of Latvia (LV) and Estonia (EE) were sampled for up to three times (showed in Figure 36 and listed in Annex 5). A total of 89 water samples (55 samples in Estonia and 34 samples in Latvia, respectively) were collected to study the hydrochemistry and seasonality of groundwater quality in the EE-LV transboundary area. In addition, 5 monitoring wells in EE were sampled to better define the aquifer systems in the transboundary area. The collected water samples were analyzed in the laboratories of University of Latvia and Tallinn University.

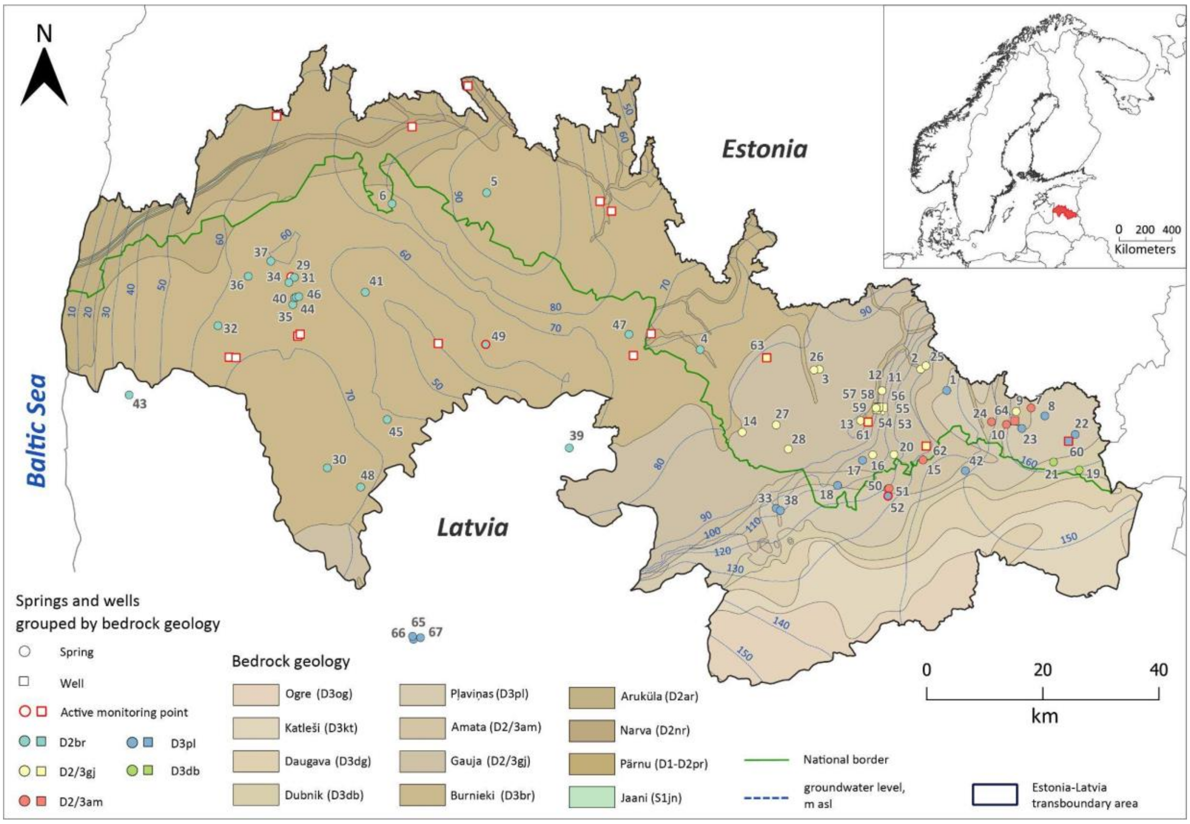


Figure 36. **Map showing bedrock geology, springs, and wells in the transboundary area of Estonia and Latvia**. See Annex 5 for more detailed data on numbered springs and wells.

The assembled dataset consisted of a total of 66 hydrochemical variables including field parameters (pH, SEC, ORP, water temperature, DO, TDS); major ions (Na^+, NH_4^-, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_2^- NO_3^-, SO_4^{2-}); log pCO_2, $SI_{calcite}$, $SI_{dolomite}$; dissolved organic and inorganic carbon (DOC and DIC); chemical oxygen demand (COD_{Mn}); macronutrients (N_{tot} and P_{tot}); stable isotopes ($\delta^{18}O$, $\delta^{2}H$ and d-excess); trace elements (Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, P, Pb, S, Sb, Se, Si, Sr, Ti, Tl, V, Zn), as well as various molar ratios (rMg/Ca, rBa/Sr, rNa/Cl, rBr/Cl, rMn/Ca, rSr/Ca, rBa/Ca). However, only selected hydrochemical variables (n=32) featuring a significant number of observations above the limit of detection threshold were involved in the further analysis. In addition to the hydrochemical parameters, other quantitative and qualitative parameters like elevation, bedrock outcrop, Quaternary cover thickness and type, water type, were also included in the dataset.

By carrying out Kruskal-Wallis tests and discriminant analysis (DA), the springs were linked to the most likely aquifer systems (Quaternary [Q], Upper-Devonian [D_3], or Middle (EE)/Upper-Middle (LV) Devonian [D_2]) in the transboundary area.

Firstly, the studied springs (n=59, also including six springs from the GroundEco project) and a selection of monitoring wells (n=32) were pre-assigned to one of the three aquifer systems by taking into account the bedrock and Quaternary cover geology maps developed for the transboundary area in the framework of EU-WATERRES project (Solovey et al., 2021), and the Quaternary cover thickness layer of the hydrogeological model of the Baltic Artesian Basin (BAB) (Virbulis et al. 2013). The pre-assigned classifications were then tested first by carrying out a series of Kruskal-Wallis tests, later followed by DA analysis.

TABLE 25

Descriptive statistics of elevation, quaternary cover thickness, discharge and specific conductance of the studied springs and wells in the Latvian-Estonian transboundary area.

Aquifer system	Aquifer type	Number		Elevation	Quaternary thickness	Discharge	Specific conductance (SEC)
				mean±SD (m asl)	mean±SD (m)	mean±SD (l/s)	mean±SD (µS/cm)
Q	Sand, gravel and loam	Springs	32	100.2±68.1	44±29.6**	0.6±0.9**	385±172**
		Wells	4	120.8±41.7	41.9±17.6		414±125
D_3	Fractured and karstified carbonate rocks	Springs	9	97.1±36.3*	20.9±8.6**	3.2±3.9**	578±88**
		Wells	13	198.5±13.3*	52.9±18.1		480±94
D_2	Sandstone (fractured)	Springs	18	62.8±10.6*	18.5±6.4**	1±0.8**	532±180**
		Wells	15	85.5±47.3*	43.1±24.8		509±95

*Note: Significant differences between classes according to Kruskal-Wallis test (at α=0.05): *D_2 vs. D_3; **Q vs. D_2/D_3*

Kruskal-Wallis tests showed that there was significant difference between the elevation of springs pre-assigned to D_3 and D_2 aquifer systems, while the Q springs did not differ from others significantly (Table 25). This was mainly because Q springs could be situated on different elevations, being independent of bedrock. As expected, the Quaternary cover thickness was the greatest in the case of Q aquifer system, which differed significantly for the two bedrock aquifer system (D_3 and D_2) springs (Table 25). Similarly, there were statistically significant differences in discharge and specific conductance median values between the Q and bedrock (D_3 and D_2) aquifer system springs, which refers to differences in dominant substrate, structure and porosity.

As the general ion chemistry (dominantly $Ca\text{-}HCO_3$ type) was relatively homogeneous in the case of all springs regardless of the aquifer system, we had to look for more specific characteristics that could be used to distinguish the springs and link them to aquifer systems. This was especially important in the case of distinguishing between the D_3 and D_2 aquifers. Among some others, barium was found to be the hydrochemical parameter that featured a statistically significant difference in median values between all three aquifer systems. It appears that D2 has the highest median barium content, followed by D3 and Q springs (Figure 37). Previously, Koit et al. (2021) found barium to be a good tracer to distinguish between Q and D2 groundwater in the transboundary area.

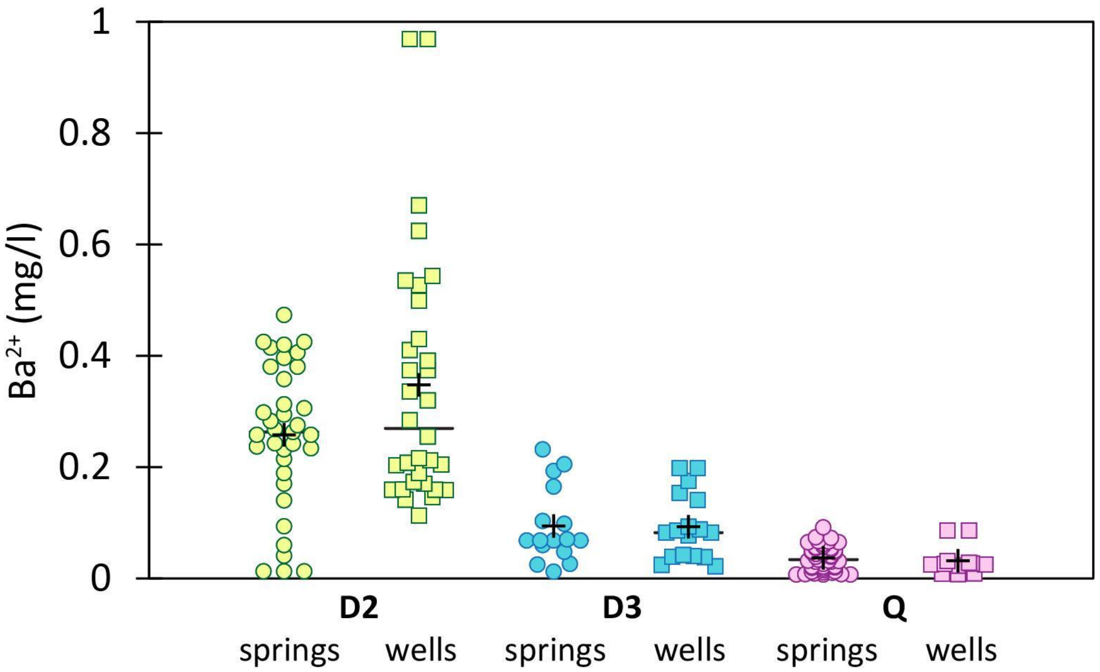


Figure 37. **Barium concentrations in the springs and wells of D2, D3 and Q aquifer systems**.

A total of 101 observations from 67 individual springs and wells (listed in Annex 5), that featured no missing values in the 39 assessed variables (Figure 38b), were then used in the final DA analysis. Among the selected observations were, for example, water samples taken from the same springs at different times to account for the seasonality. Barium, magnesium, fluoride, total iron, manganese content, along with the geological index as a qualitative variable (Figure 38b), performed well in the DA analysis, resulting in 96% of the pre-assigned springs and wells being classified to the correct aquifer system cluster (Figure 38a). The springs situated in the vicinity of the centroids of each aquifer system cluster (Figure 38a) could then be selected as representative candidates for further monitoring.

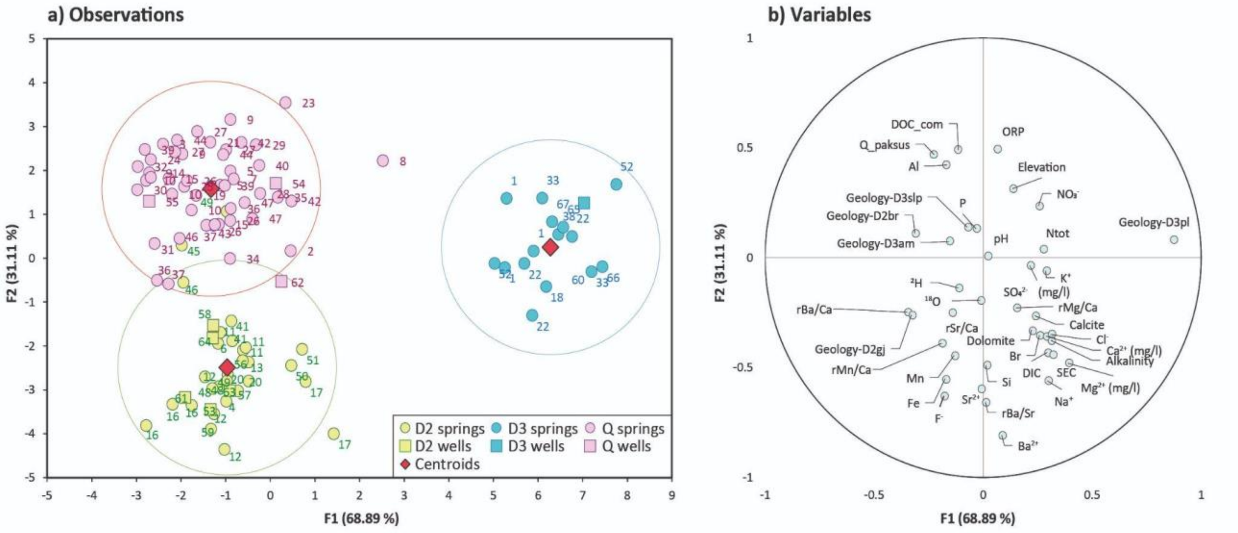


Figure 38. **The dispersion of discriminant scores of spring and well observations (a), and 39 selected variables (b) according to the discriminant analysis (DA).**

3.3. Conceptual models for recommended springs for monitoring

Conceptual models of spring water origin and potential impacts are created based on the extensive analysis carried out during the project – including data collected during the spring selection process, field works, spring water analysis, spring watershed analysis, and, finally, multivariate statistical analysis. The largest impact on the building of conceptual understanding is for multivariate statistical analysis that integrates the vast majority of the collected and calculated data and results.

Three principal spring types have been identified according to the aquifer system they belong: Quaternary aquifer system (Q), Upper Devonian aquifer system (D_3) and Upper-Middle Devonian aquifer system (D_2) (see recommended spring Table 22). Fundamental conceptual models are created for each of these spring types and the general characteristics of recommended springs are represented by the corresponding conceptual models, although each particular spring can have some particular features that arise from local aspects. These conceptual models are useful for monitoring program planning to assess the representativity of each spring type for particular aim or to understand processes that can have significant impact on the spring water chemical composition, or, vice versa – what processes within the catchment area these springs can represent.

Quaternary aquifer system (Q) conceptual model represents four of the recommended springs - Roodsi-Mõtsakunna spring, Vorstimäe spring, Velnakmens spring and Oliņu spring. These Quaternary aquifer system springs represent local catchment areas which are based on topography-derived watersheds with a relatively short groundwater residence time (see conceptual scheme in Figure 39). Catchment areas of recommended Q springs ranges from 15905 m^2 (Roodsi-Mõtsakunna spring) up to 184930 m^2 (Oliņu spring) and due to these small catchments, these springs typically have small discharges. The groundwater in these catchments can recharge at every single point within the catchment area – even relatively close to the spring. Due to the rapid groundwater flow from recharge area to spring outflow, the representative groundwater typically is low in mineralization as there is limited time for dissolution of minerals. Also, barium (Ba) and magnesium (Mg^{2+}) are in low concentrations, thus supporting a short residence time factor. As a result, these springs can have distinct seasonal fluctuations in discharge, temperature or even some chemical compounds. Dissolved organic matter (DOC) is at elevated concentrations if compared to other spring types, thus suggesting that these springs can represent soil erosion processes in local catchment scale. Q springs are also characterized with elevated oxidation-reduction potential (ORP) that indicates relatively fresh water with possible dissolved oxygen in the groundwater. Elevated ORP and DOC values implies that possible nitrate pollution from agricultural lands can easily reach springs.

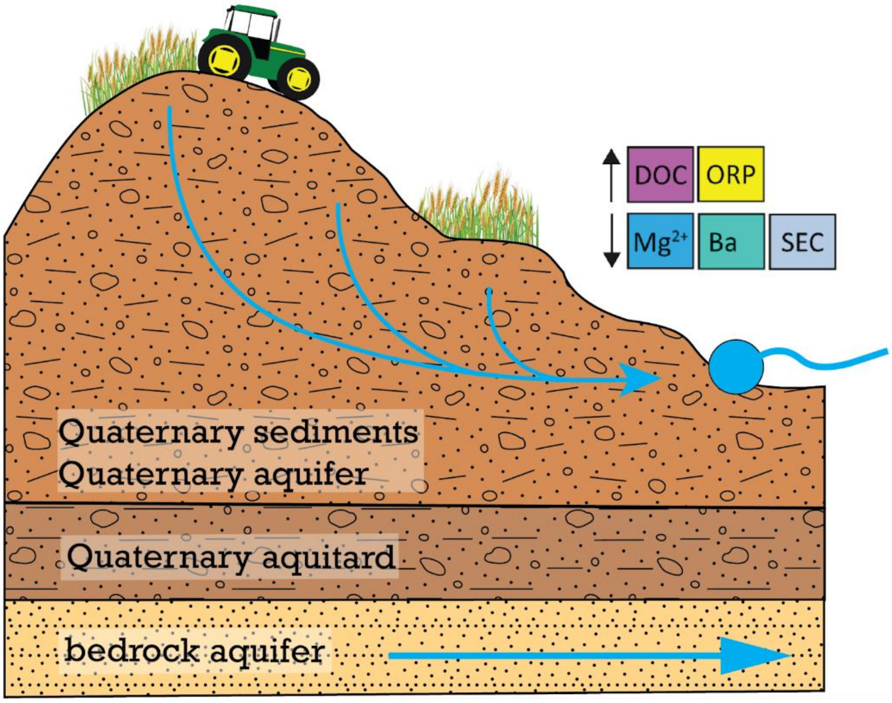


Figure 39. **Conceptual picture of Quaternary aquifer system (Q)**

Quaternary aquifer springs are suitable to monitor agricultural pollution at local scale (if there is any agricultural land within the catchment) and other processes of local scale, such as soil erosion, impact from land use changes or other anthropogenic activities. Such springs are suitable to assess groundwater dependent terrestrial ecosystems (GDTE) as GDTEs depending on Q springs can be considered more vulnerable. Due to possible seasonality of these springs, at least two samples per season (optimally four samples a year) are necessary to account for high-discharge and low-discharge conditions. However, automatic discharge measurements are required to find high- and low- discharge conditions as manual discharge measurements typically are not performed often enough.

Upper Devonian aquifer system (D_3) represents four of the recommended springs - Viinavabriku springs, Veskiläte spring, Lauvas mutes spring and Gaujienas spring. These D_3 springs represent both local and more regional catchment scales with a groundwater residence time ranging from relatively short to average residence time (see conceptual scheme in Figure 40). The primary groundwater recharge occurs within the bedrock-derived watersheds, while some part of the water can be recharged also locally at the topography-derived watershed area. Out of the recommended springs the smallest topography-based watershed is for Lauvas mutes spring (10103 m^2), while the largest is for Viinavabriku springs (21897 m^2). Nevertheless, the majority of groundwater for D_3 springs recharges in the bedrock-derived watersheds of which the smallest one is for Veskiläte spring (1.08 km^2) and the largest one for Lauvas mutes spring (39.75 km^2). The majority of water origins in the Upper Devonian aquifer system that largely consists of fractured dolomites and this aspect governs the general chemical composition of spring water that is characterized with increased mineralization and naturally elevated concentrations of calcium (Ca^{2+}), magnesium (Mg^{2+}). These springs also tend to show elevated concentrations of nitrogen compounds that indicate agricultural impact on the groundwater chemistry. Increased levels of sulphate (SO_4^{2-}) and chlorides (Cl^-) can also be attributed to agricultural or other human activities within the watershed. The nature of fracture aquifers promotes faster groundwater flow in the horizontal plane as well as increased infiltration speed in vertical scale. The conceptual understanding of D_3 springs imply that the groundwater discharged in these springs primary originates within relatively large bedrock catchment areas, but some part of the groundwater is actually relatively fresh water that originates from Quaternary aquifer system and constitutes to the elevated levels of anthropogenic indicator parameters – nitrogen compounds.

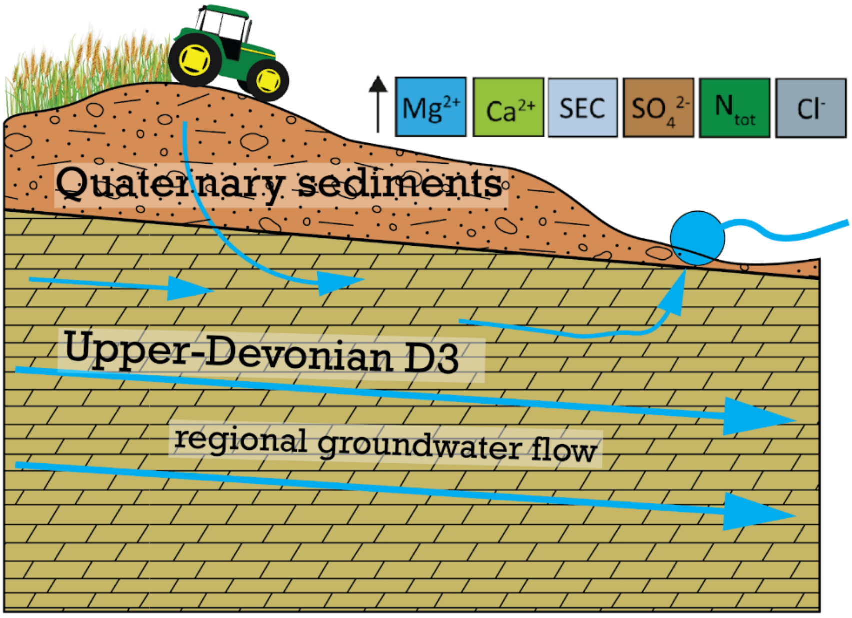


Figure 40. **Conceptual picture of Upper Devonian aquifer system (D_3)**

Upper Devonian aquifer springs are suitable to monitor the relatively larger catchment scale of fractured aquifers with some local catchment scale features. However, it would be difficult to discriminate the origin of possible impact or find the source of pollution if any changes in water chemistry arise. On the other hand, these springs are the best ones that characterize fractured aquifers in the Estonia-Latvia transboundary area. These springs can be samples once a year, while two samples per year are required in high-discharge and low-discharge periods if higher credibility of the results is needed. The best approach to find high-discharge and low-discharge periods is to equip springs with automatic discharge measurement units.

Upper-Middle Devonian aquifer system (D_2) represents four of the recommended springs - Laurimäe spring, Tuurimäe spring, Pantenes spring and Zilaiskalns spring. These D_2 springs represent solely regional groundwater flow of Upper-Middle Devonian aquifer system and the groundwater has relatively long residence time (see conceptual scheme in Figure 41). The catchments of these springs typically are large and groundwater discharge in springs is relatively stable over the seasons with a relatively stable discharge. Only bedrock-derived watersheds are important for these springs with the smallest catchment of the recommended springs being for Laurimäe spring (0.96 km^2) and the largest one for Pantenes spring (44 km^2). The aquifer consists primarily of sandstones with clay interlayers and groundwater flow is relatively slow (compared to fractured aquifers). The groundwater of Upper-Middle Devonian aquifer system has a characteristic elevated barium (Ba) and strontium (Sr) trace element concentrations that suggest long residence time/relatively old groundwater. Also fluoride (F-) and manganese (Mn) levels are higher than in other aquifer systems. Elevated dissolved iron (Fe_{tot}) concentrations indicate reducing conditions in the aquifer which is supported also by low oxidation-reduction potential (ORP) values. Such conditions suggest that the spring water would be also in lack of dissolved oxygen and nitrate pollution due to the denitrification process along the long travel path of groundwater.

