Development of a Study on the Establishment of the Klokot (Bihać) Spring Cross-Border Sanitary Protection Zones

FINAL REPORT

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ABBREVIATIONS:

BiH	Bosnia and Herzegovina
EU	European Union
FBiH	Federation of Bosnia and Herzegovina
MAC	Maximum Authorized Concentration
NPPL	See 'PLNP'
PE	Population Equivalent, unit used to define the size of a waste-water treatment plant
PLNP	Plitvice Lakes National Park (also called 'NPPL': National Park Privlice Lakes)
RC	Republic of Croatia
ToR	Terms of Reference
UNESCO	United Nations Educational Scientific and Cultural Organization
UF	Ultra Filtration
WB	World Bank
WBIF	Western Balkans Investment Framework
WFD	Water Framework Directive (European Union Directive)
WWTP	Wastewater Treatment Plan

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1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Klokot and Privilica springs are used to supply the City of Bihać in the Federation of Bosnia and Herzegovina (BiH) with potable water. Protection of this spring is of great importance for the Municipality of Bihać. The overview map in Annex 1 shows the City of Bihac and the Klokot and Privilica springs catchment area.

The estimated size of the catchment area of Klokot and Privilica is 951.5 km^2. About 90% of the catchment area is in the territory of the Republic of Croatia (RC), and only 10% is in the territory of Bosnia and Herzegovina. Several existing and potential polluters in the catchment area were foreseen to need to be either removed or remediated.

A need to protect Klokot and Privilica springs and more specifically to establish sanitary protection zones within the catchment area of the Klokot and Privilica springs, that is to say in the territories of both countries: the Republic of Croatia and the Federation of Bosnia and Herzegovina was identified. The different legal frameworks from the two afore mentioned countries must be considered to define the establishment of sanitary protection zones.

The objective of the assignment is to assist the FBiH and the RC to develop a Study on the Spring Sanitary Protection Zones (the Study), to provide baseline for (i) the establishment of the boundaries of the catchment area, and (ii) recommendations for the protection of the Klokot and Privilica springs.

Key Project Details

The key project details are summarized below:

Project Objective	The objective is the Development of a Study on the Establishment of the Klokot-Bihać Spring Cross-Border Sanitary Protection Zones
Time Schedule	12 months (September 2019 – August 2020)
Project Partners & Stakeholders	• Western Balkans Investment Framework • Water Supply Ltd. Bihać (JP „Vodovod“ doo Bihać) • Sava River Watershed Agency • Croatian Waters (Hrvatske vode) • FBiH Ministry of Agriculture, Water Management, and Forestry • Ministry of Construction, Spatial Planning and Environmental Protection of the Una Sana Canton (MCSPEP USC)
Activities	The activities cover the following areas: • Catchment Area and Protection Zones • GIS and mapping • Legal Framework • Water Quality • Identification of Polluters • Mitigation Measures
Consulting Services	HOLINGER AG, Zurich UNA Consulting LLC, Bihac Hidroinženjering d.o.o, Zagreb

Project management and consultancy team

The Consultant's team is composed of the following firms:

- HOLINGER AG, Zurich, Switzerland as the leading company, together with sub-consultants:
- Resource Centre and Consultancies for Water and Environment “UNA Consulting“LLC, Bihac, Bosnia-Herzegovina, and
- Hidroinženjering d.o.o., Zagreb, Croatia.

1.2 DESCRIPTION OF THE WATER INTAKE AT KLOKOT SOURCE

Klokot water source is the most important water source in the water supply system of the city of Bihać. It is located about 5.5 km from the city centre in the northwest-west direction.

The water source of Klokot erupts from a karst cave at the foot of the Željavski plateau, i.e. the Baljevac field, forming a watercourse of the same name which flows into the river Una. In addition to the main water source in the immediate vicinity there is another water source Klokot 2 which is used for the needs of the pond.

According to the basic characteristics, the Klokot water source is a typical karst spring that is fed from a catchment area built mainly of carbonate rocks with crack and fissure-cavernous porosity.

***Photo**: Spring Klokot*

Water intake at the spring is made by means of a concrete water intake facility located next to the water source. The water intake facility has two entrances with protective grilles and plate closures. There are two chambers, a collection chamber in which the suction basket of the transport pipeline is located, and a closing chamber. The level of water deceleration in the water intake facility is 216.60 m above sea level, which is provided by a concrete barrier in the Klokot riverbed, whose crown is at the level of 216.40 m above sea level.

The affected water is gravitationally delivered from the water intake to the collection chamber of the Klokot pumping station, by asbestos-cement pipeline (ACC) profile 1000 mm at the length of 213 meters.

The pumping station facility was built on the left bank of the Klokot River, downstream from the water intake. The pumping station was constructed as a solid masonry structure and a collection (pumping) chamber was constructed behind it. The elevation of the bottom of the chamber is 214.05 m above sea level. The water intake area and pumping station with access road are located inside the fenced area.

From the pumping station, the water is directed in two directions (reservoirs). In the first direction, the water is directed to the Komarac reservoir with two pumps with a capacity of 150 l / s, and from there it is further delivered to the water network. With the other two pumps with a capacity of 40 l / s (working and reserve pump), the water is directed towards the Klokotska glavica reservoir, i.e. towards the settlements in the north-western part of the city of Bihać. The two pumps, which were used to transport water to the Željava military complex, are no longer operational.

1.3 CATCHMENT AREA AND PROTECTION ZONES

1.3.1 GEOLOGICAL AND HYDROGEOLOGICAL CHARACTERISTICS OF THE CATCHMENT AREA

Geological Characteristics of Rocks

The greater catchment area of the Klokot and Privilica sources is built of Mesozoic and Cenozoic sediments which form very complex tectonic relationships, and in turn affect the hydrological relationships within the catchment area. The oldest formations in the terrain date back to the Lower Triassic period (T_1).

Tectonic Framework of the Terrain

Tectonic structure of the area under investigation is very complex. The area under investigation is largely built of carbonate rock which underwent significant structural deformations as a result of tectonic movements in the geologic past. Other important structural elements are faults which are the boundaries between the blocks, namely structural units. Larger faults and boundaries between the structural blocks are mainly of Dinaric-striking orientation, while local faults and fault zones within the structural framework of the terrain have various orientations.

1.3.2 Hydrogeological characteristics of the catchment area

Hydrogeological Types of Rocks

According to the lithological composition, structure of porosity, spatial arrangement of the identified geological units and water-permeability of rocks and deposits, the following hydrogeological environments have been identified: permeable clastic deposits, poorly permeable clastic deposits, highly permeable rocks with fissure and cavernous porosity, moderately permeable rocks with fissure porosity, poorly permeable rocks with cavernous porosity, impermeable clastic deposits.

Hydrogeological Functions of the Terrain

Lithological properties of the rocks present in the area, their hydrogeological characteristics, structural relationships, spatial arrangement and geometry of geological bodies and morphology of the terrain condition the hydrogeological function of specific parts of the area. Considering the earlier mentioned elements, it was possible to identify hydrogeological barriers and a permeable area within the Klokot source catchment area in the area under consideration presented in the hydrogeological map. ***Hydrogeological barriers*** in the area under investigation include parts of the terrain in predominantly folding anticlinal structures, parts built of impermeable deposits, and regional reverse faults for which there is evidence of structural compression. ***Permeable area*** built of limestones and to a lesser degree of dolomites, occupies the greatest surface in the area under consideration. In this type of terrain, permeable, secondary fractured and karstified carbonate rocks drain, without significant limitations, all precipitation into the underground and ensure underground outflow. It is especially evident in the major fault zones and in the terrain of pronounced karst morphology (ponors, holes, pot-holes, *dolines*). Either there is no surface runoff, or the water courses are insignificant and gradually disappear or directly flow into the ponor. All the water which does not return into the atmosphere by evaporation sinks very quickly into the karst underground. ***Relative barriers*** take up a smaller part of the terrain within the permeable area, where they locally direct groundwater flows.

1.3.3 Overview of the conducted groundwater flow tracings

From 1968 until today, tracing has been carried out in the basin of the Klokot and Privilica springs for the purpose of determining groundwater connections, as well as apparent groundwater flow velocities in the basin, in order to determine the protection zones of these springs. For the purposes of this study, during 2020, three additional Traces were performed.

1.3.4 Defining the hydrogeological catchment of Klokot and Privilica

In the area under consideration, water formation and travel are in direct connection with the lithostratigraphic terrain structure, structural and tectonic relationships and hydrogeological characteristics of rocks. The protection zone boundary is estimated and marked on the map by a continuous line. Considering that the largest part of the terrain is formed of significantly karstified carbonate deposits, the position of the depicted watershed should correspond to the zonal watershed, where the position may significantly vary due to the complex hydrogeological structure of the terrain or because of the changes in groundwater levels.

The results of groundwater flows tracings were the most reliable inputs for defining the sanitary protection zone boundary, that is, for establishing to which protection zone a part of the terrain belongs. Groundwater flow tracings are particularly important for delineation between the Adriatic and Black Sea basins in the west (the Krbavsko Polje to Plitvice) and in the area of the “hanging course” of the Korana River. The south-eastern part of the protection zone (between Privilica and the Krbavsko Polje) is least covered with tracing, so this is where the greatest departures from the position of the watershed – protection zone boundary are possible.

The surface area of the catchment which gravitates towards the springs along the Bihaćko Polje edge amounts to 951.5 km^2. The catchment area around the Plitvice Lakes is the area where the catchment border is of zonal character. The waters from this part of the catchment, even though in lesser part, flow towards the springs located along the Bihaćko Polje. The surface area of this part of the catchment is 218,68 km^2. Therefore, total size of the Klokot and Privilica springs hydrogeological catchment area is 951.5 km^2. Of this area, 90.5 km^2 is situated in Bosnia and Herzegovina while 861 km^2 is in Croatia. From all the above said and described, it follows that there is a significant expansion of the protection zone compared to the protection zone determined by the Study from 2004.

1.3.5 Proposed sanitary protection zones boundaries

The Recommendation for sanitary protection zones for the Klokot and Privilica sources was prepared according to the Draft rulebook on conditions for the establishment of sanitary zone protection water source zones with distribution of water from aquifers with crack and crack-cavernous porosity in the border area of Bosnia and Herzegovina and Republic of Croatia. Sanitary protection zones for sources with abstraction of water from aquifers with fissure and fissure-cavernous porosity are:

- restricted zone – Zone IV,
- restriction and surveillance zone – Zone III,
- zone of strict restriction and surveillance – Zone II,
- zone of strict protection and surveillance regime – Zone I.

Sanitary protection zones of the karst aquifers in the border area between Bosnia and Herzegovina and the Republic of Croatia are determined according to the criteria from the Table 1.1.

Table 1.1: *Criteria for determination of sanitary protection zones in karst aquifers*

<table>
<tr><th></th><th>PROTECTION ZONE</th><th>GROUNDWATER FLOW TOWARDS THE WELL FIELDS</th><th>APPARENT GROUNDWATER VELOCITY, cm/s</th><th>REQUIRED HYDROGEOLOGIAL MAPS</th></tr>
<tr><td rowspan="2">ZONE OF STRICT PROTECTION AND SURVEILLANCE REGIME</td><td>I A</td><td>IMMEDIATE WELL FIELD AREA</td><td>TO BE FENCED</td><td>SCALE 1:1,000</td></tr>
<tr><td>I B</td><td>IMMEDIATE CATCHMENT AREA (surface inflow from area around the source)</td><td>TO BE MARKED</td><td>SCALE 1:1,000</td></tr>
<tr><td>ZONE OF STRICT RESTRICTION AND SURVEILLANCE</td><td>II</td><td>24 HOURS</td><td>CATCHMENT DRAINAGE ZONE > 3 cm/s</td><td>SCALE 1:25,000</td></tr>
<tr><td>RESTRICTION AND SURVEILLANCE ZONE</td><td>III</td><td>1-10 DAYS</td><td>1-3 cm/s
PRESUMED RETENTION ZONE</td><td>SCALE 1:50,000</td></tr>
<tr><td>RESTRICTED ZONE</td><td>IV</td><td>10-50 DAYS</td><td>< 1 cm/s</td><td>SCALE 1:50,000</td></tr>
</table>

Zone of Strict Protection and Surveillance Regime – Zone I

The boundaries of the zone of strict protection and surveillance regime – Zone I are stipulated by Article 20 of the Rulebook.

The zone of strict protection and surveillance regime (Zone I A) for the Klokot spring encompasses the Klokot Pumping Station site and a belt along the left bank of the Klokot upstream to the intake structure. The Protection Zone I A of the Privilica spring encompasses an area accommodating intake structure and other facilities for water intake and conveyance from the spring to the water supply network. In addition to the Klokot and Privilica sources, Protection Zone I A also protects a ponor detected at the Vučjak Landfill site. An area of the Protection Zone I B for the Klokot and Privilica springs runs from the Zone I A boundary and encompasses the immediate surface catchment around the spring, i.e. the surface floodplain surrounding the spring.

Zone of Strict Restriction and Surveillance – Zone II

The boundary of the Sanitary Protection Zone II for the Klokot and Privilica springs was determined using the flow through the aquifer to the water intake lasting up to 24 hours as a criterion. An additional criterion was used for ponors and ponor zones according to which, in case points of collection and runoff of water towards the source (ponor zones) are situated within the boundaries of Zone IV or Zone III, such areas will be defined as Sanitary Protection Zone II. In the Klokot and Privilica spring catchment, the ponors contoured as Sanitary Protection Zone II are: Prijeboj ponor, Korenička Rijeka ponor, and Vidrovac ponor.

Restriction and Surveillance Zone – Zone III

The Sanitary Protection Zone III of sources with the abstraction of water from aquifers with fissure and fissure-cavernous porosity encompasses parts of the catchment from the outside boundary of the Zone II to the boundary from which the flow is possible through the underground to the water intake in the period from 1 to 10 days in high water conditions, i.e. areas from which apparent groundwater velocities of 1 to 3 cm/s have been determined, namely the area covering the predominant part of the catchment. The outside boundary of the Protection Zone III mainly follows the outside boundary of the Klokot and Privilica spring hydrogeological catchment, except in the south and south-west part where it borders the Protection Zone VI, and at the foot of Mt. Plješivica where it borders the Sanitary Protection Zone II.

Restricted Zone – Zone IV

In the observed area of the Sanitary Protection Zone IV, the areas in the catchment have been singled out in the south and southwest part of the Klokot and Privilica spring catchment that have not been sufficiently explored so far.

Restriction Zones in the Plitvice Lakes National Park

According to the guidelines from the *"Plitvice Lakes National Park Management Plan 2019 - 2028"*, the area of the National Park is divided into three management zones: I – strict conservation zone, II – active management zone and III – sustainable use zone. According to the Rulebook on sanitary protection zones, the Prijeboj ponor area is within the Sanitary Protection Zone II although it is situated within the boundaries of the Plitvice Lakes National Park and within the Plitvice Lakes Zone I.

In the case of the Klokot and Privilica basins, the said area, according to the criteria for sanitary protection zones, belongs to the II sanitary protection zone - Prijeboj ponor and the III sanitary protection zone - the rest of the national park, however while the said area is treated as a protected area it applies zones within the National Park that are stricter than the measures prescribed within the II and III zones of sanitary protection apply to it.

The areas occupied by specific sanitary protection zones in the Klokot and Privilica catchment in the territories of the Republic of Croatia and Bosnia and Herzegovina are given in Table 1.2.

Table 1.2: *Areas of specific sanitary protection zones in the Klokot and Privilica catchment*

	Protection zone	Area of specific protection zone related to the hydrogeological catchment area		Area of specific sanitary protection zones in Bosnia and Herzegovina		Area of specific sanitary protection zones in the Republic of Croatia	
		(km²)	(%)	(km²)	(%)	(km²)	(%)
ZONE OF STRICT PROTECTION AND SURVEILLANCE REGIME	I A	0.05	0.01	0.06	100.00	-	-
	I B	0.15	0.02	0.15	100.00	-	-
ZONE OF STRICT RESTRICTION AND SURVEILLANCE	II	37.09	3.90	23.94	64.54	13.15	35.46
RESTRICTION AND SURVEILLANCE ZONE	III	842.60	88.55	66.35	7.87	776.25	92.13
RESTRICTED ZONE	IV	71.60	7.52	-	-	71.60	100.00
PLITVICE LAKES NATIONAL PARK		218.68	22.98			218.68	100.00
		Total hydrogeological catchment area		Hydrogeological catchment area in Bosnia and Herzegovina		Hydrogeological catchment area in the Republic of Croatia	
		(km²)	(%)	(km²)	(%)	(km²)	(%)
		951.5	100	90.5	10	861.0	90

The Klokot Stream Observation and Measurement Hydrological Analysis

The Klokot Hydrological Observing Station (HOS) on the Klokot stream was reconstructed in 2003. Daily water level and discharge data has been published in Federal Hydrometeorological Institute (FMZ) Hydrological Yearbooks since 19 March 2005. The series of daily water levels and discharges available for this analysis cover the period from 19 March 2005 to 31 December 2014 (with measurement interruption between 5 January and 31 March 2010).

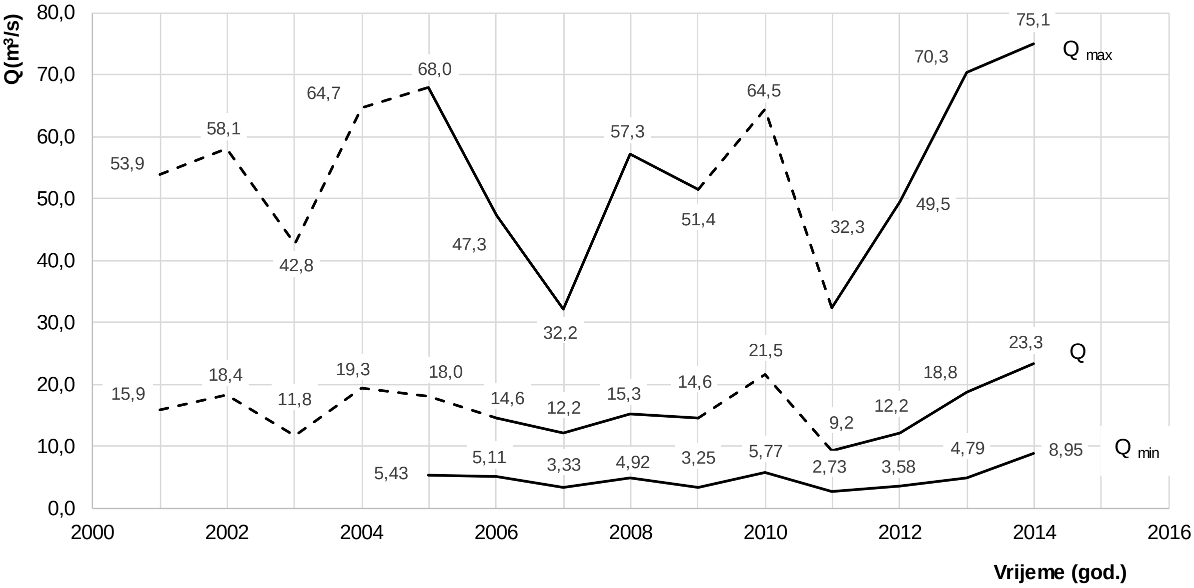
The missing Klokot mean monthly and mean annual discharges, and maximum annual discharges at the Klokot profile were defined by adequate procedures described and elaborated in section 4.3 Hydrogeological Characteristics. The series of mean annual and maximum annual discharges could have been extended; thus the series are defined for the period (2001-2014).

The Klokot influential basin area to the Klokot profile is: $\boldsymbol{A}$ = 951.5 km^2. It should be noted that, in addition to the Klokot spring, a much smaller portion of water is rising at the other springs: Privilica spring (from which 120 l/s is abstracted for water supply), Žegar, Smiljanovac, Duparica, Gata, etc. An area $\boldsymbol{A_{RH}}$ = 861 km^2 or 90 % of the catchment is located in the Republic of Croatia, and $\boldsymbol{A_{BiH}}$= 90.5 km^2 or 10 % in Bosnia and Herzegovina.

The Korenica and Plitvice Lakes Weather Stations are situated in the catchment in Croatia, and the data for several years is missing within the period 2005-2014, while the daily precipitation data is available from the Bihać Weather Station in Bosnia and Herzegovina. The analyses indicated a firm correlation between the annual precipitations recorded at the Bihać station and the Klokot mean annual discharges at the Klokot profile.

Figure 1.1 shows mean $\boldsymbol{Q}$, maximum $\boldsymbol{Q_{max}}$ and minimum $\boldsymbol{Q_{min}}$ annual discharges for the Klokot at the Klokot profile in the period (2001-2014). The discharges obtained by completion of data are marked with broken line.

***Figure 1.1**: Maximum $\boldsymbol{Q_{max}}$, mean $\boldsymbol{Q}$ and minimum $\boldsymbol{Q_{min}}$ annual discharges of the Klokot at the Klokot profile in the period (2001-2014)*



The hydrographs of the mean monthly flows in Figure 2 show the distribution of water by days. In average years, the inflows of Klokot are weaker from June to September, in dry years the water content is weaker from June to November, and in the wet year only from June to September (with much higher flows than the average of the dry year).

Figure 1.2 shows hydrographs and flow-duration curves for the Klokot mean daily discharges at the Klokot profile in characteristic years from the period (2005-2014), i.e. approximately average 2008, dry 2011 and humid 2014.

During the ten-year period (2005-2014), maximum discharge $\boldsymbol{Q_{max}}$= 75.1 m^3/s occurred and was recorded at the Klokot Hydrological Observing Station on the Klokot profile on 13 September 2014, mean discharge for the period (2005-2014) is: $\boldsymbol{Q}$ = 16.0 m^3/s, and minimum discharge of $\boldsymbol{Q_{min}}$= 2.73 m^3/s occurred and was recorded at the Klokot Hydrological Observing Station on the Klokot profile on 2 December 2011 (which is multiple times higher than maximum inflows used in water supply)..

Figure 1.2: *Hydrographs and flow-duration curves for the Klokot mean daily discharges at the Klokot profile in characteristic years: approximately average 2008, dry 2011 and humid 2014 – Source: FMZ Hydrological Yearbooks for 2008, 2011 and 2014*

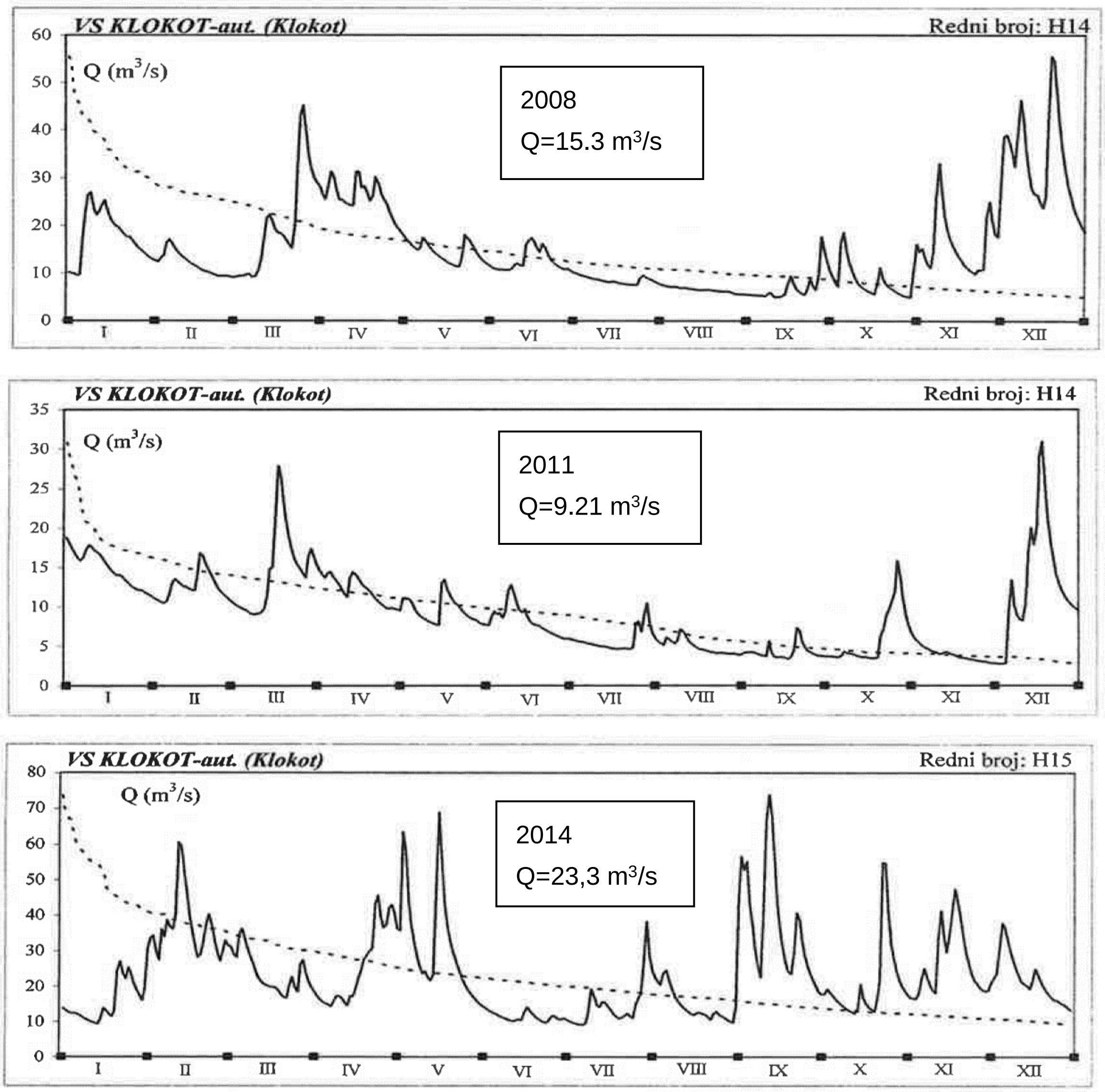


Table 1.3 is an overview of annual precipitation with different return periods for the Bihać Weather Station P_{Bp}, and the Klokot mean annual discharges Q_p, maximum annual discharges Q_{maxp} and minimum annual discharges Q_{minp} with different return periods for the Klokot profile.

Table1.3: *Annual precipitation with different return periods at the Bihać Weather Station* P_{Bp} *and the Klokot mean annual discharges* Q_p*, maximum annual discharges* Q_{maxp} *and minimum annual discharges* Q_{minp} *with different return periods at the Klokot profile.*

Probability of occurrence ***p*** (yrs)	P_{Bp} (mm)	Q_p (m^3/s)	Q_{maxp} (m^3/s)	Q_{minp} (m^3/s)
(1)	(2)	(3)	(4)	(5)
10,000	2596	30.8	94.0	-
1000	2375	28.3	88.5	1.91
100	2117	25.2	81.3	2.08
50	2029	24.1	79.3	2.38
25	1930	23.1	74.5	2.54
10	1785	21.1	70.4	2.89
5	1652	19.4	65.5	3.32
2	1417	16.1	55.6	4.45
n	10	14	14	10
D_N	$0.13 < D_0 = 0.41$	$0.12 < D_0 = 0.35$	$0.10 < D_0 = 0.35$	$0.11 < D_0 = 0.41$

In this case, because of significant bifurcations in the most part of the catchment, runoff coefficient values are no actual indication of the runoff in this karst area. Based on previous analyses and empirical values, the adopted runoff coefficient is: $c_1 = 0.63$. In analysis from 2004, for the catchments area of $A_1 = 686.5$ km^2 the runoff coefficient was: $c_2 = 0.50$. In the present analysis, for influential basin with area of $A = 951.5$ km^2, mean discharge: $c = 0.37$; for humid year: $c_d = 0.40$, and for dry year $c_h = 0.35$. It should be noted that the runoff coefficient values are defined for a catchment area of: $A = 951.5$ km^2 and the Klokot inflows at the Klokot profile – which are dominant over other sources – whose impact is evaluated as 3 – 5 % of the Klokot inflow.

There is almost no bed load on the Klokot, while the suspended sediment, namely water turbidity due to bacteria bonding with very fine particles of such sediments pose a special problem when water is used for water supply of Bihać. Out of 514 measurements of the Klokot source turbidity carried out between 27 March 2006 and 21 May 2020, in 106 cases turbidity was $M > 4.0$ NTU, and in 20 it was $M > 4.0$ NTU. It should be noted that during the last three years (according to the measurements carried out from 6 March 2017 to 21 May 2020) the situation has degraded, so there were 36 cases of: $M > 1.0$ NTU, and 8 cases of: $M > 4.0$ NTU. The highest turbidity was measured on 14 May 2019, and it was: $M_{max} = 26.0$ NTU even at high 6-year return period discharge: $Q_{max.6y} = 64.1$ m^3/s.

1.4 GIS AND MAPPING

The collected existing and newly processed data necessary for the implementation of the determination of sanitary protection zones of the Klokot spring are organized according to the principles of the Geographic Information System (GIS) and are stored in the form of Esri File Geodatabase. For all spatial layers, the MGI Balkan 5 coordinate system was defined, which can be transformed into the coordinate systems used in the Republic of Croatia (HTRS96/TM) and Bosnia and Herzegovina (MGI_Balkan_6). For the purpose of data processing, analysis, modelling and making cartographic representations, maps, cartographic compositions were made with ArcGIS Desktop software. The organization and storage of data requires the definition of a standard structure. Structured data are a prerequisite for quality use in the implementation of all tasks, in monitoring changes, and for the transfer and use of data within other systems. Accordingly, we created a standard spatial database for all thematic layers that will be transferred and loaded into multi-user databases (SDE Enterprise Geodatabase) of the FBIH Water Agencies. The database is structured in accordance with the EU Water Framework Directive (WFD), the INSPIRE Directive, the Water Information System (WIS) in the FBIH and professional requirements. The mentioned GIS database model called PA_D (Protected Area - Drinking Water) contains spatial layers and tables that are hierarchically organized and interconnected with relational classes. The content and structure of the created Geodatabase are extensible and depend on specific needs.

1.5 LEGAL FRAMEWORK

The catchment area with the sanitary protection zones of the Klokot water source is located in the border zone between Bosnia and Herzegovina and the Republic of Croatia, and for its protection it is necessary to establish interstate cooperation and work together to protect the water source in the long run. For this purpose, it is necessary to analyse the existing regulations in the two countries, determine how the establishment of sanitary protection zones is regulated, highlight possible advantages and disadvantages, and based on that make recommendations for improving bylaws that would contribute to long-term protection of Klokot and Privilica water source.

Accordingly, for the needs of the project Preparation of a Study on the Establishment of Cross-Border Sanitary Protection Zones of the Klokot Water Source (Bihać), the relevant laws and bylaws of the Federation of BiH and the Republic of Croatia were collected and analysed, as well as previously prepared available study for drinking. Furthermore, the Consultant processed and analyzed the relevant international regulations related to transboundary aquifers, namely the Convention on the Protection and Use of Transboundary Watercourses and International Lakes - the Water Convention, as well as UN Resolutions 66/104, 68/118, 63/124 which contain provisions on the law on transboundary aquifers.

The collected documents were processed and analysed, a comparison was made and the shortcomings and advantages of the legislative frameworks in BiH and the Republic of Croatia were defined, and based on that, appropriate recommendations were given for improving the current legal framework for both countries.

The document of the Recommendation of the Protection System and research methods for the protection of karst aquifers in the border areas of Bosnia and Herzegovina and Croatia, which was submitted to the Consultant for the Study for the Establishment of Cross-Border Sanitary Protection Zones of the Klokot Water Source (Bihać, BiH). This document is a product of the work of the Interstate Commission for Cross-Border Areas of BiH and the Republic of Croatia and offers a good basis for regulating the protection of drinking water sources in karst aquifers in the border areas of BiH and the Republic of Croatia.

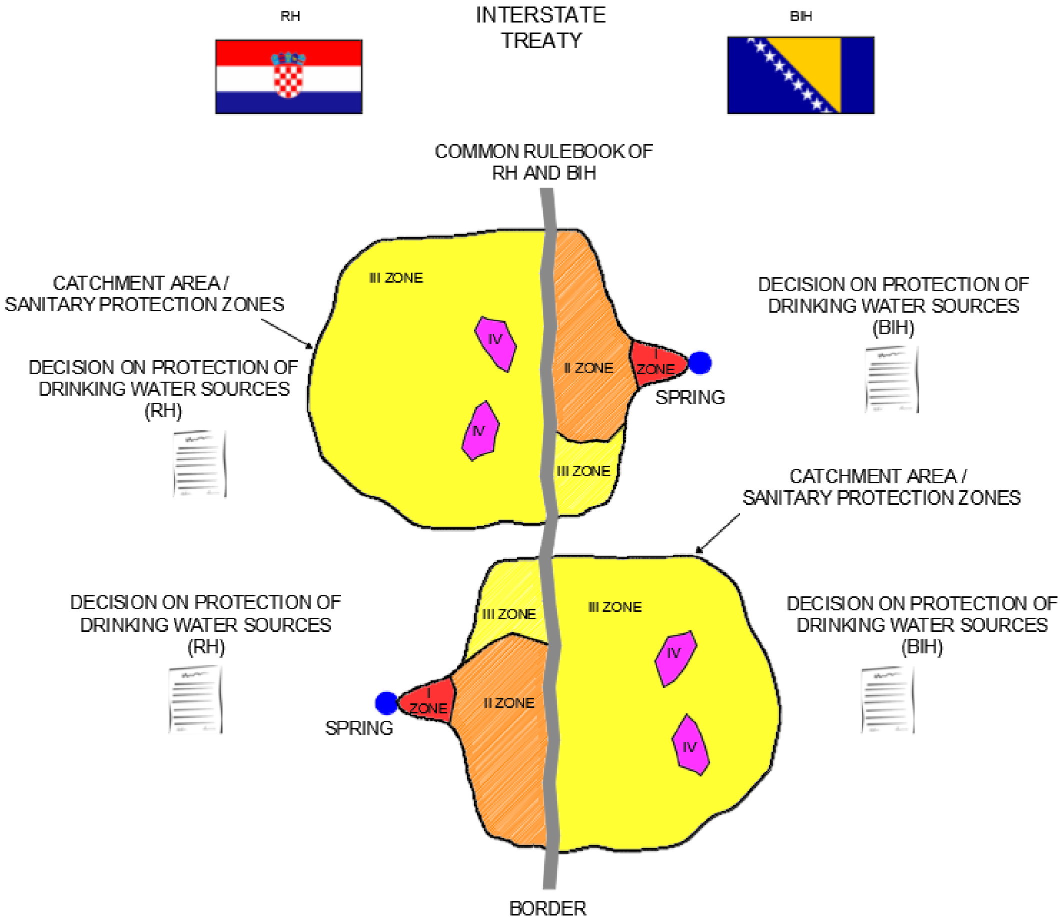
The task of the Consultant was to help the beneficiary countries of the project (BiH and the Republic of Croatia) to improve the mentioned documents, ie to make recommendations for the establishment of future cooperation between BiH and the Republic of Croatia on the protection of underground watercourses crossing the state border.

Based on the conducted analysis, the Consultant defined solutions and mechanisms for improving the legal framework and implementing key principles of cooperation on the protection of water sources in karst aquifers in the border area of BiH and the Republic of Croatia. The Consultant gave proposal for the preparation the necessary interstate documents to improve the existing legal framework regarding the definition of catchment areas and the establishment of sanitary protection zones for water sources in karst aquifers in the border area of BiH and the Republic of Croatia.

The following interstate documents have been proposed:

- Proposal for the Development of Protection System and Investigation Methods for Protection of the Karstic Aquifers in the Border Areas of Bosnia and Herzegovina and the Republic of Croatia (improved Recommendation with recommendations),
- Proposal for the Development of the Interstate Agreement between the Council of Ministers of BiH and the Government of the Republic of Croatia on rights and obligations in the protection of karst aquifers in the border areas of BiH and the Republic of Croatia
- Proposal for the Development of Rulebook on conditions for the determination of zones for sanitary protection of water sources from the aquifers with cracks and fissure-cavernous porosity in the border area of Bosnia and Herzegovina and the Republic of Croatia;
- Proposal for the Development of Decision on protection of drinking water sources (Decision on protection of drinking water sources in karst aquifers in the border areas of BiH and the Republic of Croatia).

The figure below shows the mechanisms of cooperation that need to be established according to the mentioned Recommendations of interstate documents in order to jointly define catchment areas and sanitary protection zones in karst aquifers in the border area of BiH and the Republic of Croatia.



The proposed solutions establish common mechanisms and obligations for both countries to address the issue of protection of karst aquifer sources in the border area without any additional (special) interventions in their existing legislation.

The proposition of Interstate Agreement defines the roles and responsibilities of the competent institutions for the implementation of the Agreement, the competencies for implementing the proposed measures for protection of springs on both sides of the border and the creation of preconditions for the smooth and functional work of the interstate commission, which should be responsible for monitoring and taking improvement measures if the protection measures defined by the Agreement (and its annex) are not respected.

The proposed solution is a good example in the efforts of both countries to permanently resolve the issue of protection of water sources in karst aquifers in the border area and can be used in terms of protection of all other sources in the cross-border area of FBiH and RC.

1.6 WATER QUALITY AT THE KLOKOT SPRING

Between 2004 and 2020, in order to implement the project “Development of a Study on the Establishment of the Klokot (Bihać) Spring Cross-Border Sanitary Protection Zones”, the Consultant gathered a large number of reports (results), regular (basic) and periodic ones, containing analyses of the Klokot spring water quality. The reports were made for the PUC “Vodovod” Bihać by Public Health Institute of Una-Sana Canton (PHIUSC), Institute for Public Health of Canton Sarajevo (IPHCS), and, on several occasions, by Croatian Institute of Public Health, Zagreb (CIPH). Apart from that, on several occasions during the period of project implementation and in cooperation with certified laboratories (PHIUSC and CIPH), the Consultant organized the sampling of water at the Klokot spring itself, but also at several sinkholes in its catchment area, thus obtaining laboratory reports on water quality with more than 100 parameters. All the reports made by the certified laboratories from both countries contain basic, periodical or extended physicochemical and microbiological water quality analysis results.

Between January and July 2020, the Consultant installed a special probe (Aquaprobe 2000) to automatically measuret of 10 water quality parameters at the Klokot spring, thus establishing temporary project water quality monitoring, and all the reports (results) on the regular water quality monitoring were entered into a dedicated database.

Additional data about water quality at several sinkholes within the Klokot spring catchment area was collected by the Consultant using a mobile probe (Aquaprobe 2000) which also measures 10 water quality parameters, and all the results were also entered into the dedicated database.

Additionally, Water Agency of Croatia gave the Consultant reports (results) on water quality for the water taken from the two boreholes which were drilled at the border between the Republic of Croatia and Bosnia and Herzegovina in the area of the former military airport Željava. All the gathered reports (findings) are appended to the Study on the Establishment of the Klokot (Bihać) Spring Cross-Border Sanitary Protection Zones.

All the collected reports (results) on water quality in the Klokot catchment area were processed and analyzed in detail by the Consultant. The total numbers of processed and analyzed reports (results) are: 517 for physicochemical analysis of water quality; and 474 for microbiological analysis of water quality. Out of the latter, 399 were reports (results) on basic, and 75 were reports (results) on periodic analysis of water quality at the Klokot spring. It should be noted that in the last few years, PUC “Vodovod” Bihać has been conducting physicochemical and microbiological analyses, on average, twice a month which is considered to be more than inadequate for the spring which supplies more than 50,000 people of the city of Bihać.

Physicochemical analyses of the water samples taken from the Klokot spring in the course of this protection project show that the water, according to the parameters investigated, in most cases, fulfills the conditions set in the Rules on Health Safety of Drinking Water (Official Gazette of Bosnia and Herzegovina, No. 40/10, 43/10 and 62/17). However, many of the samples analyzed in the last 5 years show tendency of water quality deterioration at the spring itself.

In the processing and analysis of the **physicochemical** parameters of water quality, the following deviations from the maximum allowable concentrations in drinking water were noted:

- significant and often increase in the value of turbidity,
- occasional increase of values indicating an increased consumption of oxygen, and
- only in a few cases, occasional increase of ammonium concentration above the maximum allowable concentrations in water.

After taking into consideration all the physicochemical analyses of water quality conducted at the Klokot spring, it can be concluded that the main reason for water being unacceptable, in almost 100% cases, is the water turbidity exceeding the maximum allowable concentration (MAC = 1,0 NTU) In the processing and analysis of the **microbiological** parameters of water quality, the following deviations from the maximum allowable concentrations in drinking water were noted:

- significant and frequent presence of Coliform bacteria,
- significant and frequent presence of Escherichia coli bacteria,
- significant and frequent presence of Enterococcus bacteria (fecal Streptococcus),
- presence of Clostridium perfringens bacteria.

After taking into consideration all the microbiological analyses of water quality conducted at the Klokot spring, it can be concluded that due to the increasing number and types of bacteria not allowed in drinking water, 100% of the periodically conducted water quality analyses did not conform to the standards set in the current Rules on Health Safety of Drinking Water in Federation of Bosnia and Herzegovina. In addition, 11% of the basic analyses did not conform to the standards set in the Rules due to the increased number and types of bacteria which are not allowed.

According to these results, raw water at the Klokot spring is bacteriologically contaminated and does not conform to the sanitary and epidemiological requirements. Bacteriological analyses, which are part of the regular water quality monitoring performed by PUC "Vodovod" Bihać at the Klokot spring, indicate bacteriological irregularity of water. It is necessary to emphasis that a considerable number of water quality analyses are performed with samples of chlorinated water (taken at the Klokot Pump Station immediately after disinfection), which is not in accordance with the conditions set in Rules on Health Safety of Drinking Water. However, it is an alarming fact that anthropogenic bacteria not allowed by the Rules were found even in the chlorinated water in the distribution network (11% of the samples), and showing that chlorine water treatment is not effective, and that bacteriological contamination in the Klokot spring water cannot always be removed by chlorine disinfection.

One factor which significantly contributes to the deterioration of the microbiological quality of water at the Klokot spring is a significant increase of human activity in the Klokot spring catchment area, especially through the intensification of tourist visits to Plitvice Lakes National Park, as visible from the rapidly growing number of nights spent in that area in the last 5 years.

Microbiological analysis of water quality was conducted for water samples collected at three locations in the Republic of Croatia, namely, at Rastovače karstic hole, Korenica sinkhole, and at Prijeboj stream sinkhole, for which the connection to the Klokot spring had been established by tracing. Through the analyses of quality, the presence of many bacteria was demonstrated in the water which sinks in Croatia and reappears at the Klokot spring.

By analyzing these correlations, especially for the period of 2015 – 2020 and for the parameters whose values were above MAC, more frequent occurrence of pollution was established, but there is also an additional increase in the values of parameters which indicate such pollution.

According to a research conducted in 2016, Plitvice Lakes National Park is annually visited by 1.3 million people. The highest concentration of tourists in the National Park occurs during the tourist season from April to October, with more that 64% of visitors coming in July, August and September. During the season, daily number of tourists reaches 15,000, and according to the statements made by the management of Plitvice Lakes National Park the optimal number would be around 8,000. Along with the increase of the number of tourists in the last 5 to 7 years, there was also an increase in the need to build new tourist facilities. Building of hotels and apartments through private initiative contributed to the increase of activities in the Klokot spring catchment area, which had direct impact on the deterioration of raw water quality at the Klokot spring. Unfortunately, construction of tourist facilities was not followed by adequate construction of a wastewater collection and treatment system, or proper construction of septic tanks at places where there is no public sewerage system.

The results of conducted water quality physicochemical and microbiological analysis at different flows, show a tendency of pollution of surface and underground waters which come mainly from the Republic of Croatia to the Klokot spring, however there is a small number of polluters which are coming from territory of BiH.

This situation is mostly caused by the hydrological occurrence of high water and anthropogenic influence from the Plitvice Lakes National Park where an increased number of tourist visits is recorded, which is followed by rapid construction of tourist facilities.

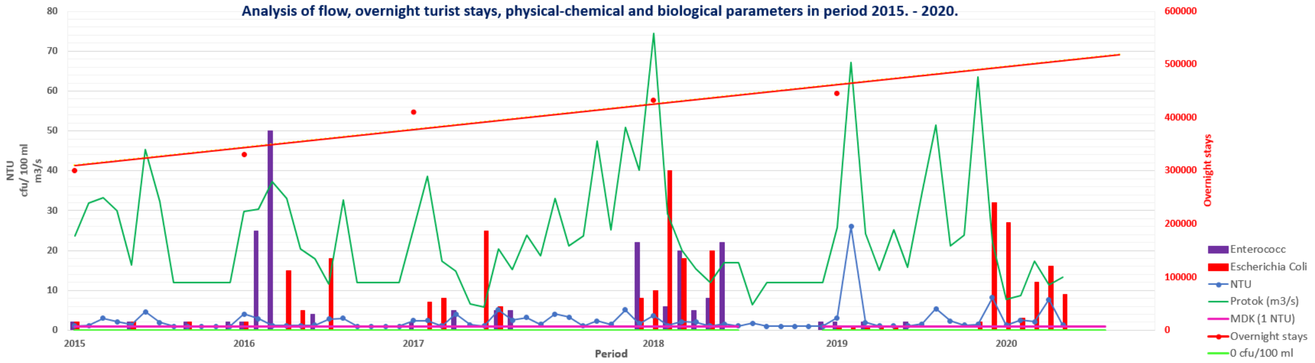


Figure 1.3: *Analysis of flow, turbidity and microbiological parameters in the Klokot spring water in different periods*

By comparing results of analyses conducted for different parameters (Figure 1.3) the following conclusions can be made:

- With the increase of tourism activities, or with the increase of the number of nights spent in the catchment area of the Klokot spring in the last 5-7 years, a significant increase in the bacteriological contamination of water at the Klokot spring also occurred. With the installation of the temporary wastewater treatment plant at Rastovača settlement at the end of 2018, bacteriological contamination was to some extent reduced (it is especially visible from the results recorded in the summer of 2019).
- After heavy precipitation, there is greater discharge of groundwater at the Klokot spring. Consequently, turbidity increases, and there is a significant presence of bacteria not allowed in drinking water. This is all indicative of anthropogenic pollution in the hinterland of the Klokot spring, as shown in the diagrams in main chapter of the Study.
- Significant presence of bacteria not allowed in drinking water was recorded at the Klokot

spring after several days of precipitation in its hinterland since this causes water to flush underground fissures. However, the presence of bacteria is also very often recorded during the summer's dry season when there is no significant precipitation. At that time, relatively huge volume of wastewater enters relatively small volume of groundwater which appears at the Klokot spring.

- The main cause for the significant presence of bacteria at the Klokot spring is the drainage of wastewater into surface and underground waters from improperly built septic tanks or direct discharge of fecal (waste) water into waterways in both countries.
- Short-lasting precipitation of high intensity causes the appearance of high values of turbidity.
- The increase of turbidity is followed by significant presence of bacteria not allowed in drinking water.

1.7 POLLUTERS IN THE CATCHMENT AREA OF WATER SOURCE KLOKOT

At the very beginning of the project implementation, the Consultant collected and reviewed the existing study and project documentation related to the identification of polluters in the catchment area of the water source Klokot, covering the territorial area of Bosnia and Herzegovina and the Republic of Croatia. The analysis of the existing study-project documentation was used by the Consultant for the preparation of field forms and maps, and the development of a plan for field research.

Field research on the territory of both countries was conducted during February and March 2020 and aimed at recording previously known and new polluters in the catchment area, with their characteristics and types of pollution.

Due to their specificity and scope, the field research was conducted on several occasions with the direct support of representatives of the competent services of local self-government units (LGUs), public utility companies (PUCs) and border police of both countries.

After collection and detailed analysis of data on polluters, the Consultant prepared a list of polluters with a detailed description of the most significant ones, including a graphical overview of their locations (identification on the map). All information on the identified polluters was presented to the representatives of the competent institutions from both countries, who reviewed and verified them.

Field research in the catchment area of the water source Klokot in the territory of Bosnia and Herzegovina (BiH) and the Republic of Croatia (RC) recorded a total of **109** polluters, which were divided according to different categories as shown in the following tables.

Bosnia and Herzegovina

Table 1.4: *Overview of recorded polluters in the water source Klokot (BiH)*

Polluter	Total number of polluters
Quarries	5
Cemeteries	2
Landfills	3
Border crossing Izačić	1
Military facilities	1
Settlements without communal infra-structure	5
Free drainage roads	3
Total:	**20**

According to the categorization of polluters in BiH, the first category of importance includes **10** polluters that can have the most significant impact on groundwater quality, namely landfills Međudražje and Vučjak, cemeteries in Zavalje and Izačić, settlements without communal infrastructure and wastewater treatment plants (WWTP) at the joint border crossing BC Izačić (BiH) / BC Ličko Petrovo Selo (RC).

Republic of Croatia

Table 1.5: *Overview of recorded polluters in the water source Klokot (RC)*

Pollutant	Total number of polluters
Quarries	2
Cemeteries	38
Landfills	7
Public institutions	8
Military facilities	5
Livestock farms	15
Agricultural activities	1
Deforestation	1
Settlements without communal infra-structure	4
Tourist urbanization	1
Free drainage roads	7
Total:	**89**

In the territory of the Republic of Croatia, **32** polluters are classified in the first category of importance, i.e. which can have a significant impact on the quality of groundwater in the catchment area of the water source Klokot. These are livestock farms, landfills, military facilities, settlements without adequate communal infrastructure, agricultural activities, tourist urbanization and deforestation.

<u>Conclusion</u>

All identified polluters in the catchment area of the water source Klokot on the territory of both countries (BiH and the RC) have been entered into the GIS and the corresponding database.

Data on potential sources of pollution were selected in terms of spatial types of hazards (point, line and polygon) and classified into 24 different layers depending on the type of characteristics of the potential polluter (quarry, military facilities, landfills, settlements, roads, industry, etc.). The result is a hazard index classification network that is presented in the form of a classified hazard map.

More detailed information on each of the listed polluters is given in Chapter 8. *"Identification of polluters",* i.e. in sections 8.1 *"Base data and analysis of existing information"* and 8.2 *"Polluters cadastre with a graphical representation of locations"*.

According to the collected information, the Consultant made an assessment of the pollution load in the catchment area of the water source Klokot, which is shown in detail in section 8.3 *"Estimation of the pollution loads in the catchment area of the Klokot spring".*

By processing and analysing data related to polluters in the catchment area of water source Klokot, the Consultant classified the identified polluters according to their affiliation to the sanitary protection zones, proposed the necessary improvement measures for all categories of polluters such as:

- Setting up warning boards;
- Rehabilitation of the Prijeboj quarry and gravel pit;
- Rehabilitation of landfills / pits with extraction and removal of landfilled waste;
- Establishment of monitoring and regular monitoring of groundwater quality;
- Establishment of monitoring of rehabilitated areas (landfill, pit, etc.)
- Intensification of work with citizens for the purpose of raising awareness (sensitization);
- Establishment of inspection supervision.
- Making municipal decisions on how to collect wastewater, etc.

1.8 VEGETATION CHARACTERISTICS OF THE SOURCE BASIN

Introduction

Vegetation cover of the entire catchment area consists of significant areas of karst pastures that are particularly pronounced in the catchment area in the Republic of Croatia, then arable and uncultivated agricultural land (meadows, orchards, etc.), and the most important areas - forest ecosystems that are the main determinant of the stability of the recharge of the Klokot spring with drinking water.

Forests and forest lands in the klokot spring basin

During the preparation of the document, the consultant collected data from the companies of the Una-Sana Forest (BiH), the Croatian Forest and the forest of the Plitvice Lakes National Park (RH). Forest areas in the entire catchment area of the Klokot spring cover an area of a total of 51,833.2 ha (BiH and the Republic of Croatia), which represents 54.46% of the total catchment area. The total mass of the forest ecosystem in the spring basin is estimated at about 9.75 million m^3 of wood mass with an average stock of 188 m^3 / ha.

In the catchment area of the Klokot spring in BiH, the forest ecosystem occupies an area of 5,589.20 ha, which is about 5.9% of the total catchment area. The catchment area includes parts of economic units of MU Plješevica with an area of 5,506.8 ha and MU Gata with an area of 82.4 ha. According to forest categories, high forests with natural regeneration, forest cultures and coppice forests predominate.

According to data from 2019, the total wood stock in the catchment area is estimated at 1,115,599.50 m3.

Forest logging (deforestation) is carried out on an area of 4,041 ha, the annual average forest logging (2009 - 2019) in the catchment area is 9,300.10 m^3. In the forest ecosystem of this part of the basin, the natural growth of the forest is particularly pronounced. According to the average increase in forest wealth of 5.49 m^3 / ha, deforestation accounts for 41.87% of the annual increase, or 2.3 m^3 / ha, which allows rational forest management on long term.

In general, compared to the situation in 2004, when the Project for the Protection of the Klokot and Privilica Springs was drafted, a significant improvement of the forest ecosystem in the spring basin is evident. This situation is partly due to the previous Decisions of the City of Bihać on the protection of the Klokot spring and strict restrictions on deforestation in protected areas.

The improvement of the forest ecosystem is certainly contributed by the fact that in the last 15 years there has been a progressive succession of forest vegetation in this part of the basin, i.e. there is a natural expansion of forests on previously cultivated areas, which significantly increases wood mass and stocks.

The total area of the forest ecosystem in the catchment area of the Klokot spring in the Republic of Croatia is 46,244 ha. The total mass of the forest ecosystem in the basin on the territory of the Republic of Croatia is estimated at about 8.6 million m^3 of wood mass reserves (including the forests of the Plitvice Lakes National Park), with an average stock of 185.7 m^3 / ha. In the catchment area covered by forests of 30,714 ha managed by the company Hrvatske šume, the total mass of the forest ecosystem is estimated at 5.74 million m^3, 81,645 m^3 of wood is been cut annually.

As in the basin area in BiH, the forest ecosystem of the Republic of Croatia is dominated by high forests with natural regeneration with a significant share of coppice forests, and natural forest growth is also pronounced. According to the ten-year average growth of forest wealth, deforestation covers 70.2% of the annual growth.

The exception to planned logging on the territory of the Republic of Croatia is certainly logging carried out by the company "Croatian Forests" in the border area with BiH in order to establish a zone to control and prevent illegal entry of migrants from BiH into the Republic of Croatia. The logging works were carried out during the months of May and June 2020 in the area of the Plješivica Mountain, above Baljevac and the Željava military airport. The logging is so controversial, because part of the logging was carried out in the economic unit (MU) Plješivica in Bosnia and Herzegovina According to available information, logging is planned on the intersection of the corridor about 8 kilometres long and 100 meters wide (80 ha), but the situation on the ground can determine that the area of felled forest is much larger, and is estimated at an area of about 150 ha. In addition to the above, what is worrying additionally, is the logging in the area of the Plješevica rainforest. The rainforest is located on the territory of both countries and covers an area of about 500 ha. Rainforests are a special value of forests and forest ecosystems, which enjoy the highest degree of protection in the world compared to other ecosystems. This example of deforestation can be characterized as a rudely violation of European nature protection directives and international environmental standards.

The previously described deforestation on the Plješevica corridor will in any case cause changes and disturbances in the biological balance (stability) of the forest ecosystem in this locality, which will result in pronounced negative influences of biotic and abiotic factors in the form of wind and snow and fractures. General condition of the forest, the occurrence of erosive processes, etc., which will ultimately be reflected in the qualitative and quantitative characteristics of the water at the source of Klokot.

In the chapter "Vegetation characteristics of the source basin", the consultant presented in detail data on stocks, the ratio of deforestation and forest ecosystem growth in the basin in BiH and Croatia, as well as data on deforestation on the corridor along the state border in Plješevica.

Conclusion

In addition to the evident progress of forest ecosystems in the catchment area of the Klokot spring in both countries in the period 2004-2019, and the unplanned crossing of the corridor, the habitat potential provides exceptional conditions for further improvement and enhancement of forest quality.

In order to improve and maintain the stability of the forest ecosystem of the catchment area and the water supply of the Klokot spring, in the chapter "Vegetation characteristics of the basin", the Consultant proposed recommendations for further sustainability and improvement of the forest ecosystem in the Klokot spring basin.

1.9 CHARACTERISTICS OF EROSION PROCESSES IN THE CATCHMENT AREA

In general, the effect of erosion processes in the catchment area is the production of sediment, which occurs by undermining torrents and soil washing, with its transfer to river flows and pits with consequences of their backfilling, eutrophication and in the end, the transported sediment reaches groundwater, where sedimentation occurs. and deposition of part of the sediment in the system of karst conductors, which is manifested by the turbidity of groundwater.

The largest part of the Klokot spring catchment area is built of carbonate rocks, which are mostly overgrown with vegetation (forests, karst pastures and meadows), and on the other hand some smaller parts of the catchment area are completely bare where the erosion process has ended. Based on that, the erosive processes in the Klokot catchment area can be characterized as weak.

There is practically no drawn sediment in the area of the Klokot spring, and the results of erosion processes in the influential Klokot catchment area are manifested as floated (dispersed) sediment or suspended and colloidal particles, respectively as occasional turbidity of water at its source. Turbidity at the source of Klokot was measured on individual days in the period from March 27, 2006 to May 21, 2020, and a total of 514 measurements were performed. It is important to note that in the past almost 15 years, the sampling intensity at Klokot spring was not at a satisfactory level. The analysis of water quality was conducted twice on average, which is insufficient for the water supply system that supplies water to about 50,000 inhabitants of the City of Bihać.

Analyses of water quality at the Klokot spring showed that the increase in turbidity parameters above the maximum allowable concentrations (MAC) was recorded mostly in spring (combination of rain and snowmelt) and in autumn (long-term rains of higher intensity).

In the considered period (27. 3. 2006. - 21. 5. 2019.) the turbidity of Klokot water above M = 2,0 NTU does not occur until Klokot flow does not pass over the limit of ***Q*** = 15,0 m^3/s. However, at the flows higher than 15,0 m^3/s there is a danger of crossing the limits of ***M*** = 4,0 NTU. For example, on 4. 1. 2007. at the flow ***Q*** = 16,0 m^3/s the recorded turbidity was ***M*** = 5,03 NTU, on 21. 5. 2020. at the flow ***Q*** = 25,0 m^3/s the recorded turbidity was ***M*** = 10,0 NTU. During the time of high-water appearance 16. 5. 2019. at the flow ***Q*** = 67,1 m^3/s the turbidity reached the maximum value: M_{max} = 26 NTU.

Measurements carried out over a period of almost 15 years show that at the source of Klokot comes a certain amount of suspended sediment (suspended and colloidal particles) which, depending on the size of the water flow, relatively often causes turbidity above the maximum allowable concentrations (MAC). In the measurement period (March 27, 2006 - May 21, 2020), it was established that the turbidity of the water at the Klokot spring out of a total of 516 sampling 106 times exceeded the limit of 1.0 NTU (22%), and 20 times the limit of 4.0 NTU (4%). In the last three and a half years (January 1, 2017 - May 21, 2020), the limit of 1.0 NTU was exceeded 36 times, and the limit of 4.0 NTU even 8 times, which indicates a deteriorating water quality trend at the Klokot spring in the several past years. Therefore, in terms of the production of suspended (dispersed) sediments, the conditions in the basin are deteriorating.

Deteriorations may be due to natural processes such as the influence of climate on the frequency and amount of precipitation in the catchment area or anthropogenic factors such as deforestation and changes in the use of certain areas in the catchment area, etc. Regardless of the cause, the occurrence of turbidity at the sources in the Dinarides karst is difficult to control in the catchment areas.

Due to the very frequent occurrence of turbidity in relation to the number of samples, which significantly disrupts the regular supply of drinking water, it is necessary to propose appropriate measures to improve water quality at the project at the water source Klokot. In turbid water, colloidal (floating) particles include bacteria as well as number of other inorganic and organic contaminants, thus preventing the mentioned bacteria from being removed from the water by chlorine disinfection.

For this reason, very often in the last 15 years, in periods of significant increase in turbidity in the water distributed to service users, representatives of PC "Vodovod" Bihac through public advertising channels reported to their service users to boil water before using it in the household.

In accordance with all the above, in the coming period at the Klokot spring it is necessary to establish regular and continuous monitoring of water quality, and according to its results to define key input parameters for selecting technology (sedimentation method, filtration, disinfection, etc.) of drinking water treatment at the future plant.

1.10 VULNERABILITY AND POLLUTION RISK MAPS

The Vulnerability Map and the Pollution Risk Map developed within the Project are the result of digital modelling based on the collected relevant data in the area of the Klokot Basin in the Republic of Croatia and Bosnia and Herzegovina. They have not been used in defining the sanitary protection zones of the Klokot Spring. Nevertheless, this chapter was prepared in the framework of this Study because the Consultant considers the information useful for the overall management of the catchment area. Preparation of the necessary layers, digitization and attribution of vector data was performed according to the standard and the needs arising according to the selected method of modelling vulnerability and risk of pollution in the Klokot source basin. Input data for spatial modelling are organized in the form of a GIS database to polygons of hydrogeological units, land use polygons, digital terrain model, hydrographic network, geomorphological objects and phenomena, average precipitation and potential polluters.

The pollution vulnerability map was prepared according to the COP method (J. Ma Vias, B. Andreo, M.J. Perles, F. Carrasco, I. Vadillo and P. Jimenez). The method uses three basic factors: C (flow concentration) - flow concentration, O (overlaying layers) - aquifer cover and P (precipitation) precipitation. According to the numerical values of the parameters, the vector layers were converted into a raster format with a cell resolution of 100 m, and their combination resulted in a map of vulnerability, i.e. a map of the natural hazard of pollution. After creating a map of natural vulnerability, the vector data of potential polluters are classified by type, and for each specific hazard index (HI). The vectors were converted to raster’s, which were summed, and the resulting hazard raster was obtained. Combining this raster with a vulnerability raster resulted in a pollution risk raster that includes natural and anthropogenic elements.

Maps of vulnerability and risk of pollution of karst aquifers are very useful in considering the hazard and risks of pollution of springs in the karst area. They indicate critical places that should certainly be avoided when planning the use of space. They have not been used in defining the sanitary protection zones of the Klokot spring, but we believe that they will serve in the implementation of sustainable development in the basin area.

1.11 RECOMMENDATION OF MEASURES TO ENSURE WATER QUALITY

1.11.1 GENERAL

Klokot and Privilica springs are needed to supply drinking water to the Bihac Municipality. The development of sanitary protection zones is relevant to protect the groundwater that is taken from Klokot spring. However, the experience has shown that protection zones set up in karstic area prove to be ineffective in making it possible to permanently guarantee the distribution of water respecting quality limits of turbidity or bacteriology. Therefore, the Consultant has developed the following approach to address this issue in an overall perspective:

- On the one hand, the groundwater in the catchment shall be protected from contamination with contemporary measures to ensure best-possible utilization of the water at Klokot
- On the other hand, the water that is used as drinking water shall be treated with an effective purification system

Therefore, the focus is on the following:

- ➢ Define measures to directly address mitigation/elimination of polluters.
- ➢ Develop an overall long-term planning approach (e.g. in form of a masterplan) in the different fields to address problems of contamination from an overall perspective.
- ➢ Develop measures to contain hazards on karstic waters (like accidents, littering etc.).
- ➢ Set up a surface and groundwater monitoring system to control the performance and ensure sustainability of the measures.
- ➢ Determine the adequate drinking water treatment for Klokot spring water.

1.11.2 PROPOSED IMPROVEMENT MEASURES FOR IDENTIFIED POLLUTERS

The table below indicates the measures to directly address mitigation/elimination of polluters, which can be initiated at short notice. In addition, it also mentions the mid-term/long-term measures, which need to be planned and implemented in the framework of the overall protection approach concerning the whole region.

Federation of Bosnia & Hercegovina

POLLUTER with (ID)	Zone	PROPOSED IMPROVEMENT MEASURES
Quarries		
Željava/Baljevac (347) Baljevac 2 (2001) Baljevac 3 (2002) Zavalje (2005)	**II**	**Short-term Measures:** • Blocking access roads to the quarry to prevent uncontrolled entry and waste disposal; • Placement of warning boards (prohibition of access and waste disposal); • Integration of polluter location in a groundwater quality monitoring system; • Establishment of inspection supervision. **Mid-term/Long-term Measures:** • Professional closure of the sites based on a project design.
Međudražje (2007) (part of the quarry that is not used)	**III**	**Short-term Measures:** • Blocking the access road to the part of the quarry that is not used to prevent uncontrolled access and waste disposal; • Placement of warning boards (prohibition of access and waste disposal) on the part of the quarry that is not used; • Integration of polluters in a groundwater quality monitoring and control system; • Establishment of inspection supervision. **Mid-term/Long-term Measures:** • Professional closure of the site that is not used based on a project design.
Landfills		
Vučjak landfill (2006)	**II**	**Short-term Measures:** • Blocking the access road to the landfill; • Placement of warning boards (prohibition of access and disposal); • Carrying out hydrogeological and other exploration works in order to determine the condition of the landfill in terms of wastewater seepage and the impact on the water source of Klokot; • Integration of polluter in a groundwater quality monitoring system; **Mid-term/Long-term Measures:** • Preparation of study-project documentation for landfill sanitation; • Landfill sanation with disposal of landfilled waste.
Landfills with uncontrolled waste disposal Baljevac (JNA), (2004) Međudražje (Bezdan), (2008)	III II	**Short-term Measures:** • Enable access to the Baljevac landfill (clearing bushes and shrubs); • Waste removal and sanitation of the landfill surface; • Establishment of monitoring of rehabilitated areas (landfills, sinkholes, etc.) • Placement of warning boards (prohibition of access and waste disposal); • Intensification of work with citizens for the purpose of raising awareness (sensitization) • Establishment of inspection supervision.

Border crossing		
GP Izačić (BiH) / L. P. Selo (RC), (2010)	**III**	**Short-term Measures:** A WWTP has been installed at the Izačić border crossing, where overhaul and servicing works are currently being carried out.. • Conducting a test run with monitoring of the parameters of the discharged water; • Introduction of regular monitoring of the quality of discharged water after treatment; • Establishment of a reporting system to the competent institutions; • Integration of polluter in a groundwater quality monitoring system; • Establishment of inspection supervision.
Roads		
Main road (M5) Regional road (R403a) Local road	**III** **II / III** **II**	**Short-term Measures:** Roads in the Klokot water source catchment area are roads with free drainage without built gutters and oil and fat separators. • Marking of the sanitary protection zone of the water source with traffic signs; • Establishment of an alert system in case of incidental pollution (M5). **Mid-term/Long-term Measures:** • Modernization of roads (M5) in the water source protection zone: it is necessary to plan the construction of facilities for collection and treatment of surface water from traffic areas.
Settlements in the catchment area		
V. Skočaj M. Skočaj Međudražje Zavalje (Vučjak) Izačić	**III** **III** **III** **II** **III**	**Short-term Measures:** Settlements in the catchment area of the Klokot water source do not have an established system of organized wastewater collection and treatment. • Record wastewater infrastructure and collection from existing facilities; • Develop a strategic plan on how to collect and treat wastewater; • Adopt municipal Decisions according to which existing and future septic tanks are in use according to proper waste water management standards (watertight, volume etc.); • Establish inspection and control system for wastewater collection and treatment.

Republic of Croatia

POLLUTER with (ID)	Zone	PROPOSED IMPROVEMENT MEASURES
Quarries and gravel pits		
Prijeboj (1011) Frkašić (1023)	**III**	**Short-term Measures:** • Placement of warning boards (prohibition of access and waste disposal); • Integration of polluters in a groundwater quality monitoring system; • Establishment of inspection supervision.
		Mid-term/Long-term Measures: • Professional closure of the sites based on a project design.
Landfills with uncontrolled waste disposal		
Rastovača pit (2042) Pony pit (2043) Plitvice water source pit(2044) Poljanak pit (2045) Golubnjača pit (20_)	**III**	**Short-term Measures:** • Sanitation of landfills with extraction and removal of waste; • Establishment of monitoring of rehabilitated areas (landfill, pit, etc.) • Placement of warning boards (waste disposal bans) • Intensification of work with citizens for the purpose of raising awareness (sensitization); • Establishment of inspection supervision. These pits / landfills need to be rehabilitated as soon as possible, in order to stop further waste disposal and prevent groundwater pollution.
Military facilities		
Aerodrom i kasarna Željava (1001, 1002, 1003, 1004, 1005)	**II**	**Short-term Measures:** • Conduct detailed research of the interior of the facility from the point of view of identifying the type of pollution, with special reference to storage facilities and contents in them; • Examine for the presence of radiation in and around the building; • Establish continuous groundwater monitoring and provide access to monitoring results to the competent institutions in both countries; • Establish an alert system in case of incidents.
Livestock farms		
Municipality Udbina (14 livestock farms) (1024 – 1032) (2020 – 2024) Municipality P. Jezera (1018)	**III**	**Short-term/Mid-term Measures:** • Establish accurate records of the characteristics of all farms (number and type of livestock, barn capacity, manure production, livestock health surveillance, as well as other relevant data) in the catchment area of the Klokot water source.; • According to the valid regulations of the Republic of Croatia, in the next 5-7 years on the mentioned farms to ensure the construction of devices for collecting low tide and wastewater treatment; • Establish supervision and control over the collection and use of manure on agricultural land; • Establish inspection supervision.

Tourism and tourist facilities		
NP Plitvička jezera (302) Korenica (1015) Ličko Petrovo Selo (1007)	**III**	**Short-term/Mid-term Measures:** • Establish accurate records of existing tourist facilities (hotels, motels, restaurants, camps, private apartments, etc.);; • Establish records on the manner of collection and treatment wastewater of existing tourist facilities with records of constructed septic tanks (improperly constructed - watertight and properly constructed - watertight); • Adopt municipal Decisions or Decisions at the level of NP "Plitvice Lakes" according to which the construction of new tourist facilities can be done exclusively by collecting wastewater in watertight septic tanks or in the sewer system whose wastewater is treated at wastewater treatment plants
Agriculture		
Ličko Petrovo Selo (100 ha), (1001)	**III**	**Short-term/Mid-term Measures:** • Recording of locations and areas with intensive agricultural activities; • Registration of quantities and periods of use of pesticides and fertilizers on agricultural land; • Educating and informing farmers about alternative phyto-sanitary products; • Establish a ban on the storage of fertilizers, insecticides and pesticides in the catchment area; • Establish monitoring of fertilizer use and monitor groundwater quality; • Establishment of inspection supervision
Roads		
Highways in the catchment area (D1, D504, D217 D218/D506, D25 D52, D42)	**III**	**Short-term Measures:** Roads in the catchment area of the Klokot water source in the Republic of Croatia are roads with free drainage without built gutters and oil and grease separators, the Recommendations of basic protection measures are:: • Marking of the sanitary protection zone of the water source with traffic signs;; • Establishment of an alarm system in case of accidental (incidental) pollution.
		Mid-term/Long-term Measures: Modernization of roads (M5) in the water source protection zone: it is necessary to plan the construction of facilities for collection and treatment of surface water from traffic areas.
Inhabited places		
Udbina Korenica Prijeboj P. Jezera L. P. Selo	**III**	**Short-term/Mid-term Measures:** In the area of the Klokot spring basin on the territory of the Republic of Croatia, most settlements do not have an established system of organized wastewater collection and treatment. • Record wastewater infrastructure and collection from existing facilities; • Develop a strategic plan on how to collect and treat wastewater in the catchment area; • Adopt municipal Decisions according to which existing and future wastewater treatment facilities will use watertight septic

		tanks or will discharge them into the sewage system whose wastewater is treated at wastewater treatment plants; • Establish inspection and control system for wastewater collection and treatment.
		Mid-term/Long-term Measures: • Build planned sewerage systems and wastewater treatment plants in the agglomeration of Plitvice Lakes 1 and 2 as well as in the catchment area as needed.

Costs for the implementation of proposed short-term improvement measures

Catchment area	EURO (€)
Bosnia and Herzegovina	340,000
Republic of Croatia	1,700,000
TOTAL:	**2,040,000**

1.11.3 MEASURES IN THE FRAMEWORK OF THE OVERALL PROTECTION APPROACH

1.11.3.1 Overall Planning Approach

The "European Water Framework Directive" (WFD) adopted in 2000 by the European Union defines the framework for the management and protection of water by large hydrographic basin. The measures taken to protect the Klokot and Privilica springs catchment area should be inserted in this wider strategic planning.

Urban Wastewater Treatment Directive (UWWTD) obliges the EU member states to collect wastewater and install treatment plant in agglomerations with more than 2,000 people equivalent (2,000-10,000 PE). Moreover, agglomerations with less than 2,000 people which already have a collection system must set up appropriate treatment.

	Agglomerations with up to 2,000 PE	Agglomerations with up to 2,000 PE having a wastewater collection system	Agglomerations with 2,000-10,000 PE	Agglomerations with 2,000-10,000 PE discharging to sensitive areas
Urban Wastewater Treatment Directive *applies*	*no*	*yes*	*yes*	*yes*
Requirements		*Provision of a wastewater treatment system*	*Provision of a sewerage and wastewater treatment system*	*Provision of a sewerage and wastewater treatment system*
		Removal of organic matter (BOD, COD, SS)*	*Removal of organic matter* (BOD, COD, SS)*	*Removal of organic matter* (BOD, COD, SS)* *Nutrients ** (N, P)*
Water Framework Directive applies	*yes*	*yes*	*yes*	*yes*
Requirements	*Setting up measures to achieve a good water and groundwater status to protect drinking water, implying provision of sanitation and wastewater treatment for communities*			
	* BOD_5=25 mg/l O_2 (70-90% reduction) COD=125 mg/l O_2 (75% reduction) SS=35 mg/l (90% reduction)		** Total phosphorus=2 mg/l (80% reduction) Total nitrogen=15 mg/l (70-80% reduction)	

Table 12.1: *WFD requirements depending on the size and situation of each agglomerations.*

In less densely populated area, centralized wastewater management presents disadvantages: cost/benefit ratio is not very favorable, and leaks can cause contamination of the soil and groundwater. On-site treatments present advantages: better adjustment to individual situation, more flexibility and adjustability to changing conditions (tourism etc.). They also better fit the landscape, allow to re-use treated water and nutrients (Nitrogen, Phosphorus). There are different criteria that need to be considered (see Figure 12.1). In addition, there is a need for education to allow their correct usage and qualified personal for operation/maintenance. Moreover, the re-use of treated wastewater is sometimes forbidden in protection zones.

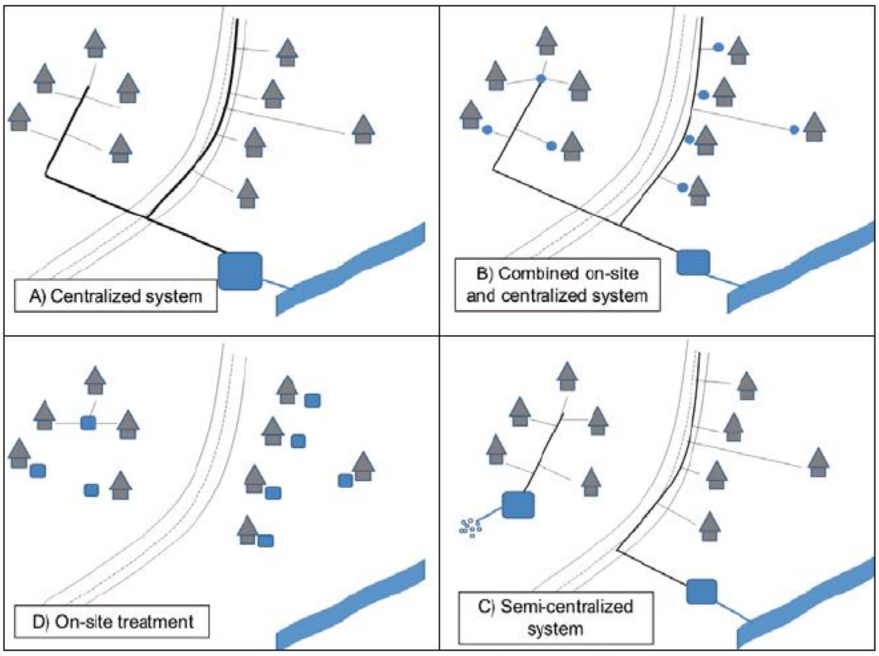


Figure 12.1: *Different wastewater treatment systems*

All in all, based on Table 12.1 and the evaluation of the different options related to wastewater management (Fig. 12.1), it is required to design, construct and operate Wastewater Treatment Plants for the agglomerations with more than 2'000 Person Equivalent (PE) in the Klokot catchement area of Republic of Croatia.

1.11.3.2 Measures to contain hazards of karstic water

The high speeds of underground water in karstic aquifers means that accidental pollution affecting the underground drainage network can be quickly evacuated in springs such as Klokot and Privilica. In other terms, following an accident, the pollution arrives quickly at the source, and disappears also relatively quickly compared to non-karstic aquifers.

Therefore, specific actions should be taken to prevent negative impacts of an accidental pollution. The inventory and monitoring of potential polluters within the catchment area enable to set up an alert network system. In case of an accidental contamination, the local authorities can be warned in time. Thus, the authorities can immediately contact the water utilities so that they suspend the water intake and rely on other sources or their water storage to supply water to the population.

1.11.3.3 Surface and Groundwater Quality Monitoring System

Surface and groundwater quality monitoring is of high importance. The locations need to be carefully selected under consideration of the results expected and of the overall strategy. The planning and implementation of such a surface and groundwater monitoring system is a key for a sustainable solution.

1.11.3.4 Selection of an adequate Water Treatment

Sanitary protection zones in karstic area prove not to be effective enough to permanently guarantee the distribution of water respecting quality limits about turbidity and bacteriological contamination for human consumption.

Therefore, a water treatment plant is required for the water supply of Bihac. It is important to focus on the turbidity parameter to determine the means of treatment to be implemented to respect the limit value imposed by the legislations. There are different technologies which can be used for the purification of carstic water. Ideally, the operator should test the effectiveness of the technology with a pilot treatment plant during a full calendar year in order to receive results from different seasons. The implementation of a pilot plant project would also allow to validate the expenses of such a treatment process and eventually to adapt it to best fit to the characteristics of Klokot and Privilica springs water.

Ultrafiltration has become a very regularly used technology for the treatment of karstic waters over the last 15 years.

The cost estimate of a water treatment plant following the treatment steps below is around € 6 Mio. assuming a population of 70.000 inhabitants in Bihac in 2040.

2 INTRODUCTION

2.1 PROJECT BACKGROUND

The Klokot and Privilica springs are used to supply the City of Bihać in the Federation of Bosnia and Herzegovina (FBiH) with potable water. Protection of this spring is of great importance for the Municipality of Bihać. Approximately 60,000 inhabitants live in the service area of the local utility: Public Enterprise (PE) „Water Supply "Ltd. Bihać (local language: JP „Vodovod "doo Bihać) (Bihac: 56,261 inhabitants according to census 2013).The overview map in Annex 1 shows the City of Bihac and the Klokot and Privilica springs catchment area.

In 2009 „Decision on Protection of the Klokot and Privilica Potable Water Springs "(„Official Gazette of the Municipality of Bihać "number 15/09) was passed for the Klokot and Privilica springs. The surface area of the catchment area under this decision was 686.5 km2. An additional catchment area that is in the territory of the Plitvice Lakes was found to be linked to the Klokot spring through the water course tracings in 2005-2007. Thus, following these tracings the new estimated catchment area of Klokot and Privilica springs was about 1,000 km2. About 90% of the catchment area is in the territory of the Republic of Croatia (RC), and only 10% is in the territory of Bosnia and Herzegovina. Several existing and potential polluters in the catchment area were foreseen to need to be either removed or remediated.

From the legal perspective, the water laws of FBiH and RC are not harmonized. Under Article 68(6) of the FBiH Water Law, a decision on protection of the spring whose sanitary protection zones span the territories of Bosnia and Herzegovina and a contiguous country must be aligned with the international agreement to be signed by FBiH. The Water Law of the Republic of Croatia does not provide for a decision-making procedure for the springs whose zones span the territory of a contiguous country.

A need to protect Klokot and Privilica springs was therefore identified. More specifically, sanitary protection zones should be established in the territories of the Republic of Croatia and of the Federation of Bosnia and Herzegovina, where the catchment area of the springs is located. This needs to be done based on the two different legal frameworks defining the establishment of sanitary protection zones: in Federation of Bosnia and Herzegovina and in the Republic of Croatia.

The bilateral water management commission of Bosnia and Herzegovina and the Republic of Croatia partially prepared „Recommendation of the Protection System and Investigation Methods for Protection of the Karstic Aquifers in the Border Areas of Bosnia and Herzegovina and the Republic of Croatia ", an updated version of which should in this case be applied to the Klokot and Privilica springs. The WBIF approved the funding for the Study entitled „Development of a Study on the Establishment of the Klokot-Bihać Spring Cross-Border Sanitary Protection Zones "

The objective of the assignment is to assist Bosnia and Herzegovina and Croatia to develop a Study on the Spring Sanitary Protection Zones (the Study), to provide baseline for (i) the establishment of the boundaries of the catchment area, and (ii) recommendations for the protection of the Klokot and Privilica springs.

Key Project Details

The key project details are summarized below:

Project Objective	The objective is the Development of a Study on the Establishment of the Klokot-Bihać Spring Cross-Border Sanitary Protection Zones
Time Schedule	12 months (September 2019 – August 2020)
Project Partners & Stakeholders	• Western Balkans Investment Framework • Water Supply Ltd. Bihać (JP „Vodovod“ doo Bihać) • Sava River Watershed Agency • Croatian Waters (Hrvatske vode) • the FBH Ministry of Agriculture, Water Management, and Forestry • Ministry of Construction, Spatial Planning and Environmental Protection of the Una Sana Canton (MCSPEP USC)
Activities	The activities cover the following areas: • Catchment Area and Protection Zones • GIS and mapping • Legal Framework • Water Quality • Identification of Polluters • Mitigation Measures
Consulting Services	HOLINGER AG, Zurich UNA Consulting LLC, Bihac Hidroinženjering d.o.o, Zagreb

2.2 PROJECT MANAGEMENT AND CONSULTANCY TEAM

The Consultant's team is composed of the following firms:

- HOLINGER AG, Zurich, Switzerland as the leading company, together with sub-consultants:
- Resource Centre and Consultancies for Water and Environment “UNA Consulting“LLC, Bihac, Bosnia-Herzegovina, and
- Hidroinženjering d.o.o., Zagreb, Croatia.

The association brings together the international firm HOLINGER AG and two local firms to undertake the assignment as required in the scope of this project.

HOLINGER is one of the leading consultancy firms in Switzerland, specialized in the fields of water resources management, water supply, wastewater treatment, urban drainage, renewable energy and industrial environmental engineering, with an excellent performance record of more than 85 years.

Local partner UNA Consulting is a Bihac-based consulting company. The main activities of the company are related to the provision of consulting services in the sector of water, environment and communal infrastructure, technical support and engineering services, technical survey and analysis, database design and management, and other related activities.

Local partner Hidroinženjering is a Zagreb-based company, working on structures and facilities used for water harnessing, water impact control, water contamination control, architectural design, town planning and environmental impact studies.

Team Composition

The team composition is presented in the table below:

Specialist	Project Role
HOLINGER AG	
Philipp Derungs	Project Director / Water Expert
Hanna Niafiodava	Environmental Engineer / Water Resource Management
Dr Suzanne Mettler	Water Analysis / Chemical Expert
Dr Daniel Beihler	Hydrogeological Expert / Backstopper
Franziska Griger	Hydrogeological Expert
Christian Pecoud	Operation and Maintenance Expert
Uli Steiner	Quality Management / Backstopper
Fredrik Pitzner	Financial Expert
Cynthia Martin	Public Management / Water Expert
UNA Consulting LLC	
Sandi ZULIĆ	Local Team Leader
Dr Janislav KAPELJ	Water Resource Expert / Hydrogeologist
Jasmin Pehadzic	Legal Expert
Amel Muslic	Economic Expert
Davorin Singer	GIS Expert
Aida Moranjkić	Project Administration and Translation
Hidroinženjering	
Ana Turcinov Mikulec	Geological Expert
Dr. Ranko Zugaj	Hydro engineer / Hydrology Expert
Željko Štefanek	Local Project Manager
Nikola Vukelić	Project Coordinator

2.3 IMPLEMENTATION CONCEPT

The implementation concept divides the various activities in 5 different main study areas.

Study Areas	Activities and information to be considered
1 Catchment Area and Protection Zones	• Tracing program performed by a licenced company according to RC regulations • Collection of historical data and new tracing data • Collection of hydrological and precipitation data • Proposition and implementation of methodology to determine the delineation of the: ➢ catchment area ➢ sanitary protection zones in karst waters
2 GIS Database and Mapping	• Measures related to GIS System: upgrade of database structure, harmonization of data, update of database with new data • Preparation of GIS maps
3 Legal Framework	• Update of the "Recommendation of the Protection System and Investigation Methods for Protection of the Karstic Aquifers in the Border Areas of Bosnia and Herzegovina and the Republic of Croatia " • Recommendations for possible future cooperation between the two countries to protect the groundwater bodies intersected by state borders • Clarification of which legal framework should be applied in defining boundaries of the catchment area
4 Water Quality	Water quality monitoring program as follows: • Laboratory water quality analysis of specific parameters based on rulebooks in FBiH and RC • Continuous Water Quality Monitoring using a multiprobe
5 Identification of Polluters and Mitigation Measures	• Identification of polluters (existing and new ones) and collection of data on them (location, type of pollution etc.) • Recommendations for interventions within the protection zone according to the needs and priorities

3 DESCRIPTION OF KLOKOT WATER SOURCE

3.1 WATER INTAKE AT THE SOURCE OF KLOKOT

Klokot water source is the most important water source in the water supply system of the city of Bihać. It is located about 5.5 km from the city centre in the northwest-west direction with coordinates Latitude: 44,824678 / Longitude: 15,801834.

Figure 3.1: *Location of the Klokot water source in relation to the city of Bihać*

The water source of Klokot erupts from a karst cave at the foot of the Željavski plateau, i.e. the Baljevac field, forming a watercourse of the same name which flows into the river Una. In addition to the main water source in the immediate vicinity there is another water source Klokot 2, which is used for the needs of the pond.

According to the basic characteristics, the Klokot water source is a typical karst spring that is fed from a catchment area built mainly of carbonate rocks with crack and fissure-cavernous porosity.

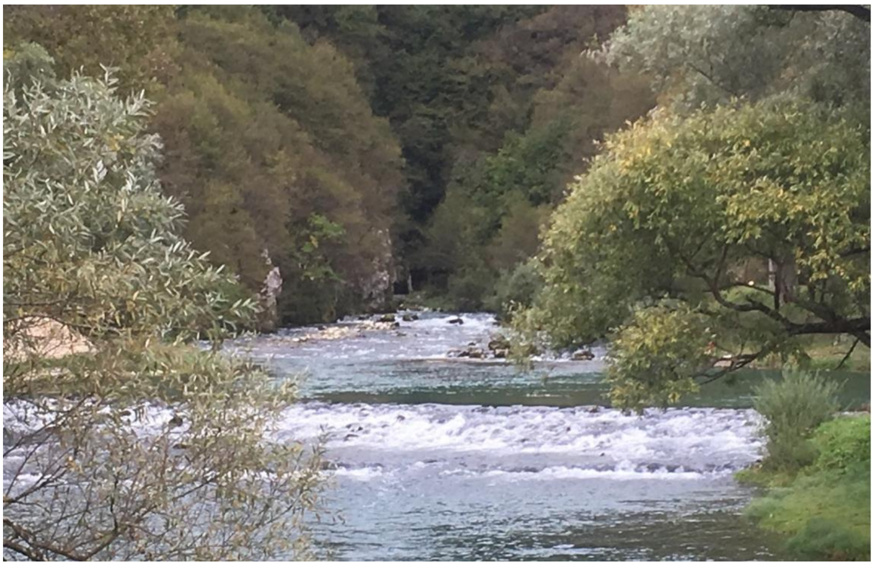


Figure 3.2: *Klokot water source area*

Water intake at the spring is made by means of a concrete water intake facility located next to the water source. The water intake facility was built in 1968, and reconstructed in 1982 and 1998/99, together with the pumping station facility.

Figure 3.3: *Water intake facility at the Klokot water source*

The water intake facility has two entrances with protective grilles and plate closures. There are two chambers, a collection chamber in which the suction basket of the transport pipeline is located, and a closing chamber. The level of water deceleration in the water intake facility is 216.60 m above sea level, which is provided by a concrete barrier in the Klokot riverbed, whose crown is at the level of 216.40 m above sea level.

Figure 3.4: *Plate closure on the water intake facility*

The affected water is gravitationally delivered from the water intake to the collection chamber of the Klokot pumping station, by asbestos-cement pipeline (ACC) profile 1000 mm at a length of 213 meters.

The pumping station facility was built on the left bank of the Klokot River, downstream from the water intake. The pumping station was constructed as a solid masonry structure, and a collection (pumping) chamber was constructed behind it. The elevation of the bottom of the chamber is 214.05 m above sea level. The water intake area and pumping station with access road are located inside the fenced area.

From the pumping station, the water is directed in two directions (reservoirs). In the first direction, the water is directed to the Komarac reservoir with two pumps with a capacity of 150 l / s, and from there it is further delivered to the city network. With the other two pumps with a capacity of 40 l / s (working and reserve pump), the water is directed towards the Klokotska glavica reservoir, i.e. towards the settlements in the north-western part of the city of Bihać. The two pumps, which were used to transport water to the Željava military complex, are no longer operational.

Figure 3.5: *Pump station Klokot*

Pumps regularly pump between 250-280 l / s of water in mentioned two directions. The yield of Klokot springs varies significantly during the year, which is a common feature of karst springs. The minimum yield is estimated at about 3.0 m3 / s, which is a very small percentage in relation to the amount of water captured from the source, so that the required amounts of water can be taken from the source in all hydrological situations.

During the underwater surveys of the spring in 2003 and the analysis of the mechanism of water occurrence, the spring is of an upward character. The contact of water with the spring takes place through a complex system of caverns, which are connected to the limestone aquifer.

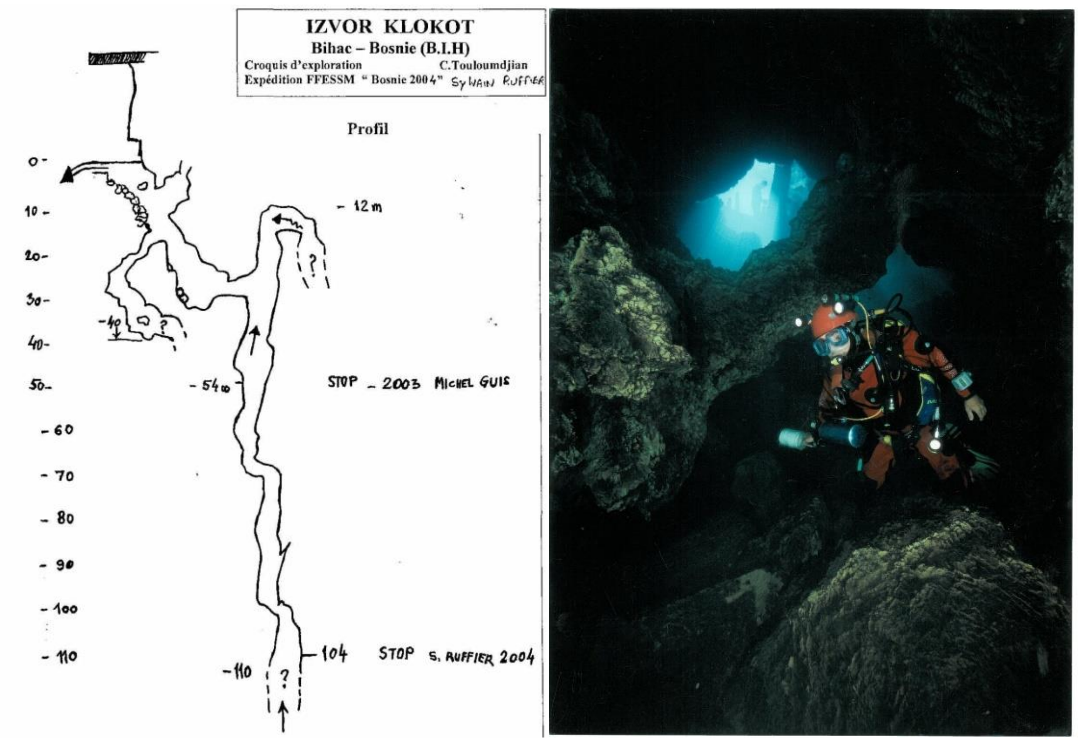


Figure 3.6: *Water source profile of Klokot and the interior of the cavern*

At a depth of 28 meters below the spring level, a short gallery was discovered, 2 m long and 5 m high. Behind the gallery there is a vertical cavern with a diameter of about 6x8 m, which was explored to a depth of 110 m below the spring level. This vertical cavern extends above the gallery, to a depth of 12 meters below the level of the spring, after which the next cavern reappears. It has been established that the underground current comes from the direction of the vertical cavern. Another cavern was discovered on the left side, which ends at a depth of 40 m below the level of the water source. It is estimated that this is a 2-meter-wide fault, which has several side caverns. No sludge was registered in the caverns during underwater recording.

3.2 SPELEOLOGICAL OBJECTS IN THE VICINITY OF KLOKOT WATER SOURCE

On the left bank of Klokot, directly downstream from the pump station, there is an area that is used as a city picnic area of Bihać. On the right bank of the Klokot, downstream from the water intake, a pond was built, on which consumer fish (trout) are raised.

Speleological research conducted in 1986 identified four speleological objects in the vicinity of the source of Klokot:

1. a cave above the Klokot water source,
2. a pit on a plateau above a water source,
3. a cave in a ditch above a pond, and
4. a cave above the pond.

The location of these facilities is shown in Figure 3.7. Facility number 1 is located on a rock above the Klokot water source. The other three facilities are located south of the main water source, at 140 - 180 meters.

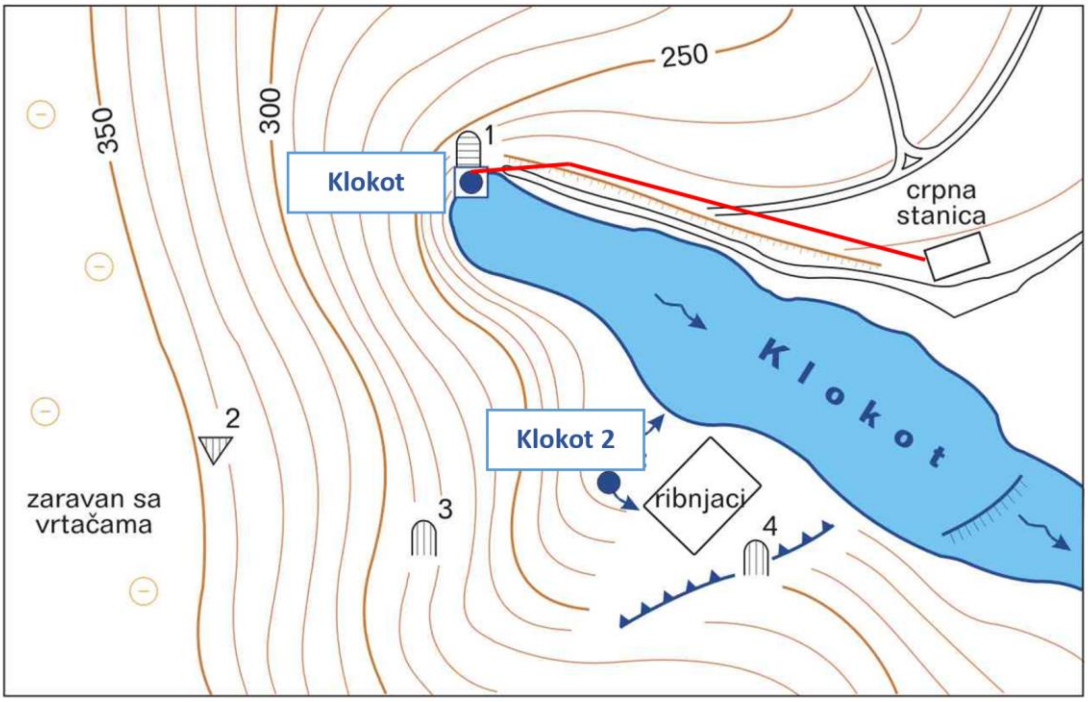


Figure 3.7: *Position of speleological objects in the narrower area of the water source Klokot*

4 CATCHMENT AREA AND PROTECTION ZONES

4.1 GEOLOGICAL CHARACTERISTICS OF ROCKS

The greater catchment area of the Klokot and Privilica sources is built of Mesozoic and Cenozoic sediments which form very complex tectonic relationships, and in turn affect the hydrological relationships within the catchment area.

The oldest formations in the terrain date back to the Lower Triassic period ***(T_1).*** The Lower Triassic formations include Seisian clastics created in the shallow water marine environment, while limestones are dominant in the upper parts of the Campilian stage. The area south of Bihać, the southern part of the Koreničko Polje field as well as Bijelo Polje field are built of Seisian deposits which are identified as reddish-brown to purple-brown sandstones and claystones of shale texture and psammite and alevrite structure.

The Campilian deposits ***(T_1^2)*** were discovered in the Meljnikovačka Draga area, at the north-east rim of the Bijelo Polje, south of Korenica and north of Crkvina. They comprise grey flaglike limestones, marly limestones and occasionally dark-grey schists. The upper deposits comprise interbeds of light-grey crystalline dolomite.

The Middle Triassic – the Anisian stage ***(T_2^1)*** of the Triassic was discovered in the area of the Skočaj anticline and along the edge of the Koreničko Polje. In the Meljinovci area, this member is built of white to light-grey dolomite of massive to poorly stratified texture and crystalline structure. The transition from the Lower Triassic to the Anisian stage is gradual with a continuous boundary. The thickness of Anisian sediments is about 400 m.

The Upper Triassic ***($^2T_3$)*** lies transgressively over the Anisian, the Middle Triassic. It was found within the Skočaj anticline, along the south-western rim of the Koreničko Polje and in the large area spanning from the Plitvice Lakes, Plitvički Leskovac, Korenička Kapela to Mihaljevac. In these areas, light-grey well-stratified crystalline dolomites lie over the Upper Triassic clastic deposits.

In the area under investigation, the Jurassic ***(J)*** formations are predominantly represented by dolomites, and less by limestones. The Lower Jurassic – Lias ***(J_1)*** was identified in the area between Skočaj and Lohovo, and then between Međudražje and Crkvina, as well as and in the area of Srbljani. It is represented by thinly stratified dolomites, with occasional occurrence of limestones.

In the Lower Lias ***(J_1^{1+2})*** structure, there are limestone dolomites alternating with grey, dark-grey and brown well-stratified and flaglike limestones. In the Plitvički Ljeskovac - Korenička Kapela – Mihaljevac area, the Lower Lias is almost completely built of dolomites with very rare interbeds of limestones. The total thickness amounts to 200 m.

The Middle Lias ***(J_1^3)*** mostly comprises well-stratified grey and brown limestones. Dolomites rarely occur as thin interbeds. The thickness of deposits amounts to 200 m.

The Lower Lias ***(J_1^4)*** consists of a body of flaglike grey and brown limestones, while in the upper stages there are marly and dolomitized limestones. The total thickness amounts to 100-150 m.

The Middle Jurassic – Dogger ***(J_2)*** is mostly distributed in the area south of the Plitvice Lakes, from Plitvički Ljeskovac over Mali Javornik to Ljeskovi Vršak, then in the Brezovac and Homoljačko Polje field area and within the Skočaj anticline. The Dogger deposits predominantly consist of limestones and to a lesser degree of dolomites. Limestones are usually well-stratified, light-grey to light-brown, and can occasionally be oolitic to pseudo-oolitic, and very rarely slightly bituminous. Dolomites occur as thicker and thinner interbeds within limestones. The total thickness amounts to 300 – 400 m.

The Upper Jurassic – Malm ***(J_3)*** is made of dolomites with intercalations of limestones. The Upper Jurassic ***($J_3^{1,2}$)*** is found in the area between Končarev kraj and Homoljac, then between Vrpile and Bjelopolje. Limestones and dolomites belong to this stage of Late Jurassic, alternating in horizontal and vertical direction. Limestones are rather thickly stratified, grey, dark-grey and brown and occasionally highly oolitic. Dolomites are grey and brown, of crystalline structure. The dolomites are more represented at certain locations, and in such cases limestones occur as thin lenses. The thickness of this member is 200 – 300 m.

The Upper Jurassic ***($J_3^{2,3}$)*** is distinguished by a greater diversity of facies. At certain locations, there is a differentiation between the ridge facies and flaglike limestones with cherts. Dolomites are dominant in the Upper Jurassic – Malm stage, and limestone deposits occur as thicker and thinner lenses within them. Dolomites are generally thickly-stratified or massive, mostly white or light-grey, and of crystalline structure. They were identified near Plitvički Ljeskovac, Končarev Kraj, Homoljac and Korenica, then in the Zavalje – Međudražje area and near Oštrelj. In the area between Zavalje and Međudražje, the dolomites are occasionally significantly bituminous and often comprise interbeds of grey cherts. The limestones are encountered only in the lower part of this body, while in the upper part of the dolomite deposits, thinner or thicker lenses of ridge limestones have developed. The total thickness of this formation is 200 – 400 m.

In the area under investigation, the Cretaceous ***(K)*** formation has developed in two characteristic facies: carbonate and clastic. The carbonate development is dominant in the area of Mala Kapela, Lička Plješivica mountain and in the greater area of the Koreničko Polje, while the clastic development is dominant in the eastern part of the catchment.

The Lower Cretaceous ***(K_1)*** deposits were discovered in the area south of Bihać, in the section spanning from Sadilovac, over Vaganac to Izačići, in the Željava - Baljevac - Međudražje area, and finally near Korenica and in the Žegar - Vedro Polje field - Ripač area. The Lower Cretaceous, which has uniform lithological composition in the entire area, is made of limestones and dolomites. Marls occur as thin interbeds near Zavalje and Ličko Petrovo selo, where encountered limestones and dolomites alternate in horizontal and vertical direction.

The well-stratified limestones are more frequently encountered in the upper part of the Lower Cretaceous stage. Dolomite-limestone breccias occur as lenses within the Lower Cretaceous deposits.

The Lower Cretaceous ***(K_1^{1+2})*** (valangian-hauterivian) is represented by dolomites, limestones and breccias, and the upper stages of the Lower Cretaceous (barremian-aptian-albian)**(K_1^{3-5})** have a similar composition. Limestones, followed by dolomites, marly limestones and breccias are predominantly encountered.

The Upper Cretaceous ***(K_2)*** encompasses the largest part of the area under investigation. It includes the terrain between the Plitvice Lakes, Priboj and Ličko Petrovo Selo, and forms a spacious massif of the Gola Plješivica mountain, as well as a large area around Užljebić, Koprivna and from Tihotina to Međudražje.

The Upper Cretaceous – Cenomanian – Turonian ***(K_2^{1+2})*** is made of stratified limestones with occasional interbeds of dolomites.

Limestones are light-brown and light-grey. The layer thickness varies from 0.5 – 1.0 m. The total thickness of the Cenomanian – Turonian formation amounts to 500 - 700 meters.

The Upper Cretaceous – Senonian ***($_{1\text{-}3}K_2^3$)*** is made exclusively of limestones with rudist remains. The said limestones include interbeds of flaglike brown and black limestones with interbeds of cherts. The thickness of this stage is 600 – 800 metres.

The Lower and Middle Eocene ***($E_{1,2}$)*** was identified north-west of Koreničko Polje. This term includes the miliolid, alveolinid and mummulitid limestones. The boundary towards the older deposits is defined by regional faults. The thickness of these deposits is 80 – 120 meters.

Eocene and Oligocene ***(E,Ol)*** deposits were identified within the Krbavsko Polje and Koreničko Polje fields, at the foothill of Kremen and west of Bihać. They are made of coarse clastic sediments and limestone breccias. The cement in breccias is microcrystalline and occasionally limonite-clay.

The Middle Miocene ***($^2M_2$)*** formations were identified in the Bihaćko Polje field. The said sediments rest on basal conglomerates and breccias. They are made of white and greyish-yellow well-stratified limestones comprising interbeds of sandstones, tuffs and coal. The limestones often alternate with limestone marls grading into clayey marls. The sedimentation of limestones and marls in certain areas of the Bihaćki basin was followed by the sedimentation of clastites: marls alternating with conglomerates and breccias, clays and marly clays with interbeds of coal and sands with interbeds of gravel. Near Ripač, limestone marls alternate with conglomerates and breccias in the lower stage, while conglomerates and breccias are dominant in the upper stages.

The Quaternary formations include the Pleistocene and Holocene deposits. The Pleistocene in the Krbavsko Polje area is built of quartz sands, while tufa deposits ***(j),*** deluvial ***(d)*** alluvial ***(al)*** and marsh deposits ***(b)*** sedimented during Holocene. Tufa deposits were identified in the valleys of the Una and Korana Rivers, as well as near stronger springs. Marsh sediments are represented by clays of various colours, silty sands and gravels covered with humus. Deluvial deposits are made of limestones and dolomite fragments which form the slopes they are sedimented on. Alluvial deposits are sedimented along the Una and Korana River beds and are formed of gravels, sands and sandy clays.

4.2 TECTONIC FRAMEWORK OF THE TERRAIN

Tectonic structure of the area under investigation is very complex. The area under investigation is largely built of rock mass which underwent deformations as a result of tectonic movements in the geologic past. The consequence of these processes is structural tectonic texture of the terrain with folding (anticlinal and synclinal) structural forms. Another important structural element is faults which are the boundaries between the blocks, namely structural units. Larger faults and boundaries between the structural blocks are mainly of Dinaric-striking orientation, while local faults and fault zones within the structural framework of the terrain have various orientations.

The following Structural-Tectonic Units have been identified in the area under investigation (Annex 2):

- The Bihaćko Polje - Bosanski Petrovac Structural-Tectonic Unit,
- The Mala Kapela - Lička Plješivica Structural-Tectonic Unit,
- The Bruvno Structural-Tectonic Unit,
- The Kremen Structural-Tectonic Unit,
- The Pišač - Udbina Structural-Tectonic Unit, and
- The Lička Plješivica Structural-Tectonic Unit.

The Bihaćko Polje - Bosanski Petrovac Structural-Tectonic Unit represents a tectonically downthrown block between the Gata - Čekrlije - Ripač fault zone and several covered faults (by the Tertiary deposits), from Izačići over Klokot and Žegar to Sokolac and Ripač. The Cretaceous formations near Klokot and Prišlen are relatively less uplifted blocks. Smaller faults at the contact between the Cretaceous and Tertiary deposits near Izačići are partially reversed. The Tertiary deposits mostly slope towards the central parts of the Tertiary basin.

The Mala Kapela - Lička Plješivica Structural-Tectonic Unit encompasses the central part of the area under investigation. Due to its geological structure, this tectonic unit has been divided into structural units of lower order:

- The Trovrh - Lička Plješivica structural unit,
- The Meljinovac structural unit,
- The Brezovac - Krbavica structural unit,
- The Plitvice Lakes - Koreničko Polje structural unit.

The Trovrh - Lička Plješivica structural unit encompasses the Lička Plješivica mountain massif which is built only of Cretaceous deposits. This Dinaric-striking structural unit is located between Biljevica, Čatrnja, Vaganjac, the Plitvice Lakes and Prijeboj. In terms of structure, the unit is a syncline with the core formed of Late Cretaceous deposits. The syncline is bordered by fault zones from the northeast and southwest, by a regional vertical fault stretching to Bihać and Bihaćko Polje from the northeast, and the Biljevica - Prijeboj – Mihaljevac fault on the southwest side. In this area, there is a boundary towards the Plitvice Lakes - Koreničko Polje Triassic – Jurassic intrusion. Within the syncline, there is a series of longitudinal and transverse faults, the most dominant ones being the faults near the Lower Plitvice Lakes, the Korana River and on the Rešetar - Arapov dol section, along the Gola Plješivica massif.

The Meljinovac structural unit is situated in the continuation of the previously mentioned unit, towards the south. It represents an asymmetrical anticline, with Early Triassic sediments at its core. The northern part of the anticline is disturbed by a series of longitudinal faults, along which there is multiple repetition of Late Jurassic sediments. It is separated from the previous structural unit by several vertical faults, which bring the Late Jurassic and Early Cretaceous deposits into tectonic contact. On the southern side, the Meljinovac anticline is disrupted by the Užljebić - Gornji Frkašić fault.

The Brezovac - Krbavica structural unit is located in the area between Babin potok, Turjanski, Korenica and Krbavica. It is built of Late Jurassic and Early Cretaceous carbonates. It represents the remains of intensely faulted anticlinal structure. The Dinaric-striking vertical faults with a series of transverse faults are dominant within this unit.

The Plitvice Lakes - Koreničko Polje structural unit encompasses the tectonic intrusion of Triassic and Jurassic deposits. On the north-east, it is bounded by the Dinaric-striking regional fault from the Saborsko to Koreničko Polje. Along this fault, the Late Triassic and Late Cretaceous deposits were brought into an abnormal contact. North of the Koreničko Polje, this fault is divided and transits into a fault zone, which comprises a series of predominantly vertical faults of different spatial orientation. In the south-west, this unit is also bounded by the regional Dinaric-striking fault stretching from Kušelj towards Plitvički Ljeskovac and further on to Korenica.

The Bruvno Structural-Tectonic Unit is located west and south of the Krbavsko Polje, and it is separated by the Ljeskovac - Stračkovo selo dislocation from the Pišač – Udbina structural unit. In this area, it is a closed structure in the form of a brachianticline, where there is an insertion of the Paleozoic core around which younger Mesozoic deposits are sedimented.

The Kremen Structural-Tectonic Unit is located south of the Krbavsko Polje. It is bounded by the Pišač - Udbina and Lička Plješivica structural units in the north, and by the Čemernica - Kulen Vakuf tectonic unit in the east. The dominant sediments in this unit belong to the Lower Triassic, which in the area of the Bruvno structure have been thrust over the northern wing of the Bruvno structure and completely reduced. Apart from the Lower Triassic deposits, there are also the Upper Jurassic Lemeš limestones.