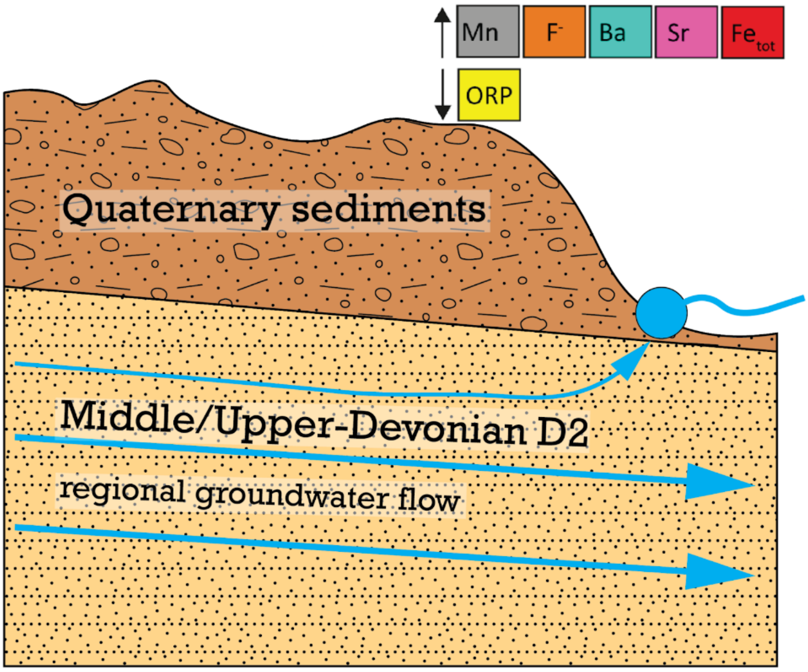


Figure 41. **Conceptual picture of Upper-Middle aquifer system (D_2)**

Upper-Middle Devonian aquifer system springs are appropriate for regional groundwater monitoring needs without signs of local impact. In general, these springs represent background chemical composition of groundwater that is most likely used by towns and households of a large part of the Estonian-Latvian transboundary area. It must be noted that Zilaiskalns spring is technically an old well, but due to the artesian nature of the groundwater and the excellent representativity of the D_2 aquifer system it was selected as good candidate for monitoring. The D_2 springs can be sampled less often – once a year up to once per 4 years because such regional groundwater typically doesn’t change chemical composition at rapid pace (though, that can change with significant human activities). These springs can be used also for quantity monitoring as these springs characterize regional groundwater resources, but to do that, automatic spring discharge equipment must be installed.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions on WP2 activities

1. In the Wateract project, a total of 8 transboundary GWBs were delineated in the Gauja/Koiva and Salaca/Salatsi transboundary river basins: in Upper Devonian aquifer system - GWBs D6 and 26, in Upper-Middle Devonian aquifer system - GWBs A8, A10, 23 and 25, but in Middle-Lower Devonian aquifer system – GWBs P and 21. Based on collected materials, it was concluded that no intensive anthropogenic pressure has been detected in Latvian-Estonian transboundary area.
2. According to GWB characteristics and developed conceptual models, an assessment of the status of transboundary GWBs was carried out. According to the results of the assessment tests, all transboundary GWBs are in good quantitative and chemical status. Therefore, it was considered that at the current pressure, the existing groundwater monitoring network can provide groundwater quality and quantity monitoring in the transboundary area on a regional scale (mainly focusing on drinking water resources).
3. In order to improve the management of common groundwater resources in Latvian-Estonian transboundary area, a long-term transboundary groundwater monitoring program was developed, as well as a common database was created for further exchange and storage of monitoring data. The existing 24 active groundwater monitoring points are included in the transboundary monitoring network, of which 19 monitoring points will provide quality monitoring and 14 monitoring points will provide quantity monitoring data. In addition, information was collected on monitoring points that characterize GWB 21 and 24 (currently, within the framework of the WaterAct project, these GWBs no included in transboundary monitoring).
4. In the Latvian-Estonian Salaca/Salatsi and Gauja-Koiva river basins, 12 new springs were identified in the transboundary area, which can be integrated into the current groundwater monitoring network. It was concluded that 4 quaternary aquifer springs represents primarily local catchment areas and are not suited for GWB background monitoring, but these springs could be used as reference monitoring points to assess groundwater dependent ecosystem dependency on groundwater and vulnerability, as well as for groundwater assessment. Pre-quaternary aquifer springs can be great sources of information on groundwater quality in a wider catchment context. Since understanding catchment boundaries is crucial for analyzing spring water chemical composition data and helps to understand both natural and human impact on spring water quality, respectively, the groundwater quality, a method for the spring watershed delineation was developed. As a result of spring watershed modeling in the Salaca/Salatsi and Gauja/Koiva river basins (focusing mainly on transboundary area).
5. Within the WaterAct project, also the identification of groundwater-dependent terrestrial ecosystems (GDTEs) in the Salaca/Salatsi river basin was carried out. On the Latvian side, GDTEs in the Gauja/Koiva river basin have also been revised. In total, 33 GDTEs were identified in the Salaca/Salatsi river basin (27 in Latvian side and 6 in Estonian side). Based on the latest available habitat inventory data, the GDTEs already identified in the Gauja/Koiva river basin (in GroundEco project) were reviewed, as a result - 12 GDTEs are no longer considered as GDTEs according to the expert's assessment. However, 59 new GDTEs have been identified. As a result, 89 GDTEs are

currently determined in the Gauja/Koiva river basin area. An assessment of these identified GDTEs was also carried out, according to the methodology developed within the GroundEco project.

6. Comparing Natura 2000 monitoring principles in Latvia and Estonia, it was concluded that each country has chosen specific criteria for its national monitoring methodology and it is currently not possible to harmonize it between countries. In order to ensure the protection of the groundwater-dependent ecosystems (GDE) in the future and to provide data about ecosystem status and thus indicate the overall status of GWBs, it is necessary to continue efforts to link the groundwater and GDE monitoring programs. More detailed recommendations are given in chapter 2.2.4.

4.2 Recommendations for transboundary GWB management

- It is important to continue close cooperation between Latvian and Estonian authorities, to improve the management of transboundary groundwater resources between Latvia and Estonia. More attention should be paid directly to the Gauja/Koiva transboundary area, as there is a more intense groundwater flow across the Latvian-Estonian border, and, with more intense anthropogenic pressure, possible transboundary effects.
- For the development of a joint transboundary groundwater management plan, a working group should be established and periodic meetings and discussions should be held.
- Work on the harmonization of assessment methodologies should be continued, as well as to develop a unified approach to assessing the impact of anthropogenic pressure;
- The numerical hydrogeological model should be developed and improved, in order to assess the groundwater balance in the transboundary area in more detail and specify the areas that should be paid more attention;
- A joint groundwater vulnerability map of Latvia and Estonia should be developed
- Harmonized approach for selecting additional monitoring parameters should be established, also intercalibration between laboratories should be performed;
- LEGMC and the EEA should continue to exchange groundwater quality and quantity monitoring data throughout the transboundary area, based on a joint agreement and the developed monitoring strategy. In order to improve the density of the monitoring network in the transboundary area, it is recommended to consider the possibility of integrating the proposed springs into the existing monitoring network;
- In order to ensure protection of GDTEs and to provide data about ecosystem status and thus indicate the overall status of groundwater bodies, it is necessary to ensure the connection between national Natura 2000 and groundwater monitoring programs in the future;
- Since the locations of groundwater monitoring networks and GDEs do not overlap, also established state groundwater monitoring networks in Estonia and Latvia were designed to serve different other purposes. However, an effort should be made to improve groundwater monitoring networks by establishment of new wells and selection of new springs for national monitoring needs, in order to assess the impact of groundwater on surface water bodies and terrestrial ecosystems. For the GDTEs to which no potential pressures through anthropogenically induced changes apply, establishing a monitoring network is not necessary;

REFERENCES

Auniņš A., Lārmanis V., (2013). Īpaši aizsargājamo biotopu platību izmaiņu uzraudzība, izmantojot attālās izpētes datus un valsts reģistrus (Monitoring of changes in the area of especially protected habitats using remote sensing data and national registers). Latvijas Dabas fonds, 11 lpp. (in Latvian)

Bartnik, Adam & Moniewski, Piotr. (2019). Multiannual variability of spring discharge in Southern Poland. Episodes. 42. 187-198. 10.18814/epiiugs/2019/019015.

Bystron, Ismena. 2018. GIS-Based Analysis of Spring Occurrence and Spring Source Areas in Peace River Regional District, British Columbia. Master of Science (Earth Sciences). Thesis in Partial Fulfilment of the Requirements for the Degree of Master of Science, Simon Fraser University.

Conrad, O., 2001. Tool Upslope Area. SAGA-GIS Tool Library.https://sagagis.sourceforge.io/saga_tool_doc/7.1.0/ta_hydrology_4.html

Dabas aizsardzības pārvalde, (2012). Bioloģiskās daudzveidības monitoringa pārskats 2009.-2012.gadam (Biodiversity Monitoring Report 2009-2012). Sigulda, 2 lpp. (in Latvian)

Diversity of Nature in Estonia. Estonian Nature Conservation in 2015 (2017). Estonian Environment Agency. 2017 Available: https://loodusveeb.ee/et/themes/looduskaitse/natura-2000

EC, 2007. WFD CIS Guidance Document No.15. Monitoring Guidance for Groundwater. Luxembourg: Office for Official Publications of the European Communities, 2007.

EC, 2009. WFD CIS Guidance Document No.18. Groundwater Status and Trend Assessment. Luxembourg: Office for Official Publications of the European Communities, 2009.

EC, 2010. Guidance on Risk Assessment and the Use of Conceptual Models for Groundwater, Guidance Document No 26. Technical Report - 2010 - 042. ISBN-13 978-92-79-16699-0. European Communities, Luxembourg.

Estonian Land Board, Digital Elevation Model., (2021). https://geoportaal.maaamet.ee/eng/Spatial-Data/Elevation-Data-p308.html

Hughes, J. D., Russcher, M. J., Langevin, C. D., Morway, E. D., & McDonald, R. R., (2022). The MODFLOW application programming interface for simulation control and software interoperability. Environmental Modelling and Software, 148 doi:10.1016/j.envsoft.2021.105257

Kārkliņa, I., Karuša, S., Borozdins, D., Valters, K., Demidko, J., (2020). 4.ziņojums. Izdalīto pazemes ūdensobjektu raksturojums (darba variants). LVAF finansētais projekts "Pazemes ūdeņu raksturojuma un stāvokļa novērtējuma uzlabošana nākamajam upju baseinu apsaimniekošanas plānošanas ciklam". Reg. Nr.1-08/295/2017. (Report No.4. Characteristics of delineated groundwater bodies (draft version). Project "Improving groundwater characterization and status assessment for the next river basin management planning cycle" financed by the Latvian Environmental Protection Fund. Reg. No.1-08/295/2017). VSIA "Latvijas Vides, ģeoloģijas un meteoroloģijas centrs", Rīga (in Latvian)

Koit, O., Tarros, S., Pärn, J., et. al., (2021) Contribution of local factors to the status of a groundwater dependent terrestrial ecosystem in the transboundary Gauja-Koiva River basin, North-Eastern Europe. Journal of Hydrology 600:126656. https://doi.org/10.1016/j.jhydrol.2021.126656

Langevin, C.D., Provost, A.M., Panday, Sorab, and Hughes, J.D., (2022). Documentation for the MODFLOW 6 Groundwater Transport Model: U.S. Geological Survey Techniques and Methods, book 6, chap. A61, 56 p., https://doi.org/10.3133/tm6A61

Latvian Geospatial Information Agency, Digital Elevation Model., 2021. https://www.lgia.gov.lv/lv/Digit%C4%81lais%20virsmas%20modelis

LEGMC, 2021. *River basin management* and flood risk management plans 2022-2027. VSIA “Latvijas Vides, ģeoloģijas un meteoroloģijas centrs”, Rīga (in Latvian) Available: https://videscentrs.lvgmc.lv/lapas/udens-apsaimniekosana-un-pludu-parvaldiba

Marandi, A., Osjamets, M., Polikarpus, M., Pärn, J., Raidla, V., Tarros, S., Vallner, L., (2019). Põhjaveekogumite piiride kirjeldamine, koormusallikate hindamine ja hüdrogeoloogiliste kontseptuaalsete mudelite koostamine (Characterization of the borders of the groundwater bodies, evaluation of pressures and compilation of hydrogeological conceptual models). Geological Survey of Estonia, Rakvere (in Estonian)

Marandi, A., Karro, E., Osjamets, M., Polikarpus, M., Hunt, M., (2020). Eesti põhjaveekogumite seisund perioodil 2014-2019 (Status of Estonian groundwater bodies in the period 2014-2019). Geological Survey of Estonia, Rakvere (in Estonian)

Nature Conservation Development Plan until 2020 (2012). Ministry of the Environment.

Perens, R., Savitski, L., Savva, V., Jaštšuk, S., Häelm, M., (2012). Põhjaveekogumite piiride kirjeldamine ja põhjaveekogumite hüdrogeoloogiliste kontseptuaalsete mudelite koostamine. OÜ Eesti Geoloogiakeskus, EGF: 8450, Tallinn (in Estonian)

Perens, R., Vallner, L., (1997). Water-bearing formation. In: Geology and Mineral Resources of Estonia (editors) Raukas, A., Teedumäe, A. Estonian Academy Publishers, Tallinn, 137-145

Retike I., Kalvāns A., Priede A., Tarros S., Terasmaa J., Türk K., Bikše J., Demidko J., Koit O., Küttim M., Lode E., Pärn J., Popovs K., Vainu M., Valters K., Abreldaal P., Babre A., Bīviņa I., Caune K., Marandi A., Polikarpus M., Raidla V., Rieksta M., Sisask K., (2020). Interreg Estonia-Latvia project No. Est-Lat62 “Joint management of groundwater dependent ecosystems in transboundary Gauja/Koiva river basin (GroundEco)”. Final report.

Retike et al., 2021. Methodology of lake ecosystem health assessment. Joint management of Latvian – Lithuanian trans-boundary river and lake water bodies (TRANSWAT) LLI-533. Available at: https://bit.ly/TRANSWAT-lakemethod

SIA Estonian, Latvian & Lithuanian Environment, (2007). Latvijas NATURA 2000 vietu monitoringa metodika (Latvian NATURA 2000 site monitoring methodology). Rīga, 21 lpp. (in Latvian)

SIA Estonian, Latvian & Lithuanian Environment, (2008). Latvijas NATURA 2000 vietu monitorings. B pielikums: metožu katalogs (Latvian NATURA 2000 site monitoring. Appendix B: catalogue of methods). Rīga, 42 lpp. (in Latvian)

Spalviņš, A., Krauklis, K., Lāce, I., Aleksāns, O. Latvijas hidroģeoloģiskā modeļa LAMO izveidošana, izmantošana un pilnveidošana. Boundary Field Problems and Computer Simulation, 2018, Vol. 57, 5.-14.lpp. ISSN 2255-9124. e-ISSN 2255-9132. Available: doi:10.7250/bfpcs.2018.001

Terasmaa, J., Vainu, M., Lode, E., Pajula, R., Raukas, A., (2015). Põhjaveekogumi veest sõltuvad ökosüsteemid, nende seisundi hindamise kriteeriumid ja seirevõrk (Groundwater dependent ecosystems, criteria for status assessment and monitoring network). Tallinna Ülikooli ökoloogia instituut, Tallinn. (in Estonian)

Uzule, L., Jēkabsone, J., Retike, I. (2021) “No pazemes ūdeņiem atkarīgo ekosistēmu identificēšana un novērtēšana Latvijas pazemes ūdensobjektu līmenī” (Identification and assessment of groundwater-dependent ecosystems at the level of groundwater bodies in Latvia) (Reģ Nr. 1-08/205/2020). Pārskats Nr. 3. Rīga, 2021 (in Latvian)

Vallner, L., Porman, A., (2016). Groundwater flow and transport model of the Estonian Artesian Basin and its hydrological developments. Hydrology Research 47, 814–834. https://doi.org/10.2166/nh.2016.104

Valters, K., Karro, E., Bikše, J., Borozdins, D., Demidko, J., Krauze, A., Lode. E., Marandi, A., Ojamäe, K., Osjamets, M., Pärn, J., Polikarpus, M., Retiķe, I., Tarros, S., Türk, K., Vainu, M. (2022) WaterAct project report on WP1 “Capacity building through exchange of knowledge and best management practices” activities T1.1-T1.4. Riga, 2022

Virbulis, J., Bethers, U., Saks, T., Sennikovs, J., Timuhins, A., (2013). Hydrogeological model of the Baltic Artesian Basin. Hydrogeology Journal, 4/2013, http://dx.doi.org/10.1007/s10040-013- 0970-7

Winston, R.B., (2019). ModelMuse version 4—A graphical user interface for MODFLOW 6: U.S. Geological Survey Scientific Investigations Report 2019–5036, 10 p., https://doi.org/10.3133/sir20195036

ANNEXES

Annex 1

Conceptual models for Estonian-Latvian transboundary groundwater bodies

1. GWB-1 in Upper Devonian aquifer system (LV GWB D6 & EE GWB 26)

GWB code		**D6**	**Additional visual material**
River basin district		Gauja	-
Area (km^2)		4891	-
Physiographic characteristics		The territory has a changing relief - in the western part there is a plain, the central part and the eastern part are formed by highlands, while the rest of the area formed by wavy plains. The absolute height of the terrain varies from about 90 to 265 m a.s.l., but the relative height is about 176.6 m a.s.l.	Figure 39. Transboundary GWB-1 (D6 & 26) in Upper Devonian aquifer system
Hydrogeological characteristics	*Lithology*	Geological structures that form the aquifer system are composed of sandstone and dolomite. The local aquitards consist mainly of dolomite marl, siltstone and clay. Dominated by porous rock material. Moraine loam, moraine loam, sand and clay are common in the overlapping Quaternary sediments.	Figure 40. Cross-section of the Upper Devonian aquifer system (GWBs D6 and 26)
	GWB thickness	The thickness of the bedrock reaches up to 105 meters, the average thickness - 30 m; the thickness of the overlaying Quaternary sediments in the plains is in range of 5-25 m up to 75-135 m in the hills. The average thickness of Quaternary sediments is about 50-60 m.	
	Overlying aquitard	The Quaternary sediments overlying the bedrock aquifers consist mainly of moraine loam, sand and clay.	
	Underlying aquitard	The clay, dolomite marls and clayey siltstones of Amata formation or lower part of Pļaviņas formation	
	Groundwater level	GWL is about 10-90 m a.s.l. in the lowlands and 100- 190 m in the highlands (Vidzeme highland, Alūksne highland)	
Hydrodynamics	*Flow direction*	The main groundwater flows are from Vidzeme Heights, Alūksne Heights and Haanja Heights (Estonia) in the direction of lower areas - Gauja river valley and adjacent plains	Figure 40. Cross-section of the Upper Devonian aquifer system (GWBs D6 and 26)
	Filtration coefficient	The transmissivity of the aquifers forming the groundwater body is in the range of 26-3580 m2/d (mostly 700 m2/d)	
	Recharge and regime	Main recharge areas are located in the central part of Vidzeme highland and eastern part of Alūksne highland, discharge in topographically lower regions. The amount of infiltrating water is about 1 792 000 m^3/d	
Groundwater chemical composition	*Chemical composition*	Ca-Mg-HCO_3 type freshwaters with mineralization up to 1 g/l predominate.	Figure 41. Groundwater types

	Conceptual model of the formation of chemical composition	*Not developed due to lack of data and knowledge*	in the Upper Devonian aquifer system represented in Piper diagram. (GWBs D6 and 26)
Groundwater vulnerability	*Quaternary*	• Relatively protected area - 40%; • Poorly protected area - 37%; • Protected area - 10%; • Moderately protected area - 10% • Unprotected area - 3%.	-
	Pre-quaternary	• *Low risk of contamination*: 4% of the area (eastern part of Trapene plain); • *Medium risk of contamination*: 84% of the area; • *High risk of contamination:* 12% of the area (western part of Mežole mound and Ropaži plain);	
Corine LandCover 2018		Common types: • Mixed forests – 26% • Coniferous forests – 17% • Transitional woodland-shrubs – 17% • Pastures – 11% • Non-irrigated arable lands – 11% • Agricultural land with significant natural areas – 6%	-
Nitrate vulnerable zone		*Not distributed*	-
Monitoring	*Number of monitoring station and wells (springs)*	*Quantity monitoring*: 3 stations: Dzērbene (1 well), Velēna (2 wells) and Virāne (3 wells). Total: 6 wells *Quality monitoring*: 2 stations: Velēna (2 wells) and Virāne (3 wells). Total: 5 wells. 6 springs: Bānūžu spring, Dāvida dzirnavu spring, Mežmuižas spring, Saltavots spring, Vecstrautu spring and Zīļu spring. ● Operational monitoring: correspond to quality monitoring	Figure 39. Transboundary GWB-1 (D6 & 26) in Upper Devonian aquifer system
	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m) *Quality monitoring indicators*: physico-chemical indicators (both stations and all springs), main ions (both stations and all springs), heavy metals (both stations and all springs), pesticides (both stations and all springs) and pesticide active substances used in Latvia (both stations and all springs) Frequency: from 2 and 4 times a year, varying from 1 time in 4 years to 2 times in 4 years ● Operational monitoring: correspond with quality monitoring	

Groundwater dependent terrestrial and groundwater associated aquatic ecosystems	*Groundwater associated river water bodies*	The groundwater dependent river water body: • Līgatne river	-
	Groundwater associated standing water body ecosystems and karst features	Groundwater dependent lake water body related to the groundwater body: • Sudala lake* (3150); • Mazais Baltiņš (3130); • Lielais Baltiņš (3130); • Raipala lake (3130); • Slieķu lake (3140); • Mazais Virānes lake (3140); • Lielais Virānes lake (3140); Important karst features related to the groundwater • Sinkholes in Grundzāle parish. **located in Daugava river basin district*	
	Groundwater dependent terrestrial ecosystems	• 7160 Fennoscandian mineral-rich springs and springfens (40 polyg); • 7220 Petrifying springs with tufa formation (8 polyg); • 7230 Alkaline fens (1 polyg); • 9080 Fennoscandian deciduous swamp woods (6 polyg).	
Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	*Cannot be provided due to lack of dynamic hydrogeological model*	-
	Approved groundwater resources (AGR)	3884 m3/d	
	Groundwater abstraction (GA)	1147.69 m^3/d	
	Available groundwater resources (AGR-GA)	2736.31 m^3/d	
	Minimal available natural resource (NR-AGR)	*Cannot be provided due to lack of dynamic hydrogeological model*	
	Minimal available natural resource of groundwater for abstraction (NR-GA)	*Cannot be provided due to lack of dynamic hydrogeological model*	

Background levels and threshold values

Indicator	*Background level*	*Threshold value*
Ca, mg/l	130	-
Na, mg/l	13	106.5
K, mg/l	6	-
Mg, mg/l	32	-
Cl, mg/l	18	134
HCO_3, mg/l	440	-
SO_4, mg/l	80	165
NH_4, mg/l	0.45	0.475
Mn, mg/l	0.12	0.12
Fe_{tot} (anaerobic), mg/l	2.9	2.9
Fe_{tot} (aerobic), mg/l	0.17	0.19
NO_3 (anaerobic), mg/l	4	27
PO_4 (aerobic), µg/l	30	-
As, µg/l	4.9	7.45
Hg, µg/l	0.16	0.85
Cd, µg/l	0.29	2.65
Ni, µg/l	2.2	11.1
Cr, µg/l	4	27
Cu, µg/l	10	10
Zn, µg/l	50	-