The Pišač – Udbina Structural-Tectonic Unit is characteristic for its open Triassic deposits in its south and south-eastern part, and for the extremely fractured Jurassic deposits. It stretches along the south-western rim of the Krbavsko Polje, where it is bounded by the Lička Plješivica structural unit. Triassic deposits are in tectonic contact with the Kremen and Bruvno units. In this area, Triassic deposits have been thrust over the Upper Jurassic and Lower Cretaceous deposits, with the overthrust line slightly sinking towards the north-northeast, meaning that the structure directs groundwater towards the Krbavsko Polje. In the Mekinjar area, Triassic and Jurassic deposits are fractured by faults extending in the NW- SE direction, along which there are multiple repetitions of the Triassic and Jurassic stratigraphic members. The north-eastern wings of these faults have formed as cascading hanging wings.

The Lička Plješivica Structural-Tectonic Unit stretches over the Udbina and Bihać sheets of the Basic Geological Map (scale 1:100,000). The basic form of this unit is a syncline with the axis sink direction towards the north-west. It is formed of the Jurassic and Cretaceous deposits. The western part is built of the Upper Triassic, Jurassic and Cretaceous deposits and represents the western wing and the central part of the southern Plješivica syncline. The Plješivica tectonic unit is a relatively sunk block as compared to the Pišač – Udbina tectonic unit. The global characteristic of this unit is a parquet structure formed by numerous longitudinal and transverse faults which enable groundwater to circulate in the north and north-east direction.

Based on the above described general structural characteristics, it may be concluded that the hydrological relationships are also very complex, especially regarding the exact determination of boundaries of the hydrogeological catchment of the Klokot and Privilica sources. By their spatial position the described structural units significantly affect the hydrogeological relationships in the area. Fault structures have the greatest significance, because of the intensive karstification that took place alongside of them and because of the conditions for groundwater flow that were created. The greatest significance for groundwater flow is that of longitudinal faults extending in the northwest-southeast direction, in the Međudražje and Skočaj area, where they are often found in cascade arrangement with pronounced relative movement of rock masses in the northwest direction. Such relationships are particularly noticeable along the fault which stretches through Željava and Baljevac over Rešetari and Klokot towards the Vedro Polje. Along this fault, the Upper (K_2^{1+2}) and Lower (K_1^{1+2}) Cretaceous carbonate rocks have been brought into the same level with the Miocene (M_2) clastic deposits. The faults and the accompanying fissure systems, depending on spatial relationships, may act as hydrogeological barriers or as groundwater conduits.

The fault structures most often strike in the southwest-northeast-Dinaric direction. Faults of this orientation cut through the older faults and through the entire structural forms, they are more prone to karstification processes and are important for groundwater flow vertical to the Dinaric-striking faults. It is precisely along these faults that the majority of groundwater flows from the direction of the Krbavsko Polje and Koreničko Polje towards the Klokot and Privilica sources.

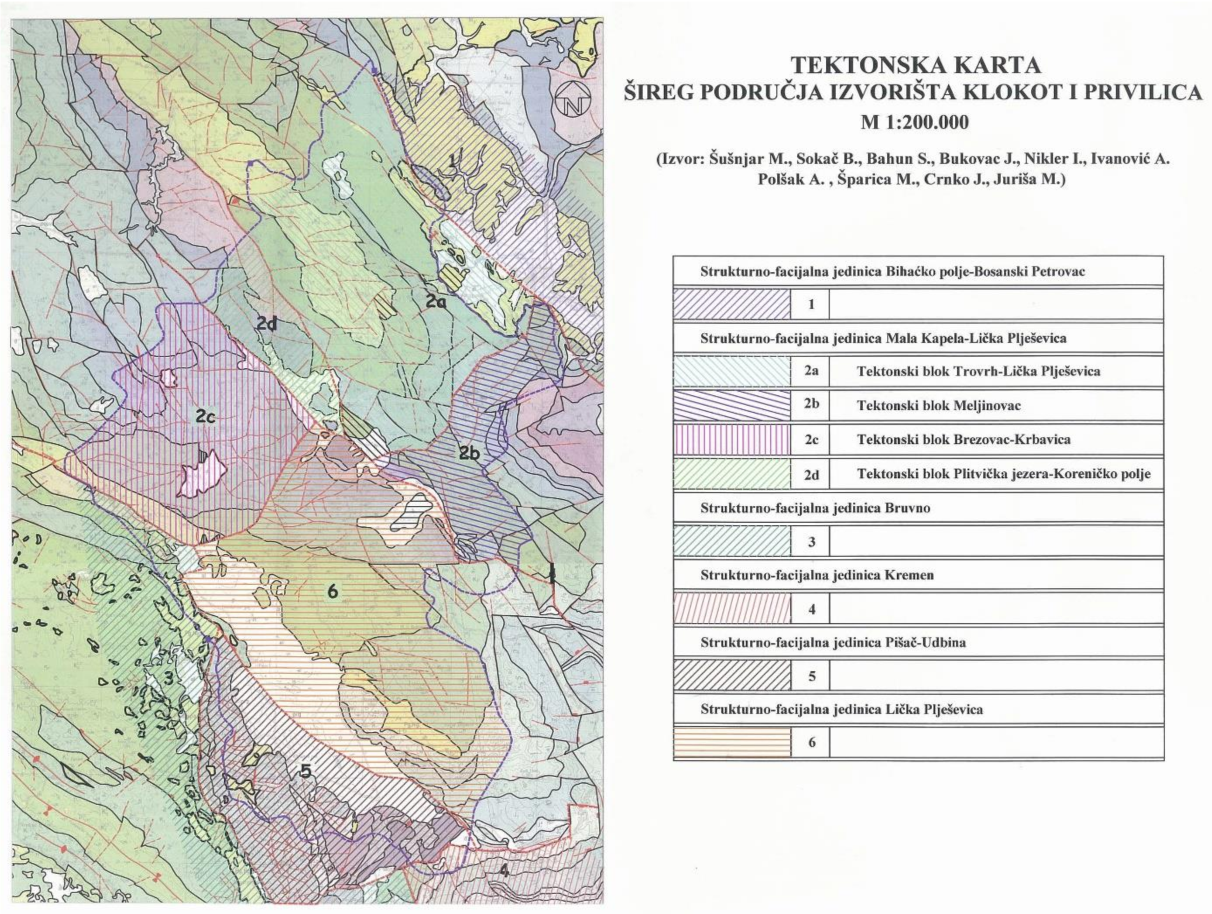


Figure: *Tectonic map of the Klokot and Privilica sources greater area (Institute of Hydrotechnics, 2004)*

1 The Bihaćko -Bosanski Petrovac structural - tectonic unit

2 The Mala Kapela – Lička Plješivica structural - tectonic unit

2a The Trovrh-Lička Plješivica tectonic block

2b The Meljinovac tectonic block

2c The Brezovac-Krbavica tectonic block

2d The Plitvice Lakes – Koreničko Polje tectonic block

3 The Bruvno structural - tectonic unit

4 The Kremen structural - tectonic unit

5 The Pilač –Udbina structural - tectonic unit

6 The Lička Plješivica structural - tectonic unit

4.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE CATCHMENT AREA

4.3.1 Hydrogeological types of rocks

According to the lithological composition, the rocks and deposits in the area under investigation are distinguished as deposits with intergranular and deposits with fracture and cavernous porosity. According to the criterion of permeability, they are divided into permeable and impermeable deposits.

According to the lithological composition, structure of porosity, spatial arrangement of the identified geological units and water-permeability of rocks and deposits, the following hydrogeological environments have been identified (Attachment 1, HGI 2004):

- permeable clastic deposits,
- low permeability clastic deposits,
- high permeability rocks with fracture and cavernous porosity,
- moderate permeability rocks with fracture porosity,
- low permeability rocks,
- impermeable deposits.

Permeable clastic deposits

Permeable clastic deposits are Quaternary sediments within which several genetic types have been identified: proluvial deposits ***(pr)***, sandy deposits ***(p)*** and alluvial deposits ***(al).***

According to their lithological composition, the said deposits are mostly built of course clastites of gravels, sands, and sandy clay.

They are mostly encountered within the alluvial sediments which were created by the recent Una River and Korana River flows, as well as by the water courses running through the Krbavsko Polje. Likewise, the deposits sedimented by the activity of water-courses with great share of sand have also been encountered among the said deposits in the Krbavsko Polje.

Generally speaking, although the alluvial sediments are mostly aquifers, in this case, due to the significant karstification of the bedrock on which the sediments rest, groundwater infiltrates into the karstified underground.

This group of deposits is marked in light-blue in the Annex 2.

Low permeability clastic deposits

Low permeability clastic deposits are Quaternary deposits within which several genetic types have been identified: silty clay deposits ***(prg)***, deluvial deposits ***(d)*** and marsh deposits ***(b).***

They have been sedimented on several locations within the area under investigation. Marsh sediments are represented by clays of various colours, silty sands and gravels covered with humus.

These deposits are characterized by small thicknesses and varying lithological composition. Although they are a mix of different clastites, clayey and silt deposits are dominant, thus contributing to their lower permeability, depending on the thickness of the said deposits.

This group of deposits is marked in yellow in the Annex 2.

High permeability rocks with fracture and cavernous porosity

Unstratified limestone breccias of Eocene and Oligocene ***(E,Ol)*** age, limestones and limestone breccias of the Lower Cretaceous ***(K_1),*** limestones of the *Cretaceous* ***(K_2^3 , $K_2^{1,2}$, K_1)*** and to a lesser degree of the Jurassic ***$J_3^{2,3}$*** age belong to the group of high permeability rocks.

The limestones are mostly well-stratified and with layer thickness of 20-50 cm. Locally, they may be thicker, while bulky varieties have also been registered. Locally, smaller interbeds and dolomite lenses may be found within this group of limestone development rocks.

In hydrogeological terms, secondary porosity prevails in these rocks. It is primarily fissure, that is, fissure and dissolution type of porosity, with the cave porosity not to be excluded in the underground, which is the consequence of fractures and karstification that took place along the faults and cracks.

Therefore, they are characterized by large vertical and horizontal permeability, which enables infiltration of precipitation and horizontal circulation of groundwater. On the surface, numerous ponors and karren have developed.

Due to tectonic fractures, high fissuring and karstification of rock mass, a very specific surface and underground hydrography has developed in the limestones.

In the locations where the Triassic, Jurassic and Cretaceous limestones and dolomites are encountered on the ground surface, the underground is recharged by direct infiltration of precipitation, and by underground inflow from west and south-west.

According to the structure of porosity, groundwater is collected in underground retentions developed along the network of fissure passages, depending on the depth and degree of rock karstification. Groundwater is mostly drained at the lowest erosion base, through the springs of varying capacity. The Jurassic and Cretaceous limestones are basic aquifers of the Klokot and Privilica sources catchment area, which are largely discharged along the south-west rim of the Bihaćko Polje, at the Arkovac, Klokot, Vedro Polje, Žegar, Privilica and Dobrenica springs.

The described rocks at the same time build the larger part of the ground which may be said to have ***a hydrogeological function of permeable area***. They are marked in dark-green in the Annex 2.

Moderate permeability rocks with fracture porosity

The Carbonate Mesozoic rocks also belong to this group, but to a lesser degree of Cretaceous $K_2^{1,2}$, $K_1^{1,2}$, and mostly of Jurassic age $J_3^{2,3}$, $J_3^{1,2}$, J_2, J_1^3, $J_1^{1,2}$ and J_1.

In lithological terms, these rocks are mostly limestones and dolomites in alternation, dolomite limestone breccias, locally reef flaglike limestones, and limestones with lenses and dolomite interbeds. The permeability of these rocks (shown in graphics) is fracture porosity. These rocks are expected to have lower permeability which is manifested as lower infiltration capacity (vertical seepage). Moreover, the hydrogeological function of the rocks becomes close to impermeable with depth. We believe that the rocks which form the structures in the area under investigation have the ***function of a relative hydrogeological barrier.*** They are marked in a lighter shade of green in the Annex 2.

Low permeability rocks

Low permeability rocks include low permeability clastic deposits and low permeability carbonate deposits.

Low permeability clastic deposits identified in the eastern borderline part of the terrain (in the Bihaćko Polje area), include smaller outcrops of limestone marls, marls and tuffs with interbeds of coal in alteration of Miocene age (M^2_2). Their surface distribution in this part of the terrain is also limited, so they may only have the function of a ***local hydrogeological barrier.***

Next are the Cretaceous carbonate rocks, dolomites and dolomite limestones of the Cenomanian and Turronian age ($K_2^{1,2}$), dolomites and dolomite breccias of the Lower Cretaceous (K_1), and dolomites and flaglike limestones with cherts (J_3, $J_3^{2,3}$). In this group, there are also flaglike clay limestones of the Upper Lias (J_1^4). Since these rocks form various structural relationships, which have not yet been understood to a satisfactory degree, the function of these rocks may be defined as that of ***relative hydrogeological barrier*** to karst groundwater movement. The said deposits form groundwater basins of very low capacity and present a floor barrier to karst aquifers of Jurassic limestones and dolomites.

In places where the dolomites have been brought to the same level with limestones as a result of tectonic movements, the dolomites act as lateral hydrogeological barrier.

The oldest rocks, the Upper Triassic dolomites ***($^2T_3$)***, are developed in the central part of the terrain.

These rocks are significantly less distributed in the area under investigation, and due to their position terrain structural framework, they have the function of a ***complete surface and underground hydrogeological barrier*****.**

In graphic illustrations, low permeability carbonate deposits are marked in a light shade of green, and low permeability clastic deposits are pink in Annex 2.

Impermeable deposits

Impermeable deposits in the area under investigation include the Lower Triassic ***(T_1^1)*** deposits which are built of sandstones, schists and limestone breccias of the Seisian stage, and schists, sandstones, limestones and dolomites of the Campilian stage ***(T_1^2).*** Within these formations, there are individual members which according to their lithological properties belong to partially permeable or even permeable members, but they do not affect the impermeability of the entire complex. In the area under investigation, these deposits represent a hydrogeological barrier in the floor of more permeable deposits. Impermeable rocks in the area under investigation are located in the Krbavsko Polje area and in the south-western part of the Koreničko Polje in transition towards the Bijelo Polje.

The group of impermeable rocks also includes the Quaternary tufa deposits ***(i),*** which in the greater area form the Plitvice Lakes waterfalls, as well as the waterfalls on the karst rivers of Slučnjica, Korana and Una. These rocks have a relatively small spatial distribution, so their hydrogeological function is limited. Their function may therefore be defined as a ***complete hydrogeological barrier to surface water flows.*** In the attachment, these deposits are marked in light brown in Annex 2.

4.3.2 Hydrogeological functions of the terrain

Lithological properties of the rocks present in the area, their hydrogeological characteristics, structural relationships, spatial arrangement and geometry of geological bodies and morphology of the terrain condition the hydrogeological function of specific parts of the area. Considering the earlier mentioned elements, in the area under consideration presented in the hydrogeological map (Annex 2), it was possible to identify hydrogeological barriers and a permeable area within the Klokot source catchment area.

Hydrogeological barriers in the area under investigation include parts of the terrain in predominantly folding anticlinal structures, parts built of impermeable deposits, and regional reverse faults for which there is evidence of structural compression.

In the area under investigation the Plitvice – Korenica structure acts as hydrogeological barrier built of poorly permeable Upper Triassic dolomites at its core and the Lias dolomite deposits in the wings. This entire area prevents deeper underground circulation of water. In the area of this structure, there are springs of lower capacity and occasional surface streams which disappear in ponors in the field along the fault contact with the Trovrh – Gola Plješivica structure, which belongs to the permeable area.

A full hydrogeological barrier is made of the Lower Triassic deposits on the surface of the anticline which forms the Pišač – Udbina tectonic unit.

Further on, there are anticlinal structures near Meljinovac and the Plitvice Lakes with the core made of impermeable and poorly permeable deposits.

Hydrogeological barrier is also the regional (transcurrent horizontal) fault along the south-east rim of the Bihaćko Polje which cuts off the paleo groundwater flow paths. The cut off paleo groundwater flow paths along with the poorly permeable Miocene deposits resulted in occurrence of large karst springs along the field rim (Arkovac, Brišovac, Klokot; Vedro Polje, Žegar, Privilica).

Permeable area built of limestones and to a lesser degree of dolomites, occupies the greatest surface in the area under consideration. In this type of terrain, permeable, secondary fractured and karstified carbonate rocks drain, without significant limitations, all precipitation into the underground and ensure underground outflow. It is especially evident in the major fault zones and in the terrain of pronounced karst morphology (ponors, holes, potholes, *dolines*). Either there is no surface runoff, or the water courses are insignificant and gradually disappear or directly flow into the ponors. All the water which does not return into the atmosphere by evaporation sinks very quickly into the karst underground. In the area under consideration, these areas are formed of unstratified limestone breccias of Eocene and Oligocene age ***(E,Ol)***, limestones and limestone breccias of the Lower Cretaceous ***(K_1)***, limestones of Cretaceous **(K_2^3 , $K_2^{1,}$, K_1)** and to a lesser degree of the Jurassic $J_3^{2,3}$ age.

Relative barriers take up a smaller part of the terrain within the permeable area, where they locally direct groundwater flows (northwest and southeast of the Plitvice Lakes, southeast part of the Koreničko Polje). This group also includes carbonate Mesozoic rocks, to a smaller degree of Cretaceous (**$K_2^{1,2}$, $K_1^{1,2}$**) and mostly of Jurassic age. ***($J_3^{2,3}$, $J_3^{1,2}$, J_2 , J_1^3 , $J_1^{1,2}$*** and ***J_1).***

4.4 OVERVIEW OF THE CONDUCTED TRACINGS

Since 1968, a series of dye tracings have been conducted in the Klokot and Privilica source catchment area in order to determine groundwater relations and apparent groundwater velocities in the catchment and establish the protection zones for the said sources. The tracings are presented in Annex 3.

4.4.1 TRACINGS CONDUCTED FROM 1968 TO 2020

Tracing of the Korenička River, Jaruga River (Krbavsko Polje) and Prijeboj ponor

The Protection of the Klokot Spring in Bihać, Hydrogeological Investigative Works – Phase 1, Industroprojekt Zagreb 1982 analyses all the tracings conducted until that year.

The initial hydrogeological dye tracing in the Klokot and Privilica catchment area was conducted from the Korenička River ponor in 1968. Soon after, in 1969, dye tracing was conducted from the Jaruga stream ponor in the Krbavsko Polje, and in 1982 from the Prijeboj ponor.

The Korenička River dye tracing was conducted on 23 May 1968 by using 30 kg of uranine. The dye was monitored at fifteen locations, but it was recorded only at springs on the Bihaćko Polje rim (Dobrenica, Privilica, Vedro Polje, Žegar and Klokot). The Klokot spring is about 11 km away from the Korenička River ponor and the apparent groundwater velocity was established at about 3.0 cm/s (Annex 3).

The Jaruga River ponor dye tracing was conducted on 26 June 1969 by releasing 50 kg of uranine in the Jaruga stream ponor. The dye was monitored at several locations near the Klokot spring. It was registered only at the Klokot spring which is located about 23 km away from Jaruga. The apparent groundwater velocity was calculated at about 4,4 cm/s (Annex 3).

On 16 September 1982 dye tracing of the Prijeboj ponor in the vicinity of the Plitvice Lakes was conducted. Fifty kilogram of uranine was injected in the ponor. The dye was monitored at ten observation points, and it was established that it appeared at all the observed locations (Annex 3).

The study *Water Investigation Works on Simultaneous Groundwater Tracing at the Prijeboj and Koreničko Polje Locations, GeoAqua, Zagreb, March 2020* describes tracings carried out from the Prijeboj and Koreničko Polje ponor.

The dye tracings were conducted simultaneously from the Prijeboj and Koreničko Polje ponor on 6 March 2020. At the time of the dye injection into the Prijeboj and Koreničko Polje ponor, 4 l/s and 8-10 l/s of water respectively was sinking into the ponor. The tracing was conducted by simultaneous injection of uranine (sodium fluorescein, CAS-No. 518-47-8) from the Koreničko Polje ponor location and naphtionate (sodium naphtionate, CAS-No. 130-13-2) from the Prijeboj ponor.

The tracer observation points were: the water supply sources Klokot (designated as Klokot 1), Privilica and Žegar, and Klokot 2 spring where a fish pond is situated. In addition to the said observation points, after visual determination of the uranine tracer (tracer injected into the Koreničko Polje ponor) at the Ilijića Vrelo spring in Vedro Polje, the Water Supply company staff started an additional sampling at the Vedro Polje springs (Ilijića Vrelo, Panjak and Pećina).

The water sample analyses show that the first appearance of uranine injected into the Koreničko Polje sponor was observed at the Klokot 1 source in sample taken on 11 March 2020 at 23:00, namely 5 days and 9.5 hours after the tracer injection on 6 March 2020 at 13:30. Peak concentration at the Klokot 1 location was recorded for the sample taken on 13 March 2020 at 6:00 am, i.e. 6 days and 16.5 hours after the tracer injection. The distance from the Koreničko Polje ponor to Klokot 1 source location (11,158 m) was used to calculate an apparent velocity of the first tracer appearance v_1= 2.39 cm/s, while the apparent velocity of the maximum measured concentration is $v_{max.conc}$.=1.93 cm/s. At the Klokot 2 sampling location the uranine tracer appearance was recorded for a sample taken on 12 March 2020 at 7:00 am, i.e. 5 days and 17.5 hours after the tracer injection into the Koreničko Polje pomor. Maximum uranine concentration was recorded in a sample taken on 13 March 2020 at 18:00 (elapsed time 7 days and 4.5 hours). The distance from the Klokot 2 sampling location to the tracer injection location in Koreničko Polje (11,050 m) was used to calculate an apparent velocity of the first tracer appearance v_1=2.23 cm/s, while the apparent velocity of the maximum measured concentration is $v_{max.conc}$.=1.78 cm/s. Ultimately, an analysis of water samples from the Klokot 1 and Klokot 2 and Ilijića Vrelo sources determined appearance of the uranine tracer. No appearance of uranine was observed at the Privilica and Žegar springs and in samples from additional observation locations at the Panjak and Pećina springs (Annex 3).

The analysis of the collected water samples determined appearance of the naphtionate tracer (tracer injected into the Prijeboj ponor) at the Klokot 1 source. The first tracer appearance was determined in sample taken on 21 March 2020 at 12:00, i.e. 14 days and 22 hours after the tracer injection at the Prijeboj ponor on 6 March 2020 at 14:00. Peak concentration was measured in sample taken on 27 March 2020 at 12:00 (20 days and 22 hours after injection). The distance from the Klokot 1 spring to the tracer injection location is 10,529 m, the computed apparent velocity of the first tracer appearance is v_1=0.82 cm/s, while the apparent velocity of the maximum measured concentration is $v_{max.conc}$.=0.58 cm/s. The naphtionate concentration measured in the last sample taken on 31 March 2020 is 5.9 ppb, which means that the tracer continued to leak at the subject location even after the sampling was finished (Annex 3).

The analysis of samples taken at the Klokot 2 location determined appearance of the naphtionate tracer. The first appearance was determined in sample taken on 22 March 2020 at 12:00 (15 days and 22 hours after tracer injection into the underground), while the peak concentration value for the tracer was recorded in sample taken on 26 March 2020 at 12:00 (19 days and 22 hours after injection). The presence of naphtionate was recorded in the last sample taken (5.9 ppb), which means that the tracer has not completely leaked from the underground until the end of the sampling. The distance from the Klokot 2 observation point to the

Prijeboj ponor (10,585 m) was used to determine apparent first tracer appearance velocity v_1=0.77 cm/s. The computed apparent velocity of the maximum measured concentration is $v_{max.conc.}$=0.61 cm/s (Annex 3).

The analysis of all samples for appearance of naphtionate tracer determined its presence in observation points Klokot 1 and Klokot 2, while it was not recorded in samples taken from the Privilica and Žegar springs. No appearance of naphtionate was observed at the additional observation locations at Vedro Polje, and at Ilijića Vrelo, Panjak and Pećina sources.

The dye was injected into the Pejićev Ponor at the Krbavsko Polje on 17 June 2020. Dye tracing was conducted by injecting 50 kg of uranine. The groundwater level was low, thus dye has not appeared so far (4 August 2020) at the observation locations along the Bihačko Polje rim. Based on the instructions of the Hrvatske Vode supervising engineer, water sampling at the observation locations along the Bihaćko Polje rim would have to be continued until the dye appears.

Tracing of ponor at the Vučjak solid waste landfill

The *Protection of the Klokot Spring in Bihać, Sanitary Protection Zones Phase 3, Ina Projekt Zagreb, 1984* analyses tracings conducted from the Vučjak landfill in order to establish the Klokot source sanitary protection zones.

The tracing was conducted by using 40 kg of uranine from the Vučjak ponor in which the landfill is situated. The dye was monitored at 15 locations (Table 1), and it appeared at the Klokot 1 and 2, Privilica and Vedro Polje springs located at the Bihaćko Polje rim. The apparent groundwater velocity to the Klokot spring, which is situated 4.5 km away from the said ponor, is 6.58 cm/s. The apparent velocity of groundwater to the Privilica spring, which is located 4.65 km from the Vučjak landfill, was determined as 5.86 cm/s.

Tracing of ponor at Željava military facility

The *Protection of Klokot, Privilica and Žegar Sources in Bihać, Supplemental Hydrogeological and Sanitary and Investigative Works, Phase V, Ina-projekt Zagreb, 1987* describes the tracing conducted in the area of the Željava special purpose facility. The dye was monitored at nine locations. Thirty kilogram of uranine was injected, and 40 hours after injecting the dye it was registered at the Klokot spring and after 32 hours at the Privilica spring. Dye was also recorded at other observation points along the Bihaćko Polje: Žegar, Vedro Polje, Arkovac, Brišovac and Bistrica-Gata. The apparent groundwater velocity to the Klokot was 5.47 cm/s, and to the Privilica spring 11.94 cm/s (Annex 3).

Tracing of Rastovača ponor

The Report on the Rastovača ponor Tracing, Faculty of Geotechnical Engineering in Varaždin, 2005 presents the data about the conducted tracing of a ponor in Rastovača village, which is the main recipient for wastewaters of the largest part of the Plitvice Lakes National Park. The tracing was conducted on 21 April 2005, at the time when the flood wave was receding. Thirty kilograms of uranine was injected into the ponor. The dye was monitored at seven observation points. At the Korana, Barića cave, Gavranića Vrelo spring and Kukuruzovića spring the dye was detected using activated carbon. Except at the Klokot spring, the dye did not appear at any other observation point. Sampling was done at the Klokot spring observation point, and analysis was conducted in the hydrogeochemical laboratory of the Faculty of Geotechnical Engineering in Varaždin. The Klokot spring is 17.6 km away from the Rastovača ponor and the dye appeared at that observation point 428 h after its injection in the ponor. The apparent groundwater velocity was calculated at 1.14 cm/s (Annex 3).

Tracing from PB-1 borehole

Within preparation of the *Hydrogeological Investigations at the Site of the Wastewater Treatment Plant in the Plitvice Lakes NP and the Municipality of Rakovica, Faculty of Geotechnical Engineering in Varaždin, 2007* dye tracing was conducted from the PB-1 borehole which was bored in the vicinity of Drežnik Grad. The tracing was conducted on 25 September 2007, while observation points were organized at the Gavranića, Baraćevo and Klokot springs. The samples were analysed in the hydrogeochemical laboratory of the Faculty of Geotechnical Engineering in Varaždin.

The first appearance of dye was registered at the Klokot spring near Bihać with apparent groundwater velocity of 1.128 cm/s, but in very low concentrations (Annex 3).It may be concluded from the tracing results that there is an evident underground connection with the Klokot spring near Bihać in Bosnia and Herzegovina, but also that a relatively small share of groundwater is flowing towards that spring. In this case, when tracing was carried out from the borehole, most of the dye remained in the underground at the injection point level, and it was not until the first rains (when the Korana started flowing again through its river bed) that it appeared immediately by the injection point. It is not possible to separate the surface from the underground transport of dye towards the Gavranića spring.

This proves that water is partially running under the ground towards the Klokot, but the majority of water is retained in the aquifer in the immediate vicinity. It is obvious that there is an underground barrier to groundwater flows that allows the overflow of a part of groundwater towards the Klokot, while the rest remains on the north-east side of that barrier and is directed towards Gavranića spring. Therefore, it could be concluded that there is a bifurcation, namely recharging of the Una catchment from the Korana catchment.

Tracings from Stankovića ponor in Trnovac Polje field

The report *Water Investigation Works Aimed at the Protection of the Krbavica Spring, Phase II – Tracing of the Sink in the Trnovac polje, the Croatian Geological Survey, Zagreb 2010* describes two dye tracings conducted from the ponor in the Trnovac Polje.

The initial tracing was conducted on 30 March 2010 at the time when the flood wave was receding. On that occasion, 5 kg of uranine dissolved in 100 litres of water with addition of 2 kg of NaOH was injected into the ponor. At the time of the injection of dye, 45 l/s of water was sinking into the ponor. The dye was monitored at 12 locations. It appeared at the Tonkovića vrilo, Klanac and Majerovo springs which are located in the Gacka River catchment area. At the Tonkovića spring the dye appeared after 170 hours, at the Klanac after 164 hours, and at the Majerovo spring after 212 hours. The apparent groundwater velocities were calculated at: 2.62 cm/s, 2.72 cm/s and 2.32 cm/s respectively.

The tracings confirmed that the groundwater from the Trnovac Polje area flows towards the Gacka catchment area, and that it does not gravitate towards the Klokot and Privilica sources catchment area.

Tracing of Šuputova Draga ponor in Homoljačko Polje

The report *Tracing of the Šuputova Draga Sink in the Homoljačko polje, the Croatian Geological Survey, 2013* describes the tracings which were conducted from the Homoljačko Polje for the purpose of collecting additional information required for the preparation of the Recommendation of protection zones for the Krbavica source. The tracing was conducted on 12 March 2013 at the time when flood waters were present at the Krbavica catchment by using 75 kg of sodium naphtionate. The dye was monitored at twelve locations (Table 1). The tracing of the Šuputova Draga ponor on the south edge of the Homoljačko Polje confirmed its underground hydrological connection with the Gacka River springs: Tonkovića, Klanac and Majerovo spring.

At other observed locations, the dye did not appear. The apparent groundwater velocity towards the Tonkovića spring was 4.37 cm/s, towards the Klanac spring 4.37 cm/s and towards the Majerovo spring it was 3.89 cm/s.

This tracing confirmed that the waters from the Homoljačko Polje flow towards the Gacka River catchment, and that they do not gravitate towards the Klokot and Privilica source catchment.

Tracing at Kuselj plateau

The tracing from the Kuselj ponor was conducted on two occasions: in 1978 and 1999. The tracings were performed for the purpose of defining the northern boundary of the Plitvice Lakes NP. The information on the tracings was taken over from the paper by Marušić and Ćuruvija (1990-91) and is presented in Annex 3.

The first tracing from the Kuselj ponor was conducted on 22 September 1978 by using 6 kg of uranine. The dye was recorded after 17 days at the Sartuka (Mliništa), which is a small left tributary. Within the investigations conducted in 1999, on 9 September 1999, the tracing was conducted from a borehole/well near the Kuselj spring (Ivičić, 1999) by injecting 20 kg of uranine. The dye appeared at the Kuselj spring after 15 minutes, slowly sinking into the water in the pre-ponor retention. The dye did not appear at the expected observation points even after 30 days when the monitoring and sampling was concluded.

The tracing conducted at the borehole/well, that is, indirectly at the Kuselj ponor, indicates that the waters from the Kuselj are drained in the north direction towards the Slušnica, or towards the Korana River upper course. The tracing was used to define the northern boundary between the Korana catchment and the Klokot spring catchment.

Tracing from Kozjan area

The tracing from the Kozjan area was conducted on 21 March 1975. The dye appeared at the Tonkovića spring in the Gacka catchment after 12 days. The said tracing cannot be taken with certainty, because the analysis was conducted by visual determination, which is not considered a safe method.

The tracing in Čanak near Kozjan was conducted in 2019. The observation was arranged at the Gacka springs where the dye appeared after 33 days. This report is currently in preparation.

Tracing from Brezovac

The *Hydrogeological Investigations for the Assessment of Possibility of Drinking Water Intake at the Plitvice Lakes Greater Area, CGI, Zagreb 2003* report states that the tracing from Brezovac was conducted on several occasions in 1979 and 1980. In 1979, the dye from the cave in Brezovac appeared after 14 hours at the Crno Vrelo and Prećina springs in the Plitvice territory. The apparent groundwater velocity was established at 10.91 cm/s. In 1980, the dye from Brezovac appeared after 46 hours at the Crno Vrelo and Prećina springs, and the apparent velocity was established at 3.86 cm/s (Annex 3).

Tracing from Babin potok

The tracing at the Babin Potok brook confirmed the connection with the Gacka River springs and defined that part of the divide between the Black Sea and the Adriatic basin, that is, the protection zone boundary was defined in its western part.

<u>Table:</u> Summary of conducted tracings

Dye tracing site	Dye tracing date	Emergence Site	Distance	Apparent Velocity	
			(km)	(m/h)	(cm/s)
Korenička River ponor	23.05.1968	Dobrenica spring	12.0	99.72	2.77
		Privilica spring	12.0	99.72	2.77
		Vedro polje	10.0	70.56	1.96
		Žegar spring	10.0	70.56	1.96
		Klokot spring	11.0	124.92	3.47
	06.03.2020	Klokot 1	11.2	86.04	2.39
		Klokot 2	11.1	80.28	2.23
		Ilijića vrelo	12.4		
Jaruga ponor	25.06.1969	Klokot 1	23.0	159.72	4.44
Krbavsko polje- Pejića ponor	17.06.2020.	04.08.2020. the tracer is not yet detected on observation points			
Prijeboj ponor	16.09.1982	Klokot 1	11.5	237	6.58
		Klokot 2	11.5	137	3.81
	06.03.2020	Klokot 1	11.5	29.52	0.82
		Klokot 2	11.5	27.72	0.77
Vučjak Landfill	09.10.1984	Klokot 1	20.0	237	6.58
		Klokot 2	19.0	232	6.44
		Privilica	22.0	211	5.86
		Žegar	93.0	28.5	0.79
		Vedro polje, Pećina	124.0	13.7	0.38
Željava ponor	02.07.1987	Klokot 1	6.5	197	5.47
		Klokot 2	6.6	161	4.47
		Privilica	13.8	430	11.94
		Žegar	11.9	260	7.22
Rastovača ponor	21.04.2007	Klokot 1	17.6	41.04	1.14
PB-1, Drežnik	25.09.2007	Klokot	18.0	40.61	1.13
Stanković ponor/ Trnovac polje	30.03.2010	Tonkovićevo vrilo	16.1	94.32	2.62
		Klanac	16.1	97.92	2.72
		Majerovo vrelo	17.7	83.52	2.32
	24.04.2010	Klanac	16.1	54.36	1.51
		Majerovo vrelo	17.7	56.88	1.58
Šuputova draga - Homoljačko polje	12.03.2013.	Majerovo vrelo	19.3	140.04	3.89
		Klanac	17.9	157.32	4.37
		Tonkovićevo vrilo	17.9	157.32	4.37
Kuselj ponor	22.9.1978.	Mliništa	1.3	110.16	3.06
Brezovac	17.11.1979.	Crna rijeka	14.0	392.76	10.91
		Pećina spring	28.0	231.84	6.44
	21.3.1980.	Crna rijeka	36.0	152.64	4.24
		Pećina spring	46.0	138.96	3.86

Conclusion

This chapter presents the results of dye tracings which were conducted from 1968 to 2020 in the area of the Klokot spring catchment or its borders, thus confirming the connections of the traced ponor with the springs at the rim of the Bihaćko Polje, or establishing the boundary towards other catchments.

Different apparent groundwater velocities were registered. The measured velocities of groundwater flowing towards the Klokot spring ranged from 125 to 237 m/h, while for the Privilica spring, the determined groundwater velocities ranged from 95 to 430 m/h. Such difference is largely the result of hydrological conditions prevailing at the time of tracing, but it may also be attributed to different degree of karstification of the limestone underground.

4.4.2 DYE MASS BALANCE CALCULATION

Tracing from borehole PB-1 (2007)

To calculate the dye mass balance between the borehole PB-1 and the Klokot spring, a number of discharges measured at the Klokot spring (12 October 2007 to 21 October 2007) are used along with measured tracer concentration (ng/L).

Uranine was injected into the borehole on 25 September 2007. The tracer appeared on 12 October 2007.

Mean discharge at the Klokot spring for the period under consideration used in calculating of dye mass balance is Q_{sr}=10.09 m^3/s. Mean tracer concentration in the period under consideration is 19.92 ng/L. The resulting dye mass balance at the Klokot spring is 0.63%. It is obvious that only part of dye appeared at the Klokot spring, and that part of tracer either remained in the underground or run on the surface towards the Korana River.

Tracing from Prijeboj and Koreničko Polje ponor (2020)

During the period from 5 March 2020 (reference samples taken) to 31 March. 2020, simultaneous dye tracing was conducted of ponor in Koreničko Polje and Prijeboj using two different tracers (GeoAqua, 2020). On 6 March 2020, the ponor in Koreničko Polje was injected 50 kg of uranine tracer; simultaneously, 250 kg of sodium naphtionate tracer was injected into the ponor in Prijeboj. Tracer appearance was observed by digital GGUN-FL30 fluorometer made by Albillia Sárl (Switzerland) at the Klokot 1, Klokot 2, Privilica, Žegar, Ilijića vrelo, Pećina and Panjak springs.

Sodium naphtionate appeared at the Klokot 1 and Klokot 2 sources in concentrations higher than the detection limit set up for the instrument. Appearance of uranine was recorded at the Klokot 1 and Klokot 2 springs and the Ilijića Vrelo spring.

No tracer concentrations higher than detection limit of used digital fluorometer were detected at other sources.

Based on mean daily discharges and measured concentrations of individual tracers their mass balance in kilograms and percentages was calculated:

Table: *Calculated tracer mass balance at the Klokot source (Klokot 1 + Klokot 2)*

	Tracer mass balance (kg)	Tracer mass balance (%)
uranine	9.81	19.62
sodium naphtionate	12.81	5.12

Relatively low tracer mass balance values could be caused by several factors:

- high rate of dilution in aquifers recharging the sources, due to the tracer dispersion and diffusion,
- uneven distribution of tracer monitoring times, so it is possible that maximum tracer concentrations vanished between two measurements,
- low detection limits for tracer concentration set at the instrument used,
- quantities of tracer injected into ponor which could be increased in some future tracings.
- hydrological conditions characteristic for medium flows.

4.5 DEFINING THE HYDROGEOLOGICAL CATCHMENT AREA OF THE KLOKOT AND PRIVILICA SPRINGS

In the area under consideration, water forming and travel is in direct connection with the above described lithostratigraphic terrain structure, structural and tectonic relationships and hydrogeological characteristics of rocks. The hydrogeological functions of the terrain have the deciding role in interpretation of water flows and occurrence of springs, where apart from the hydrogeological characteristics of rocks and fault tectonics, structural forms have to particularly be taken into account. The prevalently carbonate structure of the terrain, where highly permeable, significantly fractured by faults and then karstified limestones are dominant, makes it difficult to define the groundwater flow directions and velocities and generally to interpret hydrogeological relationships, which is a baseline for determination of the protection zones.

The previous description of tectonic structure emphasizes the block tectonics, with identified individual tectonic units bounded by pronounced faults. The hydrogeological function of the terrain should hereby be emphasized where not only the hydrogeological characteristics of rocks but also the structure form is the function of water flow. It should also be taken into consideration that anticlinal forms generally act as potential barriers, which slow down or obstruct water flow.

Therefore, within the greater permeable area which is dominant in the terrain under consideration, there are individual larger structures or parts of structures (geological bodies) bordered by regional faults, which may be of use in interpretation of spring occurrence and analysis of groundwater flows, as well as in defining the protection boundaries.

The protection zone boundary is marked on the map by a continuous line regardless of the level of certainty and the assessed accuracy of its actual position. Considering that the largest part of the terrain is formed of significantly karstified carbonate deposits, the position of the depicted **divide should correspond to the zonal divide**, where the position may significantly vary due to the complex hydrogeological structure of the terrain or because of the changes in groundwater levels.

The divide is more accurately positioned in sections where it passes the terrain built of poorly permeable or impermeable rocks, at places where the terrain has the function of a hydrogeological barrier (Lička Jesenica, Plitvice Lakes, Udbina) or over the areas which belong to the anticlinal form – the Meljinovac tectonic block (south of the Žegar and Privilica springs).

The results of groundwater flows tracings were of greatest assistance in defining the sanitary protection zone boundary, that is, in establishing to which protection zone a part of the terrain belongs. Groundwater flow tracings are particularly important for dividing the Adriatic and Black Sea basins in the west (the Krbavsko Polje to Plitvice) and in the area of the “hanging course” of the Korana River. The south-eastern part of the protection zone (between Privilica and the Krbavsko Polje) is least covered with tracing, so this is where the greatest departures from the position of the divide – protection zone boundary are possible.

The western boundary, namely the boundary of the Klokot and Privilica springs is at the same time the boundary towards the Adriatic Sea basin. The Krbavsko Polje depression, which is the point from which the water is drained towards the protected springs (Klokot, Privilica), is bounded by a well-defined divide on the southwest. The divide in the greater area from Udbina to Srednja Gora crosses the terrain belonging to the anticline formed of Lower Triassic clastites (the Pišač – Udbina tectonic unit).

Further on, the west boundary continues to the Podlapača area, where the divide is defined by the occurrence of springs and ponors which gravitate towards the Krbavsko Polje, from which the water further flows towards the west (Jadova, Ričica). Further on, to the north, the divide - boundary passes the Krbavsko Polje on the west where it continues to be zonal until it reaches Bunić, with relatively small departures from the marked position. Near Bunić, the boundary towards the Gacka spring is rather well-defined by tracings conducted in the Kozjen area. Further on, the protection zone boundary turns northeast, bypassing the Krbavica springs, and east of Trnovec (confirmed by tracings) it goes on to the Homoljačko Polje through Brezovac (Crna Rijeka and Bijela Rijeka rivers, confirmed by tracings). After that, in the Vrhovine area, the boundary splits from the Adriatic and Black Sea divide and follows the divide which separates the Lička Jesenica and the Plitvice catchment.

In the area east of Kuselj, which is built of high permeability Upper Cretaceous deposits in the within the synclinal structure, the boundary continues towards the east until the permeable Cretaceous deposits come into contact with the tectonic unit built of poorly permeable dolomite deposits of the Triassic age. Therefore, at this section, the boundary is undefined and is of zonal character. From this syncline, the groundwater flows through the underground towards the Klokot (confirmed by tracings).

The most significant findings on the expansion of the area which will include the Klokot and Privilica spring protection zones were obtained by tracing of groundwater flows along the Korana River bed (the Rastovača ponor and PB-1 borehole). Therefore, the said part of the catchment will be described in more detail using the information from the report (Biondić *et al* 2007).

The regional fault stretches along the north-eastern rim of the Kozjak Lake and over the Plitvica settlement towards the Plitvice spring. It divides poorly permeable dolomites from the generally karstified medium of Cretaceous limestone. After the fault, the surface waters gradually disappear and the ponor zone begins which is eventually manifested as complete drying up of the Korana River (during the dry season) downstream of the Luketić settlement (a bit upstream of the Koranski most bridge). The fault also significantly affects the reduction of the Plitvica stream flow rate downstream of the Hajdukovića mill during the dry season, which in turn has an impact on significant reduction of water quantity of the Large Waterfall of the Plitvice Lakes.

Until the tracings were conducted in Rastovača in 2005 (Biondić *et al* 2006), the groundwater flow directions downstream of the Kozjak Lake and the great fault which stretches from Lička Jesenica to the Koreničko Polje were only presumed, but were practically unidentified. Namely, no tracings have been conducted in the area until then, and it was not possible to claim with certainty that the area was connected with the Klokot source in the Una River catchment, that is, that these two large underground systems were connected.

The Korana River downstream of Luketići, dries up and remains without water from late spring to the first autumn rains almost every year during the last decade. During that period, the Korana is dry in the belt from the Luketići settlement, which is situated between the Kozjak Lake and the Koranski bridge, to the Gavranića most bridge, where it meets the impermeable dolomite Triassic rocks, and again becomes a perennial river all the way to its mouth into the Kupa River near Karlovac.

It is evident that there is a barrier to the groundwater flows built of dolomites and dolomite limestones of Cretaceous age. It stretches along Crna Kosa and Selišta in the northern part, over Medvedak in the central part of the structure, to Ličko Petrovo Selo.

The barrier allows some of the groundwater to overflow towards the Klokot spring, while the remaining water stays on the north-eastern side of the barrier and is directed towards the Gavranića Vrelo spring. If there were no such barrier, the groundwater level in the Drežnik Grad area would be much lower than 10 meters below the Korana bed during the period when the bed is dry.

In the conditions when the Korana bed is dry, most of the groundwater is retained in the aquifer and it partly flows towards the Gavranića Vrelo spring, where it encounters dolomite rocks and resurfaces, making the Korana a perennial river, while a smaller part of water flows towards the Klokot spring. In the above described area, the Klokot and Privilica source catchment overlaps with the Korana River catchment. The border of the area is of zonal character.

The PB-1 piezometer borehole was made as the time when the Korana riverbed was dry, and it supplemented the knowledge about the hydrogeology of this part of the protection zone.

The PB-1 piezometer borehole (100m) was made for the purposes of investigations regarding the underground absorption capacity and tracing of groundwater flows. After the construction of the piezometer structure, the physical values of the aquifer (CND, T) were measured, which showed the gradual decrease of temperature, that is, the decrease of electrolytic conductivity values depending on the depth, indicating that this is “living” aquifer. In the dry riverbed conditions, the groundwater level is at about 10 m below the riverbed, which confirms that drying up of the Korana in the future facility zone is actually the result of the groundwater drawdown. After abundant rainfall, the underground recharges and because of the increase in groundwater level, Korana starts to flow again. Moreover, along the riverbed and in the very bed there are numerous intermittent springs.

Tracing of groundwater flows was conducted on 25 September 2007, after which the observation point network was established at the Klokot, Gavranića Vrelo and Baračevo Vrelo springs. The first appearance of the dye was registered at the Klokot spring with the apparent velocity of 1.128 cm/s, but in exceptionally low concentrations (27.39 ng/L). Most of the dye flowed directly into the Korana riverbed in the immediate vicinity of the injection point after rainfall and groundwater level rise. After that, numerous springs emerged in and near the Korana riverbed and Korana started to flow. It was only later, on 19 October, that the was also registered at the Gavranića Vrelo spring, and on 23 October at the Baračevo Vrelo spring. This confirms that only a small portion of water flows underground towards the Klokot spring, but that most of it is retained in the aquifer in the immediate vicinity. The dye tracing of groundwater flow was conducted in the conditions of extreme draught, but the obtained groundwater flow rates of 1.128 cm/s, even though of low concentration, correspond to the sanitary protection zone III, which confirms the need for waste water treatment plant construction. An area to the north-west from the borehole PB-1 is insufficiently investigated; however, due to the tectonic structure, hydrogeological characteristics of rocks and orography of the surrounding terrain this part of terrain has been included into the hydrogeological catchment of the Klokot and Privilica.

From all the above, it can be concluded that in the northwestern and northern part of the Klokot spring basin there is a significant bifurcation or recharge of the Klokot spring basin from the Korana river basin. In this part, the Plitvice Lakes basin is reliably defined, located on the impermeable triassic anticline and drained across the Korana River.

However, as it has already been said in the text so far, the Korana from Luketić to Gavranić Vrela has the function of a ponor zone. In this part of the river Korana has the so-called. hanging flow, which would mean that at high waters, the Korana flows in a surface stream, the waters overflow the ponor zone of the river Korana and flow downstream towards the Gavranića spring. However, at low waters the bed of the Korana in this part is dry, the waters are lost underground. On the mentioned section of the river Korana there are no permanent or occasional springs in the banks of the river, it is not an erosion base, which indicates that even in times of high water there is a runoff through the underground. Therefore, in all hydrological conditions, groundwater flows from the area of Plitvice Lakes into the Klokot basin, which was proven by tracing from Rastovača and well PB-1. As these were small concentrations of the established tracer at the springs along the Bihać field, we can talk about a relatively small amount of water from the said area. In conclusion, the waters of the Korana feed the Una basin (Klokot spring), so the possible pollution found in the river Korana or in its basin can also pollute the Klokot spring. Due to the above, it was necessary to define the entire area as a sanitary protection zone.

The eastern boundary of the protection zone passes over the Miocene deposits along the western rim of the Bihać basin, where the divide was defined by the terrain morphology within the Miocene deposits.

The south-eastern part of the boundary was defined by the hydrogeological barrier formed by the anticlinal structure with the Triassic core (the Meljinovac tectonic block). In that area, the boundary was confirmed by tracing, that is, the connection of the ponor in the Krbavsko Polje and Koreničko Polje with the Klokot and Privilica springs was confirmed, while the connection with the upstream sources along the Una River (Toplica and Loskun) was absent.

The position of the hydrogeological divide was corrected from the said barrier to the Udbina area in relation to the previous protection zone. Namely, the old boundary was defined by taking into consideration only the orographic features. Now, the hydrogeological structure of the terrain was also taken into account, so the boundary was positioned at the contact between the impermeable Jurassic and the Lower Cretaceous deposits. So far, there are no other elements which would indicate that the boundary in this area was reliable (the connection of this part of the terrain with the Loskun source is not completely defined).

All the above stated and described leads to the conclusion that there should be a significant extension of the protection zone in relation to the zone established by the Study of 2004.

The surface area of the catchment which gravitates towards the springs along the Bihaćko Polje amounts to 737,5 km^2. The catchment area around the Plitvice Lakes is the area where the catchment border is of zonal character. The waters from this part of the catchment, even though in lesser part, flow towards the springs located along the Bihaćko Polje. The surface area of this part of the catchment is 214 km^2.

Therefore, total area of the Klokot and Privilica spring hydrogeological catchment is 951.5 km^2, of which 90.5 km^2 is located in Bosnia and Herzegovina, and 861 km^2 in the Republic of Croatia.

The said extension in area of the north-western part of the catchment primarily relates to the increase of the surface area to be protected; however, the extended surface affects to a lesser degree the total water quantity encompassed by the Klokot and Privilica sources catchment.

The hydrological investigations conducted so far have proven that the catchment is also recharged from the extended part of the catchment on the north-west; however, this does not mean there are new quantities of water in the catchment since the inflows from this part of the catchment are already included in the measurement data for the sources in Bihačko Polje, which has not been known and documented so far with the results of the recent tracings and hydrological observations and measurements.

4.6 HYDROLOGICAL CHARACTERISTICS

4.6.1 Review of previous analysis from the study "the Klokot and Privilica springs in the municipality of Bihac protection project"

From the Hydro-Engineering Institute of the Faculty of Civil Engineering in Sarajevo, 2004 (mr. sc. Esena Kupusović, dipl. ing. građ.)

The study comprises 162 pages of text and 32 figures. Having in mind the subject matter of the study, this review reports not only on the section on hydrology but on the entire study.

The cover pages, list of contributors and table of contents are followed by the ***Terms of Reference***. The study was prepared in accordance with the Terms of Reference and divided into six parts. The seventh part is References. These are followed by the Draft Decision on Protection of the Klokot and Privilica Potable Water Springs, Rationale of the Decision and annexes.

Part one, ***Introduction***, contains general data on locations and capacities for water supply of Bihać from the Klokot spring (abstraction 250-280 l/s), and from the Privilica spring (abstraction 120 l/s) that would partly supply Bihać and additionally the settlements of Ripač and Sokolac. The water supply system in this area also draws water from another three springs, Žegar (about 5 l/s), Smiljanovac (about 5 l/s) and Duparica (3 l/s), with considerably lower capacity than Klokot and Privilica. The Gata spring where 8 l/s is abstracted from sub-artesian wells is one of small water sources situated in the area under consideration. The Klokot is one of the largest karst springs in Bosnia and Herzegovina and its capacity considerably exceeds the present abstraction rates. The Study emphasizes the importance of protecting these water sources.

Part two, ***Matters under Consideration***, describes the main characteristics of distribution of the abstracted water. The main characteristics of the Klokot and Privilica springs along with the protection zones I-III are described. Since it has been established that the groundwater velocities in the greater water source area are very high, the possible pollution transportation velocity from the upstream catchment is very high. Therefore, its is necessary to establish an adequate protection regime for the Klokot and Privilica sources. Based on the conducted investigations, an adequate documentation was prepared in accordance with the Federation Water Act, Ordinance on Protection Zones and other applicable regulations.

Part three, ***Previous Investigations***, is a brief overview of the results of previously conducted investigations, from defining of four sanitary protection zones relaying on the results of the first phase of complex geological investigations and their interpretation by Industroprojekt, Zagreb (1982), to determination of the sanitary protection zones based on the determined hydrogeological relations in the Klokot source by INA-Projekt, Zagreb (1983 and 1984), and Study on Geology, Hydrogeology, Engineering Geology and Seismotectonics of the Ground and Hydrogeological Cadastre by Geoinženjering, Sarajevo (1985). The Geological Survey from Zagreb conducted a preliminary investigation of speleological structures in the narrow Klokot source area in 1986. Based on the investigations carried out during the period (1982-1986), a detailed presentation of physico-chemical and bacteriological characteristics of the water from the Klokot, Privilica and other less significant springs was prepared by INA-Projekt, Zagreb. The directions of surface and groundwaters travel were presented in two studies prepared by RO Geoinženjering, OOUR Geoinstitut, Ilidža, 1987.

Part four, ***Characteristics of the Greater Water Source Area***, covers the Klokot and Privilica source areas, and consists of eight sections:

(4.1) C*atchment General Characteristics*. Total surface of the Klokot and Privilica source catchment areas is estimated at ***F*** = 686.5 km^2. About 94.5 km^2 or 13.8 % of the catchment is located in Bosnia and Herzegovina, in the Bihać Municipality territory, and about 592 km^2 or 86.2 % of the catchment is located in the Republic of Croatia, in the municipalities of Plitvice Lakes (268 km^2 or 39.0 %) and Udbina (324 km^2 or 47.2 %). A part of the catchment in the vicinity of Bihać belongs to temperate continental and temperate mountain climate zone, and the part of the catchment mostly situated in Croatia is in the mountain continental climate zone. The average annual air temperature is St_{av} = 10 – 12 °C, and average annual precipitation in the catchment is P_{av} = 900 – 1,000 mm. (The fifth part of the Study, section *Framework Water Balance for Determination of the Klokot and Privilica Source Catchment*, refers to the average annual precipitation as P_{av} = 1,250 mm.). It is noted that the average annual precipitation at the Bihać Weather Station for the period (2005-2014) is P_B = 1,417 mm (Table 4.6, section 4.3.1 herein).

(4.2) *Geological and hydrogeological characteristics.* Based on the investigations carried out in the period (1962-1966) and consolidated results of previous investigations (that started in 1862) the Croatian Geological Survey, Zagreb prepared the Basic Geological Map, Bihać sheet, in scale 1:100,000. It was concluded, based on the described and considered lithofacies characteristics of the catchments, that typical karst hydrography developed in the catchment. Formation of surface streams is not possible due to large-scale tectonic deformation, fissuring, and karstification of the rock mass. The water flows through the underground fissure systems, through interconnected underground conduits. The groundwater flows from the Krbavsko Polje and Koreničko Polje fields towards the Klokot and Privilica source areas. It is concluded that the basic Klokot and Privilica protection requirements need to focus on the area within the Trovrh – Gola Plješivica block.