-

GWB code		**26**	**Additional visual material**
River basin district		Koiva	-
Area (km²)		726.1	-
Physiographic characteristics		The territory is formed by Haanja upland, which is the highest landscape district in Estonia. A hilly terrain guards the plateau. The absolute height of the terrain varies from about 150 to 317 m a.s.l.	Figure 39. Transboundary GWB-1 (D6 & 26) in Upper Devonian aquifer system
Hydrogeological characteristics	*Lithology*	The lithological composition of the aquifer-forming rocks is quite homogenous. The aquifers are hosted by thick-bedded limestone and dolomitized limestone of the Upper Devonian Plavinas Stage and the overlying Quaternary sediments. The lower part of the formation consists of domerite and marl of the Snetnaja Gora Formation, which can be viewed as a local semi-permeable aquitard.	Figure 40. Cross-section of the Upper Devonian aquifer system (GWBs D6 and 26)
	GWB thickness	The thickness of the bedrock aquifers is in the range of 30–40 m; the thickness of the overlying Quaternary deposits is mostly in the range of 5–10 m, locally up to 20 m.	
	Overlying aquitard	The Quaternary sediments overlying the bedrock aquifers consist mainly of loamy till, which has a hydraulic conductivity of 0.1–1.0 m/d.	
	Underlying aquitard	The domerite, marl and clay of the Snetnaja Gora Formation	
	Groundwater level	The aquifers are mostly phreatic. Groundwater level is usually about 20–30 m below ground surface. The absolute height of the groundwater level is in the range of 165–175 m.	
Hydrodynamics	*Flow direction*	The most important groundwater divide in the area is the Haanja Heights, from where the groundwater flows to the south and west towards the edges of the height. Groundwater seeps out in the river valleys and a portion of its volume also infiltrates deeper into the Middle-Devonian aquifers.	Figure 40. Cross-section of the Upper Devonian aquifer system (GWBs D6 and 26)
	Filtration coefficient	The transmissivity of the aquifers forming the GWB is in the range of 30–300 m²/d (Perens et al., 2012). The lateral flow velocity of groundwater is in the range of 1–10 m/d and can reach up to 50 m/d in karst aquifers (Ibid.).	
	Recharge and regime	The groundwater flows radially away from the Haanja Heights and the local hillocks towards topographically lower regions throughout the year. The amount of infiltrating water depends on the composition of local Quaternary cover. In areas with waterlogged soils or in	

		areas underlain by clayey deposits the infiltration rate can be negligible.	
Groundwater chemical composition	*Chemical composition*	Groundwater in the groundwater body is mainly of the Ca-HCO$_3$-type, with TDS concentrations ranging from 200 to 600 mg/L. The chloride concentrations are usually <15 mg/L. The concentrations of NO3− are also low and do not exceed 5 mg/L in most cases. In terms of drinking water quality, the most important characteristic of groundwater is its high natural Fe concentration (up to 3 mg/L; 1.8 mg/L on average). Locally high NH$_4^+$ concentrations are also observed (up to 2 mg/L; 0.2 mg/L on average). The natural background concentration of sulfates is low with concentrations <20 mg/L. Groundwater in the groundwater body is usually compliant with drinking water quality standards, except groundwater with higher iron or ammonium concentrations.	Figure 41. Groundwater types in the Upper Devonian aquifer system represented in Piper diagram. (GWBs D6 and 26)
	Conceptual model of the formation of chemical composition	The chemical composition of groundwater in the groundwater body has mainly evolved through the dissolution of carbonate minerals (mostly calcite) by infiltrating meteoric water. In deeper aquifers the dolomite dissolution causes an increase in Mg2+ concentrations. High iron (Fe) concentrations in groundwater indicate that aquifers associated with the groundwater body are under reducing conditions. The sulphate probably originates from pyrite oxidation.	
Groundwater vulnerability	*Quaternary*	Not distinguished in Estonia	-
	Pre-quaternary	• Very well protected area - 26% • Well protected area - 8%; • Average protected area - 61%; • Weakley protected area - 4%; • Unprotected area - 0%	
Corine LandCover 2018		Common types: • Mixed forests – 31% • Agricultural land with significant natural areas – 25% • Coniferous forests – 24% • Transitional woodland-shrubs – 6% • Non-irrigated arable lands – 5% • Pastures – 2% • Complex cultivation patterns – 2% • Broad-leaved forest – 2%	-
Nitrate vulnerable zone		Not distributed	-

Monitoring	*Number of monitoring station and wells (springs)*	*Quantity monitoring*: 1 station: Kaubi (1 well). Total: 1 well *Quality monitoring*: 4 stations: Kalatsova; Lütä; Misso, Rõuge. Total: 4 wells. ● Surveillance monitoring: correspond with quality monitoring	Figure 39. Transboundary GWB-1 (D6 & 26) in Upper Devonian aquifer system
	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m), 12 times a year. *Quality monitoring indicators*: physico-chemical indicators (allstations), main ions (all stations), heavy metals all stations), pesticides (all stations) Frequency: 1 time a year, varying from 1 time in 6 years to 3 times in 6 years ● Surveillance monitoring: correspond with quality monitoring	
Groundwater dependent terrestrial and groundwater associated aquatic ecosystems	*Groundwater associated river water bodies*	• Obinitsa river (Obinitsa; 1001900_1); • Piusa river up to Kivioja creek (Piusa_1; 1000200_1); • Piusa river from Kivioja creek to the river mouth (Piusa_2; 1000200_2); • Rõuge river (Rõuge; 1004100_1); • Pärlijõgi from Saarlase dam to the river mouth (Pärlijõgi_2; 1155700_2. The groundwater dependent river water bodies Piusa_1, Rõuge and Pärlijõgi_2 is in good status. The status of Obinitsa river water body is moderate and Piusa_2 body has been assessed to be in bad status. Historical data on the baseflow proportions to the total river discharge are the following: -50% in the Piusa_1 river water body (in the period 1931-1962); -50% in the Piusa_2 river water body (in the period 1931-1962).	-
	Groundwater associated standing water body ecosystems and karst features	Groundwater dependent lake water bodies related to the groundwater body: • Kaussjärv (VEE2140200); • Liinjärv (VEE2140400); • Ratasjärv (Rõuge Ratasjärv; VEE2140100); • Suurjärv (Rõuge Suurjärv; VEE2140300); • Tõugjärv (VEE2140000); • Valgjärv (Rõuge Valgjärv; VEE2140500). All groundwater dependent lake water bodies related to the groundwater body are in good status. Important karst features related to the groundwater body: • Tsiistre dolines; • Poksa ponor; • Palosland karst lake.	

	Groundwater dependent terrestrial ecosystems	Spring mires of the Rõuge buried valley. Groundwater dependent terrestrial ecosystems related to the groundwater body are relatively unaltered by anthropogenic activities.	
Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	221586 m^3/d	-
	Approved groundwater resources (AGR)	-	
	Groundwater abstraction (GA)	83 m^3/d	
	Available groundwater resources (AGR-GA)	-	
	Minimal available natural resource (NR-AGR)	221586 m^3/d	
	Minimal available natural resource of groundwater for abstraction (NR-GA)	221522 m^3/d	

Background levels and threshold values

Indicator	*Background level*	*Threshold value*
Pesticides	-	0,1; 0,5 (sum)
NO_3, mg/l	-	50
NH_4, mg/l	-	0.5 (aerobic)
N_{tot}, mg/l(N)	-	1
P_{tot}, mg/l(P)	<0.01 µg/L	0.06
COD (mgO/l)	-	5
pH level	-	6-9
Trichlorethylene, µg/l	-	70
Tetrachlorethylene, µg/l	-	70
As (µg/l)	-	100
Cd (µg/l)	-	10
Hg (µg/l)	-	2
Pb (µg/l)	-	200

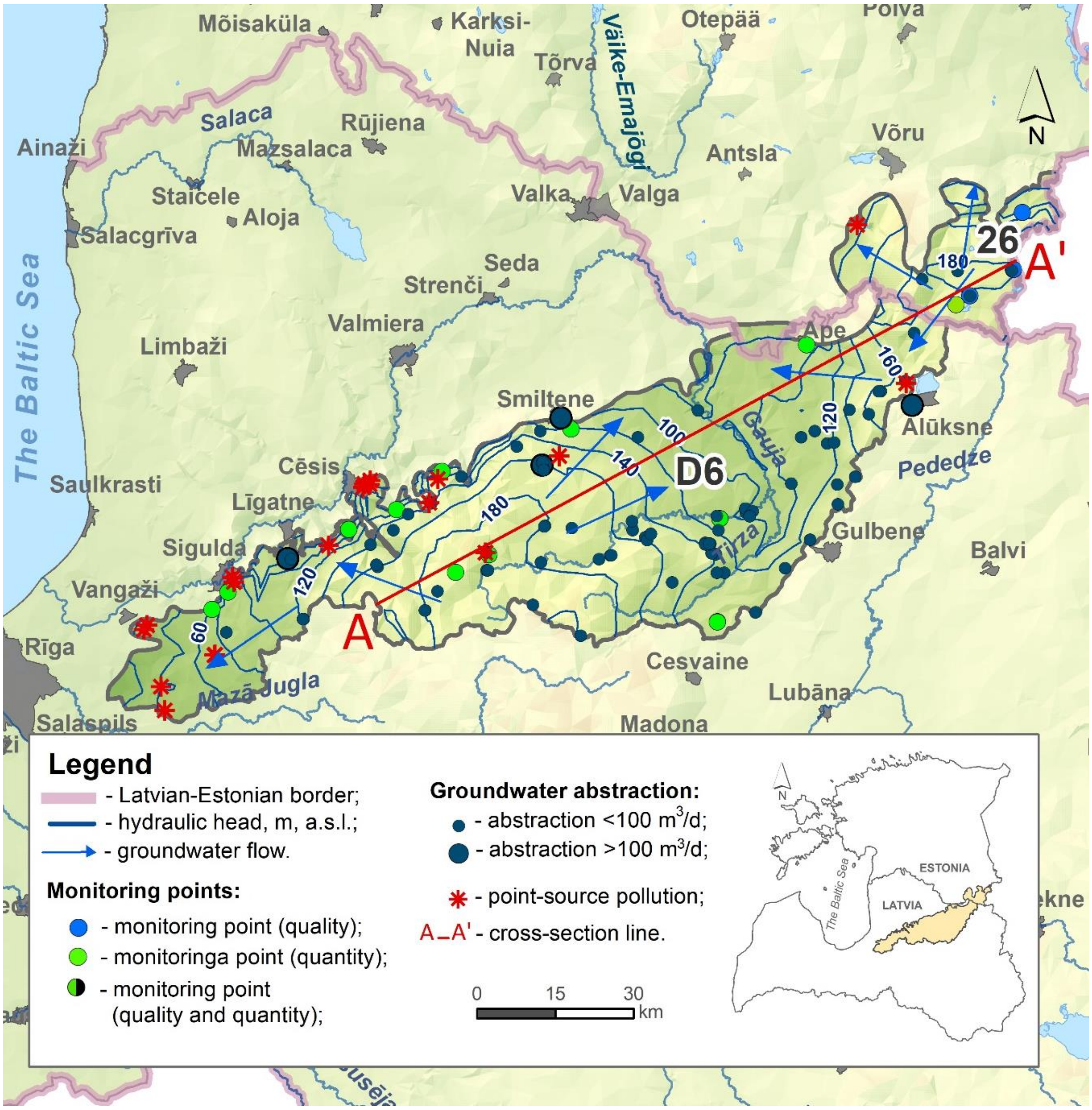


Figure 39. **Transboundary GWB-1 (D6 & 26) in Upper Devonian aquifer system.**

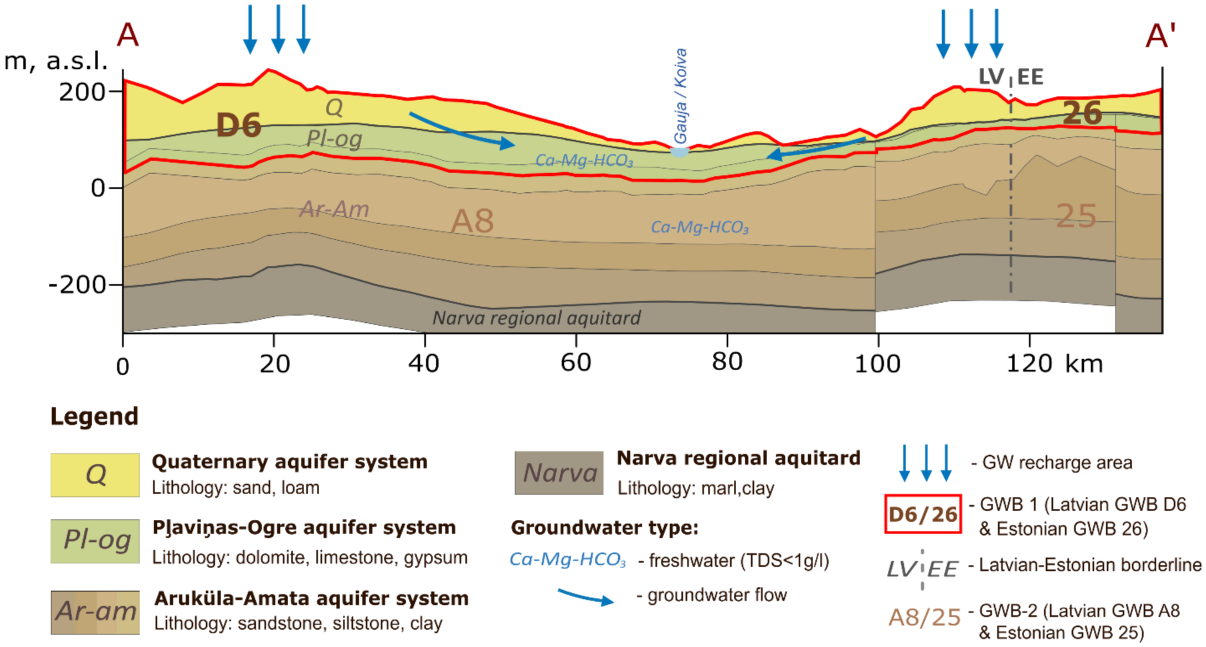
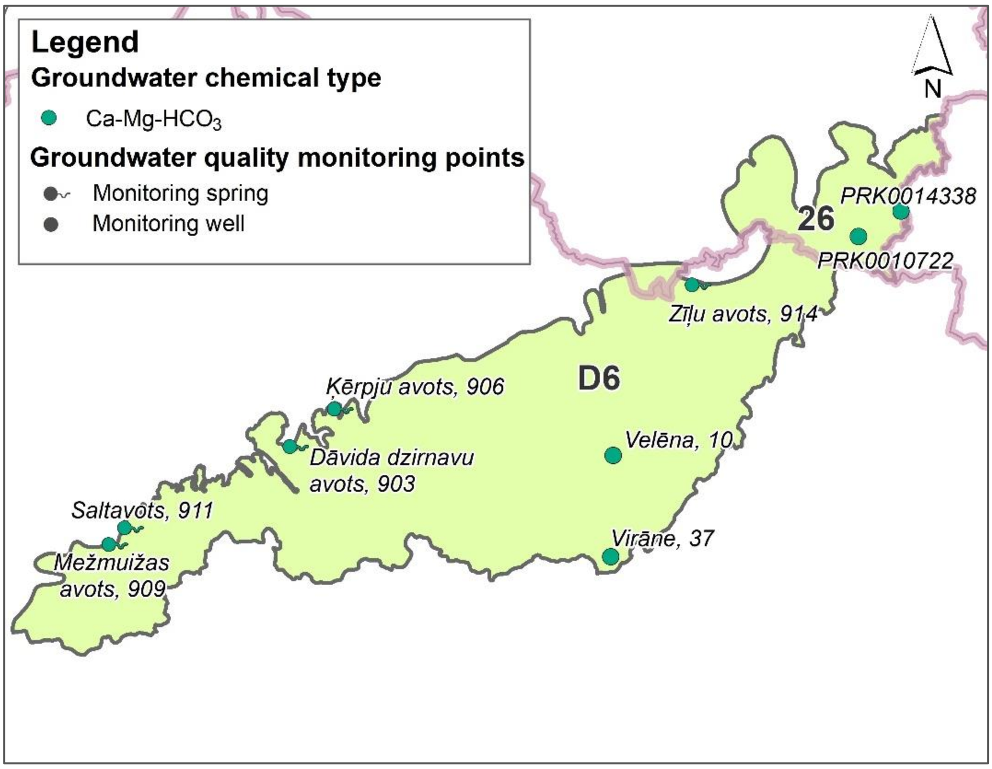


Figure 40. **Cross-section of the Upper Devonian aquifer system (GWBs D6 and 26)**



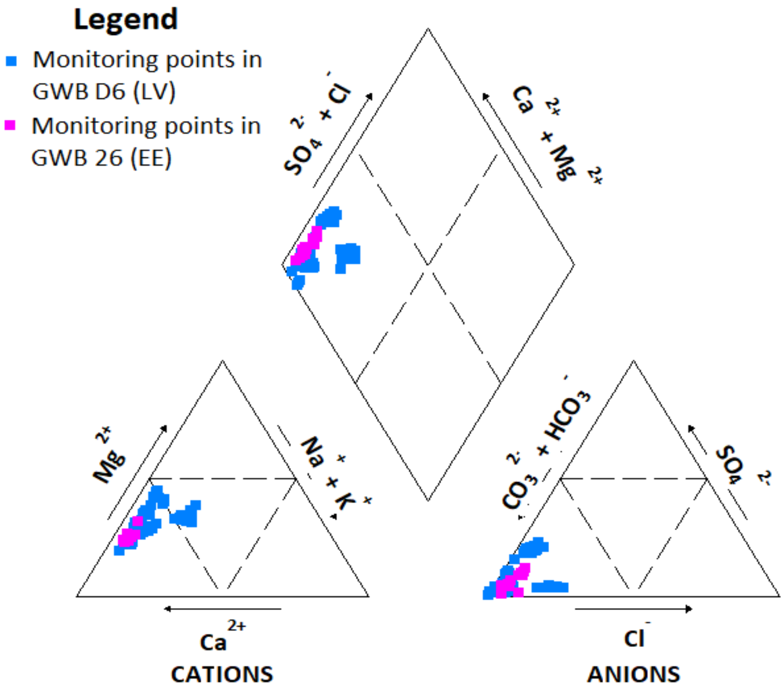


Figure 41. **Groundwater types in the Upper Devonian aquifer system represented in Piper diagram. (GWBs D6 and 26)**

2. GWB-2 in Upper-Middle Devonian aquifer system (LV GWB A8 & EE GWB 25)

GWB code		**A8**	**Additional visual material**
River basin district		Gauja, Daugava	-
Area (km^2)		27 349	-
Physiographic characteristics		Terrain is diverse because of its wide area. West part is covered by plains and wavy plains, in north and east - plains and wavy plains alternate with small hills, medium high and high hillsides, while the central and south-eastern part basically consists of small hills, as well as medium and high hills. The absolute height of the terrain varies up to 311.5 m a.s.l.	Figure 42. Transboundary GWB-2 (A8 & 25) in Upper-Middle Devonian aquifer system
Hydrogeological characteristics	*Lithology*	Geological structure that forms the aquifer system is composed of sandstone. The local aquitards consist mainly of aleirolite and clay. Dominated by porous rock material. Moraine loam, moraine loam, sand and clay are common in the overlapping Quaternary sediments.	Figure 43. Cross-section of the Upper-Middle Devonian aquifer system (GWBs A8 and 25)
	GWB thickness	The thickness of the bedrock aquifers is in the range of 115-302 m; the thickness of the overlying Quaternary deposits is mostly from 5-25 m up to 55-190 m (60-80 m average)	
	Overlying aquitard	The lower part of Pļaviņas formation (a part overlying GWB D6) sediments consist mainly of marl and clay; all other places where Pļaviņas formation is not distributed, Quaternary sediments overlying the bedrock aquifers consist of moraine	
	Underlying aquitard	The domerite, marl and clay of Narva formation (regional aquitard)	
	Groundwater level	GWL is about 10-50m a.s.l. in the east part of GWB, 50-90 m in the central part and about 90-150 in west part of GWB	
Hydrodynamics	*Flow direction*	The main groundwater flows are from Vidzeme Heights, Alūksne Heights and Haanja Heights (Estonia) in the direction of lower areas - Gauja river valley and adjacent plains	-
	Filtration coefficient	The transmissivity is in the range of 23–1100 m^2/d (mostly 800 m^2/d).	
	Recharge and regime	Main recharge areas are located in the central part (Vidzeme highland), the north-eastern part (Alūksne highland), north-western part (Idumeja highland), south-eastern part (central and northern part of Latgale highland). The amount of infiltrating water is about 6 875 000 m^3/d. Groundwater mainly discharges in the Gulf of Riga and cross-border area.	

Groundwater chemical composition	*Chemical composition*	Ca-Mg-HCO_3 type freshwaters with mineralization up to 1 g/l predominate. Na-Cl type brackish waters (Mineralization> 1g/l) may be found in the vicinity of the city of Riga (Great Riga Depression cone).	Figure 44. Groundwater types in the Upper Devonian aquifer system represented in Piper diagram. (GWBs A8 and 25)
	Conceptual model of the formation of chemical composition	*Not developed due to lack of data and knowledge*	
Groundwater vulnerability	*Quaternary*	Quaternary sediments cover 17% of the GWB A8 area. • Poorly protected area - 38% • Relatively protected area - 33% • Moderately protected - 21% • Protected area - 5% • Unprotected - 1% 2% of the surface is covered by Devonian sediments	-
	Pre-quaternary	• *Low risk of contamination*: 4% of the area (western part of Ropaži plain, central part of Gauja River Valley, eastern part of Seda plain) • *Medium risk of contamination*: 11% of the area • *High risk of contamination*: 3% of the area (northern part of Idumeja highland, Tālava lowland)	
Corine LandCover 2018		Common types: • Mixed forests – 16% • Pastures – 8% • Transitional woodland-shrub – 15% • Coniferous forests – 21% • Non-irrigated arable lands – 16 % • Complex cultivation patterns – 7%	-
Nitrate vulnerable zone		Distribution: 8% of the area (western part)	-
Monitoring	*Number of monitoring station and wells (springs)*	Quantity monitoring: 16 stations: Akmens tilts (2 wells), Bajāri (1 well), Baldone (4 wells), Baltezers (4 wells), Carnikava (3 wells), Dzērbene (2 wells), Imanta (4 wells), Inčukalns (4 wells), Jugla (4 wells), Kalngale (3 wells), Piukas (3 wells), Riga (10 wells), Salaspils (1 well), Stirniene (1 well), Upesciems (6 wells) and Valka (1 well). Total: 53 wells Quality monitoring: 14 stations: Akmens tilts (2 wells), Baldone (3 wells), Baltezers (4 wells), Carnikava (3 wells), Dzērbene (1 well), Imanta (3 wells), Inčukalns (4 wells), Jugla (3 wells), Kalngale (3 wells), Piukas (3 wells), Salaspils (1 well), Stirniene (1 well), Upesciems (3 wells) and Valka (1 well). Total: 35 wells. 6 springs: Briņķu saltavots spring, Dukuļu spring, Ķērpju spring, Līdumnieku spring, Lielā Ellīte spring, Rūcamavots spring. ● Operational monitoring: 2 stations: Akmens tilts (2 wells) and Imanta (3 wells). Total: 5 wells.	Figure 42. Transboundary GWB-2 (A8 & 25) in Upper-Middle Devonian aquifer system

		● Surveillance monitoring: correspond to quality monitoring	
	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m) *Quality monitoring indicators:* physical-chemical indicators (all stations and springs), main ions (all stations and springs), heavy metals (all stations and springs), pesticides (stations Carnikava, Dzērbene, Inčukalns, Kalngale, Piukas and Upesciems; all springs), pesticide active substances used in Latvia (stations Carnikava, Dzērbene, Inčukalns, Kalngale, Piukas and Upesciems; all springs) and other pollutants (stations Akmens Bridge, Baldone, Imanta, Jugla, Salaspils, Stirniene and Valka). Frequency: from 1 to 4 times a year, varying from 2 times in 6 years to 1 time in 2 years. ● Operational monitoring indicators: physical-chemical indicators (both stations), main ions (both stations), heavy metals (both stations) and other pollutants (both stations). Frequency: once a year, varying from 1 time in 6 years to 2 times in 4 years ● Surveillance monitoring: correspond to quality monitoring	
Groundwater dependent terrestrial and groundwater associated aquatic ecosystems	*Groundwater associated river water bodies*	The groundwater dependent river water body: • Raunis • Strīķupe • Vaive river • Rauna_1* • Brasla_3* • Amata_2* ** GAAE in bad chemical status*	
	Groundwater associated standing water body ecosystems and karst features	Groundwater dependent lake water body related to the groundwater body: • Lielais Bauzis;* • Tērpes lake; • Mazuikas lake; • Driškins; • Lieluikas lake; • Ninieris; • Pūricu lake; • Ummis; • Maizezers;* **GAAE in bad chemical status*	-
	Groundwater dependent terrestrial ecosystems	• 7160 Fennoscandian mineral-rich springs and springfens (194 polyg); • 7220 Petrifying springs with tufa formation (13 polyg); • 7230 Alkaline fens (4 polyg); • 9080 Fennoscandian deciduous swamp woods (68 polyg);	

Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	*Cannot be provided due to lack of dynamic hydrogeological model*	-
	Approved groundwater resources (AGR)	180 680 m^3/d	
	Groundwater abstraction (GA)	49 722.45 m^3/d	
	Available groundwater resources (AGR-GA)	130 957.55 m^3/d	
	Minimal available natural resource (NR-AGR)	*Cannot be provided due to lack of dynamic hydrogeological model*	
	Minimal available natural resource of groundwater for abstraction (NR-GA)	*Cannot be provided due to lack of dynamic hydrogeological model*	

Background levels and threshold values

Indicator	*Background level*	*Threshold value*
Ca, mg/l	95	116
Na, mg/l	32	-
K, mg/l	8.7	-
Mg, mg/l	36	-
Cl, mg/l	18	134
HCO_3, mg/l	390	-
SO_4, mg/l	80	165
NH_4, mg/l	0.35	0.425
Mn, mg/l	0.12	0.12
Fe_{tot} (anaerobic), mg/l	2.9	2.9
Fe_{tot} (aerobic), mg/l	0.17	0.19
NO_3 (anaerobic), mg/l	0.4	25.2
NO_3 (aerobic), mg/l	4	27
PO_4 (aerobic), µg/l	30	-
F, mg/l	0.54	1
Pb, µg/l	1.65	5.83
As, µg/l	4.9	7.45
Hg, µg/l	0.16	0.85
Cd, µg/l	0.29	2.65
Ni, µg/l	2.2	11.1
Cr, µg/l	4	27
Cu, µg/l	10	10
Zn, µg/l	50	-

-

GWB code	**25**	**Additional visual material**
River basin district	Koiva	-
Area (km^2)	1322	-

Physiographic characteristics		The terrain is diverse - the west part is covered by Võru-Hargla depression, eastern part is covered by Haanja upland, which consists of medium and high hills. The absolute height of the terrain varies from 48 m a.s.l up to 205 m a.s.l.	Figure 42. Transboundary GWB-2 (A8 & 25) in Upper-Middle Devonian aquifer system
Hydrogeological characteristics	*Lithology*	Aquifers related to the groundwater body are hosted by brownish fine-grained sand- and siltstones of the Middle Devonian Aruküla, Gauja and Burtnieki Formations that contain interlayers of clay. The groundwater body also comprises the aquifers in Quaternary sediments overlying the Middle Devonian rocks. The most important of those Quaternary aquifers are the aquifers hosted by glaciofluvial gravels and sands in the Haanja and Varstu parishes in the Võru County. These aquifers are usually located as lenses in a more widespread till complex (Perens et al., 2012).	Figure 43. Cross-section of the Upper-Middle Devonian aquifer system (GWBs A8 and 25))
	GWB thickness	Mostly 150–280 m, reaching up to ~280 m in its southern border, depending on the thickness of the Quaternary sediments covering the bedrock.	
	Overlying aquitard	The western part of the groundwater body is overlain by relatively impermeable loamy till with a hydraulic conductivity of 0.1–1.0 m/d. In the eastern part of the groundwater body, the bedrock sequence is covered by a clayey Snetnaja Gora-Amata aquitard with a thickness of 8–10 m (Perens & Vallner, 1997).	
	Underlying aquitard	The underlying aquitard associated with the groundwater body is the regional Narva aquitard in the clayey siltstones, clays and dolomitic marls of the Middle Devonian Narva Formation. The aquitard has a transversal hydraulic conductivity of 10^{-4}–10^{-5} m/d on average, locally decreasing down to $\leq 10^{-6}$ m/d.	
	Groundwater level	In the Haanja Upland the potentiometric surface lies at depths of 112–122 m from the ground surface (120–123 m asl). In the depressions between the uplands the potentiometric surface occasionally reaches above the ground surface. In the unconfined Quaternary aquifers, the groundwater levels are located at depths of 0.5 to 57 m below the ground surface (on average 10 m; Perens et al., 2012).	
Hydrodynamics	*Flow direction*	The direction of the groundwater flow is mainly determined by the Haanja and Karula Uplands. The groundwater flows to the south and east from the Karula Upland and to the south and west from the Haanja Upland. A local discharge area is found in the valley of the Mustjõgi river located between the two uplands.	Figure 43. Cross-section of the Upper-Middle Devonian aquifer system (GWBs A8 and 25)

	Filtration coefficient	The lateral hydraulic conductivity of the bedrock aquifers varies from 1 to 3 m/d and the hydraulic conductivity of the Quaternary aquifers is 5 m/d on average (Perens et al., 2012). The transmissivity of the aquifers is very variable, having values of 30–300 m^2/d, that increase southwards together with an increase in the thickness of the aquifer-forming rocks. The hydraulic gradient of aquifers in the vicinity of the south Estonian uplands vary from 0.0001 to 0.1 and the lateral groundwater flow velocity in the sandstones has been estimated to be 0.001-0.005 m/d (Perens et al., 2012). The estimated lateral groundwater flow velocity in Quaternary sediments is ~0.001-0.15 m/d (in gravel up to 10-15 m/d; Ibid.).	
	Recharge and regime	Groundwater flows from the recharge areas in the Karula and Haanja Uplands to discharge areas in the lower lying regions. The amount of recharge is dependent on the thickness and composition of the Quaternary sediments. In areas with loamy overburden and waterlogged soils the recharge is low or does not occur at all. Seasonal variations in groundwater levels are mostly between 0.3 and 2 m.	
Groundwater chemical composition	*Chemical composition*	Groundwater in the groundwater body is mainly of Ca-HCO$_3$-type with low TDS concentrations varying from 200 to 600 mg/l. The Cl– concentrations are ≤25 mg/l. NO$_3$– concentrations are low and are below 10 mg/l. In terms of drinking water quality, the most important characteristic of groundwater is its high natural Fe concentrations (about 4.5mg/l on average in the sandstones and 1.0-3.0 mg/l in the Quaternary sediments; Perens et al., 2012). The natural SO$_4^{2-}$ concentrations are low and do not exceed 20 mg/l. Groundwater in the groundwater body is usually compliant with drinking water quality standards, bar groundwater with higher iron concentrations.	Figure 44. Groundwater types in the Upper-Middle Devonian aquifer system represented in Piper diagram. (GWBs A8 and 25)
	Conceptual model of the formation of chemical composition	The chemical composition of groundwater in the GWB has mainly evolved through the dissolution of carbonate cement in the Devonian sandstones by infiltrating meteoric water. In deeper aquifers, dolomite dissolution also plays an important role, which is evident in the increasing Mg^{2+} concentrations. The Ca-HCO$_3$- type groundwater found in the Quaternary sediments is related to carbonate minerals found in tills. High iron concentrations in groundwater indicate that aquifers associated with the groundwater body are under reducing conditions. The sulphate probably originates from pyrite oxidation.	
	Quaternary	Not distinguished in Estonia	-

Groundwater vulnerability	*Pre-quaternary*	• Very well protected area - 24% • Well protected area - 7%; • Average protected area - 69%; • Weakley protected area - 0%; • Unprotected area - 0% 33 % of the surface is covered by overlying GWB 26.	
Corine LandCover 2018		Common types: • Coniferous forests - 29% • Mixed forests – 27% • Agricultural land with significant natural areas - 21% • Non-irrigated arable land - 9% • Transitional woodland-shrub – 5% • Pastures – 3% • Complex cultivation patterns – 3%	-
Nitrate vulnerable zone		Not distributed	-
Monitoring	*Number of monitoring station and wells (springs)*	*Quantity monitoring*: 2 stations: Ruusmäe; Krabi. Total: 2 wells *Quality monitoring*: 3 stations: Varstu; Lüllemäe; Krabi. Total: 3 wells ● Surveillance monitoring: correspond with quality monitoring	Figure 42. Transboundary GWB-2 (A8 & 25) in Upper-Middle Devonian aquifer system
	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m). Frequency: 12 times a year *Quality monitoring indicators*: physico-chemical indicators (all stations), main ions (all stations), heavy metals (all stations), pesticides (all stations) Frequency: from 1 time a year to 3 times in 6 years ● Surveillance monitoring: correspond with quality monitoring	
Groundwater dependent terrestrial and groundwater associated aquatic ecosystems	*Groundwater associated river water bodies*	● Mustjõgi river to Antsla-Litsmetsa road (Mustjõgi; 1031000_1); ● Kolga river (Kolga; 1158400_1); ● Pärlijõgi river from Saarlase dam to river mouth (Pärlijõgi_2; 1155700_2). The groundwater dependent river water bodies related to the groundwater body are in a good status.	-

	Groundwater associated standing water body ecosystems and karst features	Groundwater dependent lake water bodies related to the Quaternary aquifers of the groundwater body: • Hanija lake (VEE2150700); • Kikkajärv (VEE2152100); • Liivajärv (Paganamaa Liivajärv; VEE2152300); • Maiori lake (VEE2152000); • Mudajärv (Paganamaa Mudajärv; VEE2152310); • Murati lake (VEE2155900); • Palujüri lake (VEE2150800); • Sarapuujärv (Paganamaa Sarapuujärv; VEE2152200); • Sarise lake (VEE2154800); • Väiku-Palkna lake (VEE2151710). The status of the Murati lake is moderate due to pH values and water transparency. Other groundwater dependent lake water bodies have a good status, or their status has not been assessed.	
	Groundwater dependent terrestrial ecosystems	Spring fens of the Mustjõe river valley. Groundwater dependent terrestrial ecosystems related to the groundwater body have been influenced by drainage canals and occasionally also by beaver dams.	
Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	536689 m^3/d	-
	Approved groundwater resources (AGR)	-	
	Groundwater abstraction (GA)	234 m^3/d	
	Available groundwater resources (AGR-GA)	-	
	Minimal available natural resource (NR-AGR)	536689 m^3/d	
	Minimal available natural resource of groundwater for abstraction (NR-GA)	536525 m^3/d	

Background levels and threshold values

Indicator	*Background level*	*Threshold value*
N_{tot}, mg/l(N)	-	3
P_{tot}, mg/l(P)	<0.01 µg/L	0.08
NH_4, mg/l		0.5 (aerobic)
NO_3, mg/l	-	50
Pesticides	-	0.1 0.5 (total)
COD (mgO/l)		5
pH level	-	6-9
Trichlorethylene, µg/l	-	70

-

Tetrachlorethylene, µg/l	-	70
As (µg/l)	-	100
Cd (µg/l)	-	10
Hg (µg/l)	-	2
Pb (µg/l)	-	200

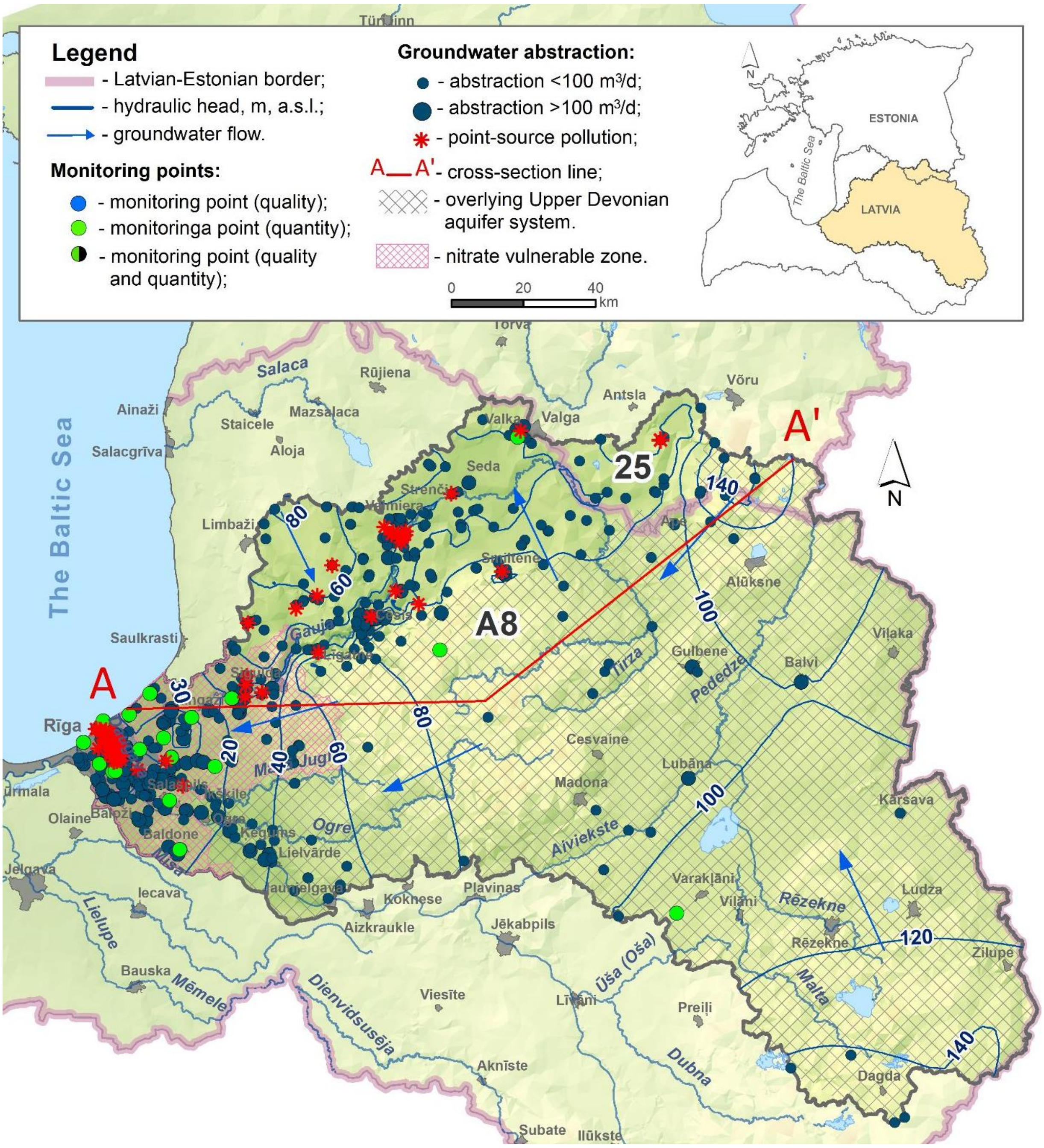


Figure 42. **Transboundary GWB-2 (A8 & 25) in Upper-Middle Devonian aquifer system.**

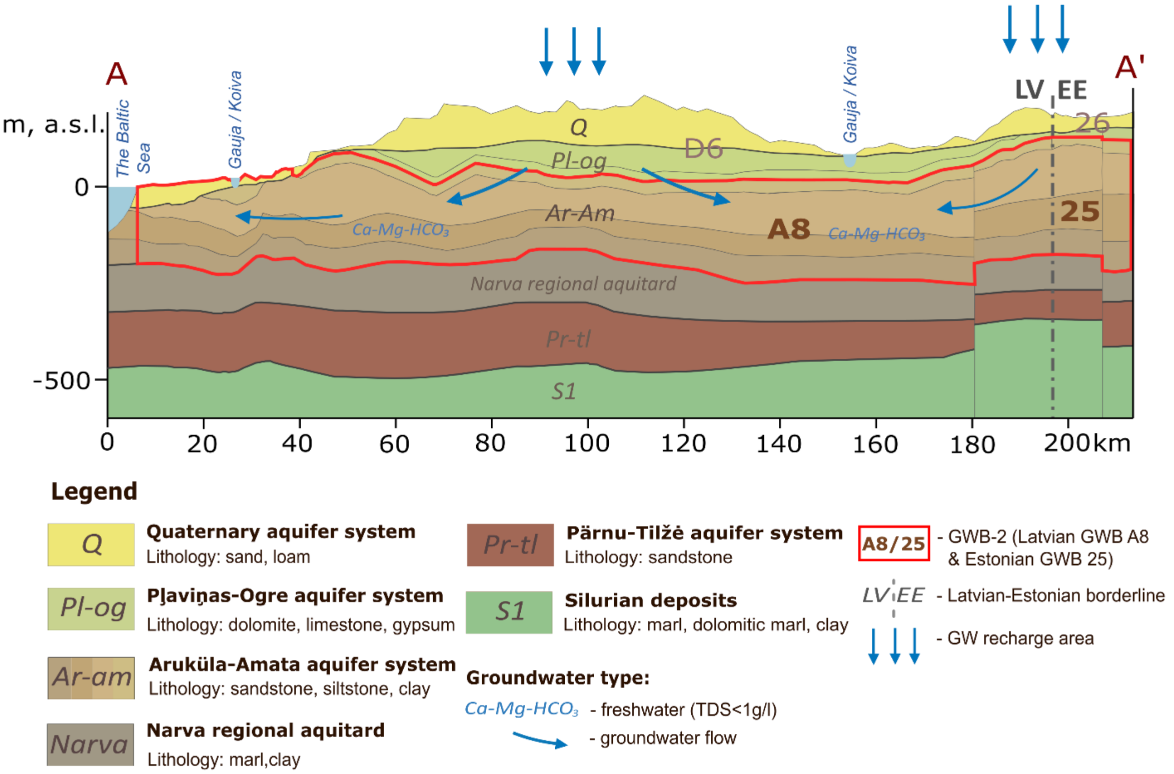
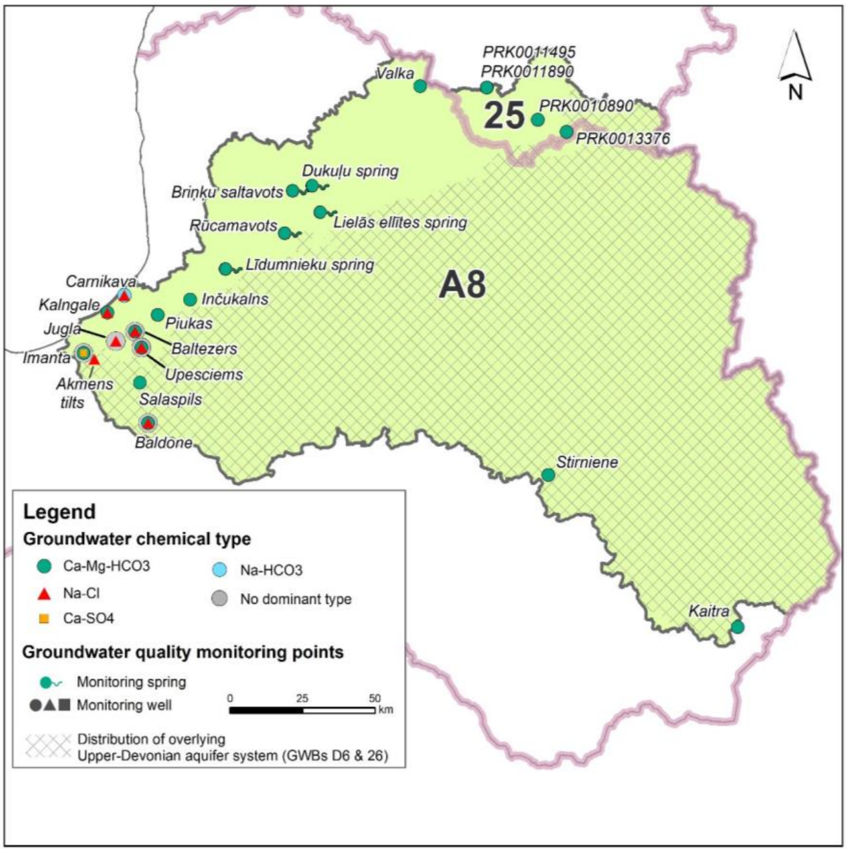


Figure 43. **Cross-section of the Upper-Middle Devonian aquifer system (GWBs A8 and 25)**



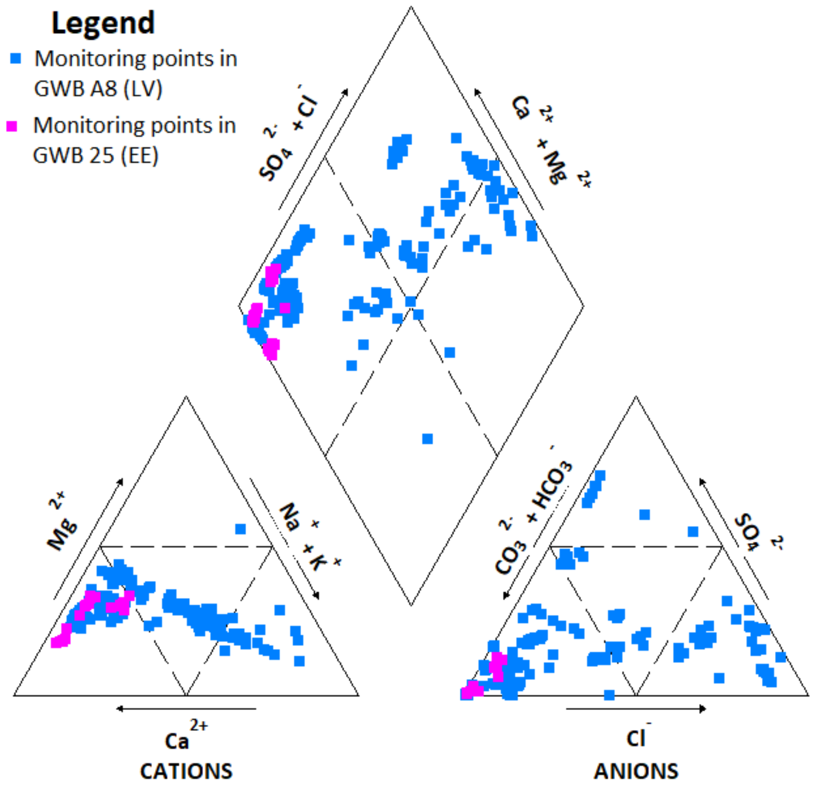


Figure 44. **Groundwater types in the Upper-Middle Devonian aquifer system represented in Piper diagram. (GWBs A8 and 25)**

3. GWB-3 in Upper-Middle Devonian aquifer system (LV GWB A10 & EE GWB 23)

GWB code		**A10**	**Additional visual material**
River basin district		Gauja	-
Area (km^2)		3321	-
Physiographic characteristics		Lowlands are widespread in the western part, but the east part are covered mostly by wavy plains. The absolute height of the terrain varies up to 119.8 m a.s.l.	Figure 45. Transboundary GWB-3 (A10 & 23) in Upper-Middle Devonian aquifer system
Hydrogeological characteristics	*Lithology*	Geological structure that forms the aquifer system are composed of sandstone. The local aquitards consist mainly of siltstone and clay. Dominated by porous rock material. Moraine loam, moraine loam, sand and clay are common in the overlapping Quaternary sediments.	Figure 46. Cross-section of the Upper-Middle Devonian aquifer system (GWBs A8 and 25)
	GWB thickness	The thickness of the bedrock aquifers reaches up to the 73 m; the average thickness of the overlying Quaternary deposits is in the range of 30-40 m (max. 80 m)	
	Overlying aquitard	The Quaternary sediments overlying the bedrock aquifers consist mainly of moraine loam, sand and clay	
	Underlying aquitard	The domerite, marl and clay of Narva formation (regional aquitard)	
	Groundwater level	GWL is about 10-30 m a.s.l. in the east part and 40-70 m in the central and west part of GWB	
Hydrodynamics	*Flow direction*	The main groundwater flows are from the Idumejas Heights and the Sakala Heights (Estonia) to the lower areas - the Salaca river valley and the adjacent plains	Figure 46. Cross-section of the Upper-Middle Devonian aquifer system (GWBs A10 and 23)
	Filtration coefficient	The transmissivity is in the range of 144–361 m^2/d	
	Recharge and regime	Main recharge areas are located in the southern part. The amount of infiltrating water is about 809 000 m^3/d. Groundwater mainly discharges in Gulf of Riga and cross-border area.	
Groundwater chemical composition	*Chemical composition*	Ca-Mg-HCO_3 type fresh waters with mineralization up to 1 g/l predominate.	Figure 47. Groundwater types in the Upper Devonian aquifer system represented in Piper diagram. (GWBs A10 and 23)
	Conceptual model of the formation of chemical composition	*Not developed due to lack of data and knowledge*	