According to the available data, dye tracing of individual ponors within the catchment started in 1968. Significance of individual tracing activities for defining of the sanitary protection zones is described and emphasized. During the investigation phase 2, carried out by Industroprojekt, Zagreb in 1984, it was established that the most dangerous contamination of groundwater draining into Klokot spring is that from the Krbavsko Polje and Koreničko Polje fields.

(4.3) *Analysis of hydrogeological and hydrodynamic relations and parameters for determination of protection zones.* An adequate analysis of hydrogeological and hydrodynamic relations and parameters was carried out for the area under consideration. The results of measurements of water velocity in the underground carried out in the period (1968-1987) were analysed and used as the basis for determination of protection zones. The water rises in two points: in the primary ascending spring Klokot 1 (with the highest inflows), and its water is used for water supply of Bihać, and in the secondary Klokot 2 spring, where a fish pond is situated. Annual discharge fluctuation for the Klokot spring is from 1:7 to 1:12, which classifies it as a spring with rather stable capacity.

The Privilica spring is concentrated in a single outflow point and it has, similar to Klokot, relatively stable capacity with annual discharge fluctuations of 1:10 and minimum discharge of Q_{Pmin} ≈ 50 l/s.

The map in Figure 4.1 is taken over from the project documentation under consideration and it shows groundwater flow directions, and Table 4.1, taken from the same source, gives values of apparent groundwater velocities.

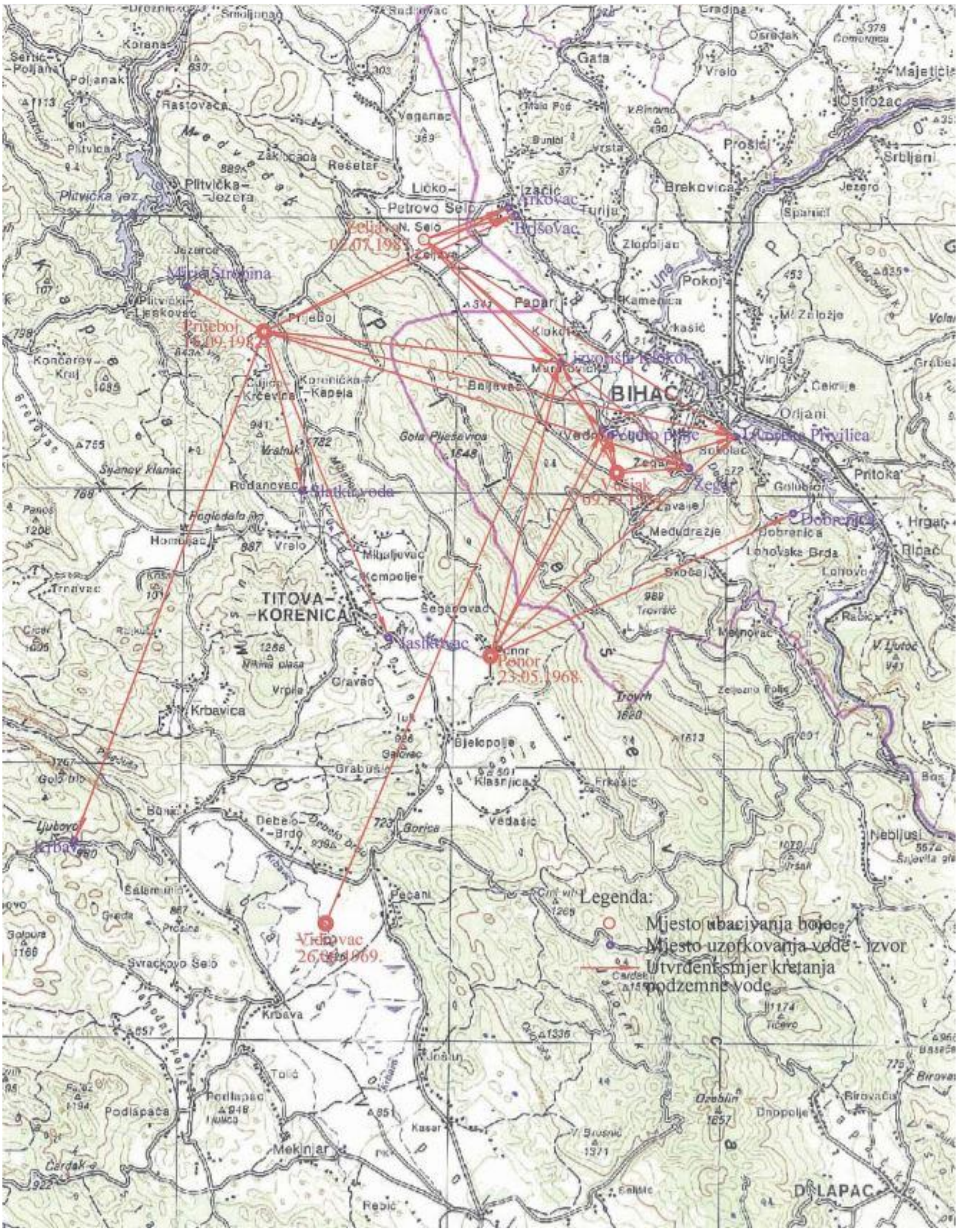


Figure 4.1: *Overall plan of hydrogeological dye tracing and water sampling sites, scale 1:200,000 – Source: The Klokot and Privilica Springs in the Municipality of Bihać Protection Project, Hydro-Engineering Institute of the Faculty of Civil Engineering in Sarajevo, 2004.*

Table 4.1: *Apparent groundwater velocities in the Klokot and Privilica catchment – Source: The Klokot and Privilica Springs in the Municipality of Bihać Protection Project, Hydro-Engineering Institute of the Faculty of Civil Engineering in Sarajevo, 2004.*

Dye tracing site	Dye tracing date	Observa-tion point	Distance (km)	Travel time (h)	Apparent velocity (m/h)	Estimated hydrological conditions
Koreni č.r. ponor	23/5/1968	Klokot 1	11.0	88	125	low mean water
Jaruge ponor	26/6/1969	Klokot 1	24.0	102	237	mean water
Prijeboj ponor	16/9/1982	Klokot 1	11.5	48	237	low water
Prijeboj ponor	16/9/1982	Klokot 2	11.5	84	137	low water
Prijeboj ponor	16/9/1982	Privilica	16.0	170	95	low water
Prijeboj ponor	16/9/1982	Žegar	16.5	84	196	low water
Vučjak landfill	9/10/1984	Klokot 1	4.5	20	237	high mean water
Vučjak landfill	9/10/1984	Klokot 2	4.4	19	232	high mean water
Vučjak landfill	9/10/1984	Privilica	4.65	22	211	high mean water
Vučjak landfill	9/10/1984	Žegar	2.65	93	28.5	high mean water
Vučjak landfill	9/10/1984	Vedro Polje - Pećina	1.7	124	13.7	high mean water
Željava ponor	2/7/1987	Klokot 1	6.5	33	197	mean water
Željava ponor	2/7/1987	Klokot 2	6.6	41	161	mean water
Željava ponor	2/7/1987	Privilica	13.75	32	430	mean water
Željava ponor	2/7/1987	Žegar	11.9	46	260	mean water

The measurements were conducted under varying conditions thus large differences were established in apparent groundwater velocities. It was decided to adopt the mean velocity of $\boldsymbol{v}_{gav}$ = 200 m/h for future analyses of the groundwater flow towards the Klokot and Privilica source areas.

(4.4) *Soil properties*. Based on a detailed description of the properties of soil in the catchment area, it was concluded that the major part of the catchment is located in the highland area and karst, with an exception of the lowland area in the Una River valley and its smaller tributaries in the north-western part. The soils in the lowland zone are mainly anthropogenic soils with high utilisation rates. Overuse of fertilizers, manure and pesticides is not to be allowed on such soils.

(4.5) *Analysis of condition of forests and forest land*. About 1/7 of the Klokot and Privilica catchment is situated in Bosnia and Herzegovina (BH), and about 6/7 in the Republic of Croatia (RC). Based on an overview of forest areas in the Klokot and Privilica catchment, high forests in Plješivica and Gata Management Units account for 5.8 %, culture of seedlings on bare soil 13.8 %, and the rest is degraded forests and shrub stand. Such situation is assessed as poor structure of catchment coverage with forest ecosystems. In the Bihać Municipality, high forests account for 0.6 % only, while shrub and bare land to be afforested occupy 26.7 % of area. The data on mine contaminated areas is also presented, thus 1/3 of the Klokot and Privilica catchment in BH is not suitable for afforestation. The situation in forest management in the Klokot and Privilica catchment in RC is similar to the situation in BH, i.e. the forest areas are divided into commercial, protection and special purpose forests. Felling per hectare is below 2 m^3/ha, which is estimated to be rational forest management. Based on the Forest Management Schemes (ten-year plan, field conditions and forestry operations) no major activities are planned that would impair the ecosystem stability. It is recommended that forest areas in BH and RC be expanded, namely that better quality cover be established by direct conversion (felling of the existing coppices) and planting of conifers or gradual conversion of coppice into the forest of high silvicultural form. Designation of the Una River narrow belt as protected area is an example for the catchment under consideration. Assuming conversion of forests on 100 ha per year (50 ha own resources, 50 ha wider community) in the Klokot and Privilica catchment in BH, all coppices, shrubberies and bare land would be converted into forests of a high silvicultural form in 11 years. The benefit would be higher inflow of water and more stable recharging of source with drinking water.

(4.6) *Erosion processes*. The Klokot and Privilica catchment is mostly overgrown with vegetation. The forests are dominant, but there is also some impact of grassland. Total annual erosion sediment yield $\boldsymbol{W_{av}}$ is calculated according to the formula of S. Gavrilović, presuming the catchment under consideration, given the intensity of erosion processes, is classified in category V (very low erodibility). It was empirically estimated that 20 % of total sediment amount deposited in the catchment is transported by water:

$\boldsymbol{G_{av}} = 0.2 \cdot \boldsymbol{W_{av}} = 0.2 \cdot 177{,}846 = 35{,}569$ m^3/yr

It is also noted that, having in mind karst characteristics and sinking of water into the underground, part of sediment is deposited within the system of underground karst conduits. For that reason small amounts of sediment are discharged at the Klokot and Privilica springs, as evidenced by a slight turbidity of water with rare severe turbidity when high waters occur during wet periods. It is warned that uncontrolled use of space could lead to incidents.

(4.7) *Population of the area*. Based on the 2001 estimates, there were approximately 2,500 inhabitants in the Klokot and Privlaka catchment area in BH, about 4,668 persons in the Plitvice Lakes Municipality, and about 3,650 in the part of the Udbina Municipality located in the Klokot and Privilica catchment in RH.

(4.8) *Polluters in the Catchment*. Section 4.8.1 *Characteristics of Polluters* specifies major active and potential polluters in the Klokot and Privilica catchment area:

- permanent population and tourists,
- Željava Airport with a complex of barracks and military facilities,
- Izačić border crossing,
- quarry and gravel pits in BH and RC,
- solid waste landfills and dumps,
- trade, crafts and industrial companies in BH and RC,
- tourist capacities within the Plitvice Lakes National Park,
- agricultural activities,
- forestry activities,
- cemeteries,
- Izačić - Bihać road and traffic on state roads in RC.

The characteristics of each polluter listed are described in detail and the descriptions are supported by adequate photographs. It is noted here that the catchment area population data in this section differ from the population data in section 4.7. of the study under consideration. Pollution load assessment was carried out and an overview is given in Table 11 on page 64 of the Study. It is estimated that the highest pollution in the catchment area is generated by population (44%), felling of forests (37%) and quarry (11%). Extreme situations where polluters such as pesticides, fuel, mineral oils and heavy metals may occur have not been considered. Their intensity could not be estimated because it depends on many unpredictable factors.

Part five, **Quantitative and Qualitative Spring Characteristics,** consists of four sections.

(5.1) *Hydrological Characteristics*. The catchment area shared by the Klokot (215 m a.s.l.) and the considerably smaller Privilica (230 m a.s.l.) source is $\boldsymbol{F}$ = 686.5 km^2. In the area of both sources climate is temperate continental, in the hinterland it is temperate mountain, and in higher areas of the catchment the climate is mountain continental. In most parts of the basin, snowfall is prominent in winter and it significantly affects the capacity of both sources. Although hydrological observations and measurements at the Klokot and Privilica had been conducted for about fifty years, systematic measurement data were not available for further analysis.

(5.1.1) *The Klokot source capacity*. Table 4.3, taken from the project documentation under consideration, gives an overview of the results of measuring the Klokot source capacity under various hydrological conditions. The minimum capacity $\boldsymbol{Q'_{min}}$ = 3.87 m^3/s was recorded on 9 August 2000.

Table 4.2*: Overview of Klokot source capacity measurement results under various conditions – Source: The Klokot and Privilica Springs in the Municipality of Bihać Protection Project, Hydro-Engineering Institute of the Faculty of Civil Engineering in Sarajevo, 2004.*

Date	**Overflow rate *Q* (m^3/s)**	**Abstraction rate (m^3/s)**	**Total capacity (m^3/s)**	**Remark**
24/04/1982	21.5			Abstraction rate not known
21/05/1982	12.63			Abstraction rate not known
17/07/1982	5.56			Abstraction rate not known
11/11/1982	7.65			Abstraction rate not known
14/04/1983	21.83			Abstraction rate not known
29/06/1983	6.52			Abstraction rate not known
24/08/1983	3.66			Abstraction rate not known
13/10/1983	4.60			Abstraction rate not known
27/12/1983	10.64			Abstraction rate not known
14/12/1983	2.99			Minimum water level observed. Discharge from the curve
09/08/2000	3.61	0.260	3.87	Measured during drought in 2000

Table 4.3: *Overview of Klokot source discharges in 1983 – Source: The Klokot and Privilica Springs in the Municipality of Bihać Protection Project, Hydro-Engineering Institute of the Faculty of Civil Engineering in Sarajevo, 2004.*

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	26.60	12.10	10.80	31.80	10.60	6.98	5.87	4.00	3.83	4.00	4.26	4.53	125.37
2	26.10	12.00	12.10	29.50	10.10	6.98	5.69	4.00	3.75	3.92	4.18	4.44	122.76
3	25.80	11.80	12.80	30.20	9.76	6.98	5.51	4.00	3.75	3.83	4.18	4.20	122.81
4	26.10	11.50	12.10	29.80	9.76	6.89	5.33	4.18	3.83	3.83	4.09	4.09	121.50
5	25.90	11.60	11.90	30.00	9.56	6.89	5.06	4.18	3.83	3.83	4.00	4.00	120.75
6	25.50	11.80	12.10	28.40	9.17	6.89	5.24	4.09	3.92	3.83	3.92	3.92	118.78
7	25.40	12.10	13.70	20.30	8.88	6.89	5.24	4.09	4.00	3.83	3.83	3.83	112.09
8	25.40	12.20	15.90	25.90	8.69	6.89	5.15	4.09	4.09	3.75	3.83	3.66	119.55
9	25.40	12.50	17.60	23.90	8.50	6.89	5.06	4.00	4.09	3.75	3.83	3.49	119.01
10	25.30	12.90	21.70	23.30	8.21	6.89	5.06	3.92	4.18	3.66	3.83	3.32	122.27
11	25.00	13.10	23.40	22.30	8.02	6.84	5.06	3.83	4.26	3.66	3.83	3.24	122.54
12	24.70	13.40	23.90	22.20	7.83	6.98	4.97	3.83	4.35	4.70	3.75	3.15	123.76
13	24.90	13.80	22.20	22.40	7.83	6.98	4.88	4.00	7.92	4.35	3.75	3.07	126.08
14	24.40	14.00	18.40	22.10	7.64	7.07	4.79	4.26	7.73	4.18	3.75	2.99	121.31
15	24.10	13.80	16.30	21.90	7.45	6.98	4.70	4.53	7.54	4.00	3.66	3.32	118.28
16	21.70	13.60	15.90	21.80	7.26	6.89	4.70	4.26	7.35	3.83	3.66	3.49	114.44
17	18.30	12.80	15.20	21.40	7.26	6.98	4.53	4.18	6.98	3.83	3.66	3.92	109.04
18	16.60	12.10	16.90	18.40	7.26	6.98	4.53	4.09	6.77	14.80	3.58	8.50	120.51
19	15.30	11.70	19.50	17.30	7.17	6.61	4.44	4.09	6.61	13.20	3.58	16.70	126.20
20	14.60	11.40	20.20	16.60	7.17	6.33	4.53	4.00	6.33	11.10	3.58	16.10	121.94
21	15.20	11.20	20.80	16.30	7.07	6.15	4.53	3.92	5.60	9.66	3.49	15.50	119.42
22	14.90	11.00	21.70	16.20	6.98	6.05	4.53	3.83	5.48	9.21	3.41	14.60	117.89
23	14.60	10.20	21.70	15.70	6.98	5.96	4.53	3.83	5.24	6.61	3.32	13.80	112.47
24	14.40	9.76	22.40	15.20	6.89	5.96	4.18	3.75	4.97	6.05	3.24	13.10	109.90
25	13.90	9.17	23.30	14.70	6.89	5.87	4.18	3.66	4.79	5.51	3.15	11.90	107.02
26	13.60	8.02	29.50	14.00	7.07	5.87	4.09	3.75	4.70	4.97	3.15	11.20	109.92
27	12.80	8.69	39.40	13.40	7.17	5.87	4.00	3.83	4.44	4.62	3.24	10.20	117.66
28	12.10	9.66	34.20	12.80	7.26	5.78	4.09	3.75	4.26	4.53	3.41	9.95	111.79
29	11.90		29.50	12.10	7.45	5.78	4.00	3.66	4.18	4.44	4.88	7.73	95.62
30	11.60		27.20	11.40	7.26	5.87	4.00	3.75	4.09	4.44	4.70	7.07	91.38
31	11.50		29.40		7.07		4.00	3.83		4.35		6.70	66.85
Total	613.60	327.90	631.70	621.30	246.21	196.97	146.47	123.18	152.86	170.27	112.74	225.71	3568.91
Min.	11.50	8.02	10.80	11.40	6.89	5.78	4.00	3.66	3.75	3.66	3.15	2.99	2.99
Mean	19.79	11.71	20.38	20.71	7.94	6.57	4.72	3.97	5.10	5.49	3.76	7.28	9.79
Max.	26.60	14.00	39.40	31.80	10.60	7.07	5.87	4.53	7.92	14.80	4.88	16.70	39.40

Table 4.3 shows mean daily discharges recorded at the Klokot source in 1983. On 14 December 1983, minimum capacity of Q''_{min} = 2.99 m^3/s was recorded. However, the Federal Hydrometeorological Institute (FMZ) of BH assessed the discharge measurements from the period (1982-1991) as unreliable (section 4.2). However, if the discharge rates from Tables 4.2 and 4.3 are still accepted as indicative, it should than be noted that, given the data from the period (2006-2014) in Table 4.4, the year 1983 belongs among very dry years on the Klokot stream.

Mean daily flow-duration curve for the Klokot source for 1983 is given in Figure 4.2.

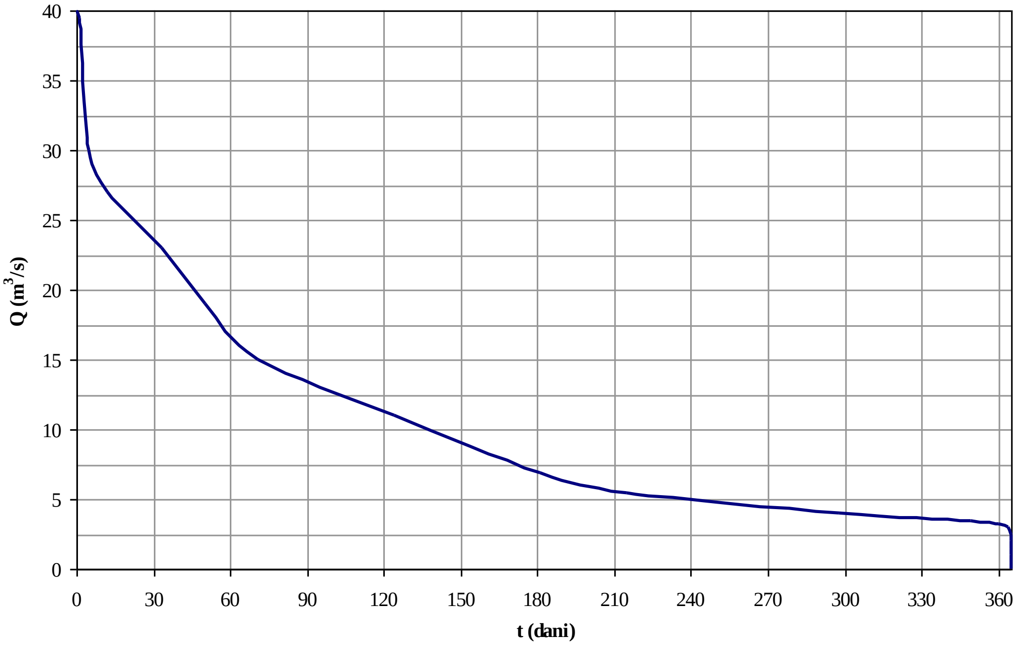


Figure 4.2: *Flow-duration curve for the Klokot source, 1983 – Source: The Klokot and Privilica Springs in the Municipality of Bihać Protection Project, Hydro-Engineering Institute of the Faculty of Civil Engineering in Sarajevo, 2004.*

(5.1.2) *The Privilica Source Capacity.* During the wet season, 127 l/s of water can be abstracted from this spring; however, the data from hydrological observations and measurements were not available although a staff gauge is situated directly downstream from the spring. Low water in the driest period of the year is estimated at about 50 l/s. It is also emphasized that during very dry periods there are no overflows at the Privilica source, but it is assumed that about 30% of the water is discharged underground.

(5.1.3) *Framework Water Balance for Determination of the Klokot and Privilica Source Catchment*. Based on the formula for average runoff coefficient, an indicative check was made of the size of the catchment area. Using the presumed values of mean discharge at the Klokot source of Q_m = 12.8 m^3/s, number of seconds in a year T = 31.54 · 10^6 s, average runoff coefficient η = c' ≈ 0.50 and average annual precipitation P_{av} ≈ 1250 mm, the size of the catchment area was determined as F_1 = 645 km^2. This confirms the adopted surface of the catchment area of F = 686.5 km^2.

(5.2) *Physico-chemical and Bacteriological Characteristics*. Water quality was tested four times in 2003 and 2004. The following components were determined: odour, taste, turbidity, pH, total evaporation residue at 105 °C, suspended particulate matter, dissolved oxygen and oxygen saturation, conductivity, total, carbonate and non-carbonate hardness, calcium, magnesium, potassium, sodium, manganese, iron, free carbon dioxide, chlorides, ammonium, nitrate and nitrite nitrogen, orthophosphates, silicon dioxide, sulphates, hydrogen sulphide, $KMnO_4$ demand, Biochemical Oxygen Demand (BOD_5) and hydrocarbons. During the last sampling conducted on 5 December 2003, an analysis was carried out for presence of heavy metals: arsenic, copper, zinc, cadmium, total chromium, cobalt, nickel, lead and silver.

(5.2.1) *The Klokot source*. Tests carried out at the Klokot source indicated that water quality was satisfactory. (Only the content of suspended matter was slightly increased ranging from 0.70 to 2.0 mg/l.) Earlier tests from the period (1982-1985) gave slightly less favourable parameters, which were successfully corrected by chlorination.

(5.2.2) *The Privilica Source.* At the Privilica source, coliform bacteria contamination was detected from wastewater from nearby settlements. Water from this source must be disinfected.

(5.2.3) *The Korenička Rijeka*. The water quality of the Korenička Rijeka River was tested in December 2003. It was concluded that the water quality of the Korenička Rijeka River is satisfactory.

(5.3) *Hydrobiological Characteristics.* Due to underground connections of the Korenička Rijeka River with the Klokot and Privilica springs, water was sampled on 5 December 2003 at the Korenička Rijeka sinking point at the ponor which is at the lowest height level. Analysis of the hydrobiological characteristics showed that the water is clean, which, according to the level of contamination, corresponds to the category of oligosaprobic or catarobic waters.

(5.4) *The Korenička Rijeka Water Category.* The Korenička Rijeka River water at the ponor site is of category 1 / 2. It can be used for drinking and in food industry after usual treatment (coagulation, filtration, disinfection, etc.)

Part six, ***Protection of Water Sources,*** consists of eight sections.

(6.1) *Water Source Protection Legal Framework*. Article 117 of the Federation Water Law from 1998 (Official Gazette of the Federation of BH No. 18/98, pp. 2297-2302) stipulates that the protection zones and protection measures are established by a body specified by cantonal / county water law. However, there is no explicit provision for the case when a protection area is located in another state. As regards a general act on the protection of the Klokot and Privilica sources, it is necessary to obtain an opinion on authority for issuing such general act on protection from the competent authority that has passed the Federation Water Law.

(6.2) *Approach*. In accordance with Article 117 of the Federation Water Law, the protection of water sources is established by a general act, which prescribes the size of protection zones and land use regime in the protection zones, including restrictions and prohibition of works, construction of facilities and activities that might contaminate water sources.

(6.3) *Sanitary Protection Zones*. It was emphasized that the underground runoff conditions are very complex in the karst catchment area of the Klokot and Privilica sources, with large and sudden changes in groundwater velocities. In accordance with the Ordinance on protection zones, Official Gazette of the Federation of BH, 51/02, three sanitary protection zones have been designated. The attention should be drawn to very stringent requirements that cannot be fully satisfied at acceptable costs. For this reason, it is proposed to introduce special controls in accordance with the Ordinance.

(6.3.1) *Protection Zone 1 (strict protection and monitoring zone – immediate water source area)* – within which specifically defined are: *protection zone Ia* (strict protection and monitoring zone – immediate water source area) and *protection zone Ib* (strict protection zone) as shown in Annexes 4.3 4.4 and 4.5 to the study under consideration. Area of *protection zone Ia* for the Klokot source is A_{IaK} = 0.94 ha, and for the Privilica source A_{IaP} = 0.76 ha. Area of *protection zone Ib* (where the Klokot and Privilica sources are situated) is: A_{Ib} = 45.0 km^2, and the perimeter is: O_{Ib} = 46.9 km.

(6.3.2) *Protection/zone II (restrictive/moderate protection zone)* – the boundary of this zone is defined on the basis of the condition that groundwater travels four days to reach the source, provided that this boundary must not be closer than 1.0 km from the source. The protection zone II is scarcely populated. However, it is emphasized that the Izačić border crossing located in the area is a potential polluter for which a method of wastewater collecting, distribution and treatment is provided as described in section 4.8.1, p. 53 of the project documentation under consideration. The area of *protection zone II* of the Klokot and Privilica source is: $\boldsymbol{A_{II}}$ = 49.5 km^2.

(6.3.3) *Protection Zone III (moderate protection zone).* It covers that part of the entire catchment outside the area of the protection zones I and II. The entire area of the protection zone III is situated in the territory of RC.

(6.4) *Sanitary Protection Measures*. Conditions for establishing of sanitary protection measures for the protection zone I and II are stipulated by the Ordinance on protection zones, Art. 29, OG of the Federation of BH 51/02, and described in sections (6.4.1) – (6.4.3). The protection measures described in section (6.4.4) refer to the Klokot and Privilica catchment area situated in RC, which entirely belongs to the protection zone III, and they are defined by the Ordinance on protection zones, Art. 34, OG of the Federation of BH 51/02.

(6.5) *Special Control of Activities in the Catchment*. Two control measures are envisaged in the protection zones of the Klokot and Privilica source: 1. setting up a network of surface and groundwater monitoring points, and 2. inspection controls of production and commercial companies and residential buildings.

(6.6) *Implementation of Protection and Remediation Measures in the Catchment*. Based on the identified characteristics of the catchment and polluters, appropriate remediation measures were proposed to be implemented at the polluters. Special control measures in the catchment area represent a continuous activity carried out in accordance with the monitoring project and the plans of the inspection bodies responsible for the inspection control of the implementation of protection measures in this area.

(6.7) *Schedule of Protection Measures Implementation*. The project documentation details the schedule for the implementation of protection measures and measures for remediation of the Klokot and Privilica sources as give in Table 17 therein. The protection measures could be divided according the degree of urgency into urgent and less urgent measures.

(6.8) *Indicative Cost Estimate for the Implementation of Protection Measures*. After the analysis, total costs for the enforcement of decisions on protection and individual protection measures were estimated at KM 1,000,000. It is noted here that the estimate from the project under consideration was made in 2003, namely 17 years ago.

4.6.2 Processing of hydrological observation and measurement results for the Klokot stream

Observations and measurements of hydrological values at the Klokot stream are carried out regularly at the hydrological observing station of the same name. There are no systematic measurements of hydrological values for the Privilica source.

In addition to the fact that the largest portion of water is rising at the Klokot spring, the water from the underground hinterland of this spring also rises in a number of much smaller springs for which there are no organized hydrological measurements. According to data from 2004 these are: Privilica spring (from which 120 l/s is abstracted for water supply), Žegar (estimated capacity about 5 l/s), Smiljanovac (about 5 l/s), Duparica (about 3 l/s), Gata source (about 8 l/s) and a number of other sources (Arkovac, Brišovac, Vedro Polje, etc.).

Based on the hydrogeological analysis described in section 4.1, 4.2 and 4.3 about Geological and Hydrogeological Characteristics, the size of the catchment area of the Klokot and other springs in the area mentioned herein was determined to be ***A*** = 951.5 km^2. Of this area only A_{BiH} = 90.5 km^2 (9.51 %) is in Bosnia and Herzegovina while A_{RH} = 861 km^2 (90.49 %) is in Croatia. It is important to note that in most part of the Klokot underground catchment water flows not only into the area where the Klokot spring is located but it also overflows, depending on the conditions in the underground, into other catchments (the Krbava and Korana catchments). Based on the investigations conducted so far, aside from the hydrogeological divide in total, it is not possible to define parts of catchment areas from which water occasionally reaches the Klokot spring and, occasionally, other springs.

According to the data of the Federal Hydrometeorological Institute (FMZ) of BH, the Klokot Gauging Station (GS) on the Klokot stream was set up on 12 November 1982 and operated until 1991. However, the analysis of the collected data performed by the Federal Hydrometeorological Institute (FMZ) of BiH lead to the conclusion that the hydrological data from the Klokot Gauging Station (GS) for the period (1981-1991) is not acceptable for further processing. (Source: FMZ of BH).

The Klokot GS on the Klokot stream was reconstructed in 2003. The station is automated and set up downstream from the bridge. The staff gauge zero level is 209.854 m a.s.l. The distance between the Klokot GS and the Klokot stream mouth into the Una River is 4,300 m. Daily water level and discharge data have been published in FMZ Hydrological Yearbooks since 19 March 2005.

Series of daily water levels and discharges available for this analysis cover the 10-year period (2005-2014). Only the data for the period 1 January to 18 March 2005 are missing because the Klokot Hydrological Observing Station started operating on 19 March 2005, and the data for the period 5 January to 31 March 2010, when the measurement was interrupted.

Basic difficulties in compiling and processing of data series of mean and extreme annual Klokot discharges at the Klokot profile are: (1) short data series and (2) determination of hydrological profile with similar runoff characteristics for completing of the existing series. The Klokot stream runoff is strongly affected by the underground in a very wide spring hinterland, while this important characteristic is much less pronounced in nearby hydrological profiles on nearby streams. A general impression after the insight into the data on mean daily and extreme monthly and annual water levels and discharges for the Klokot and other hydrological profiles in the Una catchment from the FMZ Hydrological Yearbooks available for this analysis is that the data was revised before publication, and the review of data consist of adequate tables and informative graphs (which, in addition to commonly used hydrographs also contain valuable flow-duration curves). It is estimated that the data is of good quality and sufficiently reliable for further analysis.

Figures 4.4 and 4.5 show hydrographs of the Klokot mean daily discharges at the Klokot profile in 2005 and 2010. The source of figures is the FMZ Hydrological Yearbooks for 2005 and 2010. The figures also contain mean daily discharge hydrographs for the nearby Sana stream at the Ključ and Sanski Most profiles. If discharges for those three months could be defined approximately but with sufficient reliability, then complete hydrological series of mean and extreme discharge rates would be available. It is estimated that the data could be completed on a monthly basis.

4.6.3 Completing the Klokot discharge series at the Klokot profile

4.6.3.1 Mean annual discharges

Completing the series of the Klokot mean monthly discharges at the Klokot profile was carried out using the following approach:

1. Analysing of interrelation between the annual precipitation P recorded at the weather stations situated in the Klokot catchment and the Klokot mean annual discharges Q at the Klokot profile.
2. Defining the Klokot mean annual discharges at the Klokot profile in 2005 and 2010: Q2005 and Q2010, on the basis of values of the Klokot double cumulative mean annual discharges (double-mass analysis) at the Klokot profile ΣQ and cumulative precipitation ΣP or cumulative mean annual discharges at the hydrological profile with similar runoff characteristics.(ΣP refers to annual precipitation in the catchment or at the weather station whose annual precipitation has firm correlation with the Klokot mean annual discharges.)
3. Determining of hydrological observing station in the Una catchment with similar runoff characteristics as the Klokot at the Klokot profile and defining of a coefficient that can be used for completing of mean monthly discharge series for January, February and March 2010 and mean annual discharge for 2005 and 2010.

The above approach results in an integral series of mean monthly and mean annual discharges for the Klokot at the Klokot profile in the period (2005-2014).

Since the Klokot discharge is strongly affected by the underground in the Klokot spring hinterland, and hydrological observing stations with similar runoff characteristics and data in Bosnia and Herzegovina were very scarce before 2005, it was not easy to find a hydrological observing station with a data series longer than the data series for the Klokot with similar main runoff characteristics. Only the data on water levels were available for the Bihać Hydrological Observing Station, thus the data acquired at the Sanski Most Hydrological Observing Station were used for completing since this station, as shall be shown in corresponding graphs and the coefficient of correlation r, satisfies the request for runoff similar to the Klokot.

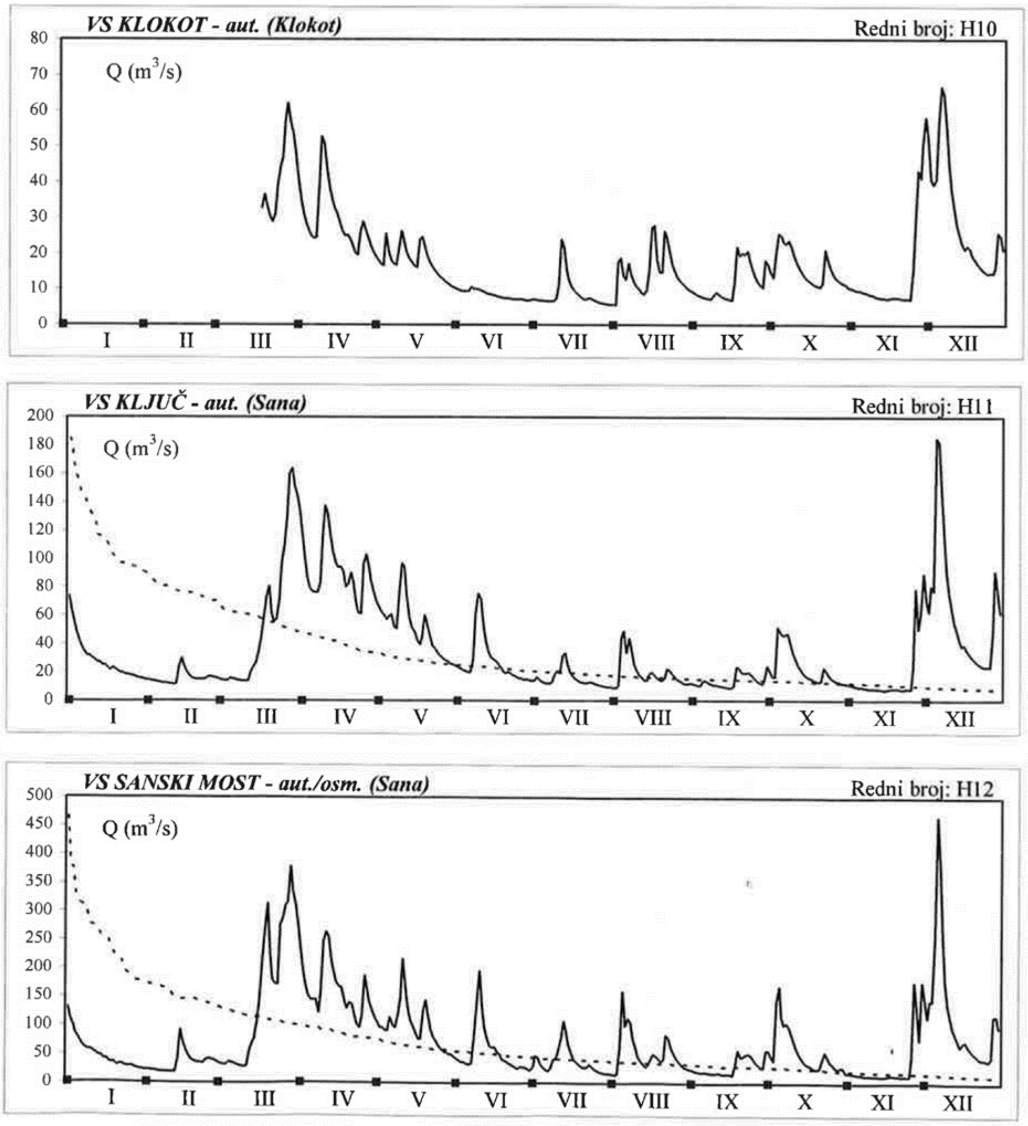


Figure 4.3: *Hydrographs and flow-duration curves for the Klokot mean daily discharges at the Klokot profile and the Sana River at the Ključ and Sanski Most profiles in 2005 – Source: FMZ Hydrological Yearbook for 2005*

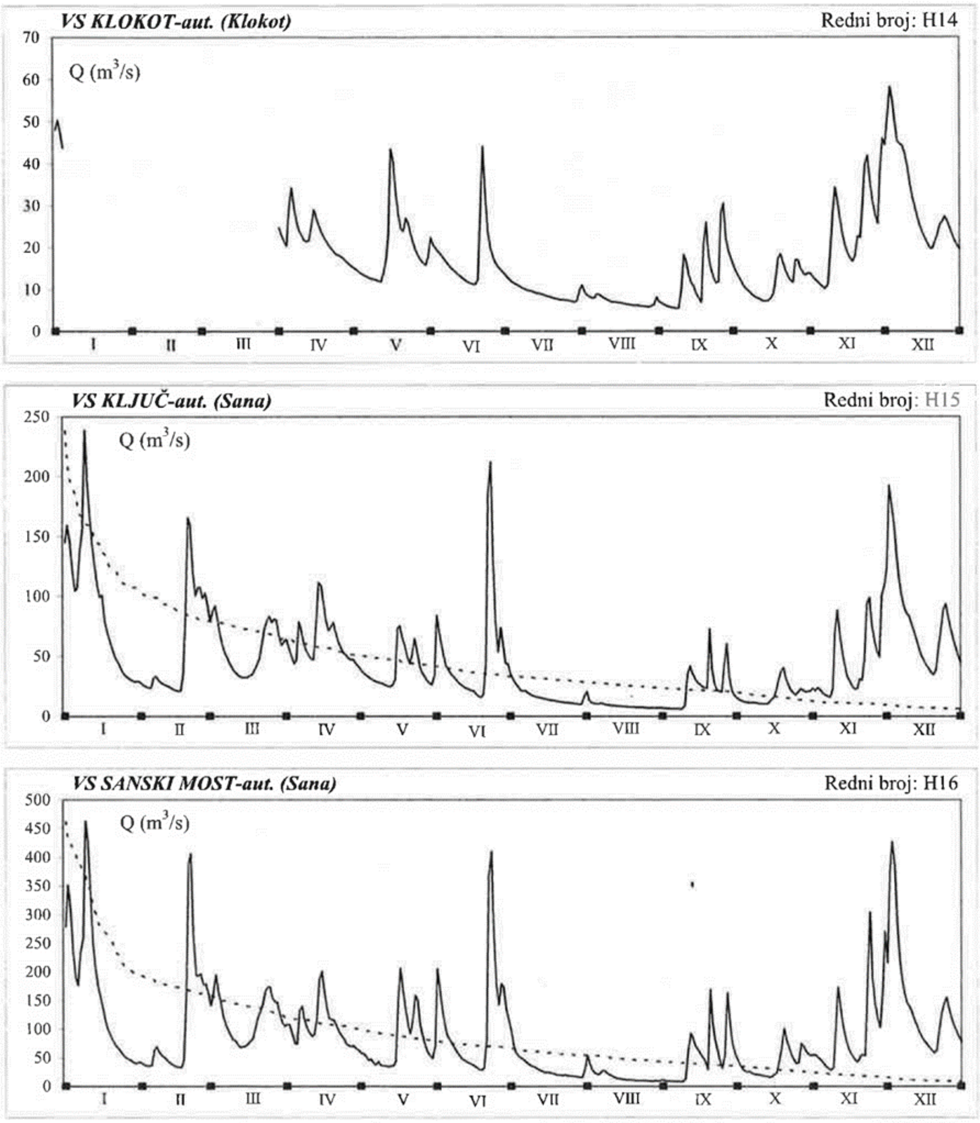


Figure 4.4: *Hydrographs and flow-duration curves for the Klokot mean daily discharges at the Klokot profile and the Sana River at the Ključ and Sanski Most profiles in 2010 – Source: FMZ Hydrological Yearbook for 2010*

The following correlations were examined: (1) the correlation between the Klokot mean annual discharges at the Klokot profile $\boldsymbol{Q}$ and annual precipitation at the Bihać station $\boldsymbol{P_B}$ (Figure 4.5), and (2) the correlation between the Klokot mean annual discharges at the Klokot profile $\boldsymbol{Q}$ and the Sana mean annual discharges at the Sanski Most profile $\boldsymbol{Q_{SM}}$ (Figure 4.6). Only the data from years with all daily discharges available (number of series members $\boldsymbol{n}$ = 8) was used. The following relationships were defined:

$$\boldsymbol{Q} = 0.0141 \cdot \boldsymbol{P_B} - 4.415 \qquad \boldsymbol{r} = 0.973$$

$$\boldsymbol{Q} = 0.00326 \cdot \boldsymbol{P_B}^{1.1687} \qquad \boldsymbol{r} = 0.896$$

$$\boldsymbol{Q} = 0.205 \cdot \boldsymbol{Q_{SM}} + 2.557 \qquad \boldsymbol{r} = 0.942$$

$\boldsymbol{Q} = 0.580 \cdot \boldsymbol{Q_{SM}}^{0,792}$ $\boldsymbol{r} = 0.934$

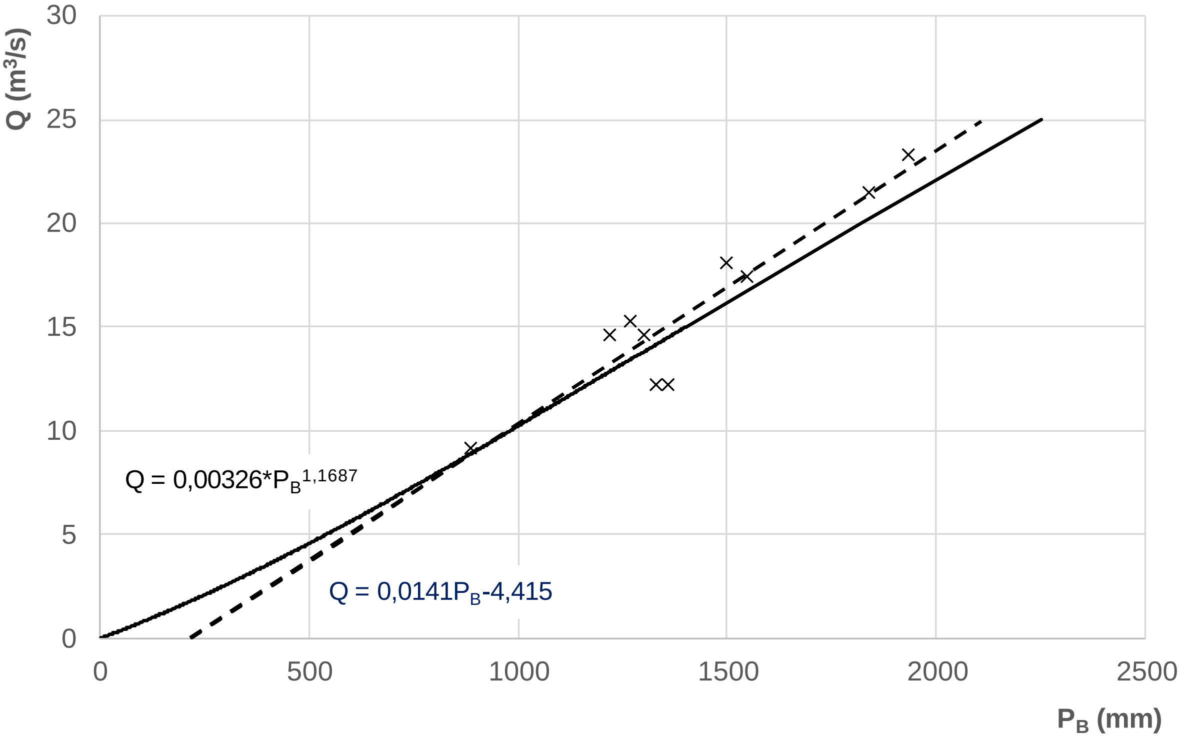


Figure 4.5**: Correlation relationships (linear and nonlinear) between annual precipitation at the Bihać station **P_B** and the Klokot mean annual discharges at the Klokot profile **Q

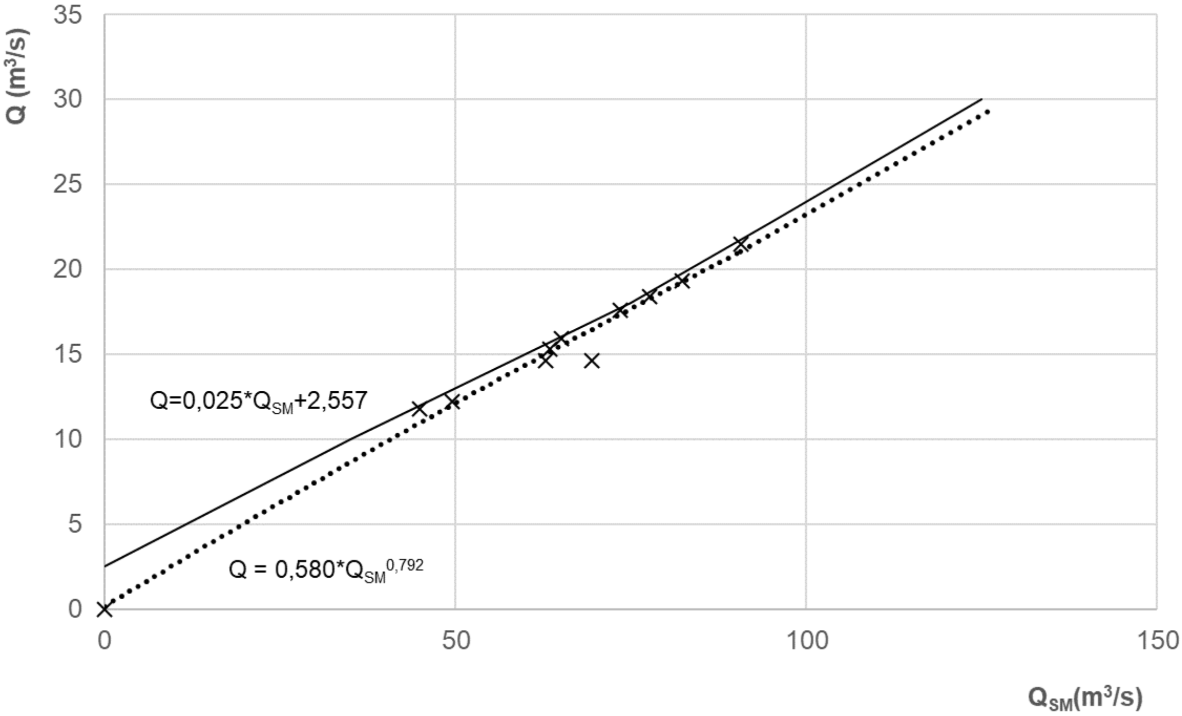


Figure 4.6:** Correlation relationships (linear and nonlinear) between the Sana mean annual discharges at the Sanski Most profile **Q_{SM}** and the Klokot mean annual discharges at the Klokot profile **Q

It could be concluded, based on the formulas and graphs from Figures 4.5 and 4.6, that the strongest linear correlation relationship is the one of the Klokot mean annual discharges at the Klokot profile Q and the annual precipitation at the Bihać station P_B (coefficient of correlation r = 0.973). Therefore, it was concluded that the annual precipitations recorded at the Bihać station are the most suitable for completing of the series of Klokot mean annual discharges at the Klokot profile.

The procedure for completing of the Klokot mean annual discharge series at the Klokot profile in the period (2006-2014) in 2010 was carried out using the *double-mass analysis* as described in literature (Žugaj, R.: *Hidrologija (Hydrology)*, University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Zagreb, 2015) – acc. to Linsley, R. K., Kohler, M. A., Paulhus, J. L.: *Hydrology for Engineers*, McGraw-Hill, Tokyo, 1975.). The Klokot cumulative mean annual discharges at the Klokot profile and cumulative annual precipitation at the selected weather station with the precipitation characteristics similar to the Klokot mean discharges were treated.

Regretfully, the series of precipitation data collected in the period (2006-2014) at the weather stations in Croatia (Korenica and Plitvice Lakes) are not complete. The data on daily precipitation for the Korenica station is missing for: 2009, 2010, 2012, 2013, 2014, 2016 and 2017, and for the Plitvice Lakes station for: 2006, 2009, 2010, 2015, 2016 and 2017. Therefore, the precipitations recorded at the Bihać Weather Station were analysed because it has an interrupted data series for the period (2006-2014).

As shown, the precipitation amounts recorded at the Bihać Weather Station P_B could be suitable for such data completing procedure. These values presented cumulatively with the Klokot mean annual discharges at the Klokot profile Q create strong linear relationships whether they are presented from 2006 towards 2010 or from 2014 towards 2010 (Figures 4.7 and 4.8).

Table 4.4 shows input computation values ΣP_B and ΣQ. Calendar years are given in column (1); annual precipitation at the Bihać Weather Station P_B in column (2); the Klokot mean annual discharges at the Klokot profile Q in column (4) and their cumulative values by year ΣP_B in column (3) and ΣQ in column (5).

Table 4.4: *Cumulative annual precipitation at the Bihać Weather Station* ΣP_B *and Klokot cumulative mean annual discharges at the Klokot profile* ΣQ *for the periods (2006-2010) and (2014-2010)*

Year	P_B **(mm)**	ΣP_B **(mm)**	Q **(m^3/s)**	ΣQ **(m^3/s)**
(1)	(2)	(3)	(4)	(5)
2006	1218	1218	14.6	14.6
2007	1331	2549	12.2	26.8
2008	1267	3816	15.3	42.1
2009	1299	5115	14.6	56.7
2010	1836	6951	**21.0**	77.7*
2014	1934	1934	23.3	23.3
2013	1496	3430	18.8	42.1
2012	1358	4788	12.2	54.3
2011	886	5674	9.21	63.5
2010	1836	7510	**22.0**	85.5*

*values read from Figures 4.7 and 4.8.

The Figures 4.7 and 4.8 are double-mass straight lines of annual precipitation at the Bihać Weather Station $\boldsymbol{\Sigma P_B}$ and the Klokot mean discharges at the Klokot profile $\boldsymbol{\Sigma Q}$. In Figure 4.7 completion is carried out for the period from 2006 to 2010, and in Figure 4.8 from 2014 to 2010. The curve in Figure 4.9 shows that the Klokot mean discharge at the Klokot profile in 2010 is Q_1 = 21.0 m³/s, while the curve in Figure 4.8 shows that discharge is Q_2 = 22.0 m³/s – thus the mean discharge adopted for 2010 is **Q = 21.5 m³/s**.

(It should be noted that a similar result is obtained for double cumulative mean annual discharges of the Sana at the Sanski Most profile and the Klokot at the Klokot profile, with which the Klokot has somewhat weaker correlation than with the annual precipitation at the Bihać station. In that case the Klokot mean discharges in 2010 are Q'_1 = 20.0 m³/s, Q'_2 = 21.1 m³/s, and mean value is Q'= 20.6 m³/s.)

In the FMZ Hydrological Yearbook for 2005 the series of daily water levels and discharges for the Klokot Hydrological Observing Station at the Klokot start on 19 March 2005. Therefore, the discharges for less than two and half months are missing, similar as for 2010. It was found that in this case its is reasonable to complete the series for the period (2006-2014) also with values for 2005 on the basis of double-mass analysis of annual precipitation at the Bihać station $\boldsymbol{\Sigma P_B}$ and mean annual discharges of the Klokot at the Klokot profile $\boldsymbol{\Sigma Q}$. Computation data is given in Table 4.6, and curve in Figure 4.9.

The relationship in Figure 4.9 is defined by:

$$\Sigma Q = 0.01125 \cdot \Sigma P_B + 0.332 \qquad r = 1.00$$

Relationship $\Sigma Q = f(\Sigma P_B)$ is stronger than a very strong relationship $Q = f(Q_{SM})$, but extension of the series of the Klokot mean annual discharges at the Klokot profile for the period (2001-2004) could not be applied here because there is no data for the Bihać Weather Station for that period.

Table 4.5: *Cumulative annual precipitation at the Bihać Weather Station* $\boldsymbol{\Sigma P_B}$ *and the Klokot cumulative annual discharges at the Klokot profile in the period (2005-2014)* $\boldsymbol{\Sigma Q}$

Year	P_B **(mm)**	ΣP_B **(mm)**	Q **(m³/s)**	ΣQ **(m³/s)**
(1)	(2)	(3)	(4)	(5)
2014	1934	1934	23.3	23.3
2013	1496	3430	18.8	42.1
2012	1358	4788	12.2	54.3
2011	886	5674	9.21	63.5
2010	1839	7513	21.5*	85.0
2009	1299	8812	14.6	99.6
2008	1267	10 079	15.3	114.9
2007	1331	11 410	12.2	127.1
2006	1218	12 628	14.6	141.7
2005.	1547	14 175	**18.0***	159.7*

*completed values

After completion, the series of the Klokot mean annual discharges at the Klokot profile in the period (2005-2014) was presented, together with annual precipitation amounts at the Bihać station, in Table 4.7; chronologically in column (4), and by rate in column (5). The series duration was checked using the size of error of the coefficient of variation $\boldsymbol{\sigma_{cv}}$ according the Kricky-Menkel formula:

$$Df_{cv} = \frac{c_v}{\sqrt{2 \cdot (n-1)}} \cdot \sqrt{1 + 3c_v^2}$$

where: $\boldsymbol{c_v}$ – coefficient of variation, and $\boldsymbol{n}$ – number of series members. If: $\boldsymbol{\sigma_{cv}} \leq \sigma_{cv}^{0} = 0.10$, the series could be considered as long enough to be used. A minimum number of years recommended to be used for hydrological analyses of the series of mean annual discharges referred to in the literature differ significantly: from 10 years (Jevđević, V.: *Hidrologija I dio (Hydrology, Part 1)*, J. Černi, Beograd, 1956) to 30 years (Srebrenović, D.: *Primijenjena hidrologija (Applied Hydrology)*, Tehnička knjiga, Zagreb, 1986). In case of the Klokot stream, the series of mean annual discharges for the period (2005-2014) was adopted for further analysis presuming that such comparatively short series does not belong to either dry or wet part of a considerably longer period.