Groundwater vulnerability	*Quaternary*	• Relatively protected area - 56%; • Poorly protected area - 20%; • Medium protected area - 18%; • Protected area - 3%; • Unprotected area - 1% 1% of the surface is covered by Devonian sediments and 1% is covered by natural water bodies	-
	Pre-quaternary	•*Low risk of contamination*: 25% of the area, •*Medium risk of contamination*: 74% of the area •*High risk of contamination*: 1% of the area	
Corine LandCover 2018		Common types: • Non-irrigated arable lands – 20 % • Mixed forests – 20 % • Transitional woodland-shrub – 16% • Broad-leaved forests - 14% • Coniferous forests – 10% • Complex cultivation patterns – 7%	-
Nitrate vulnerable zone		*Not distributed*	-
Monitoring	*Number of monitoring station and wells (springs)*	*Quantity monitoring*: 1 station: Rimeikas (5 wells). Total: 5 wells *Quality monitoring*: 1 station: Rimeikas (5 wells). Total: 5 wells. 2 springs: Govs spring, Spiģu spring. ● Surveillance monitoring: correspond to quality monitoring	Figure 45. Transboundary GWB-3 (A10 & 23) in Upper-Middle Devonian aquifer system
	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m) *Quality monitoring indicators*: physical-chemical indicators (both stations), main ions (both stations), heavy metals (both stations), pesticides (both stations), pesticide active substances used in Latvia (both stations) and other pollutants (station Aloja). Frequency: once a year, varying from 1 time in 6 years to 1 time in 4 years. ● Surveillance monitoring: correspond to quality monitoring	
Groundwater dependent terrestrial and groundwater associated aquatic ecosystems	*Groundwater associated river water bodies*	Not common	-
	Groundwater associated standing water body ecosystems and karst features	Groundwater dependent lake water body related to the groundwater body: • Laņģezers lake (3140)	

	Groundwater dependent terrestrial ecosystems	• 7160 Fennoscandian mineral-rich springs and springfens (13 polyg); • 9080 Fennoscandian deciduous swamp forests (157 polyg);	
Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	*Cannot be provided due to lack of dynamic hydrogeological model*	-
	Approved groundwater resources (AGR)	1544 m^3 /d	
	Groundwater abstraction (GA)	325.14 m^3/d	
	Available groundwater resources (AGR-GA)	1218.86 m^3/d	
	Minimal available natural resource (NR-AGR)	*Cannot be provided due to lack of dynamic hydrogeological model*	
	Minimal available natural resource of groundwater for abstraction (NR-GA)	*Cannot be provided due to lack of dynamic hydrogeological model*	
Background levels and threshold values			-

Indicator	*Background level*	*Threshold value*
Ca, mg/l	80	-
Na, mg/l	13	106.5
K, mg/l	4.5	-
Mg, mg/l	32	-
Cl, mg/l	18	134
HCO_3, mg/l	390	-
SO_4, mg/l	30	140
NH_4, mg/l	0.45	0.475
Mn, mg/l	0.19	0.19
Fe_{tot} (anaerobic), mg/l	3.8	3.8
Fe_{tot} (aerobic), mg/l	0.17	0.19
NO_3 (anaerobic), mg/l	0.4	25.2
NO_3 (aerobic), mg/l	4	27
PO_4 (aerobic), µg/l	30	-
F, mg/l	0.54	1
Pb, µg/l	1.65	5.83
As, µg/l	4.9	7.45
Hg, µg/l	0.16	0.85
Cd, µg/l	0.29	2.65
Ni, µg/l	2.2	11.1
Cr, µg/l	4	27
Cu, µg/l	10	10
Zn, µg/l	50	-

GWB code		**23**	**Additional visual material**
River basin district		West Estonia	-
Area (km^2)		2341	-
Physiographic characteristics		Territory has a changing relief -lowlands are widespread in the western part, but the east part is covered mostly by wavy plains on Sakala upland The absolute height of the terrain varies up to 120 m a.s.l.	Figure 45. Transboundary GWB-3 (A10 & 23) in Upper-Middle Devonian aquifer system
Hydrogeological characteristics	*Lithology*	It mainly consists of white, yellow deposits from the Burtnieki and Aruküla deposits or reddish-brown sandstone or siltstone containing clay interlayers. Also included in the collection The Middle Devonian sedimentary complex is overlain by Quaternary sediments. The Quaternary sediments overlying the Middle Devonian sedimentary complex are also included in the collection.	Figure 46. Cross-section of the Upper-Middle Devonian aquifer system (GWBs A8 and 25)
	GWB thickness	The thickness of the groundwater body changes within large limits, but as a general tendency it increases towards the south and southeast up to 80 meters.	
	Overlying aquitard	The groundwater body is located in the first aquifer, which is retained from the surface, which is covered with a relatively thick layer of clayey quaternary sediments, with the filtration coefficient of 0.01-1.0 m/day.	
	Underlying aquitard	The horizontal aquifer of the groundwater body is the Narva regional aquifer, with a transverse filtration coefficient of 10^{-4}–10^{-5} m/d. In places, the filtration coefficient is 10^{-6} m/d or even less. The aquifer consists of clayey siltstone, marl, clay and dolomitic marl.	
	Groundwater level	The water level is mostly 10-15 m above the ground, but the pressure surface is directly dependent on the local relief. The main watershed of the catchment, the Sakala Upland, has a surface pressure up to 34 m above the ground (about 80 m in absolute height), and the depth of the pressure surface decreases to only a few meters towards the coast. On the coast, the surface pressure of the groundwater can sometimes extend above the ground, and the groundwater comes out to the ground in the form of springs or artesian wells.	

Hydrodynamics	*Flow direction*	GW movement directions are primarily determined by the location of the watershed Sakala upland on the eastern border of the groundwater body. The regional outlet of the groundwater body is the Gulf of Livonia, but in the central part of the groundwater body, the original valley of the Halliste river is also an important outlet. Part of the groundwater infiltrates through the Narva formation below into the Central Lower Devonian groundwater aquifer.	Figure 46. Cross-section of the Upper-Middle Devonian aquifer system (GWBs A10 and 23)
	Filtration coefficient	Lateral hydraulic conductivity of the groundwater body is quite uniform – 1–3 m/day. Due to the great variability of the thickness of the waterbody, the throughput of the water layers is relatively variable, mostly remaining within the range of 30-50 m^2/day. The specific flow rate of boreholes is mostly 0.4–1.0 L/s·m. On the Sakala upland, the lateral movement speed of groundwater is mostly 0.02–0.2 m/day, the transverse movement speed is estimated to be 0.001–0.005 m/day.	
	Recharge and regime	The main feeding area of the reservoir is the Sakala upland, where groundwater flows to the lower areas of the terrain throughout the year. The intensity of feeding depends on the composition of the Quaternary sediments covering the groundwater body. Groundwater nutrition does not occur or is low in excessively wet areas with a clayey surface coating. In general, two maxima (spring snowmelt and autumn rainfall) and two minima (summer period of increased evapotranspiration and winter period of low water levels) can be observed in the annual variation of groundwater levels. Amplitudes of groundwater level fluctuations are mostly in the range of 0.2-2.0 m	
Groundwater chemical composition	*Chemical composition*	GW is predominantly of Ca-HCO$_3$ type, with a content of minerals dissolved in water of 0.3–0.5 g/L. In coastal areas, MgCa-HCO$_3$- and Na-Ca-Mg HCO$_3$-type water occasionally occurs in coastal areas. The chloride content is low, mostly up to 25 mg/L. The nitrate content is low, generally below 5 mg/L. The collection contains high natural iron contents (up to 5 mg/L, average 1.4 mg/L), which many times exceed the permissible limit for drinking water (0.2 mg/L). Higher ammonium (up to 3 mg/L, average 0.3 mg/L) contents can sometimes be a problem when using groundwater as drinking water. Since there are no significant water bodies in the groundwater reservoir, the groundwater formed from modern precipitation spreads in the reservoir. This is also confirmed by the measured δ18O values (−11.3 to −11.7‰), which are similar to modern precipitation. According to these values, the waterbody belongs to the longer zone of active water exchange.	Figure 47. Groundwater types in the Upper Devonian aquifer system represented in Piper diagram. (GWBs A10 and 23)

	Conceptual model of the formation of chemical composition	The chemical composition of the waterbody is mainly formed by the dissolution of the carbonate cement [calcite ($CaCO_3$)] of the sandstones by the action of freshly infiltrated surface waters. When infiltrating deeper, dissolution of dolomite has been added, which has added magnesium to the chemical composition of groundwater. On the coast, where an increase in Na^+ can be observed, the chemical composition can also be shaped by mixing processes with seawater. The high natural iron content in the groundwater indicates the presence of reducing conditions in the aquifers associated with the pool	
Groundwater vulnerability	*Quaternary*	Not distinguished in Estonia	-
	Pre-quaternary	• Very well protected area - 8% • Well protected area - 30%; • Average protected area - 49%; • Weakley protected area - 9%; • Unprotected area - 3%	
Corine LandCover 2018		Common types: • Mixed forests – 26% • Coniferous forests – 25% • Non-irrigated arable lands – 16 % • Transitional woodland-shrub – 11 % • Agricultural land with significant natural areas - 5% • Broad-leaved forests – 4 % • Complex cultivation patterns – 4% • Pastures – 3% • Peat bogs – 3%	-
Nitrate vulnerable zone		Not relevant	-
Monitoring	*Number of monitoring station and wells (springs)*	*Quantity monitoring*: 3 stations: Tobraselja; Ülemõisa; Krundiküla. Total: 3 wells *Quality monitoring*: 3 stations: Matapera; Jaagupi; Ülemõisa. Total: 3 wells ● Surveillance monitoring: correspond with quality monitoring	Figure 45. Transboundary GWB-3 (A10 & 23) in Upper-Middle Devonian aquifer system
	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m). Frequency: 365 times a year. *Quality monitoring indicators*: physico-chemical indicators (all stations), main ions (all stations), heavy metals (all stations), pesticides (all stations) Frequency: from 1 time a year to 3 times in 6 years ● Surveillance monitoring: correspond with quality monitoring	
Groundwater dependent terrestrial and	*Groundwater associated river water bodies*	• Sinialliku river (Sinialliku; 1139900_1).	-

groundwater associated aquatic ecosystems	*Groundwater associated standing water body ecosystems and karst features*	Groundwater dependent lake water body related to the groundwater body: • Viljandi järv (VEE2082800); • Õisu järv (VEE2089700)	
	Groundwater dependent terrestrial ecosystems		
Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	460246	-
	Approved groundwater resources (AGR)	-	
	Groundwater abstraction (GA)	459	
	Available groundwater resources (AGR-GA)	-	
	Minimal available natural resource (NR-AGR)	460246	
	Minimal available natural resource of groundwater for abstraction (NR-GA)	459787	

Background levels and threshold values

Indicator	*Background level*	*Threshold value*
Pesticides	-	0,1 0,5 (total)
NO_3, mg/l	-	50
NH_4, mg/l	-	0,5 (aerobic)
N_{tot}, mg/l(N)	-	1
P_{tot}, mg/l(P)	<0.01 µg/L	0.06
COD, mgO/l	-	≤ 5
pH level	-	6-9
Trichlorethylene, µg/l	-	70
Tetrachlorethylene, µg/l	-	70
As, µg/l	-	100
Cd, µg/l	-	10
Hg, µg/l	-	2
Pb, µg/l	-	200

-

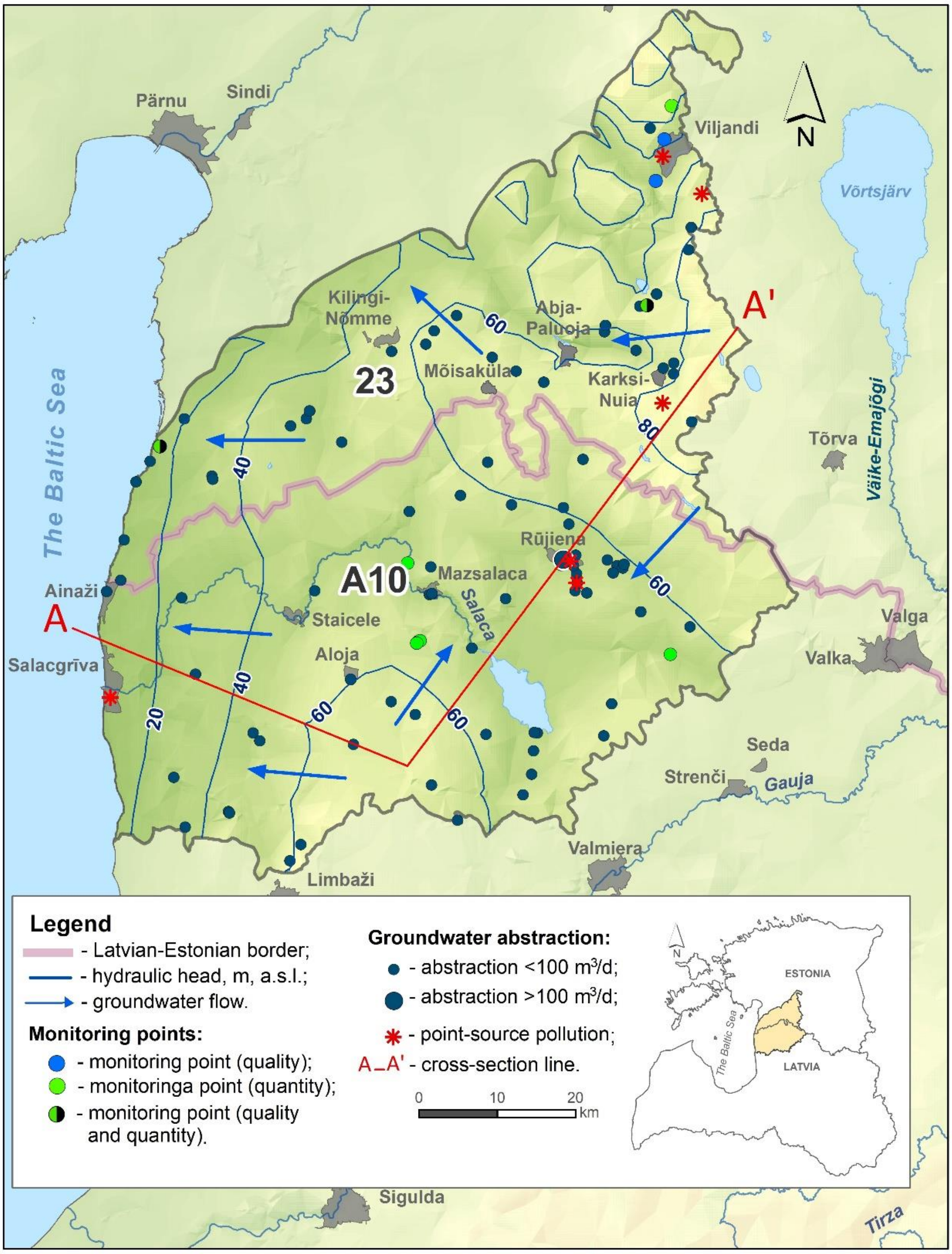


Figure 45. **Transboundary GWB-3 (A10 & 23) in Upper-Middle Devonian aquifer system.**

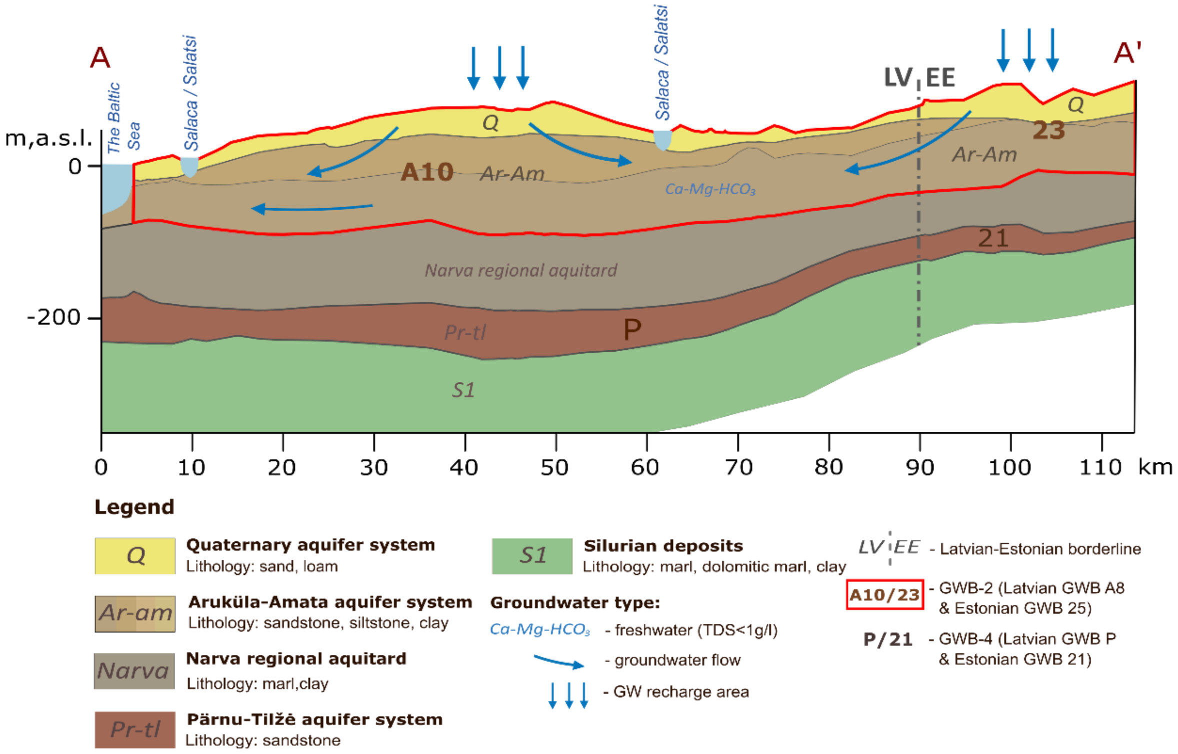
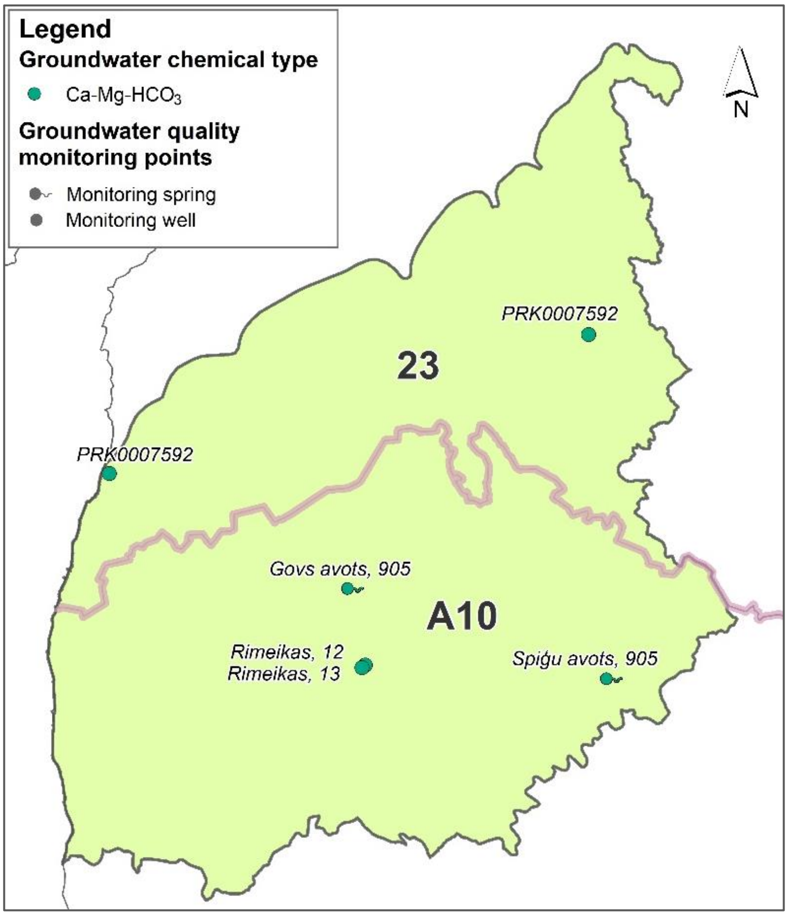


Figure 46. **Cross-section of the Upper-Middle Devonian aquifer system (GWBs A10 and 23)**



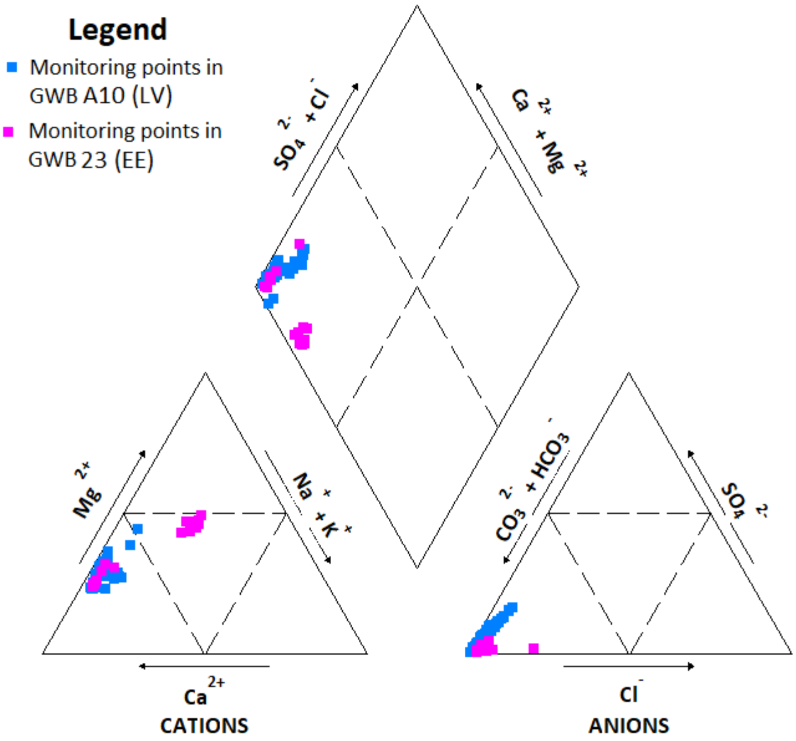


Figure 47. **Groundwater types in the Upper-Middle Devonian aquifer system represented in Piper diagram. (GWBs A10 and 23)**