As said earlier, general statistical series of ten data only is very short. Therefore, an intention was to extend individual series wherever possible. For the Klokot, this primarily refers to mean and maximum annual discharges. Since the Klokot stream runoff is strongly affected by the karst underground in the spring hinterland it has some impact on the discharge values – higher minimum discharges and lower maximum discharges – compared to streams with surface runoff only.

It is, however, mentioned that completing for the period (2001-2004) is possible for mean annual discharges only (Table 4.7), and not for mean monthly and mean daily values.

The relation between the mean annual discharges of the Sana at the Sanski Most profile $\boldsymbol{Q_{SM}}$ and the Klokot at the Klokot profile $\boldsymbol{Q}$ based on the data for the period (2005-2014) is defined by:

$$\boldsymbol{Q} = 0.542 \cdot \boldsymbol{Q_{SM}}^{0.810} \qquad \boldsymbol{r} = 0.95 \qquad \boldsymbol{n} = 10$$

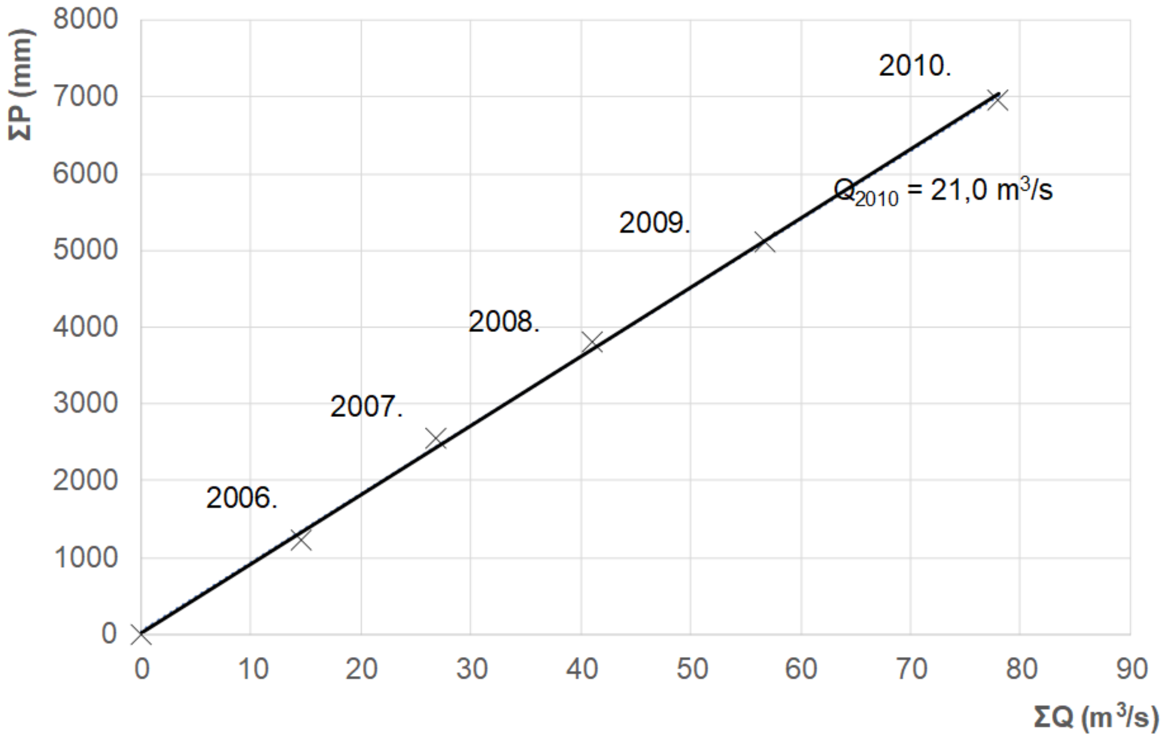


Figure 4.7: *Double-mass analysis of the Klokot mean annual discharges at the Klokot profile* ***ΣQ*** *and annual precipitation at the Bihać Weather Station* ΣP_B *for the period (2006-2010)*

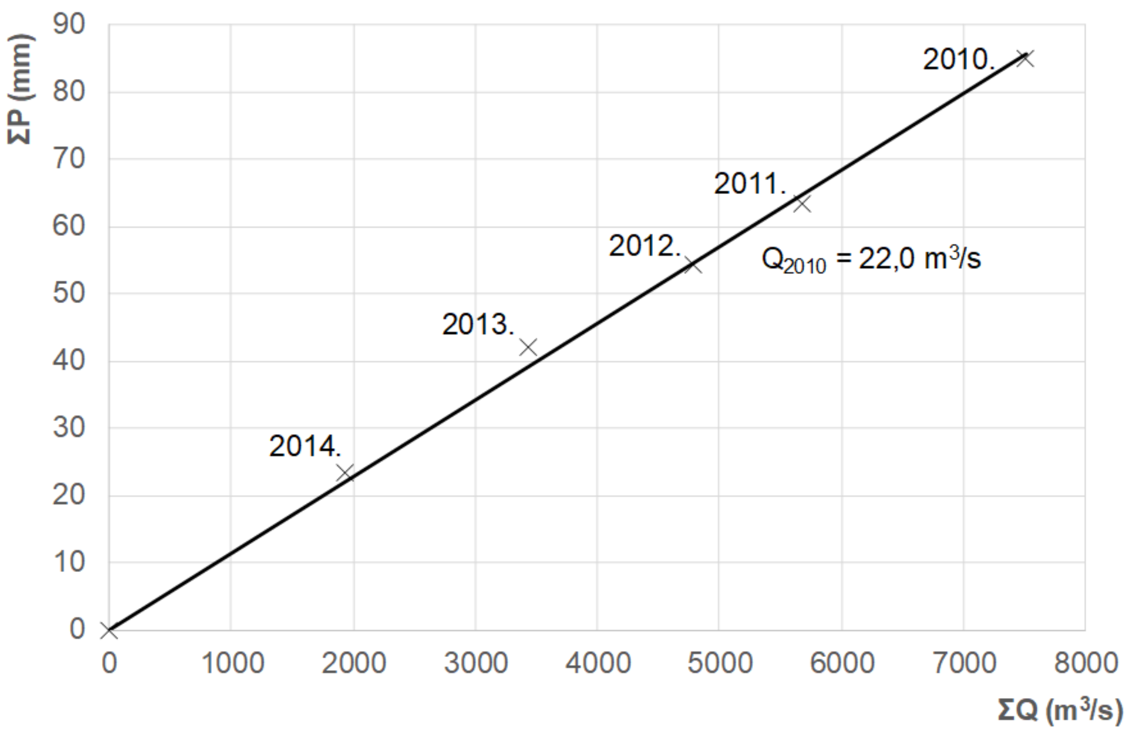


Figure 4.8: *Double-mass analysis of the Klokot mean annual discharges at the Klokot profile* ***ΣQ*** *and annual precipitation at the Bihać Weather Station* ΣP_B *for the period (2014-2010)*

Figure 4.9: *Double-mass analysis of the Klokot mean annual discharges at the Klokot profile* ***ΣQ*** *and annual precipitation at the Bihać Weather Station* ***ΣP*** *for the period (2005-2014)*

Table 4.6 shows annual precipitation recorded at the Bihać Weather Station in the period (2005-2014). In Table 4.6, years are in column (1), annual precipitation in P_B is given chronologically in column (2), and by rate in column (3). The column (4) is probability of occurrence ***p*** defined using the formula by N. N. Chegodaev:

$$p = \frac{m - 0{,}3}{n + 0{,}4}$$

where ***m*** is number of ***mth*** member of the serie***s***, and ***n*** is number of series members. The series under consideration is short (***n*** = 10), but the variations are poorly expressed (c_v = 0.20) thus, based on the adopted criterion ($\sigma_{cv} \leq 0.10$), it is long enough to apply the mathematical statistics techniques. Figure 4.10 shows theoretical distribution curve (Type-III Pearson) together with calculation input data. Amount of annual precipitation recorded at the Bihać Weather Station with different return periods P_{Bp}, together with characteristic discharges – mean Q_p, maximum Q_{maxp} and minimum Q_{minp} annual discharges– are given in Table 4.11.

Table 4.6: *Annual precipitation at the Bihać Weather Station* P_B *in the period (2005-2014)*

Year	**Chronological** P_B **(m³/s)**	**By rate** P_B **(m³/s)**	p **(%)**
(1)	(2)	(3)	(4)
2005	1547	1934	6.73
2006	1218	1839	16.3
2007	1331	1547	26.0
2008	1267	1496	35.6
2009	1299	1358	45.2
2010	1839	1331	54.8
2011	886	1299	64.6
2012	1358	1267	74.0
2013	1496	1218	83.7
2014	1934	886	93.3
P_{Bav}	1417		
σ	289		
c_v	0.20		
c_s	0.21		
σ_{cv}	0.050	n = 10	

*completed values

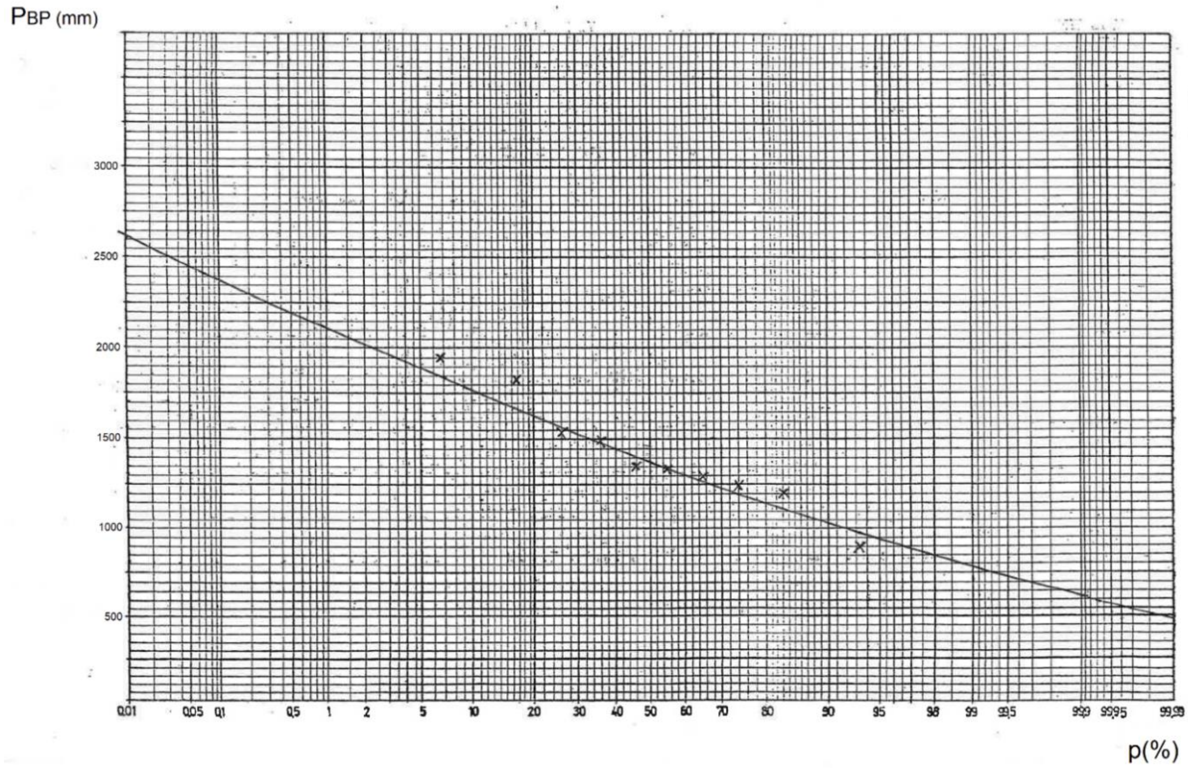


Figure 4.10: *Annual precipitation with different return periods at the Bihać Weather Station* $\boldsymbol{P_{Bp}}$ *(Type-III Pearson distribution)* $\boldsymbol{P_{Bav}}$ *= 1,417 mm;* $\boldsymbol{c_v}$ *= 0.20;* $\boldsymbol{c_s}$ *= 0.21*

Table 4.7 shows mean monthly $\boldsymbol{Q_{mo}}$ and mean annual discharges of the Klokot at the Klokot profile $\boldsymbol{Q}$ in the period (2005-2014). The data from Table 4.7 were used to construct hydrographs of the Klokot mean monthly discharges at the Klokot profile in the period (2005-2014) shown in Figures 4.11 – 4.20. Completing for the first three months of 2005 and 2010 were carried out proportionally to the values of the Sana mean monthly discharges at the Sanski Most profile.

Table 4.7: *The Klokot mean monthly* $\boldsymbol{Q_{mo}}$ *and mean annual discharges* $\boldsymbol{Q}$ *at the Klokot profile in the period (2005-2014) completing carried out in proportion with the values of the Sana mean monthly discharges at the Sanski Most profile*

Year	Q_{mo} (m^3/s)												Q (m^3/s)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
2005	13.1*	9.42*	39.6*	30.9	18.2	8.59	8.73	14.5	11.6	16.1	13.0	31.1	18.0*
2006	22.0	16.8	24.4	27.7	18.3	17.5	8.74	9.51	9.36	7.02	7.11	7.51	14.6
2007	13.8	15.4	18.7	12.6	8.98	8.84	4.20	4.16	11.2	13.9	18.5	16.5	12.2
2008	18.0	12.0	20.6	25.7	14.4	12.6	8.51	6.49	7.32	8.64	16.7	32.9	15.3
2009	21.6	26.6	19.7	22.8	12.7	9.60	8.28	4.91	4.09	6.98	13.7	25.2	14.6
2010	42.3*	28.4*	30.4*	22.6	19.6	17.8	9.27	7.29	13.1	12.0	23.7	32.0	21.5*
2011	15.0	12.7	14.4	12.4	9.61	8.38	5.80	5.02	4.29	6.04	4.06	12.9	9.21
2012	8.98	5.98	12.4	18.6	18.6	8.90	5.40	3.89	8.08	7.34	19.3	28.7	12.2
2013	30.7	22.1	38.2	34.6	13.9	15.1	7.50	5.96	5.56	9.73	29.4	13.8	18.8
2014	15.3	36.7	24.5	24.4	33.0	11.6	13.9	15.5	37.6	20.7	26.3	21.8	23.3
Q_{av}	20.1	18.6	24.3	23.2	17.3	11.9	8.03	7.72	11.2	10.9	17.2	22.2	16.0
Q_{max}	42.3*	36.7	39.6*	34.6	33.0	17.8	13.9	15.5	37.6	20.7	26.3	32.9	23.3
Q_{min}	8.98	5.98	12.4	12.4	9.61	8.38	4.20	3.89	4.09	6.04	4.06	7.51	9.21
σ	9.36	9.14	8.78	6.84	6.37	3.59	2.53	3.96	9.27	4.54	7.65	8.64	4.18
c_v	0.47	0.49	0.36	0.29	0.37	0.30	0.32	0.51	0.83	0.42	0.45	0.39	0.26
c_s	1.22	0.54	0.52	−0.17	1.07	0.64	0.73	1.02	2.18	0.91	−0.12	−0.26	0.26
σ_{cv}	0.14	0.15	**0.10**	**0.08**	**0.10**	**0.08**	**0.08**	0.16	0.34	0.12	0.13	0.11	**0.07**

*completed values

Hydrographs of mean monthly discharges Q_{mo} in the period (2005-2014) given in Figures 4.11-4.20 differ considerably from one another in different years. This has been confirmed by the values of the coefficient of variation c_v and skewness c_s in Table 4.7. The exceptions are annual values Q (column 14, Table 4.7) where during five months only (from March to July) value of the error of the coefficient of variation $\sigma_{cv} \leq 0.10$. High variability of mean monthly discharges Q_{mo} is shown, and their series are too short for the mathematical statistics method to be applied.

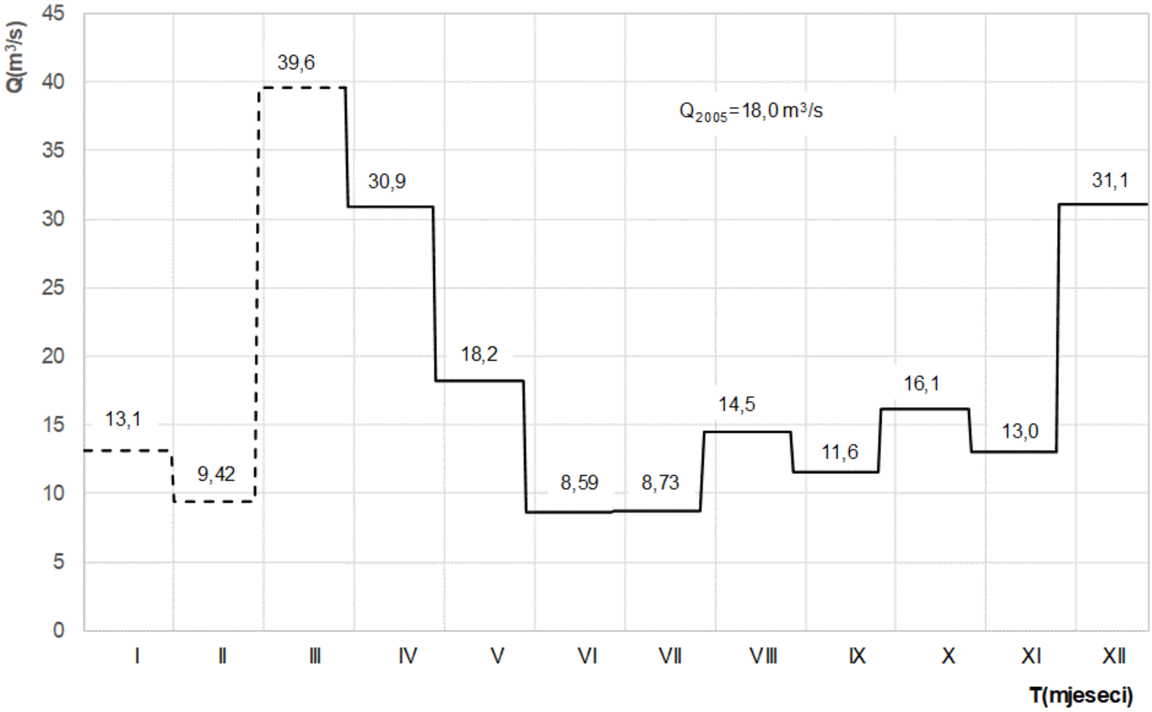


Figure 4.11: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2005*

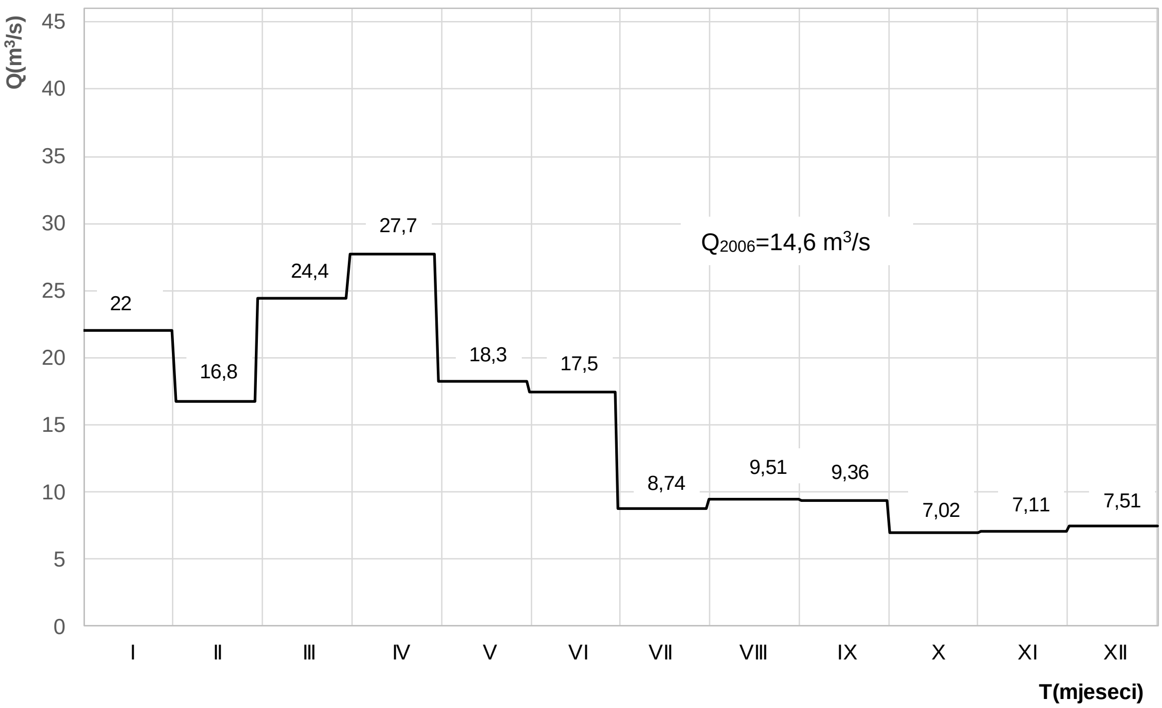


Figure 4.12: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2006*

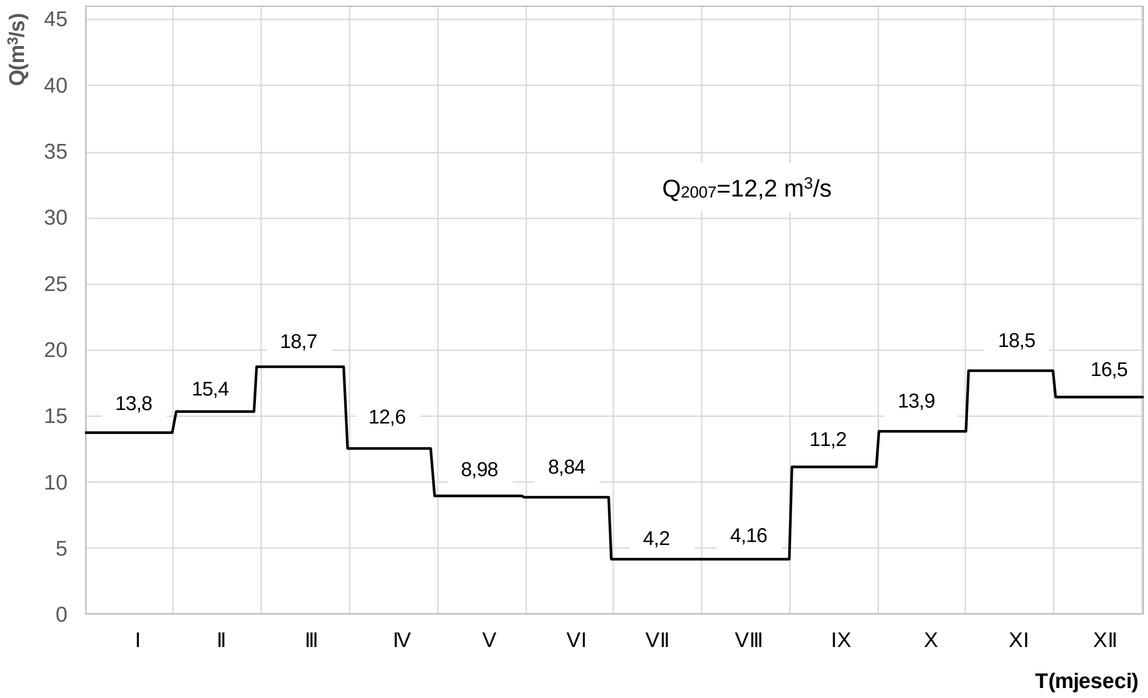


Figure 4.13: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2007*

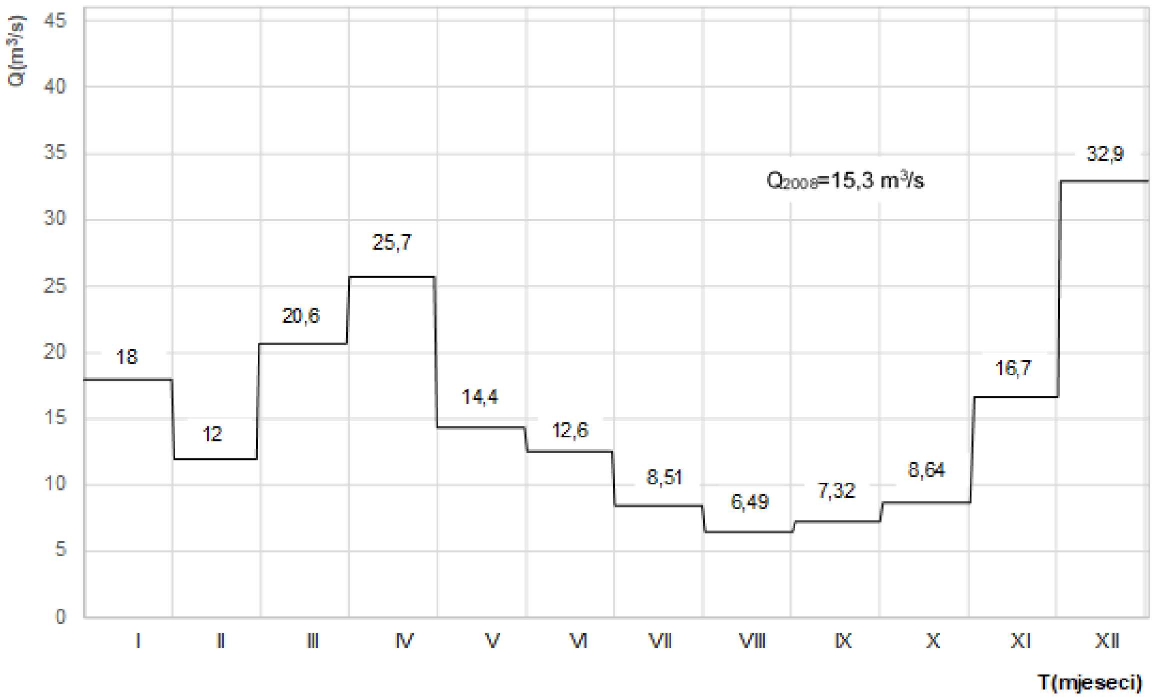


Figure 4.14: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2008 – approximately average year for the period (2005-2014)*

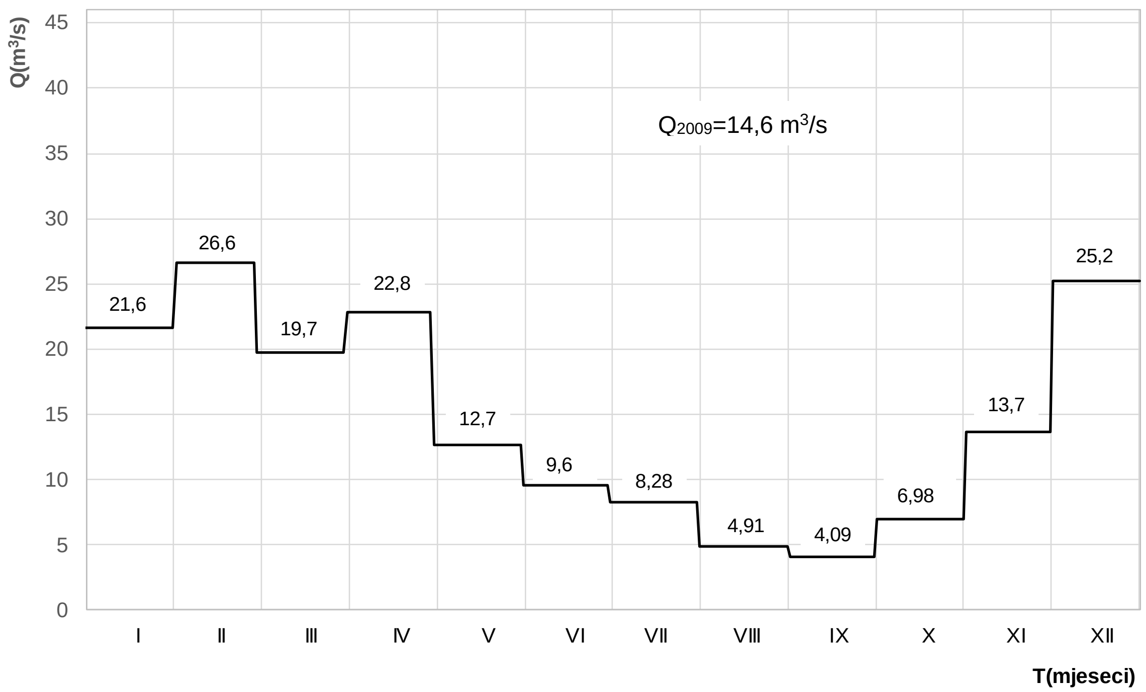


Figure 4.15: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2009*

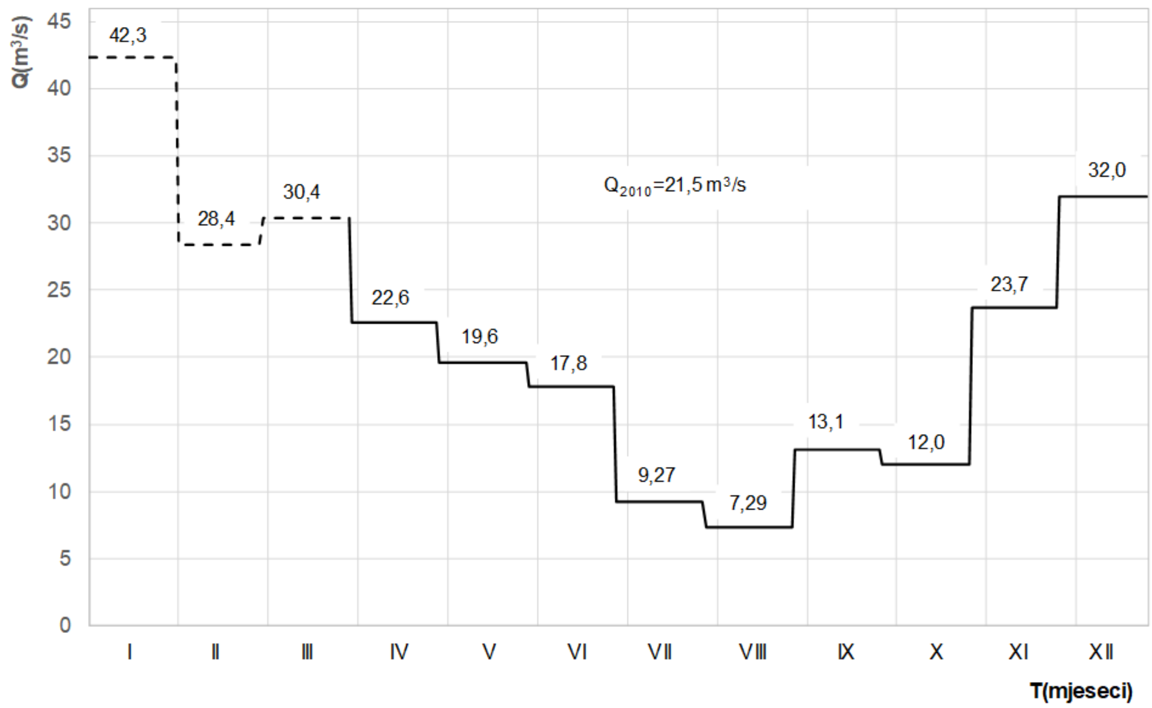


Figure 4.16: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2010*

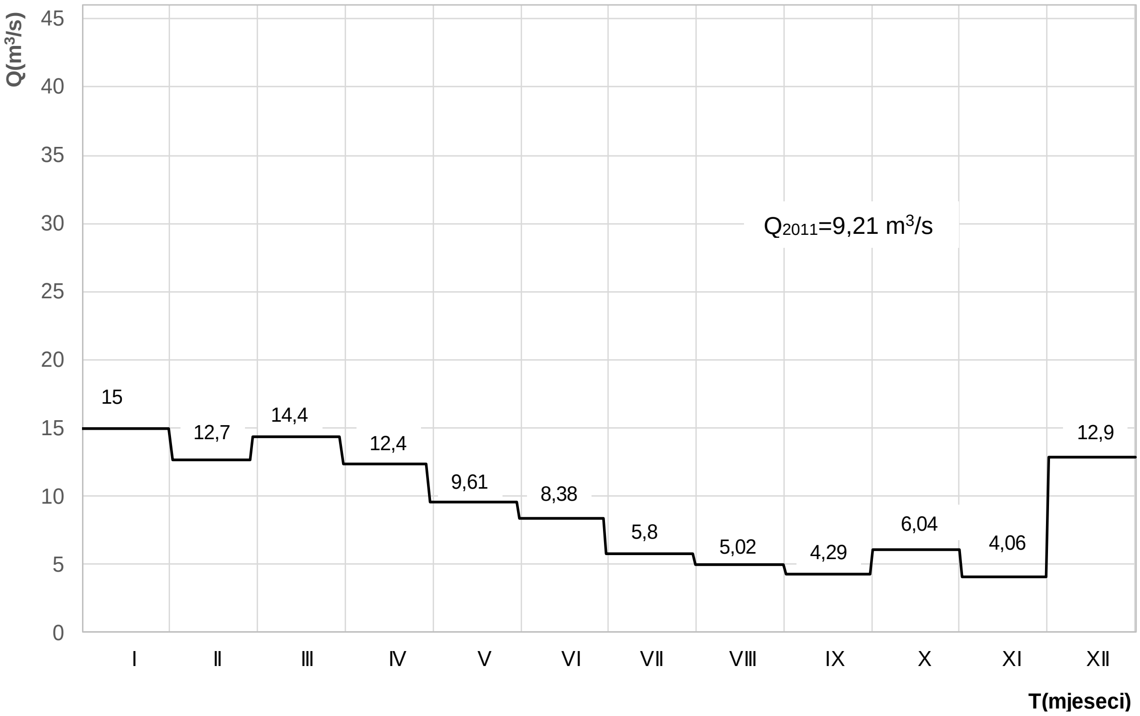


Figure 4.17: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2011 – dry year in the period (2005-2014)*

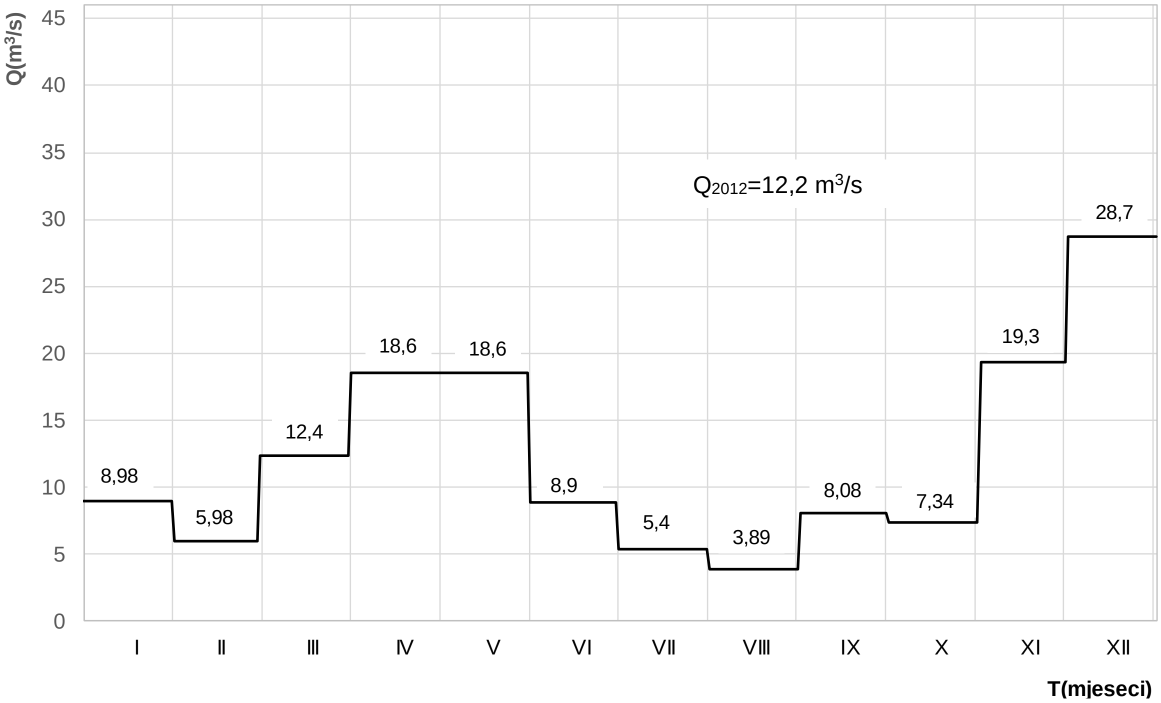


Figure 4.18: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2012*

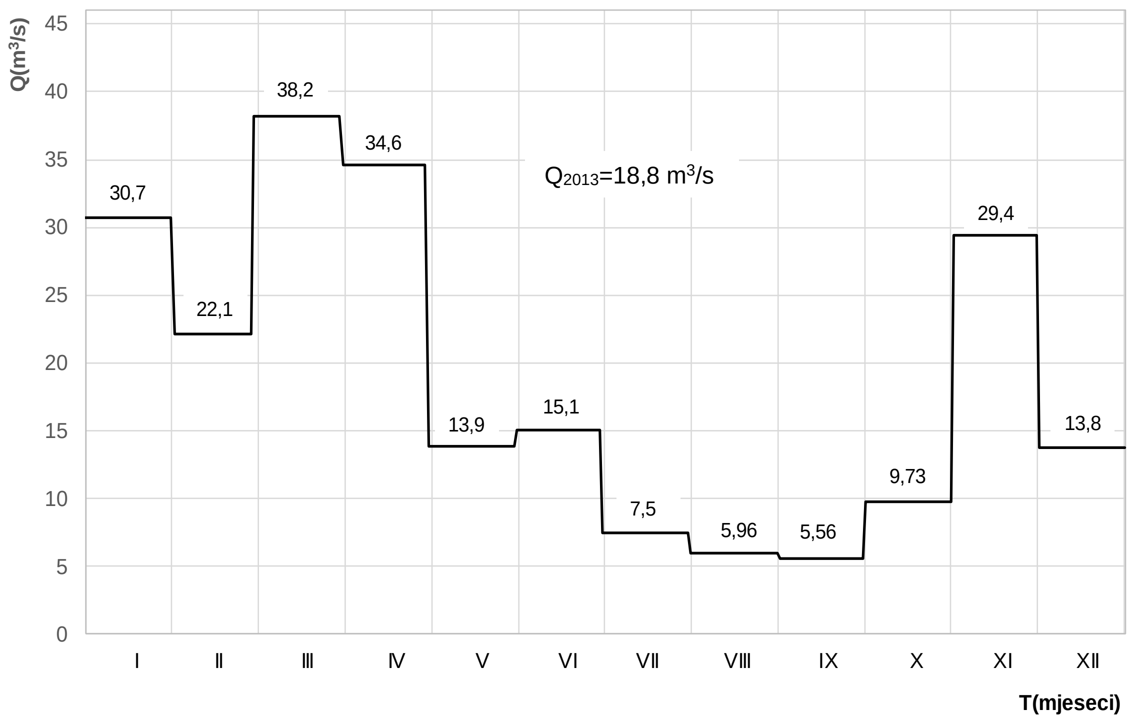


Figure 4.19: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2013*

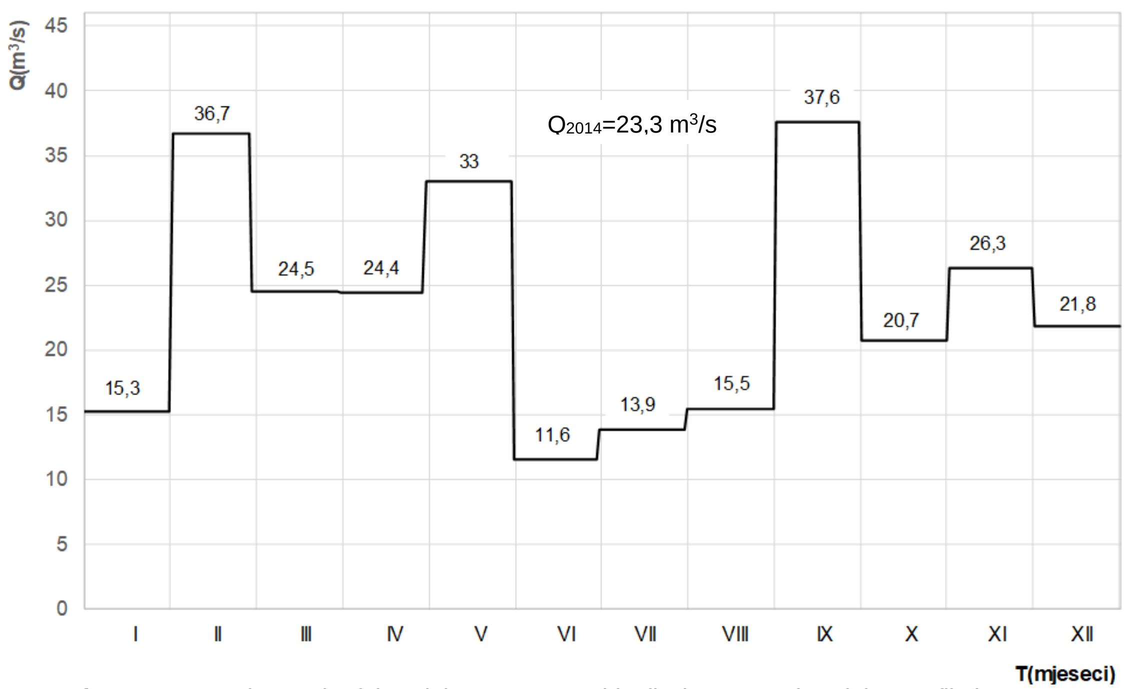


Figure 4.20: *Hydrograph of the Klokot mean monthly discharges at the Klokot profile in 2014 – humid year in the period (2005-2014)*

Based on the Klokot mean annual discharges at the Klokot profile in the period (2005-2014), column (14) in Table 4.7 shows characteristic years: approximately average 2008 (***Q*** = 15.3 m^3/s); dry 2011 (***Q*** = 9.21 m^3/s) and humid 2014 (***Q*** = 23.3 m^3/s). Figure 4.21 shows hydrographs of mean daily discharges and flow-duration curves for mean daily discharges in the said years.

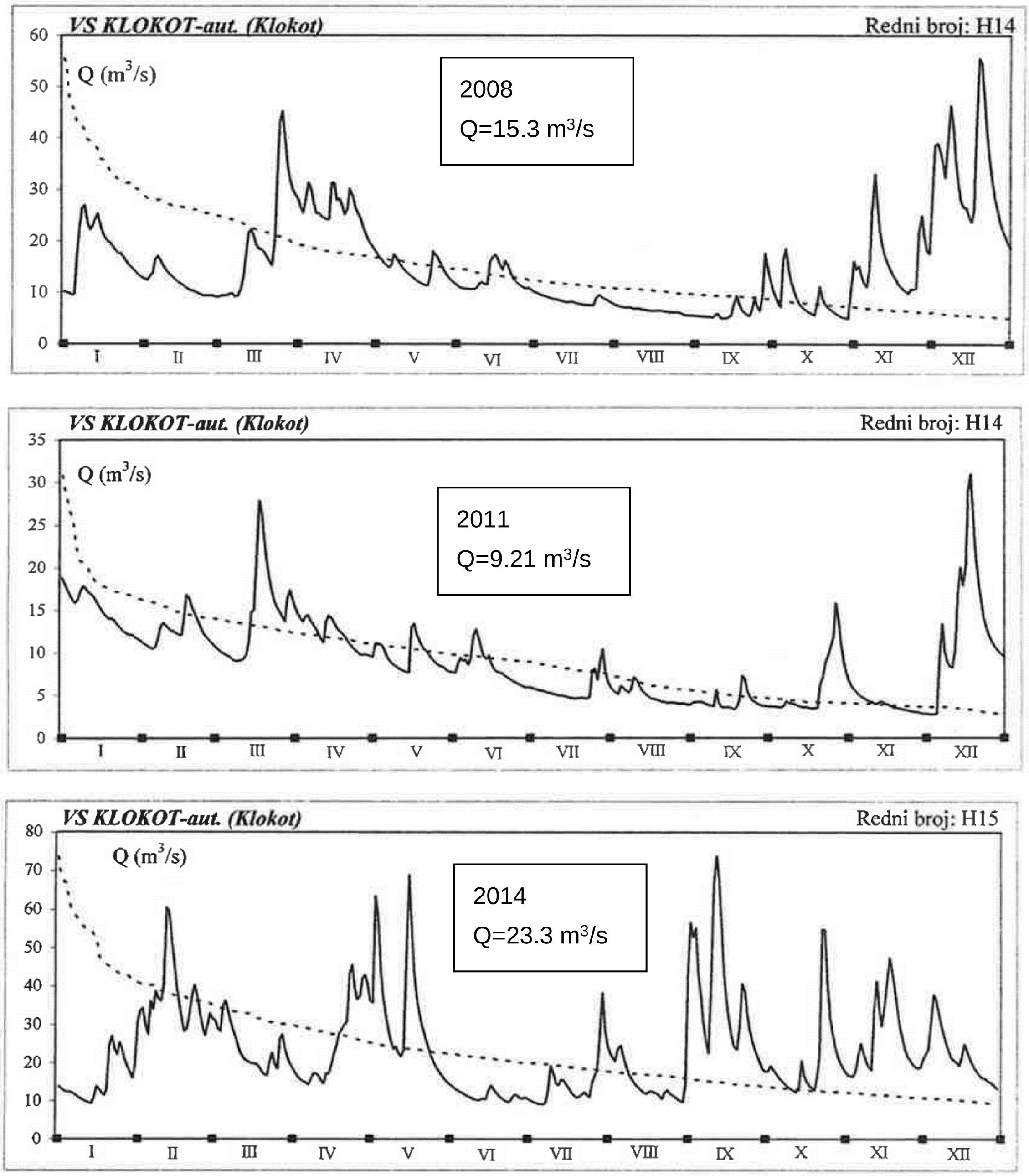


Figure 4.21: *Hydrographs and flow-duration curves for the Klokot mean daily discharges at the Klokot profile in characteristic years: approximately average 2008, dry 2011 and humid 2014 – Source: FMZ Hydrological Yearbooks for 2008, 2011 and 2014*

Table 4.8 gives the Klokot mean annual discharges at the Klokot profile in the period (2001-2014). Mean annual discharges in the first four years (2001-2004) are defined on the basis of the derived expression $\boldsymbol{Q} = 0.542 \cdot \boldsymbol{Q}_{SM}^{0.810}$.

Based on the data from Table 4.8 the mean annual discharges with different return periods of the Klokot at the Klokot profile $\boldsymbol{Q}_p$ are defined according to Type-III Pearson distribution. Their values are given in Table 4.11, and graphic presentation is given in Figure 4.22.

Table 4.8: *The mean annual discharges of the Sana at the Sanski Most profile* $\boldsymbol{Q_{SM}}$ *and the Klokot at the Klokot profile* ***Q*** *in the period (2001-2014)*

Year	Q_{SM} (m³/s)	**Chronological** *Q* (m³/s)	**By rate** *Q* (m³/s)	*p* (%)
(1)	(2)	(3)	(4)	(5)
2001	65.1	15.9**	23.3	4.86
2002	77.6	18.4**	21.5*	11.8
2003	44.8	11.8**	19.3**	18.8
2004	82.2	19.3**	18.8	25.7
2005	73.5	18.0*	18.4**	32.6
2006	69.4	14.6	18.0*	39.6
2007	49.5	12.2	15.9**	46.5
2008	63.4	15.3	15.3	53.5
2009	62.8	14.6	14.6	60.4
2010	90.6	21.5*	14.6	67.4
2011	31.6	9.21	12.2	74.3
2012	49.0	12.2	12.2	81.2
2013	61.7	18.8	11.8**	88.2
2014	101	23.3	9.21	95.24
Q_{sr}	65.9	16.1		
σ	18.0	3.86		
c_v	0.27	0.24		
c_s	0.07	0.10		
σ_{cv}	0.058	0.051	n = 14	

*completed based on double cumulative values (Table 4.5)

** completed based on expression derived from double cumulative values: $\boldsymbol{Q} = 0.542 \cdot \boldsymbol{Q_{SM}}^{0.810}$

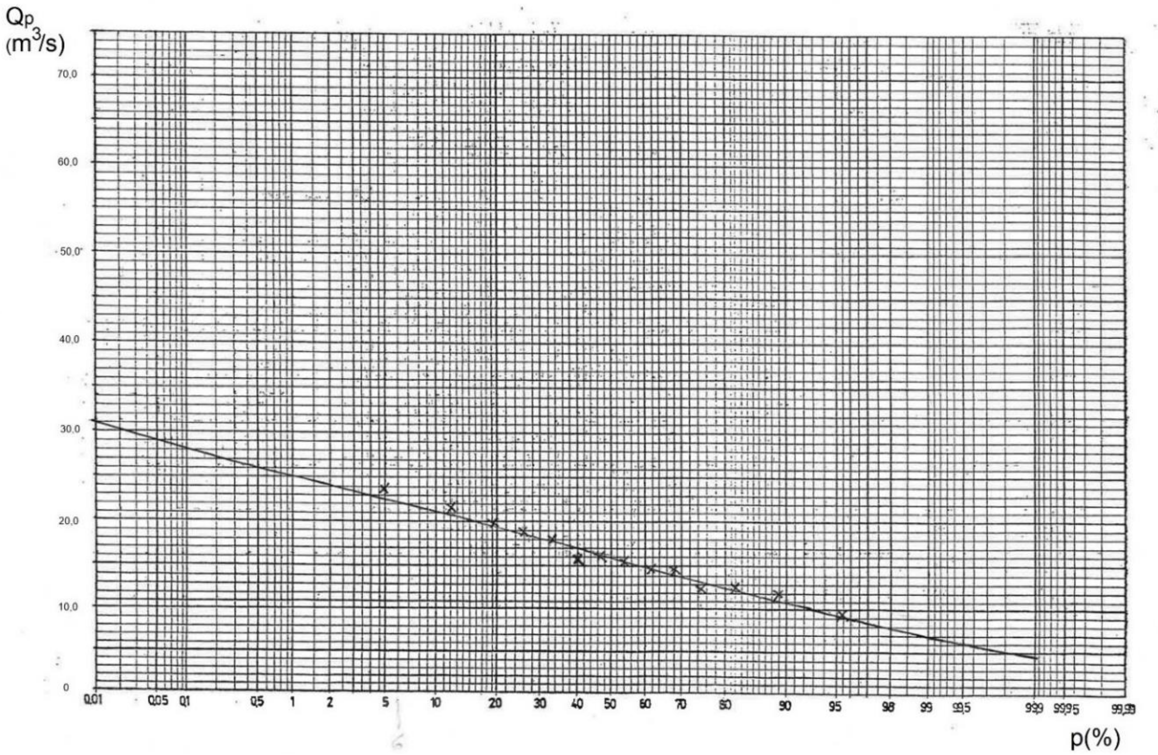


Figure 4.22: *Mean annual discharges with different return periods of the Klokot at the Klokot profile* $\boldsymbol{Q_p}$ *(Type-III Pearson)* $\boldsymbol{Q_{av}}$ *= 16.1 m³/s;* $\boldsymbol{c_v}$ *= 0.24;* $\boldsymbol{c_s}$ *= 0.10*

4.6.3.2 Maximum annual discharges

Maximum discharges for January, February and March of 2005 and 2010, when the Klokot staff gauge was not operational, are missing from the series of the Klokot maximum annual discharges at the Klokot profile. According to the data from other hydrological observing stations in the Una catchment, that was the period when the highest discharges in those years were recorded. For this reason, completing was carried out based on the nonlinear correlation in the form: $y = a \cdot x^b$.

The relationship between the Klokot maximum annual discharges at the Klokot profile and the corresponding Una maximum annual discharges at the Bihać profile could not be considered since no data on the Una discharges at the Bihać profile is available. There is no sufficient data from other nearby gauging profiles (Martin Brod, Kulen Vakuf and Kralje on the Una and Ključ on the Sana). The only hydrological observing station with similar runoff regime is the Sanski Most station on the Sana River (Figures 4.3 and

4.4). Table 4.9 contains dates of occurrence of the Sana maximum annual discharges at the Sanski Most profile in column (1), and of the Klokot at the Klokot profile in column (3), the maximum annual discharges of the Sana at the Sanski Most profile $\boldsymbol{Q_{maxSM}}$ in column (2) and the Klokot at the Klokot profile $\boldsymbol{Q_{max}}$ are given chronologically in column (4) and arranged by rate in column (5). Column (6) gives probability of occurrence $\boldsymbol{p}$ defined by N. N. Chegodaev formula.

During the first three months of 2010, maximum flood discharge was recorded in the entire Una catchment but not in the Klokot catchment. For that reason the correlations were examined between the Sana maximum annual discharges at the Sanski Most profile $\boldsymbol{Q_{maxSM}}$ and the Klokot maximum annual discharges at the Klokot profile $\boldsymbol{Q_{max}}$. Based on five simultaneously recorded maximum annual discharges (bolded in Table 4.9), a strong relationship was defined:

$$\boldsymbol{Q_{max}} = 1.907 \cdot \boldsymbol{Q_{maxSM}}^{0.564} \qquad \boldsymbol{r} = 0.96 \qquad \boldsymbol{n} = 5$$

Table 4.9: *Maximum annual discharges of the Sana at the Sanski Most profile* Q_{maxSM} *and the Klokot at the Klokot profile* Q_{max} *in the period (2001-2014)*

Date	$Q_{max\ SM}$ **(m³/s)**	**Date**	Q_{max} **(m³/s)**	**By rate** Q_{max} **(m³/s)**	***p*** **(%)**
(1)	(2)	(3)	(4)	(5)	(6)
4/ 3/ 2001	374		53.9*	75.1	4.86
24/ 9/ 2002	427		58.1*	70.3	11.8
3/ 11/ 2003	249		42.8*	68.0	18.8
12/ 4/ 2004	517		64.7*	64.7*	25.7
7/ 12/ 2005	466	**7/ 12/ 2005**	68.0	64.5*	32.6
23/ 3/ 2006	461	3/ 1/ 2006	47.3	58.1*	39.6
2/ 11/ 2007	133	**2/ 11/ 2007**	32.2	57.3	46.5
18/ 12/ 2008	422	**18/ 12/ 2008**	57.3	53.9*	53.5
24/ 12/ 2009	414	**26/ 12/ 2009**	51.4	51.4	60.4
9/ 1/ 2010	494		64.5*	49.5	67.4
13/ 12/ 2011	174	**18/ 12/ 2011**	32.3	47.3	74.3
17/ 5/ 2012	491	26/ 4/ 2012	49.5	42.8*	81.2
3/ 4/ 2013	318	22/ 12/ 2013	70.3	32.3	88.2
16/ 5/ 2014	672	13/ 9/ 2014	75.1	32.2	95.24
$Q_{maxSMsr}$	401	Q_{maxsr}	54.8		
σ	138	σ	12.8		
c_v	0.34	c_v	0.23		
c_s	-0.31	c_s	-0.31		
σ_{cv}	0.08	σ_{cv}	0.05		

* completed based on expression: $Q_{max} = 1.907 \cdot Q_{maxSM}^{0.564}$

The relationship between maximum annual discharges of the Sana at the Sanski Most profile Q_{maxSM} and the Klokot at the Klokot profile Q_{max} based on maximum annual discharges recorded simultaneously or within several days (bolded in Table 4.5) is defined by expression:

$$Q_{max} = 1.907 \cdot Q_{maxSM}^{0.564} \qquad r = 0.96 \qquad n = 5$$

The fact is that the available data is scarce, namely it is available only for eight years when the Sanski Most and Klokot Hydrological Observing Stations were operating at the same time. Only in five cases out of these years, $n = 5$, it could be taken into consideration that these events happened simultaneously or during the same occurrence of high waters. However, their correlation is very strong: $r = 0.96$, thus the derived pattern is considered acceptable. The Klokot Hydrological Observing Station was out of operation between 5 January and 30 April 2010, just when maximum annual inflows were recorded in the entire Una catchment. Thus it was presumed that the inflow at the Klokot catchment was also maximum – which was than defined using the expression given in Table 4.9 below.

Based on the data from Table 4.9 maximum annual discharges with different return period for the Klokot at the Klokot profile Q_{maxp} were defined according to Type-III Pearsion. Their values are given in Table 4.11, and graphic presentation in Figure 4.23.

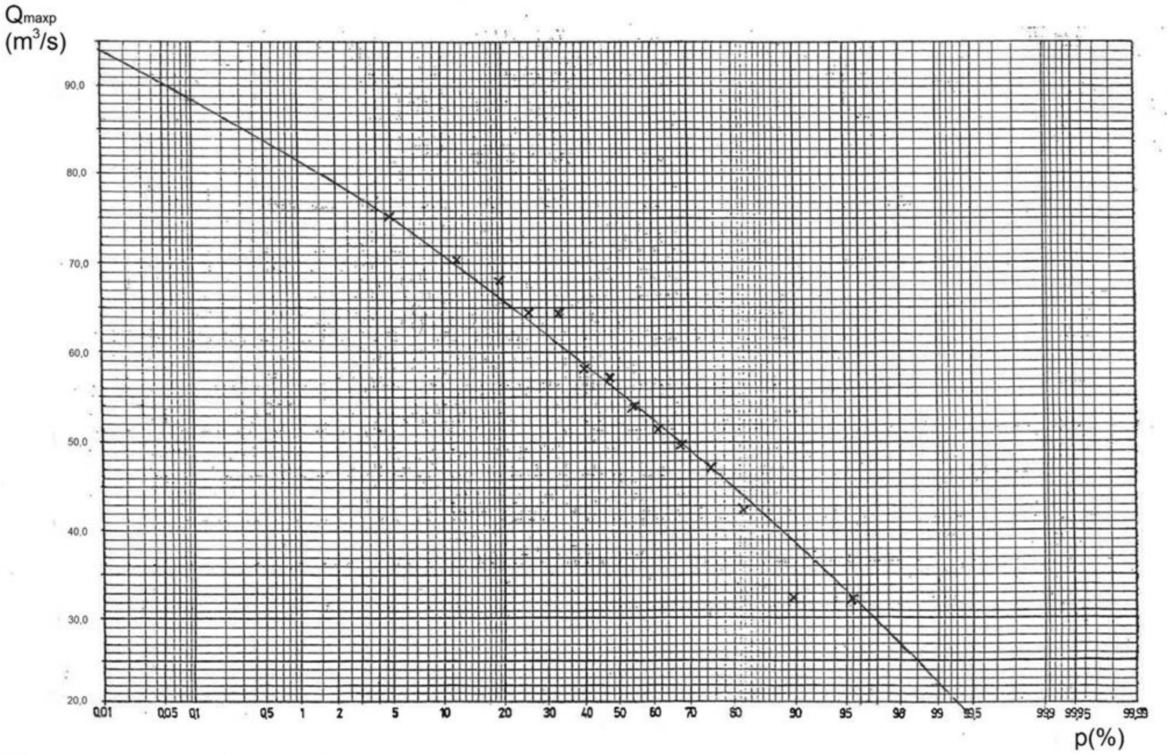


Figure 4.23: *Maximum annual discharges with different return periods for the Klokot at the Klokot profile* Q_{maxp} *(Type-III Pearson)* $Q_{maxav} = 54.8\ m^3/s$; $c_v = 0.23$; $c_s = -0.31$

4.6.3.3 Minimum annual discharges

The discharges during the first three months of 2015 and 2010 are missing from the available 10-year series of the Klokot daily discharges at the Klokot profile (2005-2014). At that time, no minimum discharges were recorded at the nearby streams, and these are the months when low waters are usually not recorded. Having this in mind, series of minimum annual discharges for 2005 and 2010 was completed with minimum discharges for dry periods recorded in August 2005 and September 2010.

The Klokot minimum annual discharges at the Klokot profile Q_{min} are given in Table 4.10: dates of occurrence in column (1), minimum annual discharges Q_{min} chronologically in column (2), by rate in column (3) and probability of occurrence as per N. N. Chegodaev in column (4).

Table 4.10: *The Klokot minimum annual discharges at the Klokot profile* Q_{min} *in the period (2005-2014)*

Date	**Chronologically Q_{min} (m^3/s)**	**By rate Q_{min} (m^3/s)**	***p* (%)**
(1)	(2)	(3)	(4)
3/ 8/ 2005	5.43	8.95	6.73
12/ 11/ 2006	5.11	5.77	16.3
8/ 8/ 2007	3.33	5.43	26.0
30/ 10/ 2008	4.92	5.11	35.6
10/ 10/ 2009	3.25	4.92	45.2
8/ 9/ 2010	5.77	4.79	54.8
2/ 12/ 2011	**2.73**	3.58.	64.6
11/ 9/ 2012	3.58	3.33	74.0
29/ 9/ 2013	4.79	3.25	83.7
8/ 7/ 2014	8.95	2.73	93.3
Q_{minav}	4.79		
σ	1.70		
c_v	0.36		
c_s	1.14		
σ_{cv}	0.099	n = 10	

Minimum annual discharges with different return periods of the Klokot at the Klokot profile Q_{minp} are given in column (5), Table 4.11, and theoretical curve of distribution, based on the Type-III Pearson distribution is given in Figure 4.24. along with input computation data.

According to the adopted criterion (σ_{cv} = 0.099 < $\sigma_{cv}^0 = 0.10$), series of only 10 members of minimum annual discharges is long enough to apply the mathematical statistics technique. Because a single, extreme data could affect the value of the skewness c_s, it is common that minimum annual discharge data series be considerably longer (at least 70 years). Therefore, the statistical analysis result should in this case be understood as indicative.

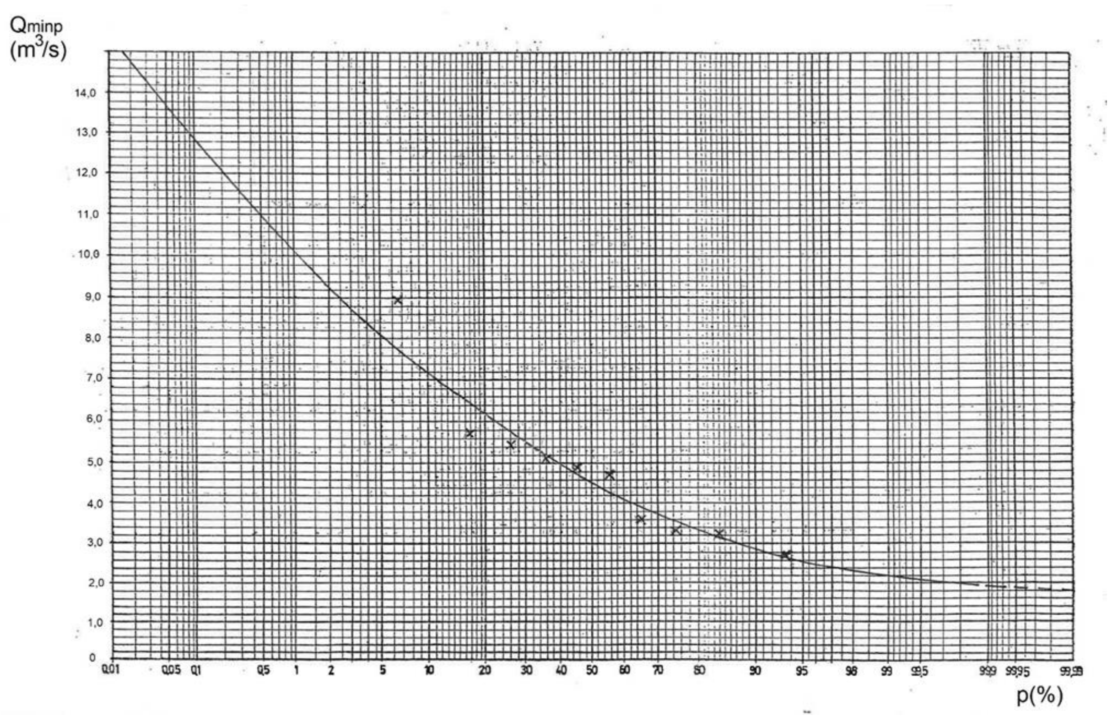


Figure 4.24: *Minimum annual discharges with different return periods for the Klokot at the Klokot profile* $\boldsymbol{Q_{minp}}$ *(Type-III Pearson)* $\boldsymbol{Q_{minav}}$ *= 4.79 m³/s;* $\boldsymbol{c_v}$ *= 0.36;* $\boldsymbol{c_s}$ *= 1.14*

4.6.3.4 Conclusion

After completion of data performed in the previous sections, Figure 4.25 shows maximum $\boldsymbol{Q_{max}}$, mean $\boldsymbol{Q}$ and minimum $\boldsymbol{Q_{min}}$ annual discharges for the Klokot at the Klokot profile in the period (2001-2014). In Figure 4.25, discharges obtained by completion are marked with broken line. During the period (2005-2014) values of mean daily discharges ranged from $\boldsymbol{Q_{min}}$ = 2.73 m³/s (2/12/2011) to $\boldsymbol{Q_{max}}$ = 75.1 m³/s (13/9/2014). Maximum annual discharges during the period (2001-2014) range is: $\boldsymbol{Q_{max}}$ = 32.2 – 75.1 m³/s, mean annual discharges in the period (2001-2014) range is: $\boldsymbol{Q}$ = 9.20 – 23.3 m³/s, and minimum annual discharges during the period (2005-2014) range is: $\boldsymbol{Q_{min}}$ = 2.73 – 8.95 m³/s.

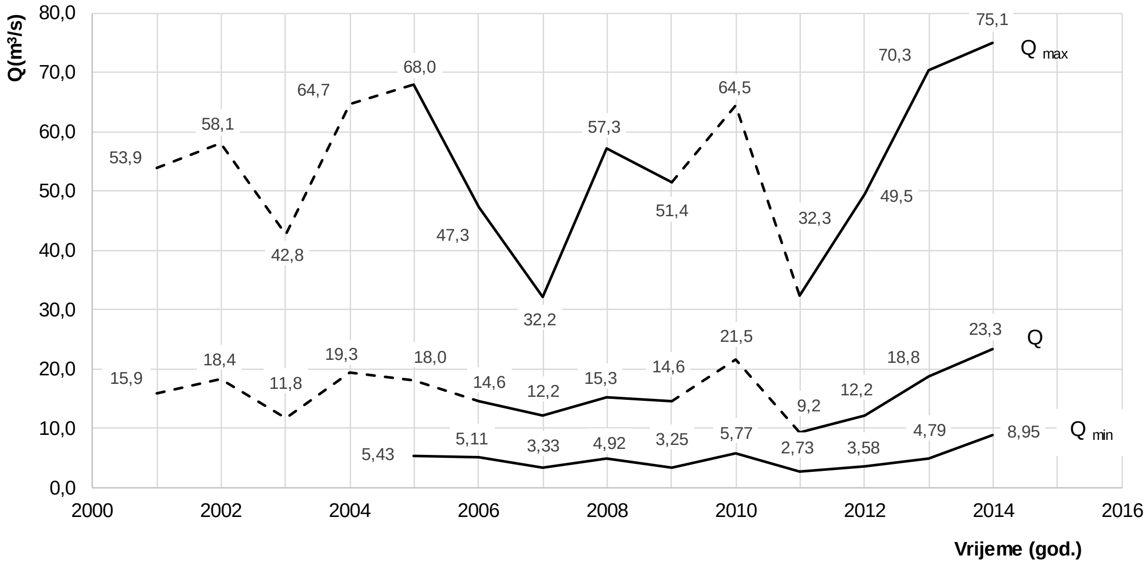


Figure 4.25: *Maximum* $\boldsymbol{Q_{max}}$*, mean* $\boldsymbol{Q}$ *and minimum* $\boldsymbol{Q_{min}}$ *annual discharges of the Klokot at the Klokot profile in the period (2001-2014)*

Table 4.11 gives an overview of annual precipitations with different return periods at the Bihać Weather Station P_{Bp} in column (2) and the Klokot mean annual discharges Q_p in column (3), maximum annual discharges Q_{maxp} in column (4) and minimum annual discharges Q_{minp} with different return periods at the Klokot profile in column (5). According to the conducted A. N. Kolmogorov test results, the applied Type-III Pearson distribution adjusts well to the data used to define it (in all cases $D_N < D_0$).

The annual precipitation distribution curve for the Bihać Hydrological Observing Station P_{Bp} is given in Figure 4.10. The distribution curves for the Klokot Hydrological Observing Station on the Klokot stream are shown as follows: mean annual discharges Q_p in Figure 4.22, maximum annual discharges Q_{maxp} in Figure 4.23, and minimum annual discharges Q_{minp} in Figure 4.24.

Table 4.12: *Annual precipitation with different return periods at the Bihać Weather Station* P_{Bp} *and the Klokot mean annual discharges* Q_p*, maximum annual discharges* Q_{maxp} *and minimum annual discharges* Q_{minp} *with different return periods at the Klokot profile.*

Probability of occurrence ***p*** **(yrs)**	P_{Bp} **(mm)**	Q_p **(m³/s)**	Q_{maxp} **(m³/s)**	Q_{minp} **(m³/s)**
(1)	(2)	(3)	(4)	(5)
10,000	2596	30.8	94.0	-
1000	2375	28.3	88.5	1.91
100	2117	25.2	81.3	2.08
50	2029	24.1	79.3	2.38
25	1930	23.1	74.5	2.54
10	1785	21.1	70.4	2.89
5	1652	19.4	65.5	3.32
2	1417	16.1	55.6	4.45
n	10	14	14	10
D_N	$0.13 < D_0 = 0.41$	$0.12 < D_0 = 0.35$	$0.10 < D_0 = 0.35$	$0.11 < D_0 = 0.41$

In the end, the size of the Klokot catchment area up to the Klokot hydrological profile A = 880 km² is considered. Within a considerable part of this area water overflows into underground and other catchments in a relatively large area, depending on the water levels in the underground. Therefore, the hydrological divide is not fixed and water does not always enter the Klokot spring from the same part of the underground. According to the data from the earlier analyses of the Una catchment the runoff coefficient is: c_u = 0.63, while this value would be considerably lower for the Klokot catchment. It should be borne in mind that the Klokot is the most dominant water source among several sources in the area under consideration, and the portion of water discharged at the Privilica and other significantly smaller springs is estimated at 3.0 – 5.0 % of the quantity reaching the Klokot. Presuming the amount of precipitation at the Bihać Weather Station is relevant for the entire Klokot catchment area and, if the entire area of the catchment area is taken into consideration, the average runoff coefficient would be:

$$c = \frac{Q \cdot T}{A \cdot P} = \frac{16{,}0 \cdot 31{,}54 \cdot 10^6}{880 \cdot 10^6 \cdot 1417 \cdot 10^{-3}} = 0{,}40$$

where: ***Q*** (m^3/s) - mean discharge, ***T*** (s) - number of seconds in a year, ***A*** (km^2) - catchment size and ***P*** (mm) - average annual precipitation. Based on the isohyets map of average annual precipitation amounts in the period (1969-1978) for the Kupa, Una and Sava catchments from the study: *Background Meteorological Precipitation Documentation for the project "Small Hydro Power Cadastre"*, Hydrological and Meteorological Service of the SR of Croatia, Zagreb, 1984, it was estimated that it is acceptable to adopt the average annual precipitation values recorded at the Bihać Weather Station for the considered Klokot catchment area.

For humid 2014, it would be:

$$c_{vl} = \frac{23{,}3 \cdot 31{,}54 \cdot 10^6}{880 \cdot 10^6 \cdot 1934 \cdot 10^{-3}} = 0{,}43$$

and for dry 2011, it would be:

$$c_{su} = \frac{9{,}21 \cdot 31{,}54 \cdot 10^6}{880 \cdot 10^6 \cdot 886 \cdot 10^{-3}} = 0{,}37$$

Such low values of runoff coefficients depart considerably from the runoff coefficient for the Una catchment: c_u = 0.63. There is also discrepancy from the runoff coefficient from the 2004 study where the catchment area is: ***F*** = 686.5 km^2, and the runoff coefficient: ***c´*** = 0.50. However, the results of all hydrogeological investigations carried out so far which are described and elaborated in section 4.5. *Defining the Hydrogeological Catchment* indicate that it is necessary to respect detected significant bifurcations in the Klokot catchment area and other sources in the area under consideration and adopt the size of the catchment area as: ***A*** = 951.5 km^2.

It is generally true of large catchments, and the Klokot influential basin is such, that the entire catchment area rarely participates in runoff. The runoff coefficient is by its definition a relation between effective precipitation and the precipitation falling on the catchment; the entire catchment area is taken into consideration in all cases, including Klokot. Significant bifurcations in the Klokot catchment are the reason for low runoff coefficients, and it is on the basis of hydrological investigation results that the areas are also defined from which the water does not regularly reach Klokot, but it could flow to other streams as well. If this were neglected and the Klokot influential basin were "forcefully" reduced to the size according to the runoff coefficient ***c*** = 0.63, an impact of a part of catchment on water runoff would be neglected and that part of the catchment would not be included in application of the contamination protection measures. This would favour occasional inflow of water from unprotected areas subject to dangerous contamination into the Klokot.

4.7 PROPOSED SANITARY PROTECTION ZONES BOUNDARIES

The Recommendation for sanitary protection zones for the Klokot and Privilica sources was prepared according to the Draft rulebook on conditions for the establishment of sanitary zone protection water source zones with distribution of water from aquifers with crack and crack-cavernous porosity in the border area of Bosnia and Herzegovina and Republic of Croatia

This Rulebook stipulates conditions for determination of sanitary protection zones for sources with abstraction of water from karst aquifer in the border area between Bosnia and Herzegovina and the Republic of Croatia used for public water supply, measures and restrictions applied to them, and deadlines and procedure for decision making on the spring protection.

Hydrogeological flow conditions, i.e. the main drainage directions of groundwater flow in karst aquifers are conditioned by lithological properties of rocks and deposits, structural-tectonic relations as well as the degree of karstification in the catchment area. Karst spring and ponor zones are usually connected, so when determining sanitary protection zones we use the term apparent velocity of underground flow between the ponor and the spring. Additionally, the hydrological conditions, namely the dynamics in the underground, depending on the time in which the tracing is carried out, also have a significant influence on the groundwater flow rate. Apparent underground flow velocities were obtained by tracing and are used in combination with other hydrogeological elements of karst catchment to determine the boundaries of zones in which it is proposed to apply adequate sanitary protection measures.

Sanitary protection zones for sources with abstraction of water from aquifers with fissure and fissure-cavernous porosity are:

- restricted zone – Zone IV,
- restriction and surveillance zone – Zone III,
- zone of strict restriction and surveillance – Zone II,
- zone of strict protection and surveillance regime – Zone I.

Sanitary protection zones of the karst aquifers in the border area between Bosnia and Herzegovina and the Republic of Croatia are determined according to the criteria from Table 1 below:

Table 1: *Criteria for determination of sanitary protection zones in karst aquifers*

	PROTECTION ZONE	**GROUNDWATER FLOW TOWARDS THE WELL FIELDS**	**APPARENT GROUNDWATER VELOCITY, cm/s**	**REQUIRED HYDROGEOLOGIAL MAPS**
ZONE OF STRICT PROTECTION AND SURVEILLANCE REGIME	I A	IMMEDIATE WELL FIELD AREA	TO BE FENCED	SCALE 1:1,000
	I B	IMMEDIATE CATCHMENT AREA (surface inflow from area around the source)	TO BE MARKED	SCALE 1:1,000
ZONE OF STRICT RESTRICTION AND SURVEILLANCE	II	24 HOURS	CATCHMENT DRAINAGE ZONE > 3 cm/s	SCALE 1:25,000
RESTRICTION AND SURVEILLANCE ZONE	III	1-10 DAYS	1-3 cm/s PRESUMED RETENTION ZONE	SCALE 1:50,000
RESTRICTED ZONE	IV	10-50 DAYS	< 1 cm/s	SCALE 1:50,000

In accordance with Articles 15, 16, 17 and 18 of the Rulebook, four sanitary protection zones are singled out at the Klokot and Privilica spring catchments (surface area 951.49 km^2), while the Plitvice Lakes National Park area is covered separately since it falls under regulated protection zones of the National Park (Annex 4). The zones within the National Park are determined in line with the Protected Areas and/or Natura 2000 Sites Management Planning Guidelines.

The protection zones established within the National Park area apply to that area. In case of the Klokot and Privilica catchment, according to the criteria for determination of sanitary protection zones, this area belongs to the Sanitary Protection Zone II (Prijeboj ponor to the Sanitary Protection Zone III – remaining part of the catchment). However, as long as this area is treated as protected area it belongs to management zones applied within the National Park, with more stringent measures stipulated than within the Sanitary Protection Zones II and III.

The method of establishing individual protection zones in the Klokot and Privilica source catchment area is described in more detail below.

The sanitary protection zones of the Klokot and Privilica springs are shown in Annexes 4 to 4.5

4.7.1 Zone of strict protection and surveillance regime – zone I

The boundaries of the zone of strict protection and surveillance regime – Zone I are stipulated by Article 18 of the Rulebook.

The boundaries of the zone of strict protection and surveillance regime (Zone I A) encompass the water resource (source area, intake, pumping site), pumping station, water treatment facility and facilities needed for operation, maintenance and protection of the pumping station. The water supply system operator is responsible for fencing of the Sanitary Protection Zone I A of the source area and posting the signs prohibiting unauthorized access, as well as for ensuring permanent electronic and/or physical supervision.

The Klokot and Privilica source Protection Zone I B encompasses the immediate surface catchment of the sources, i.e. the surface floodplain surrounding the sources.

According to the Rulebook, Protection Zone I A is an immediate area around the Klokot and Privilica sources. Annex 4.3 shows boundaries of the Klokot source Protection Zone I A, while the Annex 4.4. shows the Privilica spring Protection Zone I A.

Protection Zone I A

The Klokot source Sanitary Protection Zone I A encompasses and area of 0.026 km^2. It is entirely situated in the territory of Bosnia and Herzegovina. The said area includes a parcel under cadastral plan Nos. 883/1 and 883/2, cadastral municipality Klokot, accommodating the Klokot Pumping Station, and a belt along the left Klokot Riverbank upstream from the intake structure. This area is presently fenced,and occupied by structures used by the JP Vodovod d.o.o. Bihać Water Utility.

The Klokot spring Protection Zone I A (Prilog 4.3) boundary runs from the right bank of the Klokot River 80 meters downstream from the spring, runs along the ridge above the spring, goes around the spring along its south, west, north and north-west side, to continue along 220 m a.s.l. contour line to the north boundary of the parcel under cadastral plan No. 883, cadastral municipality Klokot, then along the northern, east and south boundaries of the parcel under cadastral plan No. 883, cadastral municipality Klokot, from where it goes westward for 16 meters to the Klokot River, and than 75 meters upstream along the left bank of the Klokot River. The fence around this area is 650 meters long.

The Protection Zone I A of the Privilica spring (Prilog 4.4) encompasses and area accommodating intake structure and other facilities for water intake and conveyance from the spring to the water supply network. It is entirely situated in the territory of Bosnia and Herzegovina.

The Privilica source Protection Zone I A boundary runs from the bridge over the Privilica brook, along the north-west boundary of the parcel under cadastral plan No.8851, cadastral municipality Bihać-Grad, then towards the south-west for 75 meters, to continue in the north-west direction for 115 meters and towards the north-east for 80 meters to the north-east boundary of the parcel under cadastral plan No.8853, cadastral municipality Bihać-Grad, and further along the north-east boundary of the parcel under cadastral plan No. 8853, cadastral municipality Bihać-Grad, and by the north-west and north-east boundary of the parcel under cadastral plan No. 8851, cadastral municipality Bihać-Grad to the bridge over the Privilica brook. The total area of the Protection Zone I A around the Privilica source is 0.0067 km^2, and the perimeter of the area is 360 m.

In addition to the Klokot and Privilica sources, Protection Zone I A also protects a ponor detected at the Vučjak Landfill site, since it is a ponor from which water (potentially contamination) reaches water intake facilities very quickly. The protection measures are identical to the measures established for the Klokot and Privilica source Protection Zone I A, so it is necessary to prohibit direct access by placing a fence at a distance of not less than ten meters from the ponor.

<u>Protection Zone I B</u>

An area of the Protection Zone I B for the Klokot and Privilica springs runs from the Zone I A boundary and encompasses the immediate surface catchment around the spring, i.e. the surface floodplain surrounding the spring, and is entirely situated in the territory of Bosnia and Herzegovina

According to the above, the outside boundary of the Protection Zone I B runs from the Klokot spring to the north by a slope above the Klokot spring to el. 356 m a.s.l. on the hill, then following 350 m a.s.l. contour line to the south for 415 meters, to close an area of a ravine on the south side and end on the right bank of the Klokot River.

Total area of the Klokot spring Protection Zone I B is 0.07 km^2, and the length of perimeter of this zone is 837 meters. The Klokot source Protection Zone I B is shown in Annex 4.3.

The Privilica spring Zone I B area is 0.08 km^2, and the length of perimeter is 720 meters. The outside boundary runs from the Privilica spring to the west to 350 m a.s.l. contour line, towards south to 380 m a.s.l. contour line, to close in the east near the Privilica spring at el. 230 m a.s.l.

Protection Zone I B of the Privilica source is shown in Annex 4.4

4.7.2 Zone of strict restriction and surveillance – zone II

The Sanitary Protection Zone II includes the main underground drainage directions in the source immediate catchment area, with possible flow through the aquifer fissure system to the water intake lasting up to 24 hours, i.e. areas from which apparent groundwater velocities greater than 3.0 cm/s were determined in high water conditions, namely the inner part of the classic catchment area.

The boundary of the Sanitary Protection Zone II for the Klokot and Privilica springs was determined using the flow through the aquifer to the water intake lasting up to 24 hours as a criterion. The said criterion was applied because of unfavourable results obtained when the criterion of velocity above 3 cm/s was applied, thus the Zone II is contoured using a criterion which provides for higher safety in protection against possible contamination.

If the areas with main points of collection and runoff of water towards the source (ponors and ponor zones) are situated within the boundaries of Zone IV or Zone III, such areas will be defined as Sanitary Protection Zone II of sources with abstraction of water from aquifers with fissure and fissure-cavernous porosity.

Ponors and ponor zones are fenced with firm fence and marked as Zone II. In the Klokot and Privilica spring catchment, the following ponors are contoured as Sanitary Protection Zone II:

- Prijeboj ponor,
- Korenička Rijeka ponor,
- Vidrovac ponor.

The Protection Zone II area determined in this way is mostly situated in the territory of Bosnia and Herzegovina, while all three protection areas protecting the above ponors are situated in the territory of the Republic of Croatia.

The outside boundary of the Protection Zone II in the north starts in the territory of Bosnia and

Herzegovina at el. 351 m a.s.l. in the Urije location, and it is contoured to west to el. 342 m a.s.l. near Debeli Lug in the territory of Croatia. The boundary than turns towards south-west, to the Željava area, to cross again to the territory of Bosnia and Herzegovina at el. 392 m a.s.l. near Odakove Pećine. Towards south, the boundary runs along the Mt. Plješivica slopes over el. 344 m a.s.l. at the Baljevačko Polje slope, to el. 413 m a.s.l. in Žliba area and el. 513 m a.s.l. near Grabovo Rame. Then it crosses the Karolinka area to reach el. 615 m a.s.l. at Vršak, and el. 421 m a.s.l. at Zavalje. After that, the outside boundary of the Protection Zone II goes west, across Skočajska Draga to Glavica at el. 446 m a.s.l. The boundary ends in an area about 320 meters from the Privilica spring.

The above described zone encompasses an area of 26.56 km^2, of which 9.9 % is in the territory of the Republic of Croatia (2.62 km^2), and 90.1 % in the territory of Bosnia and Herzegovina (24.14 km^2).

Prijeboj ponor area is entirely situated in the Plitvice Lakes National Park territory in the Republic of Croatia, and it covers an area of 1.15 km^2.

The boundary was determined so that the upstream part of the watercourse sinking in the said ponor was contoured, as the orography of the area around the ponor was taken into account. The area from which the water flows into the ponor was three hours, was also taken into account. The water velocity in the ponor was estimated at 0,25 m/s.

The boundary in the north starts from the road to Prijeboj, includes Marasovo Vrelo, to continue towards south-east and south across Oljavčev Vršak (786 m a.s.l..), over the area of Čujića Krčevina to el. 723 m a.s.l. above Mira Vrela. The boundary goes west across Čujića Krčevina, passes el. 708 m a.s.l. and turns north to the road to Prijeboj.

Ponor area in Koreničko Polje field encompasses an area of 2.29 km^2 in the territory of the Republic of Croatia.

The boundary was determined so that the upstream part of the watercourse sinking in the said ponor was contoured, as well as the orography of the area around the ponors was taken into account. The area from which the water flows into the ponor was three hours, was also taken into account.

In the north-west, the boundary starts from the area of Gradina Korenička, to follow 640 m a.s.l. contour line to the area of Vedrište. After Vedrište, the boundary turns east and encircles the area of the Ponor Korenički. From Ponor Korenički towards the west, it goes across Lug along the right bank of the Matica to Gradina Korenička.

Ponor area in Krbavsko Polje field encompasses and area of 7.1 km^2 in the territory of the Republic of Croatia.

The boundary is determined so that the contour is a wider ponor zone within which are located active ponors that gravitate towards the Una basin. The orography and hydrogeological structure of the observed terrain were also taken into account.

The said area includes a part of Krbavsko Polje field from the place Zecovi in the north, then towards the north-east the boundary of Zone II follows 635 m a.s.l. contour line which runs along the right edge of the D1 road towards Udbina. Then, to the east, the boundary follows 640 m a.s.l. contour line to the settlement of Budisavljevići. From Budisavljevići to the south the boundary still follows 640 m a.s.l. contour line to Zalić Ponor. From the Zalić Ponor towards west the boundary runs along the right bank of the Krbavica to the area of Vedro Polje. From Vedro Polje to the north, the boundary continues along the right bank of the Krbavica to Rosulje.

Total area of the Klokot and Privilica source Protection Zone II, including the areas around ponor Prijeboj and ponors in the Koreničko Polje and Krbavsko Polje fields is 37.1 km^2. Of that area, 64.5 % is in the territory of Bosnia and Herzegovina (23.94 km^2) and 35.5 % in the territory of the Republic of Croatia (13.15 km^2)

The Protection Zone II is shown in Annex 4.2.

4.7.3 Restriction and surveillance zone – zone III

The Sanitary Protection Zone III of sources with the abstraction of water from aquifers with fissure and fissure-cavernous porosity encompasses parts of the catchment from the outside boundary of the Zone II to the boundary from which the flow is possible through the underground to the water intake in the period from 1 to 10 days in high water conditions, i.e. areas from which apparent groundwater velocities of 1 to 3 cm/s have been determined, namely the area covering the predominant part of the catchment.

The Protection Zone III covers an area of 842.60 km^2. The vast majority of the Protection Zone III is in the territory of the Republic of Croatia – 92.1% (776.3 km^2), while 7.9% of the area (66. 4 km^2) is in the territory of Bosnia and Herzegovina.

The outside boundary of the Protection Zone III mainly follows the outside boundary of the Klokot and Privilica spring catchment, except in the south and south-west part where it borders the Protection Zone VI, and at the foot of Mt. Plješivica where it borders the Sanitary Protection Zone II.

The Zone III boundary begins in the territory of Bosnia and Herzegovina near Urije at el 351 m a.s.l. It runs towards northeast across the area of the Arkovac and Brišovac springs, after which it crosses into the territory of the Republic of Croatia at Jasen peak (el. 375 m a.s.l.).

Towards the north, the boundary crosses Gornji Vaganac, and following the right bank of the Korana (Cvetničko Selo), it goes towards the area of Čatrnja, where the boundary crosses the Korana River. The boundary continues through Crkvina (409 m a.s.l.), Deriguz (709 m a.s.l.) to Pištenica (908 m a.s.l.) in the very north of the catchment. Then the boundary goes to the northwest through Veliki Bil (934 m a.s.l.) and Preka Kosa (774 m a.s.l.). From west to southwest, the boundary goes through Bačinovci (1,043 m a.s.l.), Vršak near Mileusnića Draga to the boundary with Sanitary Protection Zone IV near Kamenjak (982 m a.s.l.). From Kamenjak, the boundary continues through Fundukov Vrh (983 m a.s.l.) and Vrelo Koreničko. At Slatka Voda, the boundary turns to the north through Oštri Mihaljevac (1,048 m a.s.l.), Plandište (768 m a.s.l.), Kapela Korenička to the area of Protection Zone II near the Prijeboj ponor. After Prijeboj, the boundary turns to the northeast across Dražica (642 m a.s.l.) and Pavetnjak to Ličko Petrovo Selo in the north. After Ličko Petrovo Selo, the boundary goes to the northwest through Zaklopača (599 m a.s.l.), Rastovača and Gorica (559 m a.s.l.), where it crosses the Korana River near the Korana bridge. The boundary then continues through Suha Draga (715 m a.s.l.), M. Manduševac (863 m a.s.l.) to Gornja.

The Protection Zone III is shown in Annex 4.1.

4.7.4 Restricted zone – zone IV

According to Article 15 of the Rulebook, Sanitary Protection Zone IV of the sources includes a part of the catchment area outside the Protection Zone III to the outside boundary of the catchment. In this area, according to the existing regulations, the possibility of flow through the fissure and fissure-cavernous underground in the conditions of high waters to the water intake is defined in the period of:

- 10 to 20 days for sources referred to in Article 10, paragraph 1, subparagraph 1 of this Rulebook,
- 20 to 40 days for sources referred to in Article 10, paragraph 1, subparagraph 2 of this Rulebook, and

- 40 to 50 days for sources referred to in Article 10, paragraph 1, subparagraph 3 of this Rulebook.

Notwithstanding paragraph 1 of this Article, Sanitary Protection Zone IV of sources with the abstraction of aquifer waters with fissure and fissure-cavernous porosity can be determined so as to include the source catchment outside the Protection Zone III, in which apparent groundwater velocities of less than 1 cm/s have been determined, as well as the total catchment area participating in recharge of waters in the associated source.

In the observed area of the Sanitary Protection Zone IV, the areas in the catchment have been singled out that have not been sufficiently explored so far in the south and southwest part of the Klokot and Privilica spring catchment, with a total area of 71.6 km^2 (7.5% of total area of the Klokot and Privilica hydrological catchment).

According to the hydrogeological structure, tectonics and orography, the mentioned areas deviate from the characteristics of the surrounding area, and although they have not been sufficiently researched, they can be singled out as areas from which there are no concentrated flows. The flows in the underground are due to all the above dispute and it is to be assumed that the flow time would be longer than the time prescribed by Article 15 of the Rulebook.

The outside boundary of the south part of the catchment which is singled out as Sanitary Protection Zone IV goes from Sertić Brdo in the southwest part across Karaula (826 m a.s.l.), Matić Strana (768 m a.s.l.), Vukov Vrščić (779 m a.s.l.) to Popuša in the south.

The outside boundary of the south-west part of the catchment which is in the Sanitary Protection Zone IV goes from Ćutinovac (1,408 m a.s.l.) in the south part of the zone, across Plješivica-Čardak (1,550 m a.s.l.), Šmanjkovo Bilo (1,259 m a.s.l.) to Škorin Vrh (1,218 m a.s.l.) in the north part of the contoured zone.

The Protection Zone VI is shown in Annex 4.1.

4.7.5 RESTRICTION ZONES IN THE PLITVICE LAKES NATIONAL PARK

The area of the Plitvice Lakes National Park within the Klokot and Privilica source catchment covers 218.68 km^2, which is 22.98% of the total catchment area of the subject sources.

The document *"Plitvice Lakes National Park Management Plan 2019 - 2028"*, section *3.6 Management Zonation* shows the distribution of zones within the National Park together with the associated protection measures. This management zoning was done in accordance with the Protected Areas and/or Natura 2000 Sites Management Planning Guidelines that provide for three main zones - from a zone where there is almost no human impact to a zone where natural space can be significantly altered by human impact. The order of the zones does not imply the value of the area but reflects the need to manage the protected area towards preservation of specific biodiversity and geodiversity.

According to the Guidelines, the area of the National Park is divided into three management zones:

- I – strict conservation zone
- II – active management zone
- III – sustainable use zone.

According to national and international standards for the category of national parks, the largest share of the Park area, i.e. 80.7% is within the Strict Conservation Zone (Zone I), 17.1% is within the Active Management Zone (Zone II), and the smallest share of about 2.2 % is in the Sustainable Use Zone (Zone III).

According to the Rulebook on sanitary protection zones, the Prijeboj ponor area is within the

Sanitary Protection Zone II, although it is located within the boundaries of the Plitvice Lakes National Park and its Zone I. It is important to emphasize that the protection measures within Zone I are very strict, so no activities other than research, monitoring and supervision are allowed. No interventions in the Zone I area are permitted.

The area of the Plitvice Lakes National Park with the contour of the area of the Prijeboj ponor zone is shown in Annex 4.

The areas occupied by specific sanitary protection zones in the Klokot and Privilica catchment in the territories of the Republic of Croatia and Bosnia and Herzegovina are given in Table 2.

Table 2: *Areas of specific sanitary protection zones in the Klokot and Privilica catchment*

	Protection zone	Area of specific protection zone related to the hydrogeological catchment area		Area of specific sanitary protection zones in Bosnia and Herzegovina		Area of specific sanitary protection zones in the Republic of Croatia	
		(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
ZONE OF STRICT PROTECTION AND SURVEILLANCE REGIME	I A	0.05	0.01	0.06	100.00	-	-
	I B	0.15	0.02	0.15	100.00	-	-
ZONE OF STRICT RESTRICTION AND SURVEILLANCE	II	37.09	3.90	23.94	64.54	13.15	35.46
RESTRICTION AND SURVEILLANCE ZONE	III	842.60	88.55	66.35	7.87	776.25	92.13
RESTRICTED ZONE	IV	71.60	7.52	-	-	71.60	100.00
PLITVICE LAKES NATIONAL PARK		218.68	22.98			218.68	100.00
		Total hydrogeological catchment area		Hydrogeological catchment area in Bosnia and Herzegovina		Hydrogeological catchment area in the Republic of Croatia	
		(km^2)	(%)	(km^2)	(%)	(km^2)	(%)
		951.5	100	90.5	10	861.0	90

5 GIS DATABASE AND MAPPING

5.1 WORKING GIS DATABASE

Data collection and processing

During the Inception phase we have reviewed and collected available data relevant to the objectives of the Study. All collected data was transformed from different formats (Shapefiles, ArcInfo Coverages, Personal Geodatabase, ACAD dwg files) and stored in working File Geo-database. For all spatial layers MGI_Balkans_5 coordinate system MGI_Balkans_5 (WKID: 31276 Authority: EPSG) was defined and, we produced cartographic composition, in a form of ArcGIS MXD file, which was used for data analysis, attribute harmonisation and presentation (Fig. 5.1).

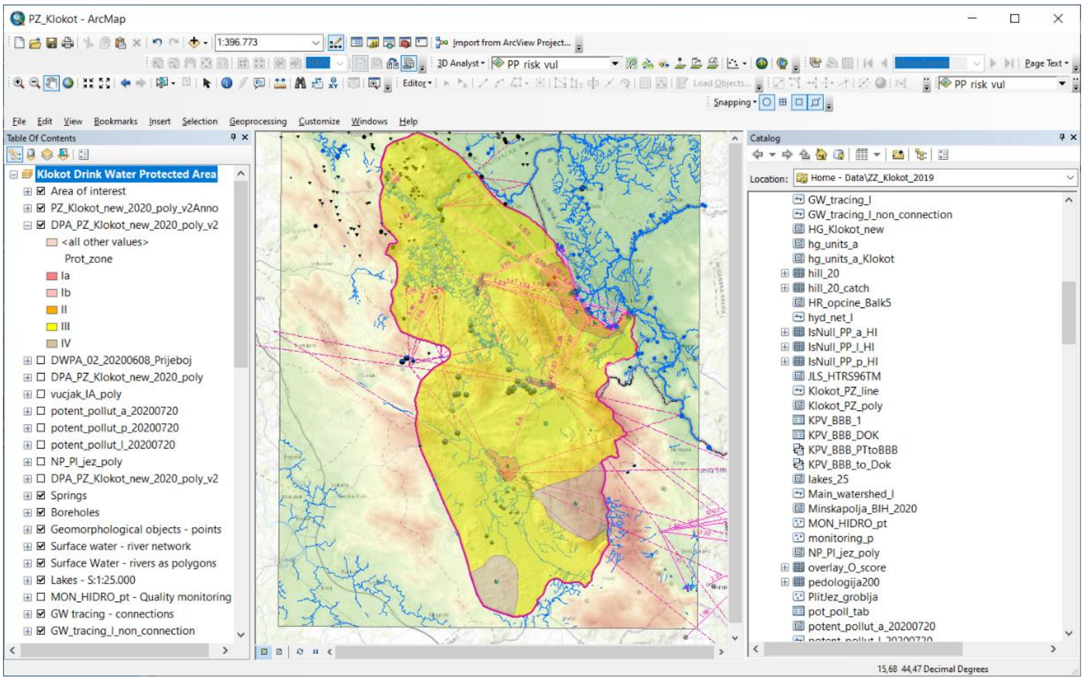


Fig. 5.1: Presentation of collected and produced data using ArcMap

The list below shows which data has been collected and processed with their main characteristics:

1. Digital elevation model – raster resolution 20*20 m, height accuracy 5-10 m
2. Hill-shade model - raster resolution 20*20 m
3. Slope percentage – raster resolution 20*20 m
4. Hydrographic network – lines with flow direction based on topo. maps S 1:25.000
5. Lakes - stagnant water polygons based on topo. Maps S 1:25.000
6. Geological boundary and tectonics – lines based on geological maps
7. Hydrogeological units – polygons based on geological maps
8. Geomorphological objects (pits, caves, ponor) – points
9. Springs – points
10. Groundwater tracing – data about tracing and connected lines
11. Monitoring station – location and data about water quality measuring
12. Centroids of swallow holes (ponikve) – points based on maps
13. The degree of karstification – density raster resolution 250*250 m
14. Catchment area of Klokot spring – polygon
15. Protection zones of Klokot spring - polygons
16. Main watershed line Black Sea – Adriatic Sea – line

17. Precipitation lines – 30 Years average 1930-1960
18. Potential sources of pollution – represented with points
19. Potential sources of pollution – represented with lines
20. Potential sources of pollution – represented with polygons
21. Land Use data – CORINE 2012 – polygons
22. Scheme of topographic maps S. - polygons
23. Scanned georeferenced Topographical maps S.– raster resolution 8*8 m

Spatial and associated attribute data in layers listed above indicated by numbers 8, 9, 10, 17, 18 and 19 contains data that was created more than 10 years ago, and during the Project we made revision and updating of spatial and attribute data. Collected data have been loaded into working File Geodatabase named PZ_Klokot_Balk5.gdb (Fig. 2). It should be emphasized that the loaded data in the working Geodatabase retained the non-standardized structures (field attributes) like was in the original data.

During the Project, the data located in the working database were used for spatial analyses and presentation of results. All maps and images were created with GIS tools based on the collected data. It should be emphasized that through the use of such organized data, all impacts can be monitored in a very simple way and the necessary changes, adjustments and upgrades can be made. Currently, the database is filled with all updated relevant data that were created during the project.

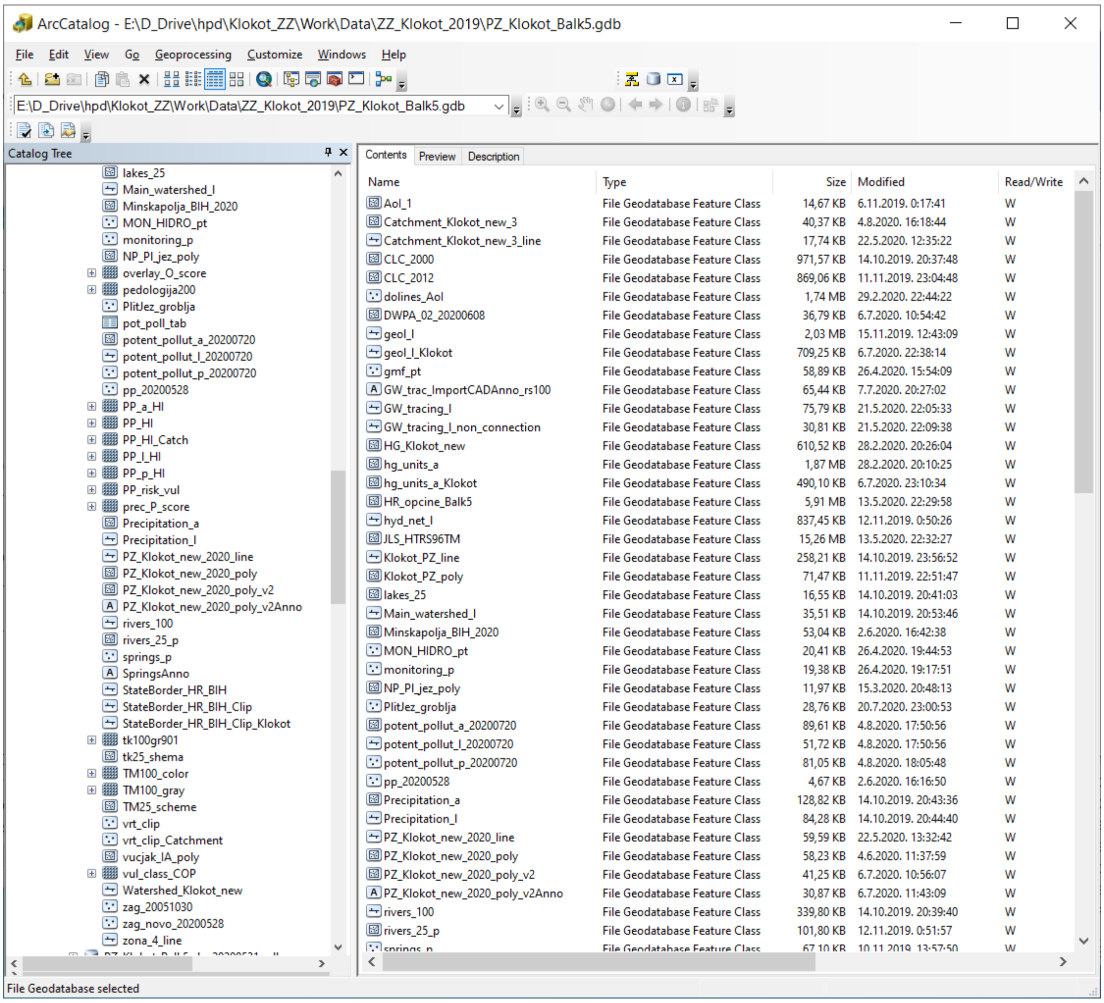


***Fig. 5.2**: Content of working File Geodatabase PZ_Klokot_Balk5.gdb*

Organization and storage of all mentioned data requires defining the standardized structure of the Geodatabase. Well-structured data are a precondition for quality usage in all intended tasks, for further monitoring of the Klokot catchment area and for possibility of loading end using this data in the Water Information System of FBIH in the future. Based on these requirements we created standardized Geodatabase for all thematic layers which will be transferred and loaded into Enterprise Geodatabases of FBIH Water Agencies. Before loading the data into a standardized database, all collected data was harmonized, which means that we were provided coding of free entries in the database text fields according to the codes of the catalogue tables (GDB Domains), adjusted formats of existing number and text fields, and we corrected the topology of the spatial elements.

5.2 CREATION OF STANDARDIZED GEODATABASE

GIS Database model in a form of Esri Geodatabase relevant for the storing of research work basic data and results have been designed and structured in accordance to EU Flood Directive, Water framework directive (WFD), INSPIRE Directive, BIH Water Information System and professional requirements. Base on conceptual model a logical data model was made with usage of Computer Aided Software Engineering (CASE) tools in form of Unified Modeling Language (UML) diagrams. Its scheme was used for generating all objects in Drinking Water Protected Area (PA_D) Geodatabase. For spatial layers are defined coordinate system and projection MGI_Balkans_5; WKID: 31275 Authority: EPSG; Projection: Transverse_Mercator. In the future will be able to transform all spatial layers from this Coordinate System to the any other standardized coordinate system. When delivering data to the FBiH Water Agencies, the spatial data will be transformed into MGI_Balkans_6 which is used in the FBIH Water Information System.

PA_D Geodatabase contains 5 Feature Datasets and 17 Feature Classes, 21 Tables (Object Classes), 26 Relationship Classes and 83 Domains. Feature Classes (spatial layers) are placed in Feature Datasets, Tables are located directly in database root and with relationship classes are interconnected or connected with spatial data organized in Feature classes.

Spatial layers and tables of PA_D Geodatabase are hierarchically organized and interconnected with relational classes. For a better understanding of content organization simplified structural schemes were made. Below on figures 5.3 to 5.6 are shown all the component parts of database, relations between them and cardinality.

***Fig 5.3**: KAV - Surface Water*

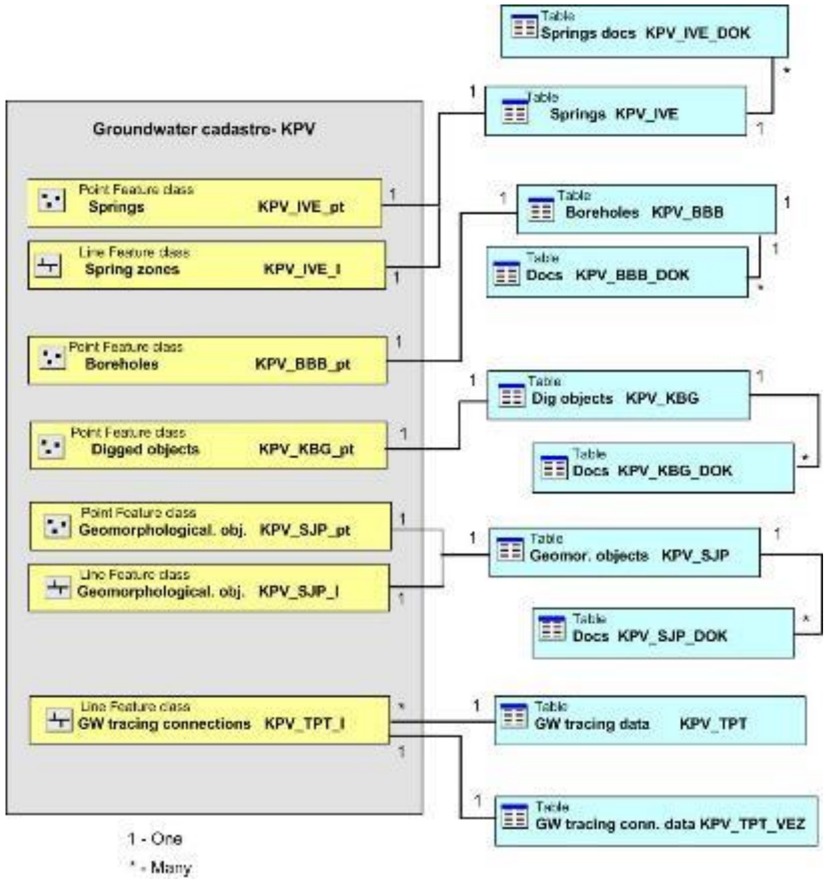


Fig. 5.4: *– KPV - Groundwater*

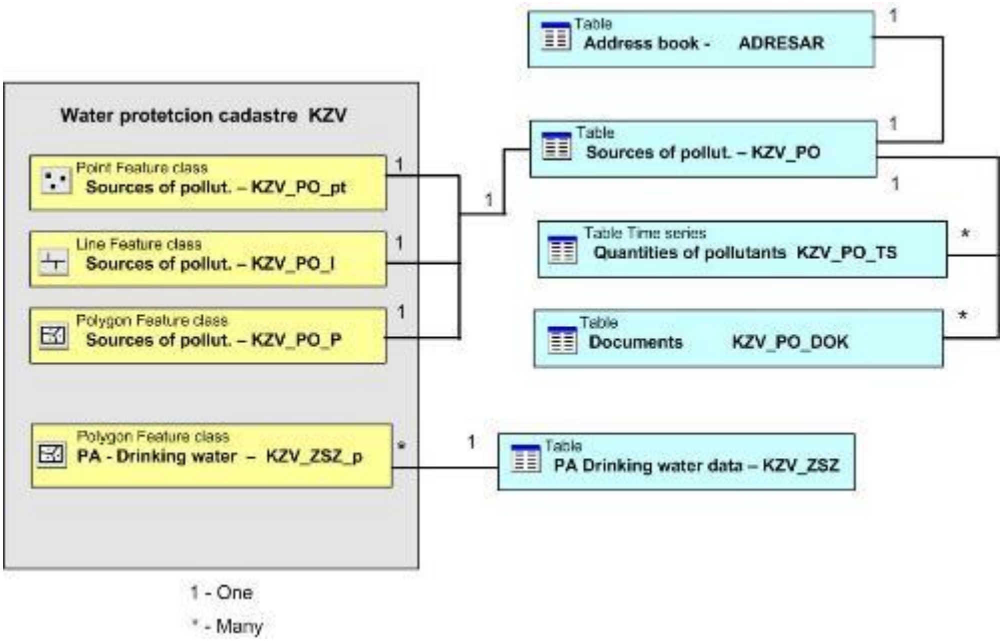


Fig. 5.5: *KZV - Water Protection*

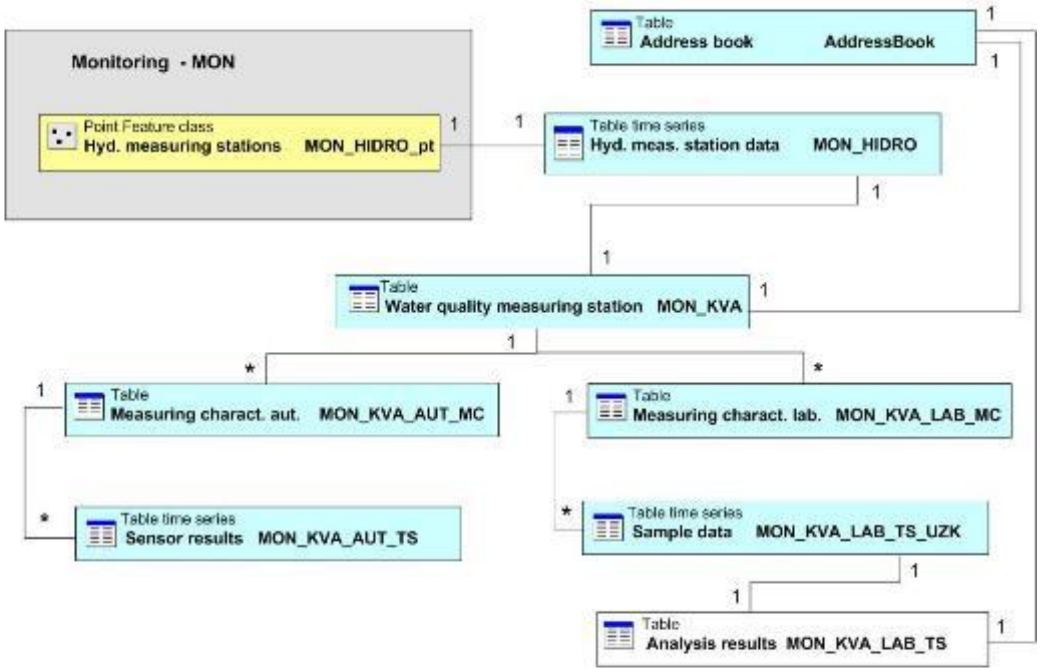


Fig.5.6: *MON - Monitoring*

The content and structure of created Geodatabase is expandable and depends on the specific needs. The database structure will be upgraded as needed with new objects or existing objects will be expanded with the necessary attributes. Also, database will be used for further storing of analysis data and for results of spatial and other analyses.