4. GWB-4 in Lower-Middle Devonian aquifer system (LV GWB P & EE GWB 21)

GWB code		**P**	**Additional visual material**
River basin district		Gauja	-
Area (km^2)		4394	-
Physiographic characteristics		GWB is embedded under GWB A10	Figure 48. Transboundary GWB-4 (P & 21) in Lower-Middle Devonian aquifer system.
Hydrogeological characteristics	*Lithology*	Geological structure that forms the aquifer system are composed of sandstone. The local aquitards consist mainly of aleirolite and clay. Dominated by porous rock material	Figure 49. Cross-section of the Lower-Middle Devonian aquifer system (GWBs P and 21)
	GWB thickness	Thickness of the bedrock aquifers is in the range of 40-100 m (thickness increases towards the south); GWB is covered by GWB A10	
	Overlying aquitard	The domerite, marl and clay of Narva formation (regional aquitard)	
	Underlying aquitard	Marl, dolomitic marl and clay of Silurian stage deposits	
	Groundwater level	GWL is about 20-30 m a.s.l. in the east part and 30-45 m in the west part of GWB	
Hydrodynamics	*Flow direction*	Groundwater flow is directed to the west - from the south of Estonia towards the Gulf of Riga	Figure 49. Cross-section of the Lower-Middle Devonian aquifer system (GWBs P and 21)
	Filtration coefficient	The transmissivity is in the range of 132-650m^2/d	
	Recharge and regime	Main recharge is located mostly outside the borders of Latvia. Groundwater mainly discharges in Gulf of Riga and the Baltic Sea. Infiltration calculations have not been made, because Ķemeri-Pärnu aquifer is not included in hydrogeological model	
Groundwater chemical composition	*Chemical composition*	Ca-Mg-HCO$_3$ type fresh waters with mineralization up to 1 g/l predominate.	Figure 50. Groundwater types in the Lower-Middle Devonian aquifer system represented in Piper diagram. (GWBs P and 21)
	Conceptual model of the formation of chemical composition	*Not developed due to lack of data and knowledge*	
Groundwater vulnerability	*Quaternary*	Not relevant	-
	Pre-quaternary	*Low risk of contamination*: 100% of the area (covered by overlying GWBs)	
Corine LandCover 2018		Not relevant	-

Nitrate vulnerable zone		Not relevant	-
Monitoring	*Number of monitoring station and wells (springs)*	*Quantity monitoring*: 1 station: Aloja (2 wells). Total: 2 wells *Quality monitoring:* 2 stations: Aloja (2 wells) and Seda (1 well). Total: 3 wells. ● Surveillance monitoring: correspond to quality monitoring	Figure 48. Transboundary GWB-3 (A10 & 23) in Upper-Middle Devonian aquifer system
	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m) *Quality monitoring indicators*: physical-chemical indicators (both stations), main ions (both stations), heavy metals (both stations), pesticides (both stations), pesticide active substances used in Latvia (both stations) and other pollutants (station Aloja). Frequency: once a year, varying from 1 time in 6 years to 1 time in 4 years. ● Surveillance monitoring: correspond to quality monitoring	
Groundwater dependent terrestrial and groundwater associated aquatic ecosystems	*Groundwater associated river water bodies*	Not relevant	-
	Groundwater associated standing water body ecosystems and karst features	Not relevant	
	Groundwater dependent terrestrial ecosystems	Not relevant	
Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	*Cannot be provided due to lack of dynamic hydrogeological model*	-
	Approved groundwater resources (AGR)	3651 m^3/d	
	Groundwater abstraction (GA)	702.44 m^3/d	
	Available groundwater resources (AGR-GA)	2948.56 m^3/d	
	Minimal available natural resource (NR-AGR)	*Cannot be provided due to lack of dynamic hydrogeological model*	

Minimal available natural resource of groundwater for abstraction (NR-GA)	*Cannot be provided due to lack of dynamic hydrogeological model*

Background levels and threshold values

Indicator	*Background level*	*Threshold value*	-
Ca, mg/l	80	-	-
Na, mg/l	62	131	
K, mg/l	8.7	-	
Mg, mg/l	29	-	
Cl, mg/l	130	190	
HCO_3, mg/l	360	-	
SO_4, mg/l	30	140	
NH_4, mg/l	0.35	0.425	
Mn, mg/l	0.12	0.12	
Fe_{tot} (anaerobic), mg/l	2.3	2.3	
Fe_{tot} (aerobic), mg/l	0.17	0.19	
NO_3 (anaerobic), mg/l	0.4	25.2	
NO_3 (aerobic), mg/l	4	27	
PO_4 (aerobic), µg/l	30	-	
F, mg/l	0.54	1.0	
Pb, µg/l	1.65	5.83	
As, µg/l	4.9	7.45	
Hg, µg/l	0.16	0.85	
Cd, µg/l	0.29	2.65	
Ni, µg/l	2.2	11.1	
Cr, µg/l	4	27	
Cu, µg/l	10	10	
Zn, µg/l	50	-	

GWB code		**21**	**Additional visual material**
River basin district		West Estonia	-
Area (km^2)		4450	-
Physiographic characteristics		Territory has a changing relief - coastal lowlands are widespread in the western part near the Gulf of Riga, but the east part is covered mostly by wavy plains on Sakala upland. The absolute height of the terrain varies from about 0 to 120 m a.s.l.	Figure 48. Transboundary GWB-4 (P & 21) in Lower-Middle Devonian aquifer system.
Hydrogeological characteristics	*Lithology*	Water-bearing rocks are represented by the Middle Devonian Pärnu deposit and The Lower Devonian Rezekne and Tilze deposits, which are weakly fine-grained cemented sandstones and siltstones containing interlayers of domerite and clay.	Figure 49. Cross-section of the Lower-Middle Devonian aquifer system (GWBs P and 21)
	GWB thickness	Increases evenly from 1-3 meters of in the open area of water layers to 40 meters on the southern border of Estonia	
	Overlying aquitard	Narva formation (regional aquitard) of siltstone, marl, clay and dolomite marl.	
	Underlying aquitard	Has not developed well. Beneath the Middle Lower Devonian rocks lie the limestones and dolomites of the Silurian deposit with good water yield. Hydrogeologically, the Silurian and Middle Lower Devonian rocks form a single groundwater complex, but due to the difference in the collector properties of the rocks, they can also be treated separately	
	Groundwater level	GWL is in the Sakala upland about 60-65 m a.s.l.	
Hydrodynamics	*Flow direction*	GW flows from the Sakala upland in the northwest and west direction. Groundwater also infiltrates into the groundwater layers below.	Figure 49. Cross-section of the Lower-Middle Devonian aquifer system (GWBs P and 21)
	Filtration coefficient	In the north <100 m2/day and increases towards the south up to a value of 550 m^2/day	
	Recharge and regime	In the Sakala uplands, groundwater recharge is estimated to be 100–120 mm per year. The amplitudes of water level fluctuations in terms of seasons are small, ranging from 0.3 to 1.8 m.	
Groundwater chemical composition	*Chemical composition*	$Ca\text{-}HCO_3$ and $Ca\text{-}Mg\text{-}HCO_3$ types of water with a minerality of 0.2-0.6 g/L. On the coast of the Gulf of Livonia from Pärnu in the south, there are a few wells with Na-HCO3 or CaCl type groundwater, where the chloride content can be up to 200 mg/L. The groundwater body is characterized by high natural iron contents (<0.01 to 5.6 mg/L), also NH_4^+ concentrations (1,5 mg/l)	Figure 50. Groundwater types in the Lower-Middle Devonian aquifer system represented in

	Conceptual model of the formation of chemical composition	The chemical composition of GW is influenced by the mixing of groundwater created by infiltration of precipitation, groundwater of marine origin, and groundwater originating from earlier climatic periods. Since the majority of the groundwater body is protected from pollution coming from the surface by the Narva regional formation, there are low concentrations of substances indicating anthropogenic pollution (e.g. organic pollution, nitrates, pesticides). The main processes affecting the chemical composition are the dissolution of carbonate minerals (calcite, dolomite) and, to a lesser extent, the oxidation of pyrite, the effect of which is more significant in $Ca\text{-}HCO_3$ type water. High iron contents indicate the importance of organic matter oxidation in the chemical composition.	Piper diagram. (GWBs P and 21)
Groundwater vulnerability	*Quaternary*	Not distinguished in Estonia	-
	Pre-quaternary	• Very well protected area - 1% • Well protected area - 54%; • Average protected area - 30%; • Weakley protected area - 14%; • Unprotected area - 1% 53% of the area covered by overlying GWB 23	
Corine LandCover 2018		Common types: • Coniferous forests - 28% • Mixed forests – 22% • Non-irrigated arable land - 13% • Transitional woodland-shrub – 10% • Peat bogs - 6% • Broad-leaved forest - 6% • Agricultural land with significant natural areas - 4% • Pastures – 3% • Complex cultivation patterns – 3%	-
Nitrate vulnerable zone		Not relevant	-
Monitoring	*Number of monitoring station and wells (springs)*	Quantity monitoring: 2 stations: Vaskrääma village; Tammuru village. Total: 2 wells ● Surveillance monitoring: correspond to quantity monitoring Quality monitoring: 5 stations: Abja-Paluoja; Tammaru village; Saarde village; Sakala municipality, Olustvere township. Total: 4 wells, 1 spring ● Surveillance monitoring: correspond to quality monitoring	Figure 48. Transboundary GWB-4 (P & 21) in Lower-Middle Devonian aquifer system.

	Types and frequency of observations	*Quantity monitoring indicators*: groundwater level from ground surface (m). Frequency: 12 times a year *Quality monitoring indicators*: physical-chemical indicators (all stations), main ions (all stations), heavy metals (all stations), Zn and Cu (Tammuru station), pesticides (all stations), and other pollutants (all stations). Frequency: once a year, varying from 1 time in 6 years to every year.	
Groundwater dependent terrestrial and groundwater associated aquatic ecosystems	*Groundwater associated river water bodies*	Weakly connected to the Pärnu River, because there are springs connected to the body along it.	-
	Groundwater associated standing water body ecosystems and karst features	Not common	
	Groundwater dependent terrestrial ecosystems	Not common	
Status assessment results	*Quantitative status*	Good	-
	Chemical status	Good	
Groundwater resources (m^3/d)	*Natural resources (NR)*	536689	-
	Approved groundwater resources (AGR)	-	
	Groundwater abstraction (GA)	757	
	Available groundwater resources (AGR-GA)	-325	
	Minimal available natural resource (NR-AGR)	523689	
	Minimal available natural resource of groundwater for abstraction (NR-GA)	522312	

Background levels and threshold values	*Indicator*	*Background level*	*Threshold value*	
	Pesticides	-	0,1 0,5 (total)	-
	COD, mgO/l	-	≤ 5	
	pH level	-	6-9	
	NO_3, mg/l	-	50	
	NH_4, mg/l	-	1,5 (anaerobic)	
	N_{tot}, mg/l(N)	-	3	
	P_{tot}, mg/l(P)	<0.01	0.08	

	Trichlorethylene, µg/l	-	70
	Tetrachlorethylene, µg/l	-	70
	As, µg/l	-	100
	Cd, µg/l	-	10
	Hg, µg/l	-	2
	Pb, µg/l	-	200

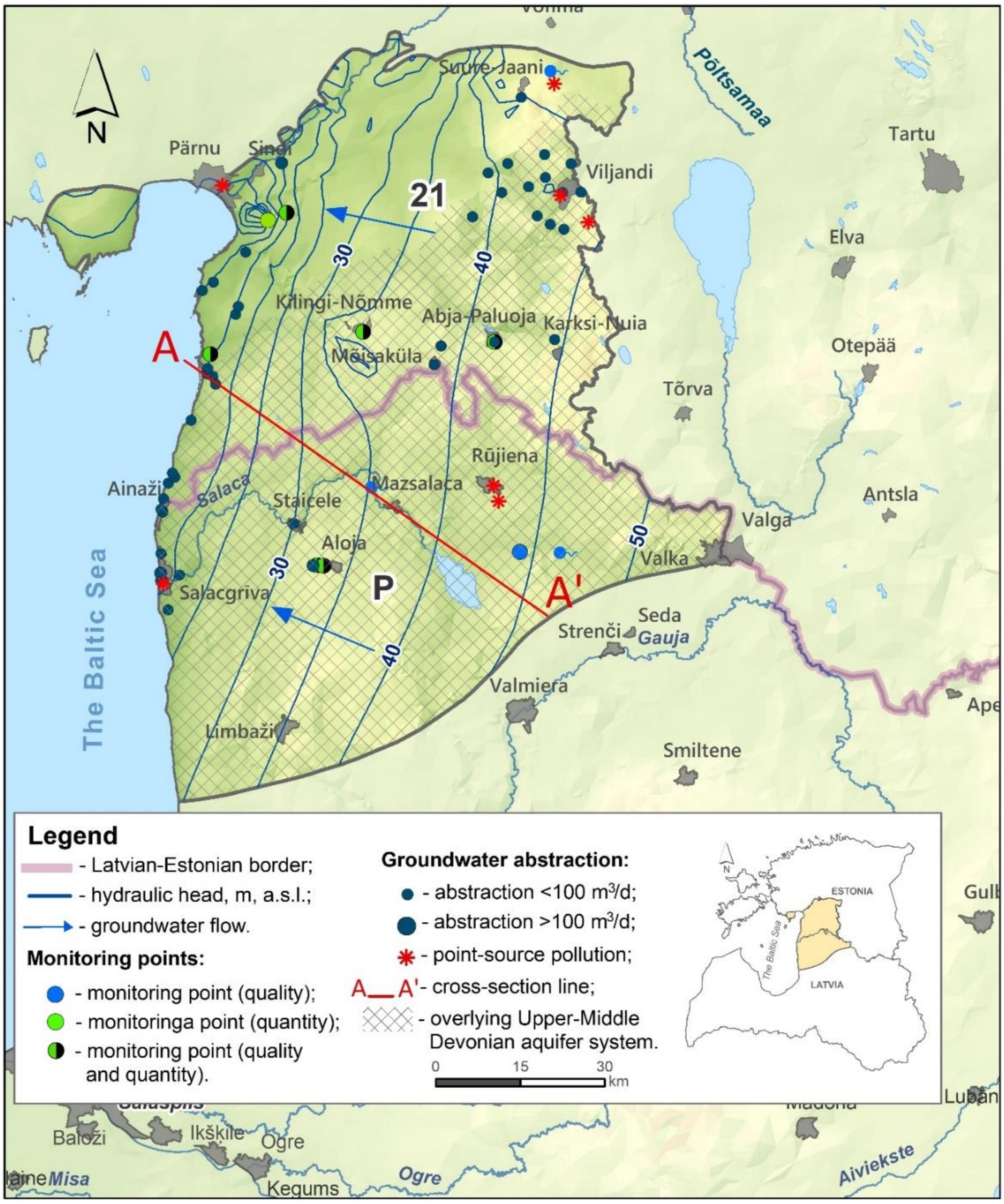


Figure 48. **Transboundary GWB-4 (P & 21) in Upper-Middle Devonian aquifer system.**

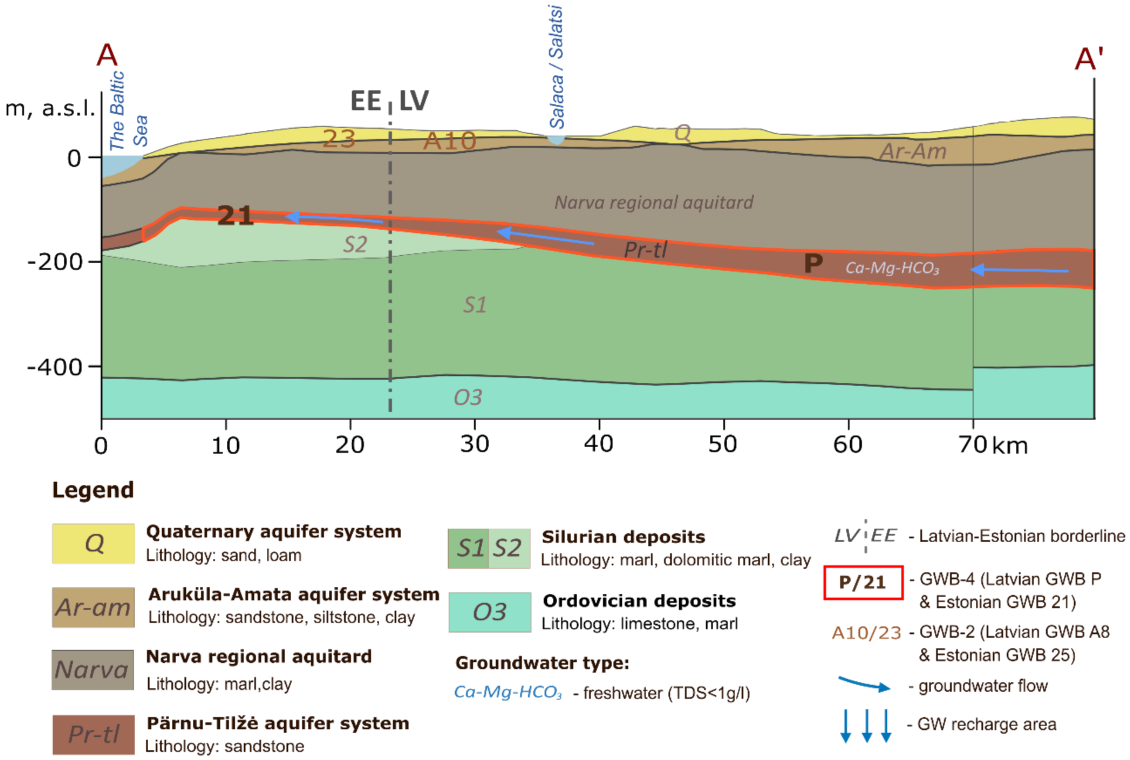
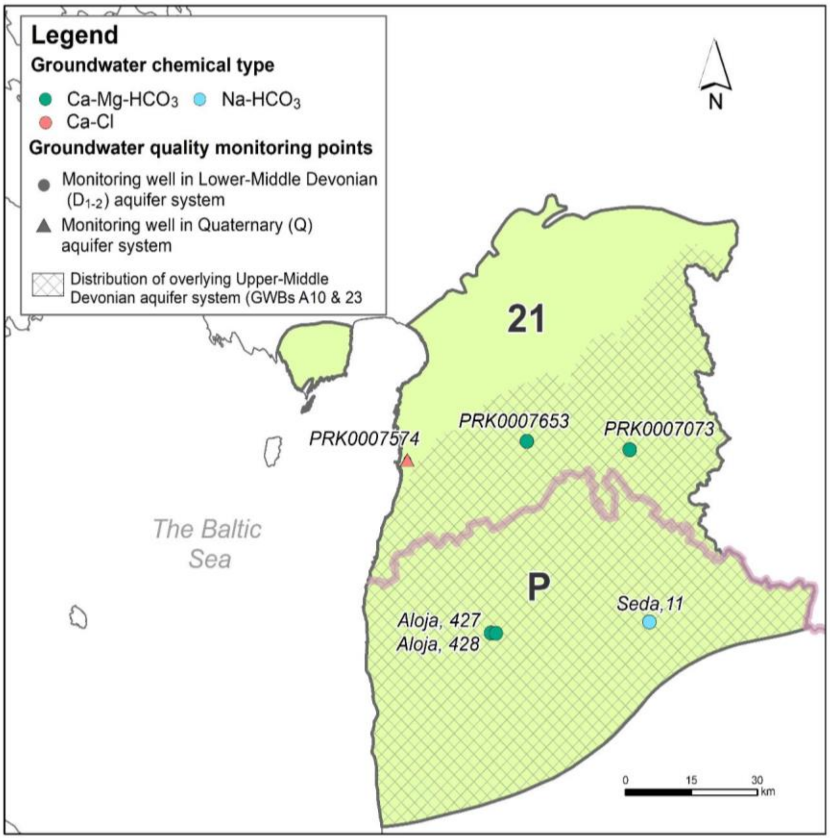


Figure 49. **Cross-section of the Lower-Middle Devonian aquifer system (GWBs P and 21)**



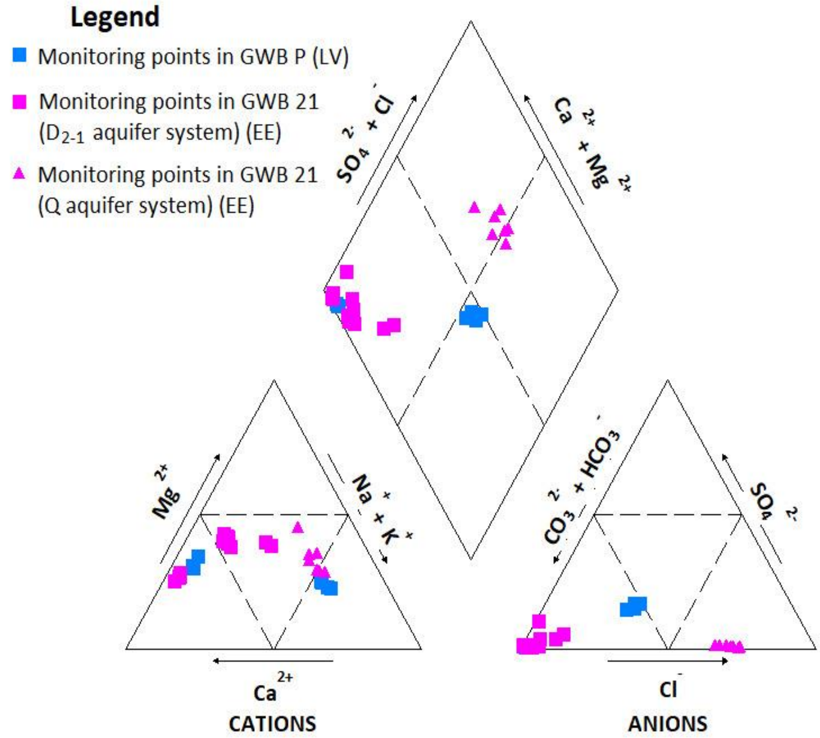


Figure 50. **Groundwater types in the Lower-Middle Devonian aquifer system represented in Piper diagram. (GWBs P and 21)**

Annex 2

Used equipment and procedure in field work for GW monitoring in Latvia and Estonia

Latvian principles	Estonian principles
Groundwater sampling procedure	
● During groundwater sampling in unpolluted or lightly polluted areas, the boreholes are pumped up to the stabilization of physico-chemical parameters (temperature, dissolved oxygen, electrical conductivity and pH index). On the other hand, in moderately and heavily polluted places, pumping is performed of 2.5-3 times the amount of water in the well, because due to the heterogeneity of water in such places stabilization of physico-chemical parameters is not technically possible. ● Before sampling, each type of bottle is prepared according to the requirements of binding standards (sampling/testing) and the bottles are ready for immediate use, without rinsing with sample water. ● The samples are filled to the top into bottles or in accordance with the marking on the bottles made by the laboratory. ● A sampling protocol is completed for all samples, filling in all fields except the section that is filled in by the laboratory. Problems encountered during the sampling (*bad weather, damage to the meters*) are reported in the "other notes" column of the report!	● During groundwater sampling, the monitoring boreholes are pumped of at least 4 times the amount of water in the borehole and up to the stabilization of physico-chemical parameters (temperature, dissolved oxygen, electrical conductivity and pH index). From working water wells used for water supply, sampling is performed after stabilization of physico-chemical parameters. ● No sample containers rinsing as we use sample containers prepared in the laboratory (purified bottle of the appropriate material and preservative added if necessary) no rinsing. ● The samples are filled to the top into bottles or in accordance with the marking on the bottles made by the laboratory. ● A sampling protocol is completed on site for all monitoring points (including all measured values and pumping data during the sampling procedure). All relevant observations and problems encountered during the sampling are reported in the sampling protocol.