6 LEGAL FRAMEWORK

6.1 BASE DATA AND REVIEW OF EXISTING INFORMATION

The Klokot and Privilica springs are the sources from which most of the population of the city of Bihac is supplied. As these are springs that can provide long-term water supply to the population with their capacity, protecting these springs is critical to the effective functioning of this community.

The catchment area of the mentioned sources, i.e. their sanitary protection zones are located in the border zone between Bosnia and Herzegovina and the Republic of Croatia, and for their adequate protection it is necessary to establish cooperation and joint action in order to adequately protect the said source in the long term in future. For this purpose, it was necessary first to analyse the existing legal frameworks in the two countries, determine the manner in which the establishment of sanitary protection zones is regulated, identify possible advantages and disadvantages, and on that basis make recommendations for improving the by-laws and effective protection of the Klokot and Privilica springs.

Accordingly, relevant legal and sub-legal acts of the Federation of BiH and the Republic of Croatia were collected for the purposes of development of the Study on the Establishment of Cross-Border Sanitary Protection Zones of the Klokot and Privilica Springs (Bihać), as well as the previously prepared project documentation related to the protection of the Klokot spring. In addition, the Consultant addressed the relevant international regulation related to transboundary aquifers, in particular the Convention on the Protection and Use of Transboundary Watercourses and International Lakes - Water Convention, as well as UN Resolutions 66/104, 68/118, 63/124, which contain provisions on the law on transboundary aquifers.

An analysis of the documents collected was carried out, a comparison was made, and the shortcomings and advantages of the legislative framework were identified and based on that a recommendation was made.

6.2 PROPOSAL FOR THE DEVELOPMENT OF PROTECTION SYSEM AND THE INVESTIGATION METHODS FOR PROTECTION OF THE KARSTIC AQUIFERS IN THE BORDER AREAS OF BOSNIA AND HERZEGOVINA AND THE REPUBLIC OF CROATIA

Recommendation of the protection system and investigation methods for protection of the karstic aquifers in the border areas of Bosnia and Herzegovina and the Republic of Croatia (hereinafter referred to as the Recommendation of the protection system and investigation methods) was submitted in draft version to the Consultant as a part of the ToR for development of the Study on the Establishment of Cross-Border Sanitary Protection Zones of the Klokot spring (Bihać, BiH). This document is a product of the work of the Interstate Commission for Water Management of the Republic of Croatia and BiH and offers a good basis for regulating the protection of drinking water sources in karst aquifers in the border areas of BiH and the Republic of Croatia. From a technical point of view, the aforementioned document contains all relevant conditions and provisions related to the designation of sanitary protection zones, mainly taken from the Guidelines for the implementation of the Rulebook on protective measures and conditions for the designation of sanitary protection zones for drinking water sources of the Republic of Croatia (hereinafter: the Guidelines). The legal-normative part of the Recommendation of the Protection System and Investigation Methods contains a Recommendation of the Rulebook on the conditions for the establishment of sanitary protection zones of springs in karst aquifers in the border area of B&H and the Republic of Croatia, which should also be further improved.

The Consultant's task is to assist the project beneficiary countries (B&H and the Republic of

Croatia) to improve the mentioned document, i.e. to make recommendations for establishing future cooperation between B&H and the Republic of Croatia in the protection of underground watercourses crossing the state border.

6.3 REVIEW AND ANALYSIS OF THE EXISTING LEGAL FRAMEWORK

(See Annex 6)

The protection of the source of drinking water Klokot from which the majority of the population of the city of Bihac is supplied is prescribed by applicable laws and by-laws, however, the protection of the source is not fully ensured in the manner prescribed.

One of the reasons is that the previously defined zones of sanitary protection of the Klokot spring are located in the territory of the Republic of Croatia, i.e. in the border area, and in order to implement the required measures of protection of the Klokot spring it is necessary to improve cross-border cooperation, as well as jointly implement adequate protection measures in these zones, all in accordance with the applicable laws and by-laws in both countries.

In order to address the issue of protection of drinking water sources in the border area, the Governments of BiH and the Republic of Croatia signed the Agreement on the Regulation of Water Management Relations, with special emphasis on transboundary watercourses between the two countries.

On the other hand, the practical implementation of the prescribed measures of the sanitary protection zones of the Klokot spring has not been fully implemented in the Republic of Croatia. For this reason, it is necessary to initiate the procedure of harmonization of legal acts and establish mechanisms for the protection of drinking water sources between the two countries as soon as possible.

The consultant has collected all relevant documentation from B&H and Croatia, including legal and by-law regulations, other related documentation (source protection studies, river basin management plans, etc.), as well as relevant EU directives. As water protection in B&H is the responsibility of its entities, the Consultant has solely addressed the regulations of the FB&H entities, which in the catchment area of the Klokot spring border with Croatia.

The following is an overview of the legal framework of B&H and Croatia.

6.3.1 Laws

The legal framework relating to the protection of sanitary protection zones in B&H and the Republic of Croatia includes the following:

- Law on Water of FBiH (Official Gazette of the Federation of BiH, No. 70/06),
- Law on Waters of the Una-Sana Canton (“Official Gazette of the USK” No: 4/2011),
- Law on Water of the Republic of Croatia (Official Gazette 66/19 in force from 18 July 2019),
- Law on Water Services of the Republic of Croatia (Official Gazette 66/19 in force from 18 July 2019).

6.3.2 By-laws

Bosnia and Herzegovina

- Rulebook on the Method of Determining Conditions for the Designation of Sanitary Protection Zones and Protective Measures for Water Sources for Public Water Supply of the FBiH Population (FBiH Official Gazette No. 88/12) (hereinafter referred to as the FBiH Rulebook),

- Decision on the Protection of the Drinking Water Source Klokot and Privilica ("Official Gazette of the Municipality of Bihać" No: 15/2009)
- Decision on Amendments to the Decision on the Protection of the Drinking Water Source for the Klokot and Privilica ("Official Gazette of the Municipality of Bihać": 10 / 12)
- Decision on the Protection of the Drinking Water Source Klokot and Privilica ("Official Gazette of the City of Bihać" No: 12/19)

Croatia

- Rulebook on the Conditions for Determining Sanitary Protection Zones of the Water Source of the Republic of Croatia („Narodne novine", broj 66/11 i 47/13) (hereinafter referred to as the RH Rulebook)
- Guidelines for the Implementation of the Rulebook on Safeguards and Conditions for the Determination of Sanitary Protection Zones of Drinking Water Sources.

6.3.3 Specific regulations

- International Treaty between the Government of Bosnia and Herzegovina and Government of Republic of Croatia on the Regulation of Water Management Relations
- Decree on ratification of the International Treaty between the Government of Bosnia and Herzegovina and Government of Republic of Croatia on the Regulation of Water Management Relations (Official Gazette of the Republic of Bosnia and Herzegovina No. 6/1996),
- International Treaty between the Government of Bosnia and Herzegovina and Government of Republic of Croatia on the Regulation of Water Management Relations Class: 325-01 / 96-01 / 02, Ur. No.: 5030114-96-6, (Zagreb, 3 October 1996).

6.3.4 Results of conducted analysis of existing regulations and improvement measures

The Consultant reviewed and analysed the existing legislative framework related to the protection of the Klokot spring and the establishment of sanitary protection zones in the cross-border area of BiH and the RC, as well as the document „Recommendation of the Protection System and Investigation Methods for Protection of the Karstic Aquifers in the Border Areas of Bosnia and Herzegovina and the Republic of Croatia", and based on the conducted analysis, proposed certain solutions and mechanism for realisation of established interstate cooperation B&H and the Republic of Croatia in the protection of drinking water sources in karst aquifers in the border area of the two countries.

The collected data and documents were processed and analysed, with a special focus on the basicFB&H and RC Water Laws as umbrella legal documents regulating water protection, and the Rulebooks on the establishment of sanitary protection zones as their basic implementing acts. On this occasion, the Consultant identified the most significant benefits and shortcomings of existing legislation in both countries.

Laws

Regarding the protection of drinking water sources in the border area, the FBiH Law on Water regulates cooperation with neighbouring countries, but only if the springs are located in the territory of the FBiH and the sanitary protection zones are in another state. So, when it comes to the opposite, that the spring is in a neighbouring country and the sanitary protection zones in the FBiH, the FBiH Law on Waters did not regulate this case.

The existing legislation in the Republic of Croatia has certain shortcomings regarding the definition of sanitary protection zones for drinking water sources, which can best be seen in the current Law on Water of the Republic of Croatia, which in its provisions does not regulate the situation in which zones of sanitary protection of drinking water sources are located in the territory of the Republic Croatia and some other neighbouring countries.

By-laws

The most significant shortcomings in the FB&H by-laws, which means in the Rulebook on the Method of Determining Conditions for the Designation of Sanitary Protection Zones and Protective Measures for Water Sources for Public Water Supply of the FB&H Population (2012), relate to the following:

- conducting of water survey works (the obligation to conduct them) is not regulated,
- guidelines for the application of the rulebook (the obligation to create it is not regulated in the rulebook),
- microzoning (not regulated in the rulebook).

The most significant shortcomings in the by-laws of the Republic of Croatia, which means in the Rulebook on the Conditions for Determining Sanitary Protection Zones of the Source of the Republic of Croatia (2011, amendments 2013), relate to the following:

- the need to classify protection measures and separate them into "complete" restrictions from "conditional" ones.

Comparison of bylaws and findings of the analysis are described in detail in Annex 6 of this document, entitled "Review and analysis of the existing legislative and legal framework on the conditions for determining sanitary protection zones of springs in FBiH and Croatia" The Consultant prepared a tabular summary of the results entitled "Legal framework - legal regulations related to the establishment of sanitary protection zones in FBiH and the Republic of Croatia"(Annex 7). The consultant also prepared a tabular summary of the technical aspect of the analysis of regulations in the document entitled "Sanitary protection zones: comparison of regulations of Bosnia and Herzegovina and the Republic of Croatia", which is in Annex 8 of this document.

Proposed solutions and mechanisms for protection of karst aquifer sources in the border areas of Bosnia and Herzegovina and the Republic of Croatia.

Members of the Interstate Commission of the Republic of Croatia and Bosnia and Herzegovina, with the aim of protecting springs in karst aquifers in cross-border areas of the Republic of Croatia and Bosnia and Herzegovina, through joint work drafted a special document "Recommendation of the Protection System and Investigation Methods for Protection of the Karstic Aquifers in the Border Areas of Bosnia and Herzegovina and the Republic of Croatia" This document offers a Recommendation for a solution to improve corporation through harmonization of the existing regulation related to the protection of drinking water sources in karst aquifers in the cross-border areas of B&H and the Republic of Croatia.

The document contains Recommendations for overcoming previously identified shortcomings in the regulations of both countries and introduces missing mechanisms for better determination of catchment areas and their sanitary protection zones (Recommendation on special interstate Regulation of protecting springs in karst aquifers in cross-border areas and propose the definition of a joint Decision on the protection of drinking water sources).

6.3.5 Water quality control at water source

The water quality at all mentioned drinking water sources is not checked or controlled according to the current Rulebook on the health of drinking water in FBiH, since the minimum frequency of sampling for regular and periodic control does not correspond to the prescribed number of samples, required by Rulebook. For this reason, it is necessary to establish water quality control as soon as possible in accordance with the applicable regulations. These improvements in the protection of drinking water springs and the proper control of their quality through establishment of joint mechanisms are indispensable in order to provide the citizens of Bihac with quality and healthy drinking water in the long run.

6.3.6 Developed and improved documents

Based on the conducted analysis, the Consultant defined solutions and mechanisms for the implementation of key principles of cooperation on the protection of springs in karst aquifers in the border area of BiH and the Republic of Croatia.

Figure 6.1 shows the process of improving the legal framework through the development of Recommendations for interstate documents related to the protection of springs in karst aquifers in the border area of BiH and the Republic of Croatia.

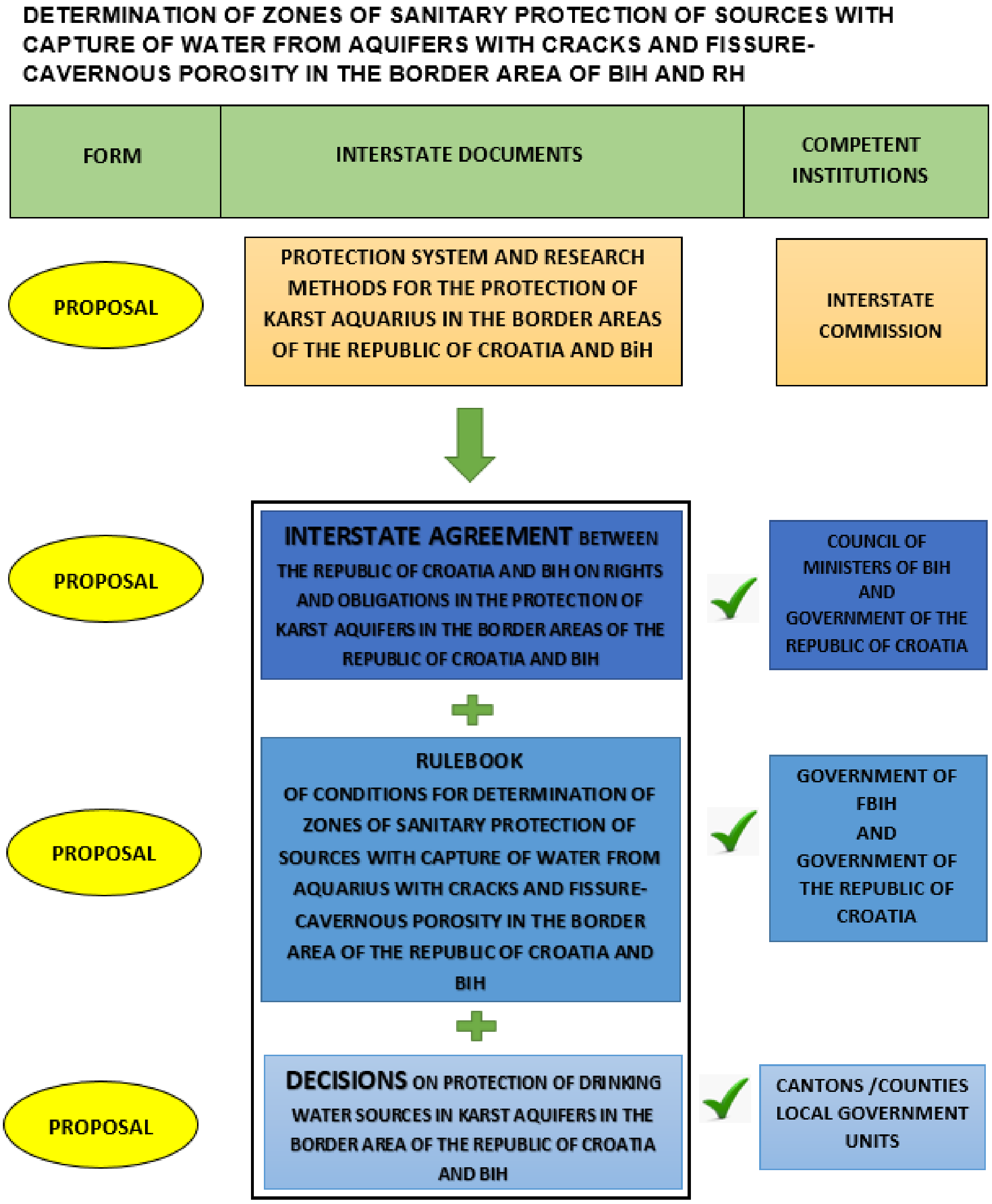


Figure 6.1: *The process of drafting interstate documents*

The consultant prepared proposal for the development of necessary interstate documents for improvement of a legal framework regarding the establishment of sanitary protection zones for water sources in karst aquifers in the border area of B&H and the Republic of Croatia. The following interstate documents has been prepared:

- Proposal for the Development of Protection System and Investigation Methods for Protection of the Karstic Aquifers in the Border Areas of Bosnia and Herzegovina and the Republic of Croatia; (improved Recommendation with recommendations),
- Proposal for the Development of Interstate Treaty between Council Of Ministers of Bosnia And Herzegovina and the Government of the Republic Of Croatia on rights and obligations in protection of karst aquifers in the border areas of Bosnia and Herzegovina and Croatia.
- Recommendations for the Development of Rulebook on conditions for the determination of zones for sanitary protection of water sources from the aquifers with cracks and crack-cavernous porosity in the border area of Bosnia and Herzegovina and the Republic of Croatia as part of Interstate Treaty;
- Proposal for the Development of Decision on the protection of drinking water sources (Decision on the protection of karst springs in the border areas of B&H and the Republic of Croatia).

6.4 CONCLUSION AND RECOMMENDATIONS BY THE CONSULTANT

(See also Annexes 9,10,11 and 12)

Taking into account the aforementioned, the consultant used the document "Recommendation of the system of protection and research methods for the protection of karst aquifers in the border areas of Bosnia and Herzegovina and Croatia" as a basis to propose joint regulations for the establishment of sanitary protection zones and protection of karst springs in trans-boundary areas.

Based on the mentioned document, the Consultant developed Interstate Treaty between Council Of Ministers of Bosnia And Herzegovina and the Government of the Republic Of Croatia on rights and obligations in protection of karst aquifers in the border areas of Bosnia and Herzegovina and Croatia.

The aforementioned Treaty should be adopted by the Governments of both countries as an interstate agreement (following the same principle as the international Agreement between the Government of the Republic of Croatia and the Government of Bosnia and Herzegovina on the regulation of water management relations in 1996). The application of this Agreement would exclusively regulate the establishment of sanitary protection zones of drinking water sources in karst aquifers in border areas of Croatia and BiH. All other interstate watercourses and drinking water sources would be subject to the existing legislation of one or the other state. The proposed interstate Treaty is in Annex 12.

Proposed interstate Treaty contains an Annex as Recommendation for a joint Rulebook on conditions for the establishment of sanitary protection zones of water sources with abstraction of waters from aquifers with crack and crack-cavernous porosity in the border area of Bosnia and Herzegovina and the Republic of Croatia, which regulates, among other things, procedure for adopting a joint (single) Decision on the protection of karst sources in the border areas of B&H and the Republic of Croatia, thus meeting all the relevant criteria for establishing a comprehensive and effective common regulation for the definition of sanitary protection zones and measures for the protection of karst water sources in the cross-border areas of B&H and the Republic of Croatia.

Based on the analysis and recommendations consultant proposed a joint Rulebook on conditions for the determination of zones for sanitary protection of water sources from the aquifers with cracks and crack-cavernous porosity in the border area of Bosnia and Herzegovina and the Republic of Croatia (hereinafter referred to as "the Common Rulebook"). The Proposal of Common Rulebook is an Annex and as such, an integral part of the Interstate Treaty between Council Of Ministers of Bosnia And Herzegovina and the Government of the Republic Of Croatia, but for the purpose of development of the Study on the Establishment of Cross-Border Sanitary Protection Zones of the Klokot spring, it is presented separately in Annex 9 for a better overview and easier understanding of the development process.

As a basis for the proposal for development of common Rulebook, the consultant used the parts of existing Rulebook on the Conditions for Determining Sanitary Protection Zones of the Source of the Republic of Croatia, since it contains certain elements that the consultant identified as necessary in the common Rulebook for example: regulated water works, micro zoning. From the FB&H Rulebook, provisions have been introduced in the joint Rulebook regarding the need to classify protection measures and separate them into "complete" prohibitions from "conditional" ones, that is, a list of activities and levels of restrictions on their application by individual sanitary protection zones.

In the next step, the Consultant has proposed recommendations for further improvement of the document "Recommendation of the system of protection and research methods for the protection of karst aquifers in the border areas of Bosnia and Herzegovina and Croatia" in accordance with the Recommendation of the common interstate Rulebook, as well as improvements based on performed analysis of existing regulations and defined shortcomings and advantages of the B&H (FB&H) and RC legislation. This document is in Annex 10.

Based on the proposal of the common Rulebook, the consultant prepared a draft Decision on the protection of drinking water sources (Decision on the protection of karst springs in the border areas of B&H and the Republic of Croatia), as act that, through a single (joint) regulation of establishing the sanitary protection zones and protection measures, defines the protection of karst water sources in the border areas of B&H and the Republic of Croatia. The Decision on the protection of drinking water sources is in Annex 11.

The proposed solutions establish common mechanisms and obligations for both countries to address the issue of protection of karst aquifers in the border area without any additional (special) intervention in their existing legislation.

The Interstate contract defines the roles and responsibilities of competent institutions for implementing the contract itself, the authority to implement the proposed source protection measures on both sides of the border, creating preconditions for smooth and functional work of the interstate commission that should be responsible for monitoring and taking promotion measures if the protection measures defined by the contract (and its annex) are not respected.

The proposed solution is a good example of the efforts of both countries to permanently address the issue of protection of springs in karst aquifers in the border area and may be useful in the protection of all other sources in the cross-border area of B&H and the Republic of Croatia.

7 WATER QUALITY AT KLOKOT SPRING

In order to implement the project “Development of a Study on the Establishment of the Klokot (Bihać) Spring Cross-Border Sanitary Protection Zones”, the Consultant gathered a large number of reports (results), regular (basic) and periodic ones, containing analyses of the Klokot spring water quality between 2004 and 2020. The reports were made for the PUC “Vodovod” Bihać by Public Health Institute of Una-Sana Canton (PHIUSC), Institute for Public Health of Canton Sarajevo (IPHCS), and, on several occasions, by Croatian Institute of Public Health, Zagreb (CIPH). Apart from that, on several occasions during the period of project implementation and in cooperation with certified laboratories (PHIUSC and CIPH), the Consultant organized the sampling of water at the Klokot spring itself, as well as at several sinkholes in its catchment area, thus obtaining laboratory reports on water quality with more than 100 parameters. All the reports made by the certified laboratories from both the countries contain basic, periodical or extended physicochemical and microbiological water quality analysis results. Periodic analysis was done by sampling and analyzing raw water from the Klokot spring itself, while the sampling for the basic analysis was taken at the Pump Station Klokot after chlorine disinfection.

Between January and July 2020, the Consultant installed a special probe (Aquaprobe 2000) for automatic measurement of 10 water quality parameters at the Klokot spring, thus establishing temporary project water quality monitoring, and all the reports (results) on the regular water quality monitoring were entered into a dedicated database.

Additional data about water quality at several sinkholes within the Klokot spring catchment area was collected by the Consultant using a mobile probe (Aquaprobe 2000) which also measures 10 water quality parameters, and all the results were entered into the dedicated database as well.

Furthermore, Water Agency of Croatia gave the Consultant reports (results) on water quality for the water taken from the two boreholes drilled at the border between the Republic of Croatia and Bosnia and Herzegovina in the area of the former military airport Željava. All the gathered reports (findings) are appended to the Study on the Establishment of the Klokot (Bihać) Spring Cross-Border Sanitary Protection Zones.

All the collected reports (results) on water quality in the Klokot catchment area were processed and analyzed in detail by the Consultant. The total number of processed and analyzed reports (results) are: 517 for physicochemical analysis of water quality; and 474 for microbiological analysis of water quality. Out of the latter, 399 were reports (results) on basic, and 75 were reports (results) on periodic analysis of water quality at the Klokot spring. It should be noted that in the last few years, PUC “Vodovod” Bihać has been conducting physicochemical and microbiological analyses, on average, twice a month which is considered to be more than inadequate for the spring which supplies more than 50,000 people of the city of Bihać.

Physicochemical analyses of the water samples taken from the Klokot spring in the course of this protection project show that the water, according to the parameters investigated, in most cases, fulfills the conditions set in the Rules on Health Safety of Drinking Water (Official Gazette of Bosnia and Herzegovina, No. 40/10, 43/10 and 30/12). However, many of the samples analyzed in the last 5 years show the tendency of deterioration of water quality at the spring itself.

In the processing and analysis of the **physicochemical** parameters of water quality, the following deviations from the maximum allowable concentrations in drinking water were noted:

- significant and often increase in the value of turbidity,
- occasional increase of values which indicate an increased consumption of oxygen,

- only in a few cases, occasional increase of ammonium concentration above the maximum allowed concentrations in water.

Taking into consideration all the physicochemical analyses of water quality conducted at the Klokot spring, it can be concluded that the main reason for water being unacceptable, in almost 100% cases, is the fact that water turbidity exceeds the maximum allowable concentration (MAC = 1,0 NTU)

In the processing and analysis of the **microbiological** parameters of water quality, the following deviations from the maximum allowable concentrations in drinking water were noted:

- significant and frequent presence of Coliform bacteria,
- significant and frequent presence of Escherichia coli bacteria,
- significant and frequent presence of Enterococcus bacteria (fecal Streptococcus),
- presence of Clostridium perfringens bacteria.

After taking into consideration all the microbiological analyses of water quality conducted at the Klokot spring, it can be concluded that due to the high number and types of bacteria not allowed in drinking water, 100% of the periodically conducted water quality analyses did not conform to the standards set in the current Rules on Health Safety of Drinking Water in Federation of Bosnia and Herzegovina. In addition, 11% of the basic analyses did not conform to the standards set in the Rules due to the increased number and types of bacteria which are not allowed. That means that even chlorine disinfection, in those cases, was not able to remove all the bacteria present.

Detailed overview of the conducted analyses is given further in this document.

7.1 EXAMINATION OF RESULTS FOR PHYSICOCHEMICAL PARAMETERS

As for physicochemical analysis of water quality, 11 to 14 parameters for basic analyses and 20 to 22 parameters for periodic analyses were processed. It was discovered that, at certain periods, parameters of turbidity, chemical oxygen demand and ammonium concentration were exceeding maximum allowable concentrations. Additionally, results of extended analyses of water quality were collected with 45 additional parameters. Out of the total 517 samples analyzed, 123 of them (23.84%) did not conform to the standards set in the Rules on Health Safety of Drinking Water because one or more physicochemical parameters exceeded its maximum allowable concentrations (Figure 9.1).

Basic water quality analyses comprises the following parameters: temperature, color, odor, taste, residual chlorine, turbidity (for treated surface water), turbidity (for other kinds of water), pH, EC – electrolytic conductivity, chloride, organic matter by $KMnO_4$, permanganate index, ammonium, nitrate, nitrite, calcium.

Basic analyzes performed with a set of multiprobe probes (Aquaread probe 2000):

- Fixed installed at the Klokot spring, which performed water sampling (online) every day at certain time intervals of the following parameters: temperature, dissolved oxygen, pH, EC - electrolytic conductivity, oxide reduction potential, pressure, turbidity, ammonia, nitrates, chlorides, ammonium, salinity, resitivity, TDS, depth and barometric pressure.
- Occasional water sampling at locations in Croatia (Rastovača pit, Korenica sink and Prijeboj sink) where the following parameters were included: temperature, dissolved oxygen, pH, EC - electrolytic conductivity, oxide reduction potential, pressure, turbidity, ammonia, nitrates, chlorides, ammonium, salinity, restivity, TDS, depth and barometric pressure.

Periodic water quality analyses comprised the following parameters: temperature, color, odor, taste, residual chlorine, turbidity (for treated surface water), turbidity (for other kinds of water), pH, EC – electrolytic conductivity, chloride, organic matter by $KMnO_4$, permanganate index, ammonium, nitrate, nitrite, calcium, magnesium, total water hardness, sulfate, iron, manganese, chromium, phosphate, HCO_3^-.

Extended water quality analyses comprised the following parameters:

- Phosphate, total phosphorus, total nitrogen, sodium, potassium, cyanide, phenol, mineral oils, detergents – anionic, benzo[*ghi*]perylene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*b*]fluoranthene, fluoranthene, indeno(1,2,3-cd)pyrene, THM – total, chloroform, bromoform, bromodichloromethane, dibromochloromethane, the sum of tetrachloroethene and trichloroethene, tetrachloroethene, trichloroethene, 1,2-dichloroethane, hydrocarbons.
- Aluminum (Al), Chromium (Cr), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb).
- Organochlorine pesticides, aldrin, p,p-DDD, p,p-DDE, o,p-DDT, p,p-DDT, dieldrin, endrin, HCB, Alpha-HCH, Beta-HCH, Gamma-HCH (Lindane), Delta-HCH, heptachlor, trans-Heptachlor Epoxide, cis-Heptachlor Epoxide, Polychloride biphenyl (PCB).

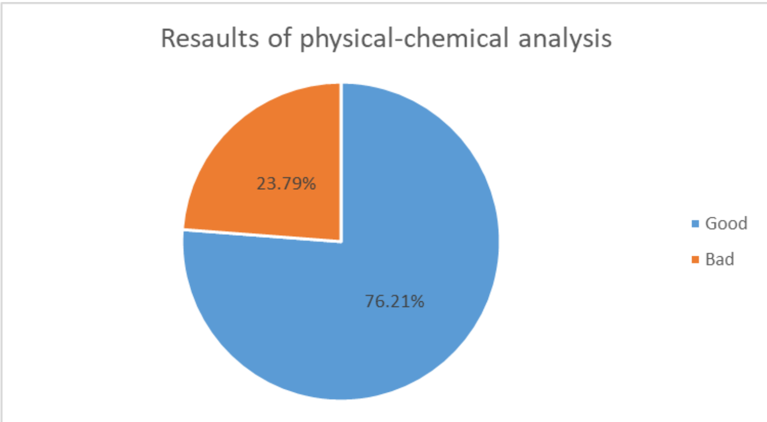


***Figure 7.1**: Percentage of total valide/invalide water samples taken from the Klokot spring from 2004 to 2020 and analyzed by physicochemical techniques and methods*

7.1.1 Frequent increase of water turbidity at the Klokot spring

Amongst all physicochemical parameters, turbidity was the most frequent concentration increase over MAC was with the parameter of turbidity, which was found in 114 samples between 2006 and 2020. The results of physicochemical analysis for increased concentration over MAC can be found in Annex 1. The results of the physicochemical analysis for the parameters of elevated concentration above the MAC are given in Annex 14.

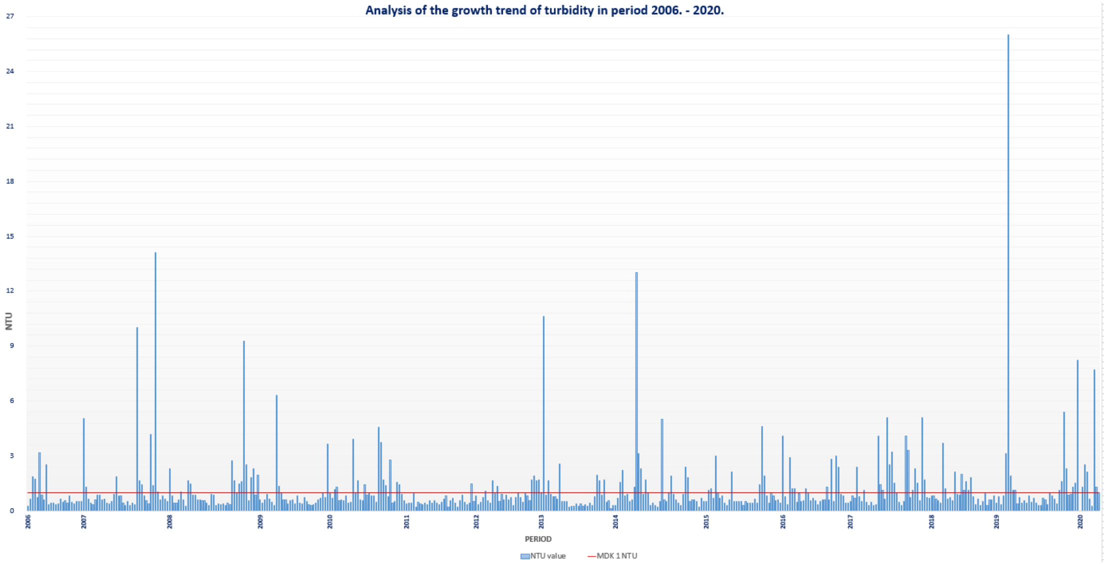


Figure 7.2: *Variations of turbidity content between 2006 and 2020 in comparison with MAC values*

Klokot spring water quality analyses have shown that the increase in turbidity beyond the maximum allowable concentrations (MAC) is mostly recorded in spring (combination of rain and thaw) and fall (long period of heavy rain). By analyzing turbidity increase trends throughout a year, it was established that the increased turbidity concentrations occur mostly in fall and winter, when there is an increased inflow to the Klokot spring due to heavy precipitation in the spring's hinterland. Increased turbidity concentrations are also observable in early spring, especially at the time of spring thaw when there is also frequent precipitation characteristic of this period.

In the observed period (27 Mar 2006 – 21 May 2019), the occurrence of high water turbidity is related to significant precipitation in the Klokot spring catchment area. In other words, it is related to the high quantity of water (flow) coming out of the spring (Figure 7.2). During high water on 16 May 2019, turbidity parameter reached the maximum value of T_{max} = 26 NTU with flow of Q = 67.1 m^3/s.

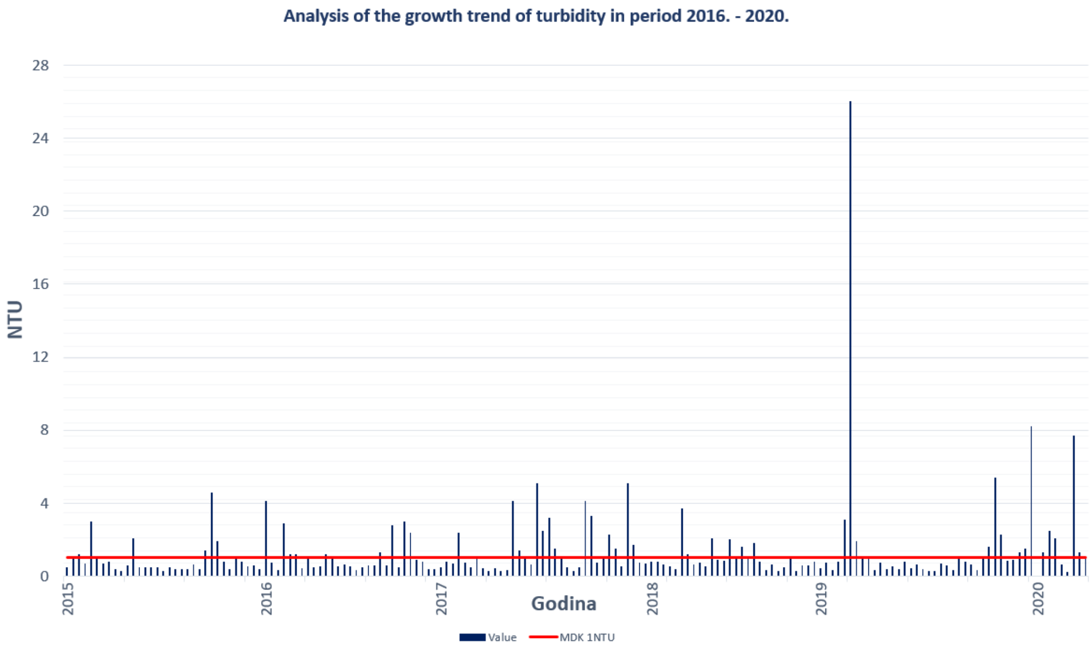


Figure 7.3: *Variations of turbidity value between 2015 and 2020 compared to MAC values*

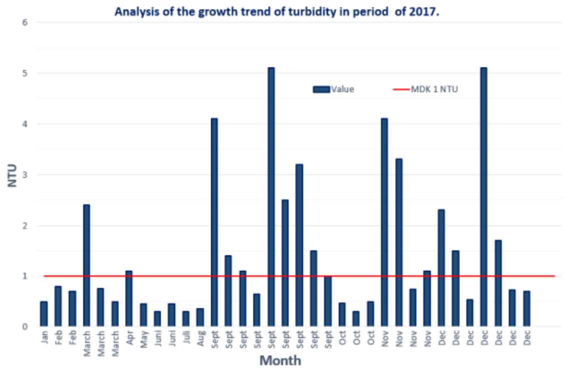


Figure 7.4: *Variations in turbidity value between January and December 2017 compared to MAC values*

From the measurements conducted over a period of almost 15 years, it is visible that the Klokot spring contains a certain amount of suspended and colloid particles which, depending on the water flow, frequently cause turbidity to exceed maximum allowable concentrations (MAC). In the period of observation (27 Mar 2006 – 21 May 2019), it is established that, out of 517 sampling, the Klokot spring water turbidity exceeded the limit of 1.0 NTU on 114 occasions (22%), and the limit of 4.0 NTU on 20 occasions (4%). Out of that, in the last three and a half years (1 Jan 2017 – 21 May 2019) the limit of 1.0 NTU was exceeded 36 times, and the limit of 4.0 NTU 8 times, which indicates a water quality deterioration at the Klokot spring in the past few years. Turbidity significantly beyond MAC (26.0 NTU) was recorded on 14 May 2019 at the time when high water and floods affected the whole Western Balkans aera. Thus, more frequent high turbidity occurrence, i.e. higher amounts of dispersed suspended and colloid particles in water above the maximum allowable concentrations, indicates that the conditions in the Klokot spring catchment area are deteriorating. The deteriorations can be the consequence of natural processes like climate effects on frequency and amount of precipitation in the catchment area, or anthropogenic factors such as deforestation, building of logging roads, and the change in the use certain areas are used within the catchment area, i.e. surface layers erosion of soil and sediments from karstic fields, etc. No matter the cause, the occurrence of turbidity at the springs of the Dinaric karst is hard to control in catchment areas.

These phenomena cannot be stopped by interventions in the catchment area. As a matter of fact, in the karstic system of fissures, fissures are partially filled with fine sediments (dimensions of fine sand and silt), clay size sediments and smaller colloid particles. This sediment is regularly washed out or deposits in springs, depending on hydrological conditions. When water velocity is higher, sediment is carried to a place where it is deposits due to the decrease of velocity. Then, when water flow accelerates, it can be again set in motion, and so it is washed out, i.e. it is carried out to the surface.

Due to the frequent occurrence of turbidity in the considered samples, which is hardly compatible with a regular drinking water supply, it is necessary to suggest appropriate measures to improve the water quality at the intake structure at the Klokot spring. When the water is turbid, suspended colloid (floating) particles can host bacteria, as well as by numerous other inorganic or organic polluters. Particles, thus, prevent the total removal of the bacteria through chlorine disinfection, since chlorine cannot act effectively on colloid particles.

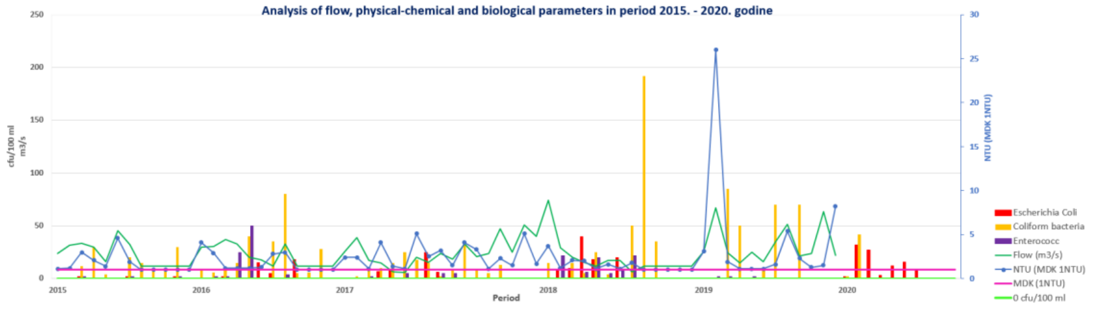


Figure 7.5: *Variations of flow and some physicochemical and microbiological parameters between 2015 and 2020 at the Klokot spring*

For this reason, very often in the last 15 years, during the periods of significant increase in drinking water turbidity, representatives of PUC ¨Vodovod¨ Bihać have, by means of public broadcasting, advised the water consumers to boil water before household use.

Having all that in mind, in the forthcoming period, it is necessary to establish a regular and continuous water quality monitoring at the Klokot spring, and, according to the results obtained, to define key input parameters to select the drinking water treatment technology (methods of sedimentation, filtration, disinfection, etc.) at the future treatment plant.

On several occasions between 2007 and 2009, an increase in the content of ammonium in water was noticed. It was above 0.1 mg NH_4/l (0.285; 0.182; 0.153), but that is still below the MAC which is, according to Rules on Health Safety of Drinking Water, 0.5 mg NH_4/l. Ammonium concentration significantly above MAC (0.773 mgNH_4/l) was recorded on 14 May 2019 in the period of heavy precipitation and floods which affected the whole Western Balkans area.

Also, between 2004 and 2008, a significant increase of organic matter by $KMnO_4$, above MAC (5.0 mg/l O_2), was recorded with values of: 6.95; 5.37; 5.06; and 6.90 mg/l O_2. Thus, it can be concluded that, in that period, there was occasional pollution of water by organic substances (compounds). The highest organic matter by $KMnO_4$ value significantly above MAC (8.85 mg/l O_2) was recorded on 14 May 2019 in the period of heavy precipitation and floods which affected the whole area of Western Balkans.

In the last 10 years, the presence of ammonium in water or increased organic matter by $KMnO_4$ was not recorded, apart from the already mentioned instance of 14 May 2019 when the values of turbidity also significantly exceeded maximum allowable concentrations.

Apart from processing and analyzing basic and periodic water quality analyses performed by PUC „Vodovod“ Bihać and Public Health Institute of Una-Sana Canton, during the project implementation period, the Consultant analyzed the quality of water at the Klokot spring twice in cooperation with Croatian Institute of Public Health from Zagreb, Croatia. These analyses comprised of 45 parameters from groups such as: aromatic hydrocarbons, pesticides, phenols, PCB, metals and metalloids, and other parameters. The results of the performed analyses showed that the concentrations of all parameters did not exceed maximum allowable concentrations, i.e. that the water was acceptable for human use.

Table 7.1: *Results of extended analyses done by CIPH at the location of Klokot*

WATER QUALITY ANALYSIS AT THE KLOKOT SPRING							
Group of basic physicochemical parameters							
MEASUREMENT PARAMETERS			**KLOKOT**				
Date			**02/12/2010**	**28/09/2011**	**20/09/2017**	**28/01/2020**	**24/06/2020**
Parameter Name	**Unit**	**MAC**	**Results**				
Temperature	°C	8 - 12	14.0	15.9			10.4
Color	without	without	without	without		without	without
Odor	without	without	without	without		without	without
Taste	without	without	without	without		without	without

Turbidity (unfiltered)	NTU			0.42		0.33	
Residual chlorine	mg/l		raw water	raw water	raw water	raw water	raw water
pH value (25°C)	pH units	6.5-9.5	7.12	7.35		7.2 (22.5 ºC)	7.71
Electro conductivity (25°C)	µS/cm	2500	359 (14ºC)	320 (15.9ºC)		447 (22.6ºC)	359
TDS	mg/l	10					323.58
Total hardness	ºdH					13	
Evaporation residue	mg/l		226	202		245	174.3
Organic Matter by $KMnO_4$	mgO_2/l	5	1.791	1.023		3.29	
Ammonium	$mgNH_4/l$	0.5	0.112	0.115		0.042	0.01
Nitrate	$mgNO_3/l$	50	1.11	2.664		2.65	3.13
Nitrite	$mgNO_2/l$	0.5	0.0003	0.0003		0	4.87
Fluoride	mg/l	1.5					
Chloride	mg/l	250	14.49	13.49		2.84	
Sulfate	mg/l	200	5.82	11.9		5.18	
Magnesium	mg/l	-	24.8	20.33		27.4	
Calcium	mg/l	-	103	108		66.4	
Manganese	µg/l	50		0		0	
Iron	µg/l	200	0.01507	11.25		0	
Chromium	µg/l	50	0.005	0		0.05	
Department for controlling health safety of water and water supply							
MEASUREMENT PARAMETERS					**KLOKOT**		
Parameter Name	**Unit**	***MAC**					
Phosphate	µg/L P	300	0.005			< 20	123 ± 32
Total phosphorus	mg/L P	-				< 0.05	0.14 ± 0.04
Total nitrogen	mg/L N	-				0.9 +/- 0.1	0.9 ± 0.1
Sodium (Na)	mg/L Na^+	200				2 +/- 0.2	1.9 ± 0.2
Potassium	mg/l	12					
Cyanide	µg/L CN^-	50	< 30			< 30	<30
Phenol	µg/L	-	<1	<1		< 5	<5
Mineral oils	µg/L		5.6				
Detergents - anionic	µg/L	200				< 50	<50
Benzo[g,h,i]perylene	µg/l	<0.1	< 0.005	< 0.005			
Benzo[k]fluoranthene	µg/l	<0.1	< 0.005	< 0.005			
Benzo[a]pyrene	µg/l	<0.01	< 0.005	< 0.005			
Benzo[b]fluoranthene	µg/l	<0.1	< 0.005	< 0.005			
Fluoranthene	µg/l	<0.1	< 0.005	< 0.005			
Indeno(1,2,3-cd)py-rene	µg/l	<0.1	< 0.005	< 0.005			
THM – total	µg/L	100				< 0.1	<0.1
Chloroform	µg/L	-				< 0.1	<0.1
Bromoform	µg/L	-				< 0.1	<0.1
Bromdichloromethane	µg/L	-				< 0.1	<0.1
Dibromochloromethane	µg/L	-				< 0.1	<0.1
The sum of tetrachloro-ethene and trichloroe-thene	µg/L	10				< 0.1	<0.1
Tetrachloroethene	µg/L	10				< 0.1	<0.1
Trichloroethene	µg/L	10				< 0.1	<0.1
1,2-Dichloroethane	µg/L	3				< 0.1	<0.1
Hydrocarbons	µg/L	50		< 2		< 5	<5
Department for metals and metalloids							
MEASUREMENT PARAMETERS					**KLOKOT**		
Parameter Name	**Unit**	***MAC**			**Results**		
Aluminium (Al)	µg/L	200	16.7			8.66 +/- 0.66	6.62 ± 0.24

Chromium (Cr)	µg/L	50				0.145 +/- 0.03	0.158 ± 0.014
Nickel (Ni)	µg/L	20	< 2	< 2		< 0.24	<0.25
Copper (Cu)	mg/L	2	< 6.7	1.9		0.00044 +/- 0.00003	<0.0001
Zinc (Zn)	µg/L	3	< 1	< 2		< 0.6	2.34 ± 0.11
Arsenic (As)	µg/L	10	< 1	< 1		< 0.06	0.096 ± 0.005
Cadmium (Cd)	µg/L	5	< 2	< 2		< 0.03	<0.03
Mercury (Hg)	µg/L	1	< 0.3	< 0.3		< 0.03	0.427 ± 0.035
Lead (Pb)	µg/L	10	< 3	< 3		< 0.05	<0.05
Department for pesticides							
MEASUREMENT PARAMETERS			**KLOKOT**				
Parameter Name	**Unit**	***MAC**	**Results**				
Organochlorine pesticides	µg/L	0.5			< 0.5	< 0.5	<0.5
Aldrin	µg/L	0.03	< 0.01		< 0.01	< 0.01	<0.01
p,p-DDD	µg/L	0.1				< 0.01	<0.01
p,p-DDE	µg/L	0.1				< 0.01	<0.01
o,p-DDT	µg/L	0.1				<0.03	<0.03
p,p-DDT	µg/L	0.1				<0.03	<0.03
Dieldrin	µg/L	0.03	< 0.01		< 0.01	< 0.02	<0.02
Endrin	µg/L	0.1	< 0.01		< 0.01	< 0.03	<0.03
HCB	µg/L	0.1	< 0.01		< 0.01	< 0.03	<0.03
Alfa-HCH	µg/L	0.1	< 0.01		< 0.01	< 0.03	<0.03
Beta-HCH	µg/L	0.1	< 0.01		< 0.01	< 0.02	<0.02
Gamma-HCH (Lindane)	µg/L	0.1	< 0.01		< 0.01	< 0.01	<0.01
Delta-HCH	µg/L	0.1	< 0.01		< 0.01	< 0.01	<0.01
Heptachlor	µg/L	0.03	< 0.01		< 0.01	< 0.03	<0.03
cis-Heptachlor Epoxide	µg/L	0.03	< 0.01		< 0.01	< 0.03	<0.03
trans-Heptachlor Epoxide	µg/L	0.03	< 0.01		< 0.01	< 0.03	<0.03
Polychloride biphenyl (PCB)	µg/L	0.5	< 0.01		< 0.01	< 0.01	<0.01

7.1.2 Physicochemical analysis of the water quality of the Klokot spring established by monitoring with a fixed multiprobe

At the Klokot spring itself, the Consultant installed a multiprobe probe (fixed installation) for a longer period on 15 January 2020, with measurements at the Klokot spring and the possibility to collect "on line" the analyzed parameters, ie water quality. The analysis of the examined parameters established that the concentrations of these parameters do not exceed the maximum allowed values, defined by the Ordinance on the health safety of drinking water. The values of the maximum and minimum recorded concentrations for the period from mid-January to the end of July 2020, except for the period when the probe was on service between March and April, are shown in the following table.

Table 7.2: Maximum and minimum concentration of physical-chemical analysis of parameters by multiprobe Aquaread 2000

Analysis	Physical-chemical			
Type	Muliprobe (Aquaread probe 2000)			
Date	January - February; May - July			
	Resaults			
Parameters	Unit	Requirments	Min	Max
Temperature	ºC	8 - 12	8.8	12
Dissolved Oxygen	mg/l	-	1.07	11.98
Dissolved Oxygen	%	-	93.9	105.3
Conductivity	µS/cm	2500	331	884
pH	pH jed.	6,5 - 9,5	7.42	7.9
pH in milliVolts	mV	-	-54.9	-40.8
ORP	mV	-	72.2	372.6
Pressure	mb	-	1070	1473
AUX1:Turbidity	NTU	1	0	0.8
AUX2:Ammonium	$mgNH_4/l$	0.5	0	0.02
AUX3:Chloride	$mgNO_3/l$	250	0.28	4.25
AUX4:Nitrate	$mgNO_2/l$	50	0	6.63
AUX7:Ammonia	mgNH3/l	-	0	0
Conductivity at 25	µS/cm	-	465.16	1219.38
Conductivity at 20	µS/cm	2500	410.12	1077.44
Restivity	ppt	-	1131.22	3021.15
Salinity	ppt	-	0.22	0.61
TDS	mg/l	-	302.35	792.6
Depth	m	-	0.8	1.54
barometer pressure	mb	-	974.49	1021.74

7.1.3 Physicochemical analysis of water quality in piezometers (boreholes) at the Željava¨ airport location

In early 2020, upon the request of Water Agency of Croatia to conduct research drilling and establish state monitoring, two boreholes (piezometers) were drilled at the location of Željava airport in the immediate proximity of state border between Croatia and Bosnia & Herzegovina. Both boreholes are in the immediate hinterland of the Klokot spring at the altitude of 345 m MSL (PCB-1) and 346 m MSL (PCB-2), both are 250 m deep. Upon the completion of drilling, underground water samples were taken from each borehole and delivered to Main Water Management Laboratory in Water Agency of Croatia, Zagreb, where detailed analyses were performed. Many physicochemical parameters were analyzed, but none of the parameters exceeded MAC. Thus, it can be concluded that the quality of underground waters in this part of the Klokot spring catchment area conforms to current Rules on Health Safety of Drinking Water in Federation of Bosnia and Herzegovina. In addition, water sampled in these boreholes had very similar characteristics to water sampled at the Klokot spring in the same month. The following table gives an overview of all the parameters analyzed along with resulting values.