Latvian principles	**Estonian principles**
Used equipment in field work for GW quality monitoring	
1) Digital multimeter with flow cell and IntelliCAL electrodes: ● CDC40101, CDC40110 – water conductivity (salinity). ● PHC10101, PHC10110 – water pH index. ● LDO10101, LDO10110 – water dissolved oxygen. ● MTC30101 – oxidation-reduction potential. ● Water temperature. ● Each IntelliCAL electrode has its own calibration procedure and standard solutions; calibration is performed according to the developed internal instructions. 2) Portable photometer for measuring the dissolved iron content. Equipment - *reagents, cuvettes, filtration kit and spare battery.* 3) Pumps (electricity supply generator, cables, frequency converter): ● Submersible pumps: Grundfos MP1 pump, Grundfos SQE7 pump – for deep well sampling. ● Whale Purgar mini pump - for shallow well sampling. ● Instructions for use and maintenance have been developed for each device 4) Groundwater samples are stored in a refrigerator or cold box, at a temperature between 4°C and 8°C.	1) Digital multimeters: ● water conductivity: HandyLab680 LF431T IDS; WTW 3110 with electrode Tetracon 325 etc. ● water pH index: HandyLab680 with electrode A7780IDS; WTW 3110 with electrode Sentix41 etc. ● water dissolved oxygen: HandyLab680 with electrode FDO1100IDS; Marvetjunior 2000 with electrode Helox 13 etc. ● water temperature: HandyLab680; WTW 3110; MarvetJunior 2000. ● Each measuring device has its own calibration procedure and calibration is performed according to the developed internal instructions. 2) Submersible pumps (electricity supply generator, frequency converter, inert hoses): ● Grundfos MP1 pump and Grundfos MP3 pump – for deep well sampling. ● Instructions for use, cleaning and maintenance have been developed for each device. 3) Groundwater samples are stored in a refrigerator or cold box, at a temperature between -3°C and 5°C.

<table>
<tr><th>Latvian principles</th><th>Estonian principles</th></tr>
<tr><td colspan="2">Used equipment in field work for GW quantity monitoring</td></tr>
<tr><td>1) Electric spirit level.
2) Automatic water level dataloggers:
● Mini-Diver,
● Micro-Diver,
● Cera-Diver,
● TD-Diver,
● Baro-Diver.
<i>Data is read once a quarter. A manual control measurement is also performed during the reading. In the future, the newly installed monitoring wells are planned to be equipped with modern water level dataloggers - reading and loading of levels will take place online. The frequency of manual measurements is ensured according to a developed monitoring program.</i></td><td>1) Electric spirit level.
2) Automatic water level dataloggers:
● TD Diver,
● CTD-Diver,
● GDT-S Prime (Global Data Transmitter Single Prime GPRS/UMTS).
● Solinst Levelogger.
<i>Data is read at site once a quarter, GDT-S Prime sends mail every day. A manual control measurement is also performed during data reading at site.</i></td></tr>
</table>

Annex 3

Methods used for field and laboratory parameters

1. Methods used for field and laboratory parameters in Latvia

Parameter		Used method	Principle of the method	MDL	QL	Unit
Main (key) parameters						
Descriptive determinants (field work)	Temperature	LVS EN ISO 10523:2012	-	-	-	-
	pH	LVS EN ISO 10523:2012	-	-	-	-
	Electrical conductivity	LVS EN ISO 5814:2013	-	-	-	-
	Dissolved oxygen (O_2)	LVS EN ISO 5814:2013	-	-	-	-
	Redox potential (Eh)	-	-	-	-	-
	Fe_{tot}	ISO 6332	-	-	-	-
Major ions, nitrogen compounds and their ionic forms	Calcium (Ca)	LVS EN ISO 7980:2000	Atomic absorption spectrometry with flame atomization	0.2	0.6	mg/l
		LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	0.04	0.1	mg/l
	Magnesium (Mg)	LVS EN ISO 7980:2000	Atomic absorption spectrometry with flame atomization	0.1	0.4	mg/l
		LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	0.04	0.1	mg/l
	Sodium (Na)	LVS ISO 9964-3:1993	Atomic absorption spectrometry with flame atomization	0.2	0.5	mg/l
		LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	0.08	0.3	mg/l
	Potassium (K)	LVS ISO 9964-3:1993	Atomic absorption spectrometry with flame atomization	0.1	0.4	mg/l
		LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	0.01	0.03	mg/l
	Bicarbonates (HCO_3)	SM 2320 B:2017	Potentiometric titration	1.2	3.7	mg/l
	Sulphates (SO_4)	LVS EN ISO 10304-1:2009	Ion chromatography	0.024	0.079	mg/l
	Chlorides (Cl)	LVS EN ISO 10304-1:2009	Ion chromatography	0.039	0.13	mg/l
	Phosphate phosphorus and phosphates (PO_4)	LVS EN ISO 6878:2005, 4.nod	Spectrophotometry, ammonium molybdate method	0.0052	0.019	mg/l
	Total phosphorus (P_{tot})	LVS EN ISO 6878:2005, 7.nod.	Mineralization with persulphate, spectrophotometry, ammonium molybdate method	0.0017	0.008	mgP/l
	Total nitrogen (N_{tot})	LVS EN ISO 11905-1:1998	Mineralization with persulphate, segmented flow spectrophotometry, Cd column method	0.02	0.06	mgN/l
		LVS EN 12260:2004	Catalytic combustion, detection of chemiluminescence	0.14	0.48	mgN/l

Parameter		**Used method**	**Principle of the method**	**MDL**	**QL**	**Unit**
	Ammonium (NH$_4$)	LVS EN ISO 11732:2005	Continuous flow indophenol spectrophotometric method	0.042	0.149	mg/l
		QuAAtro Method no. Q-080-06 Rev.2:2008	Fluorometric determination with o-phthalaldehyde (OPA) using segmented flow analysis	0.0059	0.024	mg/l
	Nitrites (NO$_2$)	LVS ISO 6777:1984	Spectrophotometry	0.00055	0.002	mg/l
	Nitrates (NO$_3$)	LVS EN ISO 13395:2004	Segmented flow spectrophotometry, Cd column method	0.053	0.19	mg/l
	Total organic carbon (TOC)	LVS EN 1484:2000	Catalytic combustion, infrared detection	0.16	0.54	mgC/l
		LVS EN 1484:2000 liqui TOC II elementar	Catalytic combustion, infrared detection	0.4	1.6	mgC/l
	Dissolved organic carbon (DOC)	LVS EN 1484:2000	Catalytic combustion, infrared detection	0.16	0.54	mgC/l
		LVS EN 1484:2000 liqui TOC II elementar	Catalytic combustion, infrared detection	0.4	1.6	mgC/l
	Permanganate index	LVS EN ISO 8467:2000	Titrimetry	0.4	1.4	mg/l
	UV absorbtion	SM 5910 B:2017*	Spectrophotometry (UV)	0.002	0.0051	cm-1
	Total hardness	SM 2340 C:2017	Titrimetry	0.034	0.12	mgeq/l
	Total iron (Fe$_{tot}$)	LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	3	10	µg/l
	Manganese (Mn)	LVS EN ISO 11885:2009		0.2	0.8	µg/l
Metals	Lead (Pb)	LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	0.4	1	µg/l
	Nickel (Ni)	LVS EN ISO 11885:2009		0.7	2	µg/l
	Cadmium (Cd)	LVS EN ISO 15586:2003	Atomic absorption spectrometry with electrothermal atomization	0.007	0.024	µg/l
		LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	0.09	0.3	µg/l
	Mercury (Hg)	LVS EN ISO 17852:2008	Cold vapor atomic fluorescence spectrometry	0.003	0.01	µg/l
	Arsenic (As)	LVS EN ISO 15586:2003	Atomic absorption spectrometry with electrothermal atomization	0.2	0.6	µg/l
Additional parameters						
Pesticides	Atrazine	EN ISO 10695:2000*	Gas chromatography /mass spectrometry	6.5	20	ng/l
	Simazine	EN ISO 10695:2000*	Gas chromatography /mass spectrometry	12	36	ng/l
	Propazine	EN ISO 10695:2000*	Gas chromatography /mass spectrometry	6.5	20	ng/l
	Bentazone	US EPA Method 8151A:1996*	Gas chromatography with electron capture detector	12	36	ng/l
	MCPA	US EPA Method 8151A:1996*	Gas chromatography with electron capture detector	15	45	ng/l
	Aldrin	ISO 6468:1996	Gas chromatography with electron capture detector	0.3	1	ng/l
	Dieldrin	ISO 6468:1996	Gas chromatography with electron capture detector	0.2	1	ng/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Heptachlor	ISO 6468:1996	Gas chromatography with electron capture detector	0.2	1	ng/l
	Heptachlor epoxyd	ISO 6468:1996	Gas chromatography with electron capture detector	0.2	1	ng/l
	2,4-D	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	MCPB	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Isoproturon	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.1	0.03	µg/l
	Aclonifen	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.0012	0.0036	µg/l
	Biphenox	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.00012	0.00036	µg/l
	Promethrin	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.008	0.024	µg/l
	Dimethoate	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Cypermethrin	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.0000008	0.0000024	µg/l
	Alpha-cypermethrin	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.0000008	0.0000024	µg/l
	Trifluralin	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.003	0.009	µg/l
	Tebuconazole	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Epoxiconazole	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Prochloraz	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Diflufenican	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Metribuzin	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Pendimethalin	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Azoxystrobin	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
	Metazachlor	BIOR-T-012-162-2015	Gas or liquid chromatography with mass spectrometry	0.01	0.03	µg/l
Chemical pollutants	Trichlorethylene	ISO 10301:1997	Gas chromatography with electron capture detector	0.2	0.6	µg/l
	Tetrachlorethylene	ISO 10301:1997	Gas chromatography with electron capture detector	0.2	0.6	µg/l
	Trichloromethane	ISO 10301:1997	Gas chromatography with electron capture detector	0.2	0.6	µg/l
	1,2-dichloroethane	ISO 10301:1997	Gas chromatography with electron capture detector	0.1	0.3	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Sum of monoaromatic hydrocarbons - benzene, ethylbenzene, toluene, xylenes (BTEX)	ISO 11423-1:1997	Gas chromatography with flame ionization detector	0.1	0.3	µg/l
	Chemical Oxygen Demand (COD)*	LVS ISO 6060:1989	Titrimetry	7	25	mg/l
		DIN 38409 Teil 44/6:1992	Titrimetry	2	8	mg/l
		DIN 38409 Teil 44/5:1992	Titrimetry	2	8	mg/l
	Synthetic Surfactants*	LVS ISO 7875-1:1996/TC1:2003	Spectrophotometry, methylene blue method	0.003	0.012	mg/l
	Perfluorooctane sulfonate (PFOS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorohexanesulfonate (PFHxS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluoropentanoic acid (PFPeA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorohexanoic acid (PFHxA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorooctanoic acid (PFOA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorodecanoic acid (PFDA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorobutanoic acid (PFBA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluoroheptanoic acid (PFHpA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluoronic acid (PFNA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorobutanesulfonate (PFBS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Prefluorundecanoic acid (PFUnDA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorododecanoic acid (PFDoDA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Prefluorotridecanoic acid (PFTrDA)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluorobutanesulfonic acid (PFBS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluoropentanesulfonic acid (PFPS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Pefluorohexanesulfonic acid (PFHxS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluoroheptanesulfonic acid (PFHpS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
	Perfluoronanesulfonic acid (PFNS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Perfluorodecanesulfo-nic acid (PFDS)	BIOR-T-012-165-2015	-	0.00001	0.000039	µg/l
Additional indicators	Strontium (Sr)*	LVS EN ISO 11885:2009	Inductively coupled plasma optical emission spectrometry	2	7	µg/l
	Bromide ions*	LVS EN ISO 10304-1:2009	Ion chromatography	0.024	0.094	mg/l
	Iodide ions*	LVS EN ISO 10304-1:2009	Ion chromatography	0.036	0.12	mg/l

Notes: Perfluorodecanesulfonic acid (PFDS) - Not in the list of key indicators; will be determined in the framework of research monitoring (if funding will be granted); Pendimethalin - This parameter in not analyzed in Estonia, Ni -, parameter measured in each country, but only at individual GWB or monitoring points - Measured only in GWBs at risk*

2. Methods used for field and laboratory parameters in Estonia

Parameter		Used method	Principle of the method	MDL	QL	Unit
Basic (key) parameters						
Descriptive determinants (field work)	Temperature	ISO 5667-11	Physical (PHYS)	-	-	°C
	pH	ISO 10523	Electrochemical determinations (EC)	1	-	-
	Electrical conductivity	EN 27888	Electrochemical determinations (EC)	1	-	µS/cm
	Dissolved oxygen (O_2)	EVS-EN 25814	Electrochemical determinations (EC)	0.2	-	mg/l
Major ions, nitrogen compounds and their ionic forms	Calcium (Ca)	EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	0.05	-	mg/l
		ISO 6058	Titrimetric determinations (TITR)	2	-	mg/l
		SFS 3003	Titrimetric determinations (TITR)	12	-	mg/l
		EN ISO 14911	Ion chromatography (IC)	0.04	-	mg/l
	Magnesium (Mg)	EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	0.02	-	mg/l
		ISO 6059	Titrimetric determinations (TITR)	2	-	mg/l
		EN ISO 14911	Ion chromatography (IC)	0.02	-	mg/l
	Sodium (Na)	EVS-ISO 9964-3	Flame-emission spectrometry (FES); Atomic absorption spectrometry (AAS)	0.01	-	mg/l
		EN ISO 14911	Ion chromatography (IC)	0.02	-	mg/l
	Potassium (K)	EVS-ISO 9964-3	Flame-emission spectrometry (FES); Atomic absorption spectrometry (AAS)	0.01	-	mg/l
		EN ISO 14911	Ion chromatography (IC)	0.02	-	mg/l
	Bicarbonates (HCO_3)	EVS-EN ISO 9963-1	Titrimetric determinations (TITR)	1	-	mg/l
	Sulphates (SO_4)	EVS-EN ISO 10304-1	Ion chromatography (IC)	0.1	-	mg/l
	Chlorides (Cl)	EVS-EN ISO 10304-1	Ion chromatography (IC)	0.07	-	mg/l
	Phosphate phosphorus and phosphates (PO_4)*	EVS-EN ISO 6878	Spectrophotometry (UV-VIS)	0.06	-	mg/l
		ISO 15681-2	Spectrophotometry (UV-VIS)	0.006	-	mg/l
	Total phosphorus (P_{tot})*	ISO 15681-2	Spectrophotometry (UV-VIS)	0.002	-	mg/l
	Total nitrogen (N_{tot})*	ISO 11905	Spectrophotometry (UV-VIS)	0.1		mg/l
	Ammonium (NH_4)	EVS-EN ISO 11732	Spectrophotometry (UV-VIS)	0.013	-	mg/l
		SFS 3032	Spectrophotometry (UV-VIS)	0.01	-	mg/l
	Nitrites (NO_2)	EVS-EN ISO 13395	Spectrophotometry (UV-VIS)	0.016	-	mg/l
	Nitrates (NO_3)	EVS-EN ISO 13395	Spectrophotometry (UV-VIS)	0.02	-	mg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
		EVS-EN ISO 10304-1	Ion chromatography (IC)	0.1	-	mg/l
	Total iron (Fe_{tot})	ISO 6332	Spectrophotometry (UV-VIS)	0.02	-	mg/l
	Chemical oxygen demand (COD)	SFS 3036	Titrimetric determinations (TITR)	1	-	mgO/l
	Carbon dioxide (CO_2)	calculated	Spectrophotometry (UV-VIS)	-	-	mg/l
	Total dissolved solids (Dry residue)	STJnrV	Gravimetric determination (GR)	20	-	mg/l
	Total hardness	ISO 6059	Titrimetric determinations (TITR)	0.1	-	mgeq/l
		SFS 3003	Titrimetric determinations (TITR)	0.9	-	mgeq/l
Additional parameters						
Metals	Cadmium (Cd)	EVS-EN ISO 17294-2	Inductively coupled plasma mass spectrometry (ICP-MS)	0.02	-	µg/l
		EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	0.02	-	µg/l
	Lead (Pb)	EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	0.1	-	µg/l
		EVS-EN ISO 17294-2	Inductively coupled plasma mass spectrometry (ICP-MS)	0.1	-	µg/l
	Mercury (Hg)	EVS-EN ISO 17852	Fluorescence spectometry (AFS)	0.005	-	µg/l
		EVS-EN ISO 12846	Cold vapor atomic absorption spectrometry (AAS)	0.015	-	µg/l
	Arsenic (As)	EVS-EN ISO 17294-2	Inductively coupled plasma mass spectrometry (ICP-MS)	0.05	-	µg/l
		EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	0.05	-	µg/l
	Barium (Ba)*	EVS-EN ISO 17294-2	Inductively coupled plasma mass spectrometry (ICP-MS)	0.2	-	µg/l
		EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	20	-	µg/l
	Zinc (Zn)*	EVS-EN ISO 17294-2	Inductively coupled plasma mass spectrometry (ICP-MS)	1	-	µg/l
		EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	0.02	-	µg/l
	Copper (Cu)*	EVS-EN ISO 17294-2	Inductively coupled plasma mass spectrometry (ICP-MS)	1	-	µg/l
		EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	0.02	-	µg/l
	Nickel (Ni)*	EVS-EN ISO 17294-2	Inductively coupled plasma mass spectrometry (ICP-MS)	0.05	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
		EVS-EN ISO 11885	Inductively coupled plasma atomic emission spectrometry (ICP-OES)	20	-	µg/l
Chemical pollutants	Trichlorethylene	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Tetrachlorethylene	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Sum of Polyaromatichydrocarbons (PAH sum)*	STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Benzene (Benseen)*	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.06	-	µg/l
	Hydrocarbon oil index (C10 - C40)*	EVS-EN ISO 9377-2	Gas chromatography (GC)	20	-	µg/l
	Watch-list indicators Pharmaceuticals*	-	-	-	-	-
	Watch-list indicators perfluor (PFAS)*	-	-	-	-	-
	Monobasic Phenolic compounds*	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	Dibasic Phenolic compounds*	STJnrU12D	Liquid chromatography (HPLC)	1	-	µg/l
Pesticides and their potential metabolites	Atrazine	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0005	-	µg/l
	Simazine	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.003	-	µg/l
	Bentazone	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.02	-	µg/l
	MCPA	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.01	-	µg/l
	Propazine	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Aldrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Dieldrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Heptachlor	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0001	-	µg/l
	2,4-D	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.02	-	µg/l
	Isoproturon	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.001	-	µg/l
	Aclonifen	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Biphenox	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Promethrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Dimethoate	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.002	-	µg/l
	Cypermethrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0004	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Trifluralin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Tebuconazole	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.002	-	µg/l
	Epoxiconazole	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Diflufenican	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.01	-	µg/l
	Metribuzin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Metazachlor	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.002	-	µg/l
	1,2-dichloroethane	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Phenol	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	3- and 4-methylfhenol	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	2-methylfhenol	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	2,3-dimethylphenol	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	2,6-dimethylphenol	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	3,4-dimethylphenol	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	3,5-dimethylphenol	STJnrU12D	Liquid chromatography (HPLC)	0.3	-	µg/l
	2,5-dimethylresorcin	STJnrU12D	Liquid chromatography (HPLC)	1	-	µg/l
	5-methylresorcin	STJnrU12D	Liquid chromatography (HPLC)	1	-	µg/l
	Resorcin	STJnrU12D	Liquid chromatography (HPLC)	1	-	µg/l
	Anthracene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Acenaphtene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Acenaphtylene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Benzo(a)anthracene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Benzo(a)pyrene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
	Benzo(b)fluoranthene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
	Benzo(g,h,i)perylene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0004	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
	Benzo(k)fluoranthene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
	Dibenzo(a,h)antratseen	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
	Phenanthren	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Fluoranthene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Fluorene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Indeno(1,2,3-cd)pyrene)	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
	Chrysene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Pyrene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Naphthalene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		STJnrU65	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
		ISO 28540	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Bromodichloromethane	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Dibromochloromethane	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Dichloromethane	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Ethylbenzene	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	m/p-Xylene	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	o-Xylene	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Styrene	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	1,1,1-trichloroethane	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Tetrachloromethane	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Toluene	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Tribromomethane	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.1	-	µg/l
	Chloroform	ISO 20595	Gas Chromatography Mass-spectrometry (GC-MS)	0.03	-	µg/l
		STJnrU91	Gas Chromatography Mass-spectrometry (GC-MS)	0.03	-	µg/l
	Azitromycin	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.003	-	µg/l
	Diclofenac	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.04	-	µg/l
	Erythromycin	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0011	-	µg/l
	Clarithromycin	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.001	-	µg/l
	1,2,3,5-/1,2,4,5-Tetrachlorobenzene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	1,2,3,4-Tetrachlorobenzene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	1,2,3-Trichlorobenzene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	1,2,4-Trichlorobenzene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0025	-	µg/l
	1,3,5-Trichlorobenzene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	2,4-D 2-ethylhexyl esther	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Alachlor	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	alpha- Endosulfan	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0003	-	µg/l
	alpha-Hexachlorocyclohexan	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001		µg/l
	alpha-Chlordane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0005	-	µg/l
	Ametryn	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.01	-	µg/l
	Amidosulfuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.01	-	µg/l
	AMPA	STJnrU93	Liquid chromatography mass-spectrometry (LC-MS)	0.05	-	µg/l
	Acetamiprid	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.001	-	µg/l
	beta- Endosulfan	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0001	-	µg/l
	beta-Hexachlorocyclohexane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0005	-	µg/l
	Bifenthrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Boscalid	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	delta-Hexachlorocyclohexane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0001	-	µg/l
	Deltamethrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0001	-	µg/l
	Desetyl-atrazine	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Diazinon	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Diflubenzuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.01	-	µg/l
	Dicamba	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.172	-	µg/l
	Dichlobenil	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Dichlorvos	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.00032	-	µg/l
	Dichlorprop-P	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0076	-	µg/l
	Dicofol	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Dimetachlor	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Dimethenamid-P	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0047	-	µg/l
	Dimoxystrobin	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.00095	-	µg/l
	Diuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0065	-	µg/l
	Endosulfan-sulfate	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Endrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	epsilon-Hexachlorocyclohexane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Esfenvalerate	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Ethopropos	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0066	-	µg/l
	Etofenprox	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.005	-	µg/l
	Fenitrothion	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Fenpropathrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Fenpropidin	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0035	-	µg/l
	Fenpropimorph	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.02	-	µg/l
	Fenpyroximate	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0098	-	µg/l
	Fenvalerate	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Fluroxypyr	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.018	-	µg/l
	Flucythrinate	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Phosphamidon	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	gamma-Hexachlorocyclohexane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	gamma-Chlordane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Glyphosate	STJnrU93	Liquid chromatography mass-spectrometry (LC-MS)	0.05	-	µg/l
	Hexachlorobenzene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Hexachlorbutadiene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Heptachlor-exo-epoxide	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0001	-	µg/l
	Heptachlor-endo-epoxide	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0004	-	µg/l
	Imidacloprid	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0041	-	µg/l
	Isobenzane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Isodrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Isoprocarb	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0014	-	µg/l
	Quinoxyfen	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0025	-	µg/l
	Chlormequat Chloride	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.01	-	µg/l
	Clopyralid	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.018	-	µg/l
	Chloridazon	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.002	-	µg/l
	Chloridazon-desphenyl	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.04	-	µg/l
	Chlorfenvinphos	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.02	-	µg/l
	Chloroxuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0007	-	µg/l
	Chlorpyriphos	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	Chlortoluron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0014	-	µg/l
	Clothianidin	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0031	-	µg/l
	Crimidine	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Quintozene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	lambda-Cyhalothrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Linuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.005	-	µg/l
	Malathion	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.005	-	µg/l
	Mepiquat chloride	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.002	-	µg/l
	Methabenzthiazuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0006	-	µg/l
	Methacrifos	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Metamitron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.01	-	µg/l
	Methiocarb	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.025	-	µg/l
	Metobromuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0067	-	µg/l
	Methoxychlor	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Metoxuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0003	-	µg/l
	Metolachlor	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	methyl-Chlorpyrifos	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	methyl-Primiphos	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.002	-	µg/l
	Mirex	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Monolinuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0008	-	µg/l
	Nopramide	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0011	-	µg/l
	Nicosulfuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0038	-	µg/l
	o,p´-DDD	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	o,p´-DDE	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	o,p´-DDT	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0025	-	µg/l
	oxy- Chlordane	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Omethoate	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0008	-	µg/l
	p,p´-DDD	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0025	-	µg/l
	p,p´-DDE	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.001	-	µg/l
	p,p´-DDT	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0025	-	µg/l
	Pentachlorobenzene	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.0001	-	µg/l
	Pinoxaden	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0048	-	µg/l
	Promethryn	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Propham	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.02	-	µg/l

Parameter		Used method	Principle of the method	MDL	QL	Unit
	Propaquizafop	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0025	-	µg/l
	Promamocarb HCl	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0011	-	µg/l
	Propiconazole	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.006	-	µg/l
	Prothioconazole-desthio	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Pyridaben	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0063	-	µg/l
	Sebuthylazin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.02	-	µg/l
	Spiroxamine	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0032	-	µg/l
	Tebuconazole	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.02	-	µg/l
	Teflubenzuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0028	-	µg/l
	Terbutryn	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0015	-	µg/l
	Tolylfluanid	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Thiacloprid	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0012	-	µg/l
	Tiamethoxam	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0025	-	µg/l
	Triadimenol	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0046	-	µg/l
	Triallate	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.005	-	µg/l
	Tritosulfuron	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.0034	-	µg/l
	Cybutrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.01	-	µg/l
	Cyanazine	STJnrU92	Liquid chromatography mass-spectrometry (LC-MS)	0.00066	-	µg/l
	Cyfluthrin	STJnrU63	Gas Chromatography Mass-spectrometry (GC-MS)	0.02	-	µg/l

Notes: Pendimethalin - This parameter in not analyzed in Latvia, Ni - parameter are measured in each country, but only at individual GWBs or monitoring points * - Measured only in GWBs with significant pressure

Annex 4

Groundwater monitoring points located in the Latvian-Estonian border area (~25 km from the state border)

Basin	GW monitoring station name	National code	Database code	International code	GWB	TGWB	Coordinates		Type	Monitoring type	Altitude, m a.s.l.	Aquifer	Screen interval, m		Start of observation	Monitoring type		Purpose of monitoring site
							Y	X					from	to		Quality	Quantity	
Estonian monitoring points																		
Weast Estonia	Põlde	SJA1060000	7073	EESJA1060000	21	x	580276	443188	well	National	72	D2pr-nr	132	165	2016	YES	NO	Survelance
Weast Estonia	Häädemeeste	SJA7071000	7574	EESJA7071000	21	x	529819	441027	well	National	6.8	D2nr	9.6	13.6	1995	NO	YES	-
Weast Estonia	Saarde vald, Saarde küla, Saarde keskuse puurkaev	SJA3137000	7653	EESJA3137000	21	x	556936	445007	well	National	62	D2pr	140	170	2014	YES	NO	Survelance
East Estonia	not applicable	SJA3955000	8705	EESJA3955000	22		614745	429751	well	National	59	D2pr	201	254	2006	YES	NO	Survelance
East Estonia	Kaarlimäe	SJA2157000	14282	EESJA2157000	22		612664	430343	well	National	72	D2pr	213	275	2015	YES	NO	Survelance
Weast Estonia	Pärnu maakond, Häädemeeste vald, Krundiküla, Jaagupi	SJA0480000	6578	EESJA0480000	23	x	527793	432248	well	National	10.5	D2	26	36.8	2014	YES	YES	Survelance
Weast Estonia	Õisust 0,8 km kagus	SJA7121000	7592	EESJA7121000	23	x	589928	450231	well	National	59.7	D2	16.6	18.5	1995	YES	YES	Survelance
Weast Estonia	not applicable	SJA2134000	7573	EESJA2134000	23*	x	529731	439569	well	National	6.7	Q	3.4	4.4	1995	YES	YES	Survelance
East Estonia	Tõrva pk, Valga-Jõgeveste ristmikust 800 m loodes	SJA9243000	7588	EESJA9243000	24		614650	428657	well	National	62.2	D2ar-br	48.3	133.5	1995	YES	YES	Survelance
East Estonia	Reemniku, Valgast 6 km kagus	SJA1400000	7598	EESJA1400000	24		626877	408540	well	National	53	D2ar	24.5	40.1	1995	YES	YES	Survelance
East Estonia	Valga, Transpordi tn 1	SJA2670000	8485	EESJA2670000	24		621469	407529	well	National	51.8	D2br-ar	50	80	2007	YES	NO	Survelance
East Estonia	Tootsi küla, Tootsi loomalaut ja noorkarjalaut	SJB1812000	10330	EESJB1812000	24		685258	408082	well	National	180	Q	28	40	2017	YES	NO	Survelance
East Estonia	Mõisamäe küla, Mõisa-Miku kinnistu	SJB2062000	23591	EESJB2062000	24		684782	407567	well	National	190	Q	28	36	2018	YES	NO	Survelance
East Estonia	Paanikse kordonelamu	SJA7613000	15122	EESJA7613000	24*		600085	437668	well	National	80	Q	10.3	30.8	2013	YES	NO	Survelance
Gauja/Koiva	not applicable	SJB1928000	10656	EESJB1928000	25	x	684137	392623	well	National	242	D2	153.1	189.3	2018	NO	YES	-
Gauja/Koiva	Varstu alevik	SJA9725000	10890	EESJA9725000	25	x	658874	392320	well	National	85.2	D2	83	123	2008	YES	NO	Survelance
Gauja/Koiva	Lillemäe	SJA7579000	11495	EESJA7579000	25	x	641226	403275	well	National	98.2	D2tr	75.5	100	2014	YES	NO	Survelance
Gauja/Koiva	Lüllemäe	SJB3122000	11890	EESJB3122000	25	x	641379	403409	well	National	95	D2tr	74.2	90	2018	YES	NO	Survelance
Gauja/Koiva	Krabi põhikooli puurkaev	SJA8742000	13376	EESJA8742000	25	x	668863	388200	well	National	120	D2; gQIII	9.6	15.5	2014	YES	YES	Survelance
Gauja/Koiva	Ahero-Alakonnu talu, Mähkli küla, Antsla vald, Võrumaa	SJA9623000	-	EESJA9623000	25	x	647952	400223	well	National	86.5	D2	-	-	2014	YES	NO	Survelance
Gauja/Koiva	Misso suurfarm	SJA6773000	10722	EESJA6773000	26	x	693403	389028	well	National	193.1	D3	44	70	2008	YES	NO	Survelance
East Estonia	Luhamaa piiripunkt	SJA5214000	14338	EESJA5214000	26	x	701730	393870	well	National	185	D3	50	60	2005	YES	NO	Survelance
Gauja/Koiva	Misso vald, Kaubi küla, Vetevana kinnistu	SJB1843000	24521	EESJB1843000	26	x	690736	387283	well	National	180	D3	42	70	2018	NO	YES	-

Latvian monitoring points																		
Salaca/Salatsi	Spiģu avots	912	24561	LV912A10_24561	A10	x	559401	417349	spring	National	52.2	D2br	-	-	2004	YES	NO	Survelance
Salaca/Salatsi	Govs avots	905	24554	LV905A10_24554	A10	x	592941	405687	spring	National	48.2	D2br	-	-	2005	YES	NO	Survelance
Salaca/Salatsi	Rimeikas	391RIM	22652	LV391RIMA10_22652	A10	x	560544	407112	well	National	68.8	gQ3ltv	3.7	5.7	2010	YES	YES	Survelance
Salaca/Salatsi	Rimeikas	391RIM	9601	LV391RIMA10_9601	A10	x	560984	407442	well	National	63.3	gQ3ltv	3.2	5.6	1973	YES	YES	Survelance
Salaca/Salatsi	Rimeikas	391RIM	9600	LV391RIMA10_9600	A10	x	560985	407436	well	National	63.3	D2br	35.8	40.2	1973	YES	YES	Survelance
Salaca/Salatsi	Rimeikas	391RIM	9602	LV391RIMA10_9602	A10	x	560544	407111	well	National	68.8	D2br	23.3	28.2	1973	NO	YES	-
Salaca/Salatsi	Rimeikas	391RIM	22653	LV391RIMA10_22653	A10	x	560818	407312	well	National	67	gQ3ltv	3.5	5.8	2008	NO	YES	-
Salaca/Salatsi	Valka	290VLK	9637	LV290VLKD5_9637	A8	x	618372	403774	well	National	60.5	D2ar	97.5	122	1980	YES	YES	Survelance
Gauja/Koiva	Zīļu avots	914	24563	LV914D6_24563	D6	x	662194	379621	spring	National	92.1	D3pl	-	-	2006	YES	NO	Survelance
Salaca/Salatsi	Aloja	320ALO	9635	LV320ALOP_9635	P	x	548750	403489	well	National	71.9	D2pr	240	265	1981	YES	YES	Survelance
Salaca/Salatsi	Aloja	320ALO	9636	LV320ALOP_9636	P	x	549905	403409	well	National	75.9	D2pr	259	267	1981	YES	YES	Survelance
Salaca/Salatsi	Seda	240SED	9639	LV240SEDP_9639	P	x	584754	405850	well	National	45.8	D2pr	243	258	1983	YES	NO	Survelance

Notes: **A quaternary welsl attached to GWB 23 and GWB 24, is currently inactives; Monitoring point status – active, no active.*

GW monitoring station name	National code	Database code	International code	Existing frequency for groundwater monitoring (from new national monitoring programme)				
				Quantity monitoring	Quality monitoring			
					Basic parameters	Metals	Chemical pollutants	Pesticides
Estonian monitoring points								
Põlde	SJA1060000	7073	EESJA1060000	-	6 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Saarde vald, Saarde küla, Saarde keskuse puurkaev	SJA3137000	7653	EESJA3137000	-	6 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Kaarlimäe	SJA2157000	14282	EESJA2157000	-	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Pärnu maakond, Häädemeeste vald, Krundiküla, Jaagupi	SJA0480000	6578	EESJA0480000	8 times a day	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Õisust 0,8 km kagus	SJA7121000	7592	EESJA7121000	8 times a day	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Tõrva pk, Valga-Jõgeveste ristmikust 800 m loodes	SJA9243000	7588	EESJA9243000	8 times a day	6 times in 6 years (exception PO4; Ntot; Ptot 3 times in 6 years)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	3 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index 2 times in 6 years; Watch-list indicators; Monobasic/Dibasic Phenolic compounds are not measured)	3 times in 6 years
Valga, Transpordi tn 1	SJA2670000	8485	EESJA2670000	-	6 times in 6 years (exception PO4; Ntot; Ptot 3 times in 6 years)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	3 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index 2 times in 6 years; Watch-list indicators; Monobasic/Dibasic Phenolic compounds are not measured)	3 times in 6 years
Mõisamäe küla, Mõisa-Miku kinnistu	SJB2062000	23591	EESJB2062000	-	6 times in 6 years (exception PO4; Ntot; Ptot 3 times in 6 years)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	3 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index 2 times in 6 years; Watch-list indicators; Monobasic/Dibasic Phenolic compounds are not measured)	3 times in 6 years

GW monitoring station name	National code	Database code	International code	Existing frequency for groundwater monitoring (from new national monitoring programme)				
				Quantity monitoring	Quality monitoring			
					Basic parameters	Metals	Chemical pollutants	Pesticides
not applicable	SJB1928000	10656	EESJB1928000	12 times a year	-	-	-	-
Varstu alevik	SJA9725000	10890	EESJA9725000	-	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Lüllemäe	SJB3122000	11890	EESJB3122000	-	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Krabi põhikooli puurkaev	SJA8742000	13376	EESJA8742000	12 times a year	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Misso suurfarm	SJA6773000	10722	EESJA6773000	-	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Luhamaa piiripunkt	SJA5214000	14338	EESJA5214000	-	3 times in 6 years (exception PO4; Ntot; Ptot are not measured)	1 times in 6 years, exception Ba; Zn; Cu; Ni are not measured	1 times in 6 years (exception PAH sum; Benzene; Hydrocarbon oil index, Watch-list indicators Pharmaceutical and PFAS; Monobasic/Dibasic Phenolic compounds are not measured)	1 times in 6 years
Misso vald, Kaubi küla, Vetevana kinnistu	SJB1843000	24521	EESJB1843000	12 times a year	-	-	-	-
Latvian monitoring points								
Spiģu avots	912	24561	LV912A10_24561	-	3 times in 6 years	3 times in 6 years	-	-
Govs avots	905	24554	LV905A10_24554	-	3 times in 6 years	3 times in 6 years	-	-
Rimeikas	391RIM	22652	LV391RIMA10_22652	2 times a day	3 times in 6 years	3 times in 6 years	-	3 times in 6 years
Rimeikas	391RIM	9601	LV391RIMA10_9601	2 times a day	3 times in 6 years	3 times in 6 years	-	3 times in 6 years
Rimeikas	391RIM	9600	LV391RIMA10_9600	2 times a day	twice in 6 years	twice in 6 years	-	twice in 6 years
Rimeikas	391RIM	9602	LV391RIMA10_9602	2 times a day	-	-	-	-
Rimeikas	391RIM	22653	LV391RIMA10_22653	2 times a day	-	-	-	-
Valka	290VLK	9637	LV290VLKD5_9637	4 times a year	twice in 6 years	twice in 6 years	twice in 6 years	-
Zīļu avots	914	24563	LV914D6_24563	-	3 times in 6 years	3 times in 6 years	-	3 times in 6 years
Aloja	320ALO	9635	LV320ALOP_9635	2 times a day	once every 6 years	once every 6 years	-	-
Aloja	320ALO	9636	LV320ALOP_9636	2 times a day	once every 6 years	once every 6 years	-	-
Seda	240SED	9639	LV240SEDP_9639	-	once every 6 years	once every 6 years	-	-

Annex 5

List of the springs sampled during the WaterAct project

ID number	Name	B	L	Type	Elevation (m asl)	Quaternary cover thickness (m) according to regional model (PUMA)	Specific conduct. (µS/cm @ 25° C)	Bedrock index	Pre-assigned aquifer system	DA predicted aquifer system	Topography-derived watershed area (m2)	Bedrock watershed area (m2)
1	Veskiläte	57.68862	26.89132	Spring	129.2	27.5	481	D_3pl	D_3	D_3	16601	1080074
2	Mõõnoja läte	57.72322	26.81884	Spring	87.4	24.7	356	D_2gj	Q	Q	236125	19841158
3	Saarjärve läte	57.72922	26.52586	Spring	81.5	51.9	469	D_2gj	Q	Q	5601	560137
4	Kaagjärve allikas	57.76632	26.18297	Spring	58.5	35.1	496	D_2br	D_2	D_2	163264	2160822
5	Timmu raviallikas	58.01804	25.57598	Spring	96.0	36.1	245	D_2br	Q	Q	20512	6843831
6	Raudpõllu allikas	58.00412	25.29948	Spring	62.1	6.0	574	D_2br	D_2	D_2	17511	2641740
7	Pikätükümäe allikas	57.65586	27.13237	Spring	201.5	70.3	250	D_3am	Q	Q	34498	79996
8	Puupõlluallikas	57.64254	27.17091	Spring	185.5	38.9	428	D_3pl	Q	Q	35997	999929
9	Vorstimäe allikas	57.65146	27.08879	Spring	237.1	111.4	490	D_2gj	Q	Q	18299	1039958
10	Hutitaja allikas	57.63206	27.05907	Spring	210.8	89.6	538	D_3am	Q	Q	7600	4959800
11	Silmäviiläte 1	57.69252	26.70453	Spring	69.8	17.0	589	D_2gj	D_2	D_2	183742	9561257
12	Silmäviiläte 2 (grifoon)	57.69247	26.70446	Spring	69.8	15.6	656	D_2gj	D_2	D_2	183742	11121457
13	Roobi läte	57.64762	26.63930	Spring	65.9	16.8	370	D_2gj	D_2	D_2	5601	11762590
14	Põrguhavva allikas	57.63642	26.29664	Spring	66.3	30.1	264	D_2gj	Q	Q	90131	2000671
15	Külmläte	57.58292	26.81457	Spring	119.6	53.6	254	D_3am	Q	Q	9801	42721145
16	Laurimäe allikas	57.59401	26.67028	Spring	73.5	12.7	533	D_2gj	D_2	D_2	12202	960161
17	Tundu läte	57.58625	26.64040	Spring	65.6	12.8	960	D_3pl	D_2	D_2	365970	7255031
18	Lilleoru allikas	57.54890	26.56582	Spring	71.9	17.5	690	D_3pl	D_3	D_3	5801	1280280

ID number	Name	B	L	Type	Elevation (m asl)	Quaternary cover thickness (m) according to regional model (PUMA)	Specific conduct. (µS/cm @ 25° C)	Bedrock index	Pre-assigned aquifer system	DA predicted aquifer system	Topography-derived watershed area (m2)	Bedrock watershed area (m2)
19	Korgõssaarõ silmaallikas	57.55647	27.26233	Spring	174.7	28.1	497	D_3slp	Q	Q	6899	3159626
20	Tuurimäe silmaallikas	57.59298	26.73124	Spring	79.0	15.5	472	D_2gj	D_2	D_2	11902	10481264
21	Lättepera allikad	57.57073	27.18956	Spring	177.0	35.8	381	D_3slp	Q	Q	1361274	2719732
22	Viinavabriku allikate seirepunkt	57.61156	27.25587	Spring	177.8	27.6	545	D_3pl	D_3	D_3	21897	2519696
23	Pütsepa allikate seirepunkt	57.62488	27.10287	Spring	214.0	93.4	368	D_3pl	Q	Q	34399	2599862
24	Kitseoru allikate seirepunkt	57.63724	27.01644	Spring	190.0	89.6	469	D_3am	Q	Q	39900	12799597
25	Süvvaoja allikate seirepunkt	57.72830	26.83424	Spring	92.7	40.9	283	D_2gj	Q	Q	106511	7840555
26	Märdeläte	57.72862	26.51029	Spring	86.1	59.0	687	D_2gj	Q	Q	4101	1760439
27	Roodsi-mõtsakunna allikas	57.64576	26.39533	Spring	79.3	57.5	241	D_2gj	Q	Q	15905	4161244
28	Valgemäe allikas	57.60791	26.42762	Spring	59.5	25.6	247	D_2gj	Q	Q	2901	29819909
29	Dauģēnu cirka avots	57.89278	25.01143	Spring	42.3	24.4	173	D_2br	Q	Q	8706	2081484
30	Dikļu avots	57.59752	25.09832	Spring	64.7	98.0	817	D_2br	Q	Q	6104	5924153
31	Dauģēnu dzelzs avots	57.89278	25.01143	Spring	42.3	24.4	317	D_2br	Q	Q	8706	2081484
32	Karogupītes avots	57.81973	24.78800	Spring	43.1	18.6	59	D_2br	Q	Q	8006	80060
33	Gaujienas avots	57.51695	26.38675	Spring	69.4	19.0	655	D_3pl	D_3	D_3	11403	9202939
34	Ģendertu avots	57.88511	24.99535	Spring	40.8	20.0	315	D_2br	Q	Q	7605	720514
35	Gudzonu avots	57.85095	25.00600	Spring	48.1	21.8	386	D_2br	Q	Q	21115	1721229

ID number	Name	B	L	Type	Elevation (m asl)	Quaternary cover thickness (m) according to regional model (PUMA)	Specific conduct. (µS/cm @ 25° C)	Bedrock index	Pre-assigned aquifer system	DA predicted aquifer system	Topography-derived watershed area (m2)	Bedrock watershed area (m2)
36	Iģes velnalas avots	57.89550	24.87745	Spring	48.8	16	192	D_2br	Q	Q	10508	9727032
37	Jaunlīču avots	57.91853	24.94393	Spring	41.7	11.6	412	D_2br	Q	Q	34125	760552
38	Lauvas mutes avots	57.51329	26.39856	Spring	71.5	16.5	681	D_3pl	D_3	D_3	10103	39745605
39	Oliņu avots	57.62026	25.79675	Spring	42.4	29.5	127	D_2br	Q	Q	184930	4625614
40	Oļu alas avots	57.86110	25.01155	Spring	52.6	25.7	420	D_2br	Q	Q	90164	320228
41	Pantenes avots	57.86807	25.21666	Spring	46.0	19.2	667	D_2br	D_2	D_2	12608	43990764
42	Sauleskalna avots	57.56348	26.93486	Spring	237.6	109	412	D_3pl	Q	Q	40002	3680106
43	Ķiršu avots	57.71394	24.52878	Spring	24.4	23.0	477	D_2br	Q	Q	118192	1874668
44	Velnakmens avots	57.86216	25.01626	Spring	42.1	19.5	190	D_2br	Q	Q	45332	440313
45	Velna pēdas avots	57.67062	25.27349	Spring	49.1	17.8	475	D_2br	D_2	Q	51534	1400917
46	Vilkaču avots	57.86296	25.02372	Spring	41.8	14.3	378	D_2br	Q	Q	525572	200142
47	Zāģavots	57.79327	25.97846	Spring	51.3	24.3	487	D_2br	Q	Q	154672	2080960
48	Zilaiskalns avots	57.56691	25.19345	Spring	53.2	22.4	610	D_2br	D_2	D_2	-	4803322
49	Spiģu avots	57.78364	25.56288	Spring	48.4	20.1	240	D_2br	D_2	Q	8805	880514
50	Veselības avots	57.54032	26.70995	Spring	74.6	23.2	466	D_3am	D_2	D_2	23904	-
51	Acu avots	57.54109	26.71339	Spring	75.8	21.7	418	D_3am	D_2	D_2	4201	-
52	Zīļu avots	57.52942	26.70954	Spring	93.6	19.2	520	D_3pl	D_3	D_3	7901	9801173
53	Lauda (10846)	57.66194	26.69821	Well	93.4	29.5	450	D_2gj	D_2	D_2	-	-
54	Liivamäe SK	57.66387	26.68735	Well	88.3	27	271	D_2gj	Q	Q	-	2520468
55	SK04	57.66689	26.70606	Well	95.1	30.6	359	D_2gj	Q	Q	-	2200324
56	Hansi_pk	57.66760	26.69301	Well	90.0	25.4	433	D_2gj	D_2	D_2	-	-
57	M1_spring	57.66691	26.68611	Spring	65.3	13.4	417	D_2gj	D_2	D_2	-	-
58	M1PA6	57.66700	26.68660	Well	67.3	13.4	437	D_2gj	D_2	D_2	-	-

ID number	Name	B	L	Type	Elevation (m asl)	Quaternary cover thickness (m) according to regional model (PUMA)	Specific conduct. (µS/cm @ 25° C)	Bedrock index	Pre-assigned aquifer system	DA predicted aquifer system	Topography-derived watershed area (m2)	Bedrock watershed area (m2)
59	M3_spring	57.66620	26.68520	Spring	64.5	15.9	458	D_2gj	D_2	D_2	-	-
60	Misso (10722)	57.60159	27.23571	Well	193.1	39.3	413	D_3pl	D_3	D_3	-	-
61	Varstu (10890)	57.64497	26.66075	Well	85.3	31.1	517	D_2gj	D_2	D_2	-	-
62	Krabi (13376)	57.60415	26.82508	Well	120.0	44.1	558	D_2gj	Q	D_2	-	-
63	Lüllemäe (11890)	57.75014	26.37472	Well	95.0	69.7	473	D_2gj	D_2	D_2	-	-
64	Ruusmäe (50567)	57.63710	27.08378	Well	235.5	101.7	501	D_3am	D_2	D_2	-	-
65	Kazu Leja spring 1	57.33008	25.33665	Spring	100.1	34	651	D_3pl	D_3	D_3	-	-
66	Kazu Leja spring 3	57.33476	25.33410	Spring	66.5	3.9	705	D_3pl	D_3	D_3	-	-
67	Kazu Leja spring 4	57.33241	25.35686	Spring	94.4	23.8	638	D_3pl	D_3	D_3	-	-
68	Govas alas avots	57.89400	25.00202	Spring				D_2br	D_3	D_3	5604	1240886