Table 7.3: *Results of extended analyses at the location of two boreholes PCB1 and PCB2*

QUALITY ANALYSIS OF WATER FROM BOREHOLES AT ¨ŽELJAVA¨ AIRPORT LOCATION				
Date				Feb 2020
GROUP OF BASIC PHYSICOCHEMICAL PARAMETERS				
Location			PCB1	PCB2
Name	Unit	MAC	Results	
pH value (25°C)	pH units	6.5-9.5	7.8	7.8
Electro conductivity (25°C)	µS/cm	2500	394	281
TDS	mg/l		264	188
Alkalinity	$mgCaCO_3/l$		216	228
Total hardness	ºdH		234	259

HCO_3	mg/l	-	285	315
Total dry suspended solids	mg/l	10	10	9
Organic Matter by KMnO4	mgO_2/l	5	2.1	0.8
BPK_5	mg/l	25	1.3	<0.5
Ammonium	$mgNH_4/l$	0.5	<0.008	<0.008
Nitrate	$mgNO_3/l$	50	0.511	0.0451
Nitrite	$mgNO_2/l$	0.5	0.0022	<0.002
Total nitrogen	mgN/l	-	2	0.216
Orthophosphate	mgP/l	0.3	0.0103	0.0102
Total Phosphorus	mgP/l	-	0.0219	0.0139
Fluoride	mg/l	1.5	0.0142	0.0083
Potassium	mg/l	12	0.911	0.822
Sodium	mg/l	200	1.76	1.22
Chloride	mg/l	250	0.704	0.608
Sulfate	mg/l	200	1.95	2.92
Magnesium	mg/l	-	12.1	24.7
Calcium	mg/l	-	73.6	63.1
Total organic carbon	mg/l	-	1.38	0.48
Total dissolved organic carbon	mg/l	-	1.22	0.62
Manganese	µg/l	50	13.7	12.7
Iron	µg/l	200	1.24	2.4
Arsenic	µg/l	10	0.313	0.517
Lead	µg/l	10	0.0564	0.0834
Nickel	µg/l	20	1.09	1,1
Chromium	µg/l	50	1.14	0.08
Cadmium	µg/l	5	0.0179	0.0142
Zinc	µg/l	3000	337	145
Copper	µg/l	2000	0.87	0.977
Mercury	µg/l	1	<0.01	<0.01

GROUP OF VOLATILE AROMATIC HYDROCARBONS				
Location			**PCB1**	**PCB2**
Name	**Unit**	**MAC**	**Results**	
Hexachlorobutadiene	µg/l		<0.037	<0.037
1,3,5 - trichlorobenzene	µg/l		<0.124	<0.124
1,2,4 - trichlorobenzene	µg/l		<0.116	<0.116
1,2,3 - trichlorobenzene	µg/l		<0.107	<0.107
Para-Xylene	µg/l		<0.121	<0.121
Ortho-Xylene	µg/l		<0.136	<0.136
Meta-xylene	µg/l		<0.11	<0.11
Benzene	µg/l	1	<0.156	<0.156
Toluene	µg/l		<0.137	<0.137
Dichloromethane	µg/l		<5.69	<5.69
1,2,-dichloroethane	µg/l	3	<0.286	<0.286
Tetrachloroethene	µg/l		<0.162	<0.162

Trichloroethene	µg/l		<0.149	<0.149
Tetrachlorocarbon	µg/l		<0.125	<0.125
1,1,1-trichloroethane	µg/l		<0.231	<0.231
Chloroform	µg/l		<0.161	<0.161
GROUP OF PERSISTANT ORGANIC SUBSTANCES – DIOXINS AND FURANS (POPs)				
Location			**PCB1**	**PCB2**
Name	**Unit**	**MAC**	**Results**	
1,2,3,4,6,7,8,9-O8CDF	µg/l		<0.000008	<0.000008
1,2,3,4,7,8,9-H7CDF	µg/l		<0.000012	<0.000012
1,2,3,4,6,7,8-H7CDF	µg/l		<0.000012	<0.000012
2,3,4,6,7,8-H6CDF	µg/l		<0.000005	<0.000005
1,2,3,7,8,9-H6CDF	µg/l		<0.000005	<0.000005
1,2,3,6,7,8-H6CDF	µg/l		<0.000005	<0.000005
1,2,3,4,7,8-H6CDF	µg/l		<0.000005	<0.000005
2,3,4,7,8-P5CDF	µg/l		<0.000004	<0.000004
1,2,3,7,8-P5CDF	µg/l		<0.000005	<0.000005
2,3,7,8-T4CDF	µg/l		<0.000004	<0.000004
1,2,3,4,6,7,8,9-O8CDD	µg/l		<0.00001	<0.00001
1,2,3,4,6,7,8-H7CDD	µg/l		<0.00002	<0.00002
1,2,3,7,8,9-H6CDD	µg/l		<0.000005	<0.000005
1,2,3,6,7,8-H6CDD	µg/l		<0.000006	<0.000006
1,2,3,4,7,8-H6CDD	µg/l		<0.000005	<0.000005
1,2,3,7,8-P5CDD	µg/l		<0.000006	<0.000006
2,3,7,8-T4CDD	µg/l		<0.000006	<0.000006
GROUP OF POLYCYCLIC AROMATIC HYDROCARBONS				
Location			**PCB1**	**PCB2**
Name	**Unit**	**MAC**	**Results**	
Indeno(1,2,3-cd)pyrene	µg/l	-	<0.00047	<0.00047
Benzo(g,h,i)perylene	µg/l	-	<0.0002	<0.0002
Benzo(k)fluoranthene	µg/l	-	<0.0004	<0.0004
Benzo(a)pyrene	µg/l	0.01	<0.00041	<0.00041
Benzo(b)fluoranhtene	µg/l	-	<0.00187	<0.00187
Fluoranthene	µg/l		<0.00026	<0.00026
Naphthalene	µg/l		0.000785	<0.00045
Anthracene	µg/l		<0.001	<0.001
GROUP OF PESTICIDES				
Location			**PCB1**	**PCB2**
Name	**Unit**	**MAC**	**Results**	
Trifluraline	µg/l	0.10	<0.0004	<0.0004
Penta chlorobenzene	µg/l	0.10	<0.0011	<0.0011
Alachlor	µg/l	0.10	<0.00039	<0.00039
Pentachlorophenol	µg/l	0.10	<0.00037	<0.00037

Chlorfenvinphos	µg/l	0.10	<0.00071	<0.00071
Chlorpyrifos	µg/l	0.10	<0.00056	<0.00056
Izadrin	µg/l	0.10	<0.00059	<0.00059
Beta endosulfan	µg/l	0.10	<0.00498	<0.00498
Alfa endosulfan	µg/l	0.10	<0.00029	<0.00029
Dieldrin	µg/l	0.03	<0.00036	<0.00036
Aldrin	µg/l	0.03	<0.00112	<0.00112
Heptachlor Epoxide	µg/l	0.03	<0.00019	<0.00019
Heptachlor	µg/l	0.03	<0.0002	<0.0002
Beta-HCH	µg/l	0.10	<0.00113	<0.00113
Endrin	µg/l	0.10	<0.00066	<0.00066
Alpha-HCH	µg/l	0.10	0.00496	<0.0014
HCB	µg/l	0.10	<0.00202	<0.00202
o,p-DDT	µg/l	0.10	0.000274	<0.00025
4,4-DDD	µg/l	0.10	<0.00145	<0.00145
4,4-DDE	µg/l	0.10	<0.00114	<0.00114
p,p-DDT	µg/l	0.10	<0.00046	<0.00046
Delta-HCH	µg/l	0.10	<0.0007	<0.0007
Lindan Gamma-HCH	µg/l	0.10	<0.00091	<0.00091
Dichlorvos	µg/l	0.10	<0.00082	<0.00082
Dicofol	µg/l	0.10	<0.00034	<0.00034
Simazin	µg/l	0.10	<0.00082	<0.00082
Atrazin	µg/l	0.10	<0.00144	<0.00144
Izoproturon	µg/l	0.10	<0.00051	<0.00051
Diuron	µg/l	0.10	0.00189	<0.00074
Cypermethrin	µg/l	0.11	<0.00016	<0.00016
Cybutryne	µg/l	0.12	0.00122	<0.00049
Bifenox	µg/l	0.13	<0.00201	<0.00201
Aclonifen	µg/l	0.14	0.0005	<0.00049
Quinoxyfen	µg/l	0.15	0.00195	<0.00246
Terbutrin	µg/l	0.16	<0.00139	<0.00139
OTHER PARAMETERS				
Location			PCB1	PCB2
Name	**Unit**	**MAC**	**Results**	
DEHP (plasticiser)	µg/l		0.169	<0.00472
Octylphenol (alkyl phenols)	µg/l		<0.0075	<0.0075
Nonylphenol (alkyl phenols)	µg/l		<0.01	<0.01

7.1.4 Physicochemical analysis of water quality at sinkholes and karstic holes in Croatia

Extended analysis was also done on samples of water taken from the three locations in Croatia: Rastovača, Korenica sinkhole and Prijeboj stream sinkhole; for which a connection to Klokot spring was established by tracing. Also, quality analysis of this water which sinks in Croatia showed that it does not exceed maximum allowable concentrations for: aromatic hydrocarbons, pesticides, phenols, PCB, metals and metalloids, nor other analyzed parameters, although the concentrations of these substances were much higher than at the Klokot spring.

Table 7.4: *Results of extended analysis done by CIPH at the locations of: karstic hole Rastovača, Prijeboj stream sinkhole, sinkhole of Korenica stream*

QUALITY ANALYSIS OF WATER FROM SINKHOLES AND KARSTIC HOLES IN CROATIA					
Date					**24/06/2020**
Department for controlling health safety of water and water supply					
Location			**Rastovača**	**Prijeboj**	**Korenica**
Parameter Name	**Unit**	***MAC**	**Results**		
Phosphate	µg/L P	300	185 ± 48	43 ± 11	51 ± 13
Total phosphorus	mg/L P	-	0.20 ± 0.06	<0.05	0.61 ± 0.18
Total nitrogen	mg/L N	-	<0.5	<0.5	8.8 ± 1.1
Sodium (Na)	mg/L Na^+	200	2.7 ± 0.2	<1	95 ± 8
Cyanide	µg/L CN^-	50	<30	<30	<30
Phenol	µg/L	-	<5	<5	<5
Detergents -anionic	µg/L	200	<50	<50	130 ± 17
THM – total	µg/L	100	<0.1	<0.1	46.3 ± 15.8
Chloroform	µg/L	-	<0.1	<0.1	42.4 ± 7.7
Bromoform	µg/L	-	<0.1	<0.1	<0.1
Bromdichloro-methane	µg/L	-	<0.1	<0.1	3.4 ± 0.8
Dibromochloro-methane	µg/L	-	<0.1	<0.1	0.5
The sum of tetrachloroethane and Trichloroethene	µg/L	10	<0.1	<0.1	<0.1
Tetrachloroethane	µg/L	10	<0.1	<0.1	<0.1
Trichloroethene	µg/L	10	<0.1	<0.1	<0.1
1,2-Dichloroethane	µg/L	3	<0.1	<0.1	<0.1
Hydrocarbons	µg/L	50	<5	<5	<5
Department for metals and metalloids					
Location			**Rastovača**	**Prijeboj**	**Korenica**
Parameter Name	**Unit**	***MAC**	**Results**		
Aluminium (Al)	µg/L	200	34.5 ± 1.2	27.1 ± 1.0	7.97 ± 0.29
Chromium (Cr)	µg/L	50	<0.14	<0.14	<0.14
Nickel (Ni)	µg/L	20	0.300 ± 0.026	<0.24	4.16 ± 0.36
Copper (Cu)	mg/L	2	0.0015 ± 0.0001	0.00045 ± 0.00002	0.0066 ± 0.0003
Zinc (Zn)	µg/L	3	1.65 ± 0.08	0.722 ± 0.035	9.11 ± 0.44
Arsenic (As)	µg/L	10	0.519 ± 0.029	0.263 ± 0.015	0.260 ± 0.015
Cadmium (Cd)	µg/L	5	<0.03	<0.03	<0.03
Mercury (Hg)	µg/L	1	0.391 ± 0.032	0.401 ± 0.033	0.611 ± 0.051
Lead (Pb)	µg/L	10	0.142 ± 0.014	0.180 ± 0.018	0.042 ± 0.004

Department for pesticides					
Location			**Rastovača**	**Prijeboj**	**Korenica**
Parameter Name	**Unit**	***MAC**	**Results**		
Organochlorine pesticides	µg/L	0.5	<0.5	<0.5	<0.5
Aldrin	µg/L	0.03	<0.01	<0.01	<0.01
p,p-DDD	µg/L	0.1	<0.01	<0.01	<0.01
p,p-DDE	µg/L	0.1	<0.01	<0.01	<0.01
o,p-DDT	µg/L	0.1	<0.03	<0.03	<0.03
p,p-DDT	µg/L	0.1	<0.03	<0.03	<0.03
Dieldrin	µg/L	0.03	<0.02	<0.02	<0.02
Endrin	µg/L	0.1	<0.03	<0.03	<0.03
HCB	µg/L	0.1	<0.03	<0.03	<0.03
Alfa-HCH	µg/L	0.1	<0.03	<0.03	<0.03
Beta-HCH	µg/L	0.1	<0.02	<0.02	<0.02
Gamma-HCH (Lindane)	µg/L	0.1	<0.01	<0.01	<0.01
Delta-HCH	µg/L	0.1	<0.01	<0.01	<0.01
Heptachlor	µg/L	0.03	<0.03	<0.03	<0.03
cis-Heptachlor Epoxide	µg/L	0.03	<0.03	<0.03	<0.03
trans-Heptachlor Epoxide	µg/L	0.03	<0.03	<0.03	<0.03
Polychloride biphenyl (PCB)	µg/L	0.5	<0.01	<0.01	<0.01

Along with extended analysis conducted by Croatian Institute of Public Health, the Consultant conducted field examination of water quality at the aforementioned locations in Croatia using specialized equipment to measure water quality (Aquaprobe). These analyses also showed that the concentrations of measured parameters were below maximum allowable concentrations.

However, high turbidity values, as well as the appearance of nitrates and ammonium, and increased oxygen demand which can come from anthropogenic factors were tecoreded and are described in more detail in the section on microbiological parameters.

7.2 EXAMINATION OF RESULTS FOR MICROBIOLOGICAL PARAMETERS

In terms of microbiological analysis, 474 samples were analyzed, out of which 399 underwent basic and 75 periodic analysis of drinking water quality. It was established that as many as 93% of periodic analysis samples (70 samples) did not conform to the standards set in Rules on Health Safety of Drinking Water i.e. that one or more parameters had concentrations exceeding MACs, while 11% of basic analysis samples (52 samples) did not conform to MACs in the same Rules (Figure 7.6).

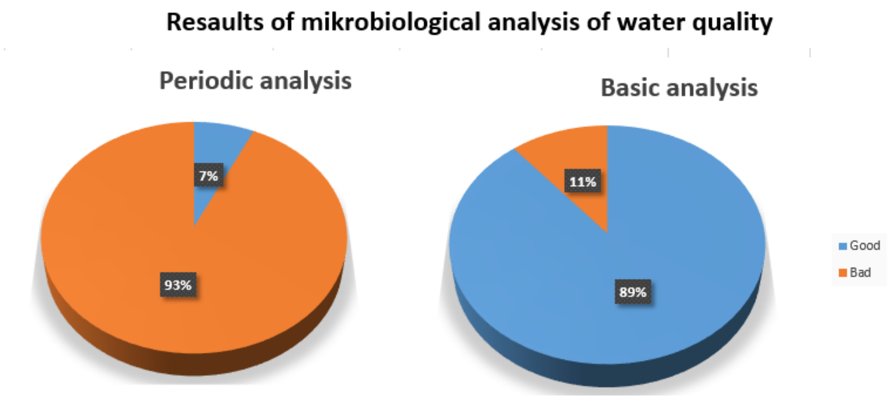
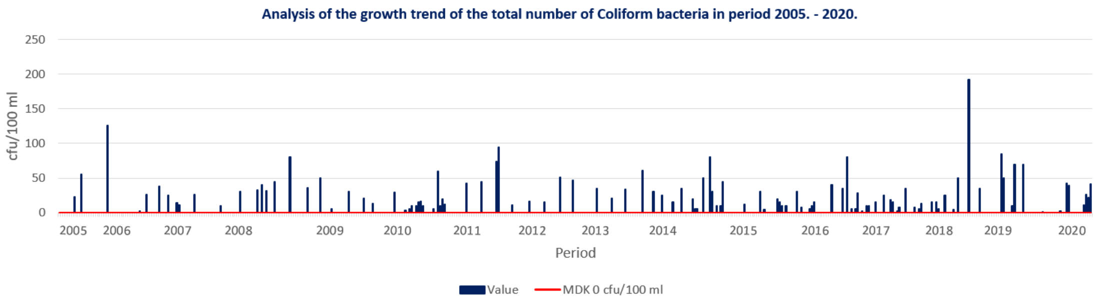


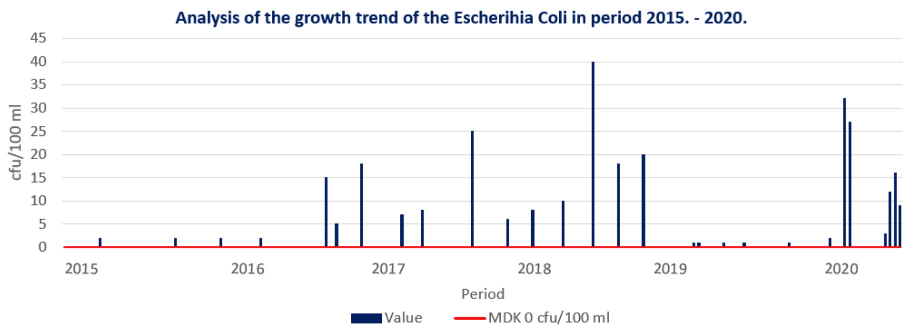
Figure 7.6: *Total validity / invalidity of the Klokot spring water samples in the period of 2004 to 2020 in terms of microbiological parameters*

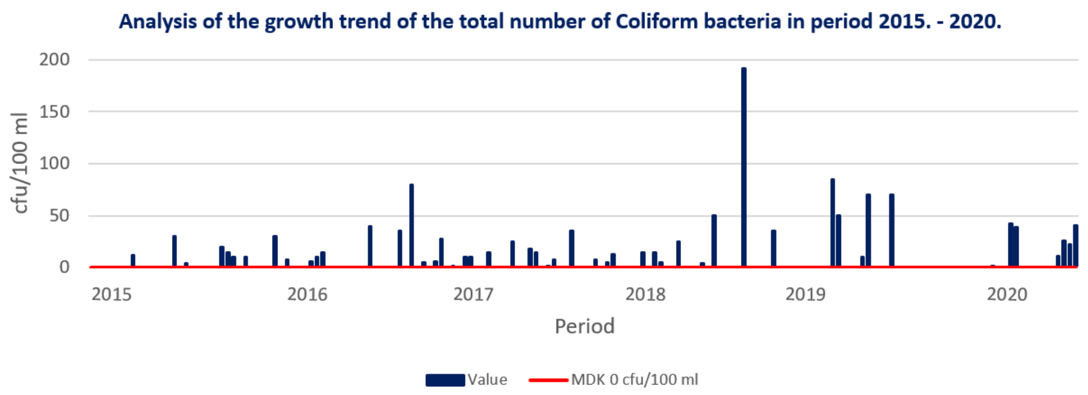
7.2.1 Frequent presence of unwanted bacteria in water

Out of 75 samples taken for the extended water quality analysis, 70 of them (93%) presence of total coliform bacteria was established, and the presence of Escherichia Coli bacteria was found in 55 water samples (73% of cases), the presence of Enterococcus bacteria (fecal Streptococcus) was established in 40 cases (53%), and Clostridium perfringens bacteria was found in 2 samples (2.7%). Total number of bacteria at 22˚C and 37˚C was found in 18 water samples which constitutes 24% of the samples. Overview of the results of microbiological analyses in given in Annex 15. The results of the microbiological analysis for parameters which concentration exceeded MAC are given in Annex 16.

Interpretation of the results is shown on the diagrams bellow.







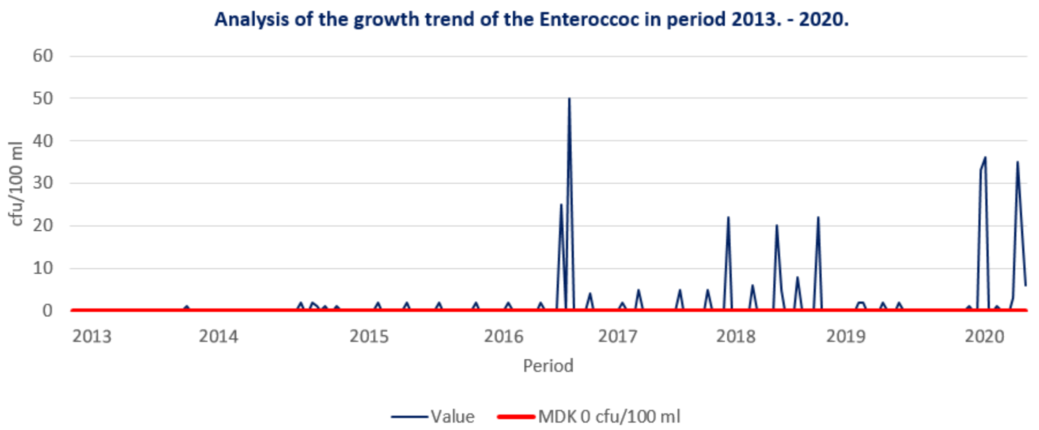


Figure 7.7: *Variation of microbiological parameters exceeding MACs at the Klokot spring from 2005 to 2020*

According to these results (Figure 7.7), raw water at the Klokot spring is bacteriologically contaminated and does not conform to the sanitary and epidemiological requirements. Bacteriological analyses, which are part of the regular water quality monitoring performed by PUC "Vodovod" Bihać at the Klokot spring, indicate bacteriological irregularity of water. It is necessary to emphasis that a considerable number of water quality analyses are performed with samples of chlorinated water (taken at the Klokot Pump Station immediately after disinfection), which is not in accordance with the conditions set in Rules on Health Safety of Drinking Water. However, it is an alarming fact that anthropogenic bacteria not allowed by the Rules were found even in the chlorinated water (11% of the samples), which means that the chlorine water treatment is not effective, and that bacteriological contamination in the Klokot spring water cannot always be removed by chlorine disinfection.

Microorganisms (bacteria) in raw water from drinking water sources come mostly from fecal origin (coliform bacteria) – human or animal. They come from sanitary wastewater from settlements, and from improperly built septic tanks. Wastewater from households finds its way to surface and underground water through sewerage systems which discharge untreated wastewater into waterways, sinking rivers or directly to karstic holes and sinkholes, while feces from improperly built septic tanks (permeable bottoms) are spilled directly into underground water. If pathogenic bacteria, viruses and parasites are present in feces, they will, along with coliform bacteria, end up in surface and underground water.

One factor which significantly contributes to the deterioration of microbiological quality of water at the Klokot spring is significant increase of human activity in the Klokot spring catchment area, especially through the intensification of tourist visits to Plitvice Lakes National Park, as visible from the rapidly growing number of nights spent in that area in the last 5 years.

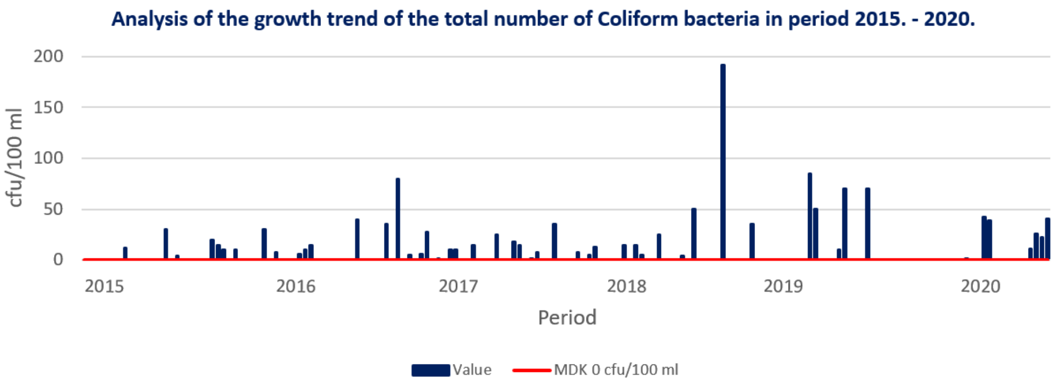


Figure 7.8: *Variation of microbiological parameters exceeding MACs at the Klokot spring in period from 2015 to 2020*

7.2.2 Microbiological analysis of water quality at sinkholes and karstic holes in Croatia

In June 2020, water was sampled in the area of Rastovače karstic hole, at the outlet of the temporary package wastewater treatment plant, and at two other locations – Korenica sinkhole and Prijeboj sinkhole. Water quality analyses at these locations demonstrated the presence of Escherichia Coli, Enterococcus, total coliform bacteria, as well as total of other aerobic bacteria. Table below gives a tabular overview of the results of microbiological analyses conducted at these three locations, as well as tabular overview of all microbiological parameters with concentrations exceeding MAC.

Microbiological analysis of water quality was conducted for water samples collected at three locations in the Republic of Croatia, namely, at Rastovače karstic hole, Korenica sinkhole, and at Prijeboj stream sinkhole, for which the connection to the Klokot spring had been established by tracing. Through water quality analyse, the presence of a large number of bacteria was demonstrated in the water which sinks in Croatia and reappears at the Klokot spring.

Table 7.5*: Results of microbiological analyzes of the CNIPH at the location of the Rastovača sinkhole, the sink of the stream on Prijeboj, the sink of the Korenički stream*

Date			**24/06/2020**	**24/06/2020**	**24/06/2020**
Type of examination			**microbiological**	**microbiological**	**microbiological**
Sampling location			**Rastovača karstic hole, after treatment**	**Prijeboju stream sinkhole**	**Korenica stream sinkhole**
Chlorinated water			**Yes (spring)**	**No (spring)**	**Open spring**
Flows		**m^3/s**			
Parameters	**MAC (for drinking water)**	**Unit**	**Results**	**Results**	**Results**
Escherichia Coli	Not allowed	cfu/100 ml	2	6	18
Total coliform bacteria	Not allowed	cfu/100 ml	20	45	50
Enterococcus	Not allowed	cfu/100 ml	3	30	25

Clostridium perfringens	Not allowed	cfu/100 ml	-	-	-
Total aerobic mesophilic bacteria at 22°C	20	cfu/1 ml	9	9	27
Total aerobic mesophilic bacteria at 37°C	100	cfu/1 ml	0	0	4

7.3 PLITIVICE LAKES NATIONAL PARK – IMPACT ON THE QUALITY OF THE KLOKOT SPRING WATER

According to a research conducted in 2016, Plitvice Lakes National Park is annually visited by 1.3 million people. The highest concentration of tourists in the National Park occurs during the tourist season from April to October, with more that 64% of visitors coming in July, August and September. During the season, daily number of tourists reaches the number of 15,000, and according to the statements made by the management of Plitvice Lakes National Park the optimal number would be around 8,000. Along with the increase of the number of tourists in the last 5 to 7 years, there was also an increase in the need to build new tourist facilities. Building of hotels and apartments through private initiative contributed to the increase of activities in the Klokot spring catchment area, which had direct impact on the deterioration of raw water quality at the Klokot spring. Unfortunately, construction of tourist facilities was not followed by adequate construction of wastewater collection and treatment system, or proper construction of septic tanks at places where there is no public sewerage system.

7.4 COMPARISON OF FLOW, APPEARANCE OF TURBIDITY AND BACTERIA PRESENCE IN WATER AT THE KLOKOT SPRING

The results presented so far were obtained by conducting physicochemical and microbiological analysis of water quality at different flows, and they show a tendency of pollution of surface and underground waters coming from the Republic of Croatia to the Klokot spring. All the collected results of the aforementioned water quality and flow analyses at the spring need to be correlated in a certain way presented below:

- flow rate ↔ water turbidity occurrence
- flow rate ↔ presence of bacteria in water
- water turbidity occurrence ↔ presence of bacteria in water
- flow rate ↔ water turbidity occurrence ↔ presence of bacteria in water
- number of tourist nights spent ↔ presence of bacteria in water
- number of tourist nights spent ↔ water turbidity occurrence ↔ presence of bacteria in water
- flow rate ↔ water turbidity occurrence ↔ presence of bacteria in water ↔ number of tourist nights spent

By analyzing these correlations, especially for the period of 2015 – 2020 and for the parameters whose values were above MAC, an increasing occurrence of pollution was noted, as well as an increase in the values of parameters indicating such pollution.

This situation is mostly caused by the occurrence of high water and anthropogenic influence from Plitvice Lakes National Park where an increased number of tourist visits is recorded, which is followed by a rapid construction of tourist facilities. Interpretation of these result is shown in diagrams bellow.

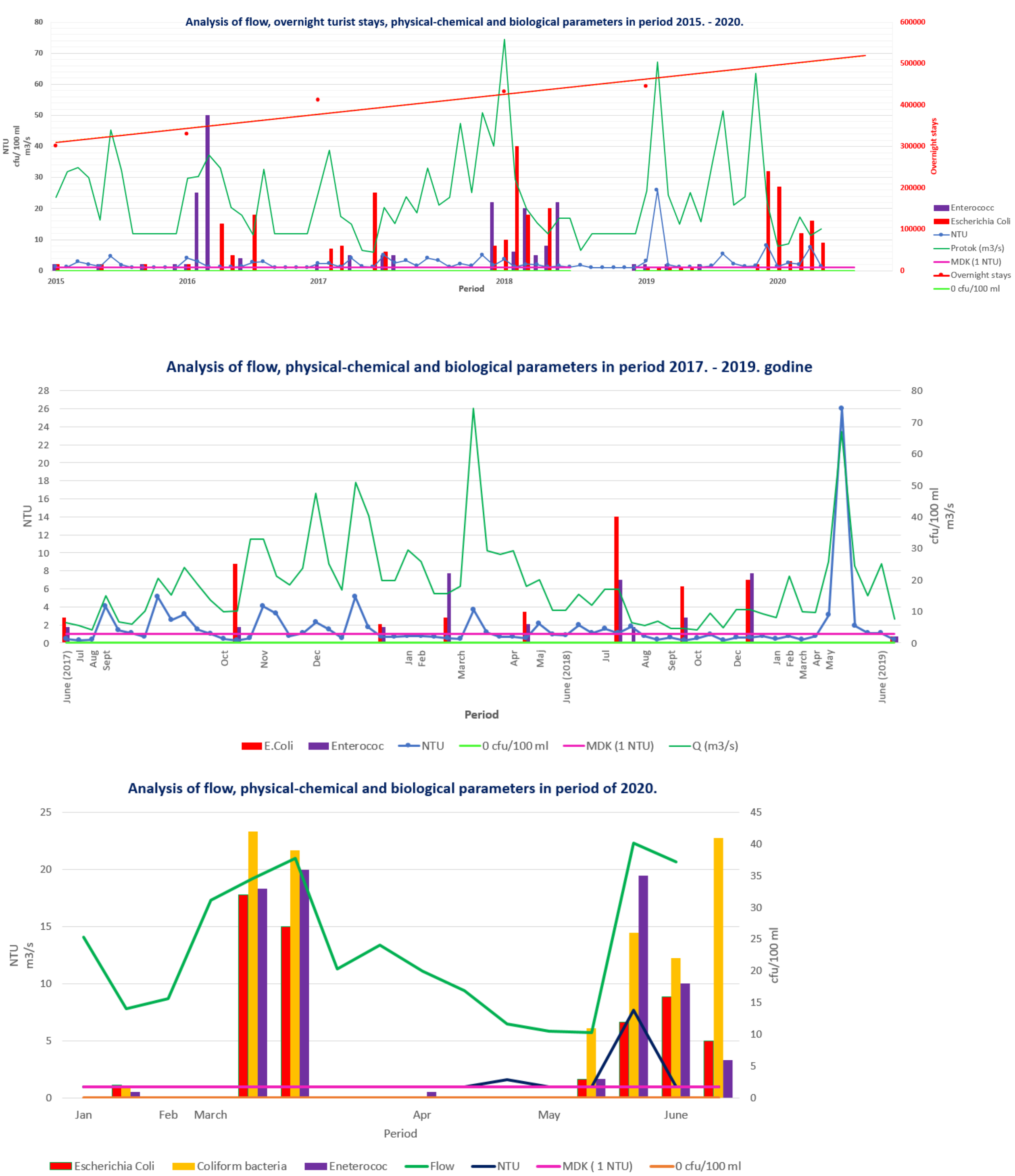


Figure 7.9: *Analysis of flow, turbidity and microbiological parameters in the Klokot spring water in different periods*

By comparing results of analyses conducted for different parameters (Figure 7.9) the following conclusions can be made:

- With the increase of tourism activities, or with the increase of the number of nights spent in the catchment area of the Klokot spring in the last 5-7 years, a significant increase in the bacteriological contamination of water at the Klokot spring also occurred. With the installation of the temporary wastewater treatment plant in Rastovača settlement at the end of 2018, bacteriological contamination was to some extent reduced (it is especially visible from the results recorded in the summer of 2019).

- After heavy precipitation, there is greater discharge of groundwater at the Klokot spring. Consequently, turbidity increases, and with it a significant presence of bacteria not allowed in drinking water. This indicates anthropogenic pollution in the hinterland of the Klokot spring, as shown in the preceding diagrams.
- Significant presence of bacteria not allowed in drinking water was recorded at the Klokot spring after several days of precipitation in its hinterland since this causes water to flush in underground fissures. However, the presence of bacteria is also very often recorded during the summer's dry season when there is no significant precipitation. At that time, relatively huge volume of wastewater enters relatively small volume of groundwater and appears at the Klokot spring.
- The main cause for the significant presence of bacteria at the Klokot spring is the drainage of wastewater into surface and underground waters from improperly built septic tanks or direct discharge of fecal (waste) water into waterways in both countries.
- Short-lasting precipitation of high intensity causes high values of turbidity.
- The turbidity increase is followed by significant presence of bacteria not allowed in drinking water.

7.4.1 Notes about the quality of water:

- Regarding the temporary wastewater treatment plant in Rastovača, it is necessary to check how often during the year it is in operation. According to certain trends, there is a possibility that this plant is in operation only during the main tourist season due to its high operational cost.
- It was not possible to conduct similar analysis in the part of the Klokot spring catchment area which belongs to Bosnia and Herzegovina, since in that area, there are no surface waterways, nor sinkholes or karstic holes where those waterways disappear underground. However, it can be assumed that most precipitation which falls in that area during the year permeates into karst medium and ends up at the Klokot spring. Consequently, it is necessary to investigate whether houses in the settlements at the foot of Plješivica Mountain in BiH have septic tanks and how many of them are watertight.
- In order to confirm all the listed conclusions in the forthcoming period, it is necessary to establish regular and continuous monitoring of surface and underground water quality in the Klokot spring catchment area in both countries, and especially at the Klokot spring.

Consequently, the analysis of water quality in the Klokot spring catchment area shows that it is necessary to intensify the following activities in both countries as soon as possible: collection and treatment of all urban waste water, proper construction of watertight septic tanks, and complete remediation of illegal waste disposal sites, but also remediation of recently closed official landfills for domestic waste (Korenica). In addition to that, it is necessary to stop intensive forests exploitation (logging) and construction of logging trails, in order to stop erosion processes in the catchment area, and consequently, the occurrence of turbidity at the Klokot spring. Additionally, it is necessary to plan the construction of a drinking water treatment plant for the city of Bihać in the vicinity of the Klokot spring, in order to remove excessive water turbidity by using appropriate treatment technology, and also to prevent occasional bacteriological contamination.

7.4.2 Notes on circumstances in which project research was conducted:

- Due to the global pandemic crisis caused by the COVID-19 virus, and in order to stop the spreading of the virus on a catastrophic scale, restrictive measures were introduced for the world population, one of them being restricting travel without justified cause. This caused huge losses for the tourist industry, i.e. for countries (places) in which a huge part of income is based on tourism. In the last few months, Plitvice Lakes National Park has recorded a huge decrease in the number of visits which reached only 5% of the last year's visits, and this is one of the reasons why results recorded in the analyses conducted in 2020 were lower than expected. However, it should be noted that the global epidemiological crisis will one day be over, and Plitvice Lakes National Park will continue to record huge numbers of visitors which will, in turn, cause the increase of physicochemical and microbiological pollution.
- Moreover, the 9-month period from September 2019 to June 2020 was recorded as one of the driest periods in the Klokot spring catchment area. There was hardly any snow in the winter of 2019/2020, and precipitation was rare in fall (2019) and spring (2020). The precipitation that did occur, was short-lasting and of low intensity.

7.5 RECOMMENDATIONS

As general conclusion, it is necessary to separate issues related to the time and frequency of sampling, adherence to legal standards for determination of individual parameters, and the need to continue to monitor them, plus the points below that need to be taken into consideration:

- Since the Klokot spring is part of the public water supply system, it is necessary to establish more frequent water quality testing on weekly, monthly and seasonal basis throughout a year. Basic physicochemical and microbiological parameters should be measured on weekly basis, extended analysis should be done on monthly basis, and complete analysis on seasonal basis – at least 4 times a year in different seasons under respectively characteristic hydrological conditions.
- Legally set standards for preparations, sampling, measuring, and presenting results should be strictly adhered to. Certain parameters need to be determined immediately on the site, like temperature of the air and water, pH value, total and carbonate hardness. Also, some samples need to be prepared for transport to a laboratory or for short-term storage in a laboratory.
- It is extremely useful to compare the obtained values of water quality parameters with hydrological parameters from future studies.

8 IDENTIFICATION OF POLLUTERS

8.1 BASE DATA AND ANALYSIS OF EXISTING INFORMATION

During the initial phase of the project, the Consultant performed the analysis of the existing documentation regarding the identification of polluters in the basin of water source Klokot.

Data about potential contamination sources – hazards were selected regarding spatial types of hazard (point, line and polygon) and classified in 24 separate layers depending on the type of potential pollution features (quarries, gas stations, mine fields, roads, industry etc.). The result is a classified grid of hazard index presented in the form of a classified hazard map.

Bosnia and Herzegovina

In the catchment area of the water source Klokot, in Bosnia and Herzegovina, many polluters were registered, the most significant are the following:

- BC Izačić (B&H) together with the BC Ličko Petrovo Selo (RC)
- Quarry Željava (Baljevac 1);
- Quarries Baljevac (Baljevac 2);
- Quarry Baljevac (Baljevac 3);
- Quarry Zavalje/Vučjak;
- Quarry Međudražje;
- Landfill Vučjak;
- Illegal landfills:
- Landfill Baljevac,
- Landfill "JNA",
- Landfill "Bezdan" Međudražje;
- Cemetery Zavalje i Izačić;
- Mine fields;
- Highway M5 (BC Izačić – Kamenica);
- Regional road R403a (Bihać – Veliki Skočaj)
- Local road (Zavalje – Vučjak - Baljevac);
- Settlements (Veliki Skočaj, Mali Skočaj, Međudražje, Zavalje i Izačić);
- Arable agricultural lands;
- Forest exploitation (Plješevica).

In addition to the above, it is necessary to add natural pollution due to the large and turbulent flow, which occasionally results in high turbidity at the springs Klokot and Privilica, during the occurrence of large water waves, which is discussed in a separate chapter.

Note: In the basin of water source Klokot in Bosnia and Herzegovina, which is extents partly in rural areas, and for the most part in uninhabited and forested aresa, there is no identified polluters such as shopping malls, gas stations or industrial plants.

Croatia

In the catchment area of the water source Klokot in the territory of Croatia, a significantly higher number of polluters has been registered, representing a higher volume of pollution compared to the polluters registered in the territory of Bosnia and Herzegovina. The most significant of these polluters are:

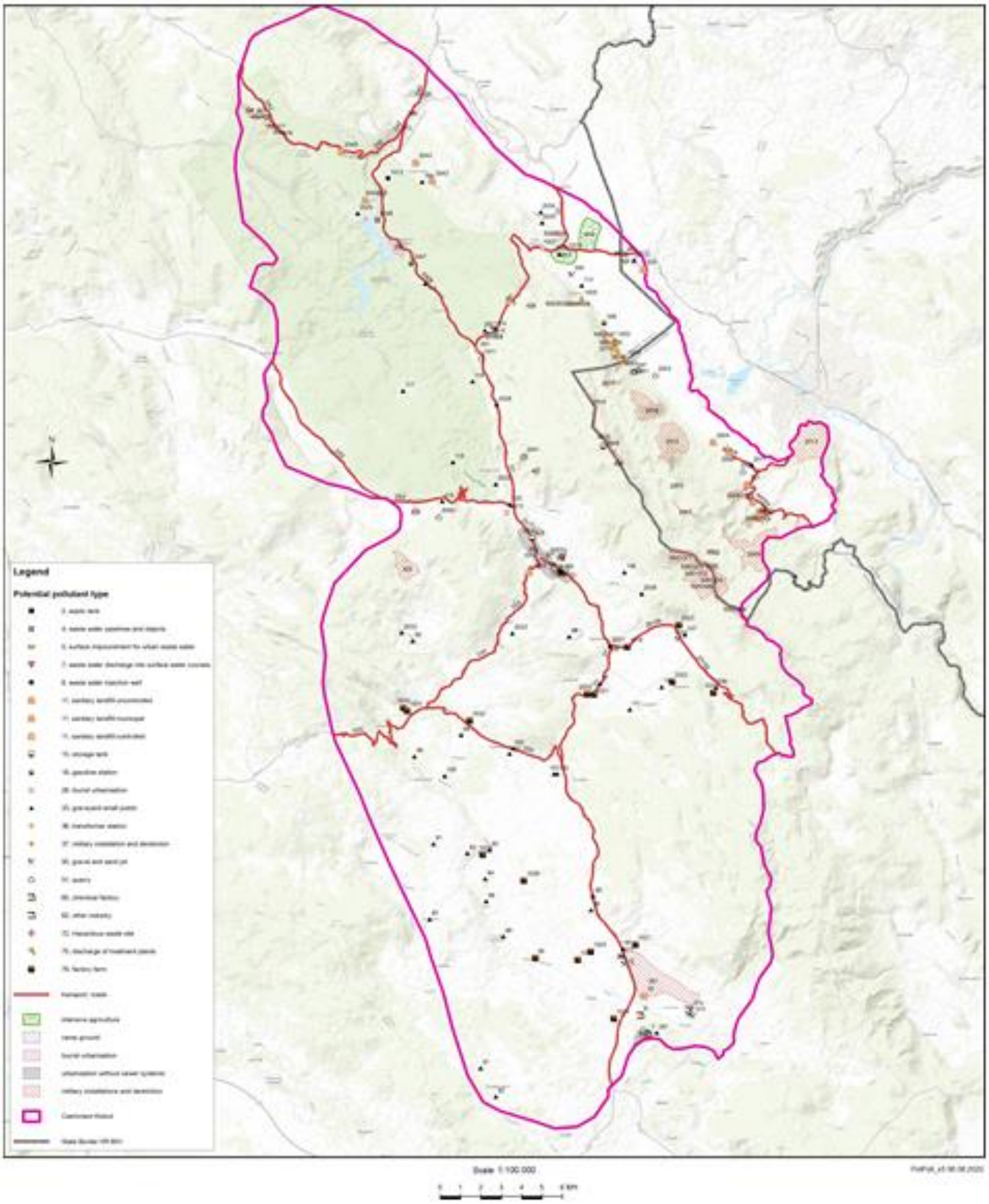
- Quarry Prijeboj;
- Material lenders and gravel pits Frkašić;
- Military airport ¨Željava¨;
- Military quarter Ličko Petrovo Selo;
- Military quarter and airport in Udbina;
- Mine fields;
- Municipal waste landfill in Korenica (Vrpile/Kalebovac);
- Municipal waste landfill in NP Plitvice (Prijeboj);
- Illegal landfills:
- Pit Rastovača,
- Pit Pony,
- Pit at the mouth of the river Plitvice,
- Pi near Poljanka;
- Industrial and other economic facilities in the municipalities of Udbina and Plitvice Lakes;
- Cemeteries (Plitvice Lakes and Udbina);
- State road D1 (Grabovac – L. P. Selo – Prijeboj - Korenica – Udbina);
- State road D504 (L.P. Selo – GP Izačić /BiH/);
- State road D217 (Rakovica – L. P. Selo);
- State road D218/506 (Korenica – Donji Lapac – Srb);
- State road D25 (Korenica Lički Osik);
- State road D52 (Borje – Otočac);
- State road D42 (Plitvice - Saborsko);
- Settlements along the state roads Udbina - Korenica - Prijeboj - L. P. Selo (Plitvice Lakes) - Grabovac;
- Drainage and wastewater treatment systems in the municipalities of Udbina, Plitvice Lakes;
- Tourist capacities of Plitvice Lakes National Park, private tourist facilities (apartments, camps and weekend resorts);
- Arable agricultural land;
- Forest exploitation.

In the preparatory phase of the project implementation, the Consultant developed a form to collect data on the existing polluters in the basin of water source Klokot, conducted field visits to review and verify these existing polluters, but also to investigate new potential polluters in the catchment area of water source Klokot.

After collection and detailed analysis of data on polluters, the Consultant prepared a detailed list of polluters, with a detailed description of the most important of them, including a graphical overview of their locations (see map in chapter 6.2. below or Annex 10.1 for better overview).

Information on identified polluters in the basin of water source Klokot was presented to the representatives of the City of Bihać, as well as to the representatives of the municipalities of Udbina and Plitvice Lakes, and was verified with minor amendments.

8.2 POLLUTERS CADASTRE WITH GRAPHICAL REPRESENTATION OF LOCATIONS



The aim of determining groundwater protection zones is to protect aquifers from all types of pollution, primarily from negative anthropogenic impact, therefore, in underground water protection zones, human activities are restricted.

These zones are the main instrument for territorial organization measures relative to underground water.

In karstic aquifers, underground water protection zones are determined in accordance with the criterion of groundwater flow rate, pollution transfer and the impact on their vulnerability. As the groundwater flow approaches the water intake, the prescribed protection measures become stricter, i.e. the more vulnerable the zone is, the more severe the prescriptions are.

During the field research in the catchment area of the water source Klokot in the territory of Bosnia and Herzegovina (BiH) and Croatia (HR), a total of **109** polluters have been identified (20 in Bosnia and Herzegovina and 89 in Croatia), which were divided into different categories: quarries, stone lending facilities, gravel excavations, military facilities, airports, waste landfills, cemeteries, tourist facilities, picnic areas, border crossings, shopping centres, manufacturing entities, industrial zones, gas stations, discharge pits, agricultural lands – intensive agricultural production areas, livestock farms, settlements and roads (local, regional and highways).

Prior to the field research, documentation about the study-project in which there are reviews of previously recorded polluters was collected and analyzed (Project of the Klokot and Privilica spring protection, Project AmthropholProt, other available documentation). Based on the information from these documents surveying plans have been developed, maps and forms were defined to prepare the information and data collection in the field.

The mentioned field research was conducted during the months of February and March 2020 on the territory of BiH and Croatia. The research was focused on hitherto known polluters and the recording of new polluters in the sanitary protection zone of the water source Klokot. Due to their specificity and scope, the field research was conducted on several occasions with the direct support of representatives of the competent services of local self-government units (LGUs) and public utility companies (PUCs), as well as representatives of NP "Plitvice Lakes" and border police of both countries who provided the Consultant with the necessary information, data and maps, and showed the locations of polluters in the field. The Consultant presented to the mentioned representatives of the competent institutions from both countries a document on all collected and processed data, information and maps, which they confirmed.

Bosnia and Herzegovina

In the territory of FBiH, in the catchment area of water source Klokot, a total of 20 polluters were recorded, which are listed in the following table.

Table 8.1: *Review of the recorded polluters in the catchment of Klokot (BiH)*

Location	Number	Status	Note	Importance category
1	2	3	4	5
Quarries, material lenders and gravity pits				
Baljevac (1 i 2)	2	Inactive		**III**
Baljevac (3)	1	Inactive		**II**
Zavalje-Vučjak	1	Inactive		**III**
Međudražje	1	Active		**II**
Cemeteries				
Zavalje	1	Active		**II**
Izačić	1	Active		**I**
Waste landfiils				
Mali Baljevac	1	Inactive	Wild landfill	**II**
Vučjak	1	Inactive	Old town landfill	**II**
Međudražje	1	Active	Wild landfill	**I**
Public institutions and shopping centres				
Border crossing	1	Active		**I**
Military facilities				
Military airport ¨Željava¨- part (hole number 4)	1	Inactive	It is located within the military airport Željava on the territory of BiH.	**II**
Settlements				

City of Bihać	5	Active	Settlements without communal infrastructure for wastewater collection and treatment. V. Skočaj (part), Mali Skočaj, Međudražje, Zavalje and Izačić (part).	**I**
Roads				
City of Bihać	3	Active	Roads with free drainage (M5; R403a and local road).	**II**
Total:	**20**			

Importance categories:

I – category of importance – high possibility of polluting the ground water;

II – category of importance – mean possibility of polluting the ground water;

III- category of importance – low possibility of polluting the ground water.

According to the above stated categorization in the area of BiH, the total number of 10 polluters is put in the first category which can have significant influence to the ground water quality (landfill Međudražje and Vučjak, cemeteries Zavalje and Izačić, WWTP Izačić and settlements without communal infrastructure).

Croatia

In the area of the RC, in the catchment area of the Klokot water source, the total number of **89** polluters have been stated in the following table.

Table 8.2: *Review of the recorded polluters in the catchment of water source Klokot (RC)*

Location	Number	Status	Note	Importance category
1	**2**	**3**	**4**	**5**
Quarries, material lenders and gravity pits				
Prijeboj	1	Inactive		**II**
Frkašić	1	Active		**II**
Cemeteries				
Udbina	25	Active		**II**
Plitvice Lake	13	Active		**II**
Waste landfills				
Prijeboj	1	Inactive	Closed and rehabilitated landfill	**II**
Korenica – Vrpila/Kalebovac	1	Inactive	Closed landfill, in preparing the rehabilitation of landfills	**II**
Pit Rastovača	1	Active	Uncontrolled disposal of municipal waste	**I**
Pit Pony Kapitalac	1	Active	Uncontrolled disposal of municipal waste	**I**
Pit at the mouth of the river Plitvice	1	Active	Uncontrolled disposal of municipal waste	**I**
Pit Poljanak (right)	1	Active	Uncontrolled disposal of municipal waste	**I**
Pit Golubnnjača	1	Active	Uncontrolled disposal of municipal waste	**I**
Public institutions and shopping centres				
L. P. Selo	1	Active	Hotel Lyra	**II**
Prijeboj	1	Active	Garages / parking and internal gas station - Prijevoz Knežević	**II**
Prijeboj	1	Active	Log landfill	**II**

Korenica	1	Active	Gas station INA	**II**
Plitvice Lake (Mukinje)	1	Active	Internal gas station NP P. Jez-era	
Korenica	2	Active	Hotel and restaurant Macola.	**II**
Udbina	1	Active	Pellets factory (wood industry).	**III**
Military facilities				
Željava (Ličko Petrovo Selo)	4	Inactive	Military airport and military quarters.	**I**
Udbina	1	Active	Military quarters and military range with airport.	**I**
Farms				
Korenica	1	Active	50 large cattle	**I**
Udbina	14	Active	1.050 large cattle and 7.400 sheep.	**I**
Deforestation				
Plješevica	1	Active	Deforestation in the zone of 100m in the upper parts of Plješevica in order to secure and control the state borders.	**I**
Intensive agricultural soil process				
Ličko Petrovo Selo	1	Active	Concession to arable land (100 ha).	**I**
Settlements				
Prijeboj	1	Active	Settlements without the communal infrastructure for wastewater collection and treatment.	**I**
Ličko Petrovo Selo	1	Active		**I**
Korenica	1	Active		**I**
Udbina	1	Active		**I**
Tourist urbanization of Plitvice Lakes National Park				
Plitvice lake	1	Active		**I**
Roads				
Korenica, Udbina, L. P. Selo, Plitvice, border crossing	7	Active	Road with free drainage.	**II**
Total:	**89**			

Importance categories:

I – category of importance – high possibility of polluting the ground water;

II – category of importance – mean possibility of polluting the ground water;

III- category of importance – low possibility of polluting the ground water.

According to the above stated categorization in the area of RC the total number of 32 polluters is put in the first category which can have significant influence to the ground water quality. These are the primarily livestock farms, military facilitates, settlements without communal infrastructure, agricultural tourist urbanization and actions and deforestation.

All identified polluters in the area of catchment Klokot water source, covering the territory of Bosnia and Herzegovina and Croatia, have been captured into the GIS and the corresponding database.

8.3 DESCRIPTION OF POLLUTERS IN THE CATCHMENT AREA OF BOSNIA AND HERZEGOVINA

Quarries

In the catchment area of the water source Klokot, in Bosnia and Herzegovina, there are a total of five quarries, which are described below:

Željava/Baljevac (1) – quarry is located near the military airport Željava. It was used for the exploitation of solid limestone, which was used for the construction of the airport as well as for other needs of the former Yugoslav Army (JNA). An explosive was used to scatter the slopes of the rock massif.

Figure 8.1: *Quarry Baljevac (1)*

Inside the exploitation area of the quarry, there are the remains of a concrete separation structure for crushing stone. The quarry was active for several years after the war but without a work permit, after which it was closed without remediation measures. The quarry covers an area of over 0,5 ha, the volume of excavated material is estimated at 70,000 m^3.

Baljevac (2) – quarry, is also located near the military airport Željava and was also used for the needs of the former Yugoslav Army (JNA). It is a surface mining of limestone with prior agitation stone explosive with area 0,1 ha. After the exploitation was completed, the pit remained unrepaired. The quarry was not used after the war. The volume of excavated material is estimated at 4,800 m^3.

Figure 8.2: *Quarry Baljevac (2)*

Baljevac (3) – quarry is located in the immediate hinterland of the water source Klokot towards the military airport Željava. The quarry is believed to have been used by the former Yugoslav Army (JNA), as indicated by a surface limestone mine. The mined material was not all removed at that time and the quarry was later used illegally, leaving the pit unrepaired.

Figure 8.3: *Quarry Baljevac (3)*

The distance of the quarry from the water source Klokot is about 1.6 km to the west, and therefore poses a danger to the source itself, in addition to the abandoned quarry (pit) leads a very well-built access road that can be abused for uncontrolled waste disposal or illegal activities. in the pit of a former quarry. The excavation area in the quarry is about 0.6 ha, and volume of excavated material is estimated at 35,000 m^3.

No traces of new illegal stone exploitation or illegal waste disposal were observed at the locations of these three quarries during the field visit. The environment is clean, but quite overgrown with low and medium-high vegetation, which makes access difficult, especially to the Baljevac quarry (1). The creation of new illegal landfills at these locations is prevented because the border zone is under the constant control of the BiH Border Police.

Zavalje - Vučjak - The quarry / material lender is located near Zavalje in the direction of the closed landfill Vučjak. Dolomite stone and sand were mined at this site. The area occupied by the quarry is about 1.6 ha. The characteristic of this quarry is that it is made of cracked dolomite material with a lot of natural sand of a smaller fraction, so no explosives were used for exploitation, but construction machines. The volume of excavated material is estimated at 80,000 m^3.

The quarry was closed without previous repairs, and access was prevented with the construction of a stone embankment on the access road. The access road is overgrown with low forest vegetation.

Figure 8.4: *Quarry / material lender of dolomite stone near Zavalje near Bihać*

Quarry Međudražje is located near the settlement Međudražje and is the only one active in the catchment area of the water source Klokot on the BiH side. Dolomite stone and sand are exploited from the quarry. Most of the exploited amount is provided by blasting the slopes of the hill.

Figure 8.5: *Dolomite stone quarry Međudražje*

The area of the quarry is about 4.6 ha, volume of excavated material is estimated at 650,000 m^3. Previously exploited areas that are no longer used have not been rehabilitated. Residents of the settlement Međudražje regularly complain to the competent services of the City of Bihać about the blasting at this quarry, during which there are significant shaking of residential buildings in the settlement Međudražje.

<u>Landfills and waste dumps</u>

Vučjak landfill is an old landfill in the city of Bihać. It is located about 5 km southwest of the city. Solid waste disposal was carried out until 1997, when the landfill was partially rehabilitated and closed. The body of the landfill is located in several sinkholes near the settlement Vučjak. By tracing the underground watercourses on October 9, 1984, a direct connection of this location with the water source Klokot was determined. Project documentation was prepared for the remediation of the landfill (The main project for the rehabilitation of the Vučjak landfill - IPZ Zagreb, 1985). The landfill was partially rehabilitated in the period from 1999 to 2001. According to the information obtained by several persons employed in public institutions of the City of Bihać, certain study and project documentation was used for the remediation of the landfill, but the landfill was rehabilitated by installing degassing pipes in the landfill body, and the landfill itself was covered with clay. in height from 1.0 - 2.0 m. The cover layer of clay is compacted and is presumed to have been constructed to prevent the penetration of precipitation and surface water into the body of the landfill. After that partial rehabilitation, a forest about 15 years old grew on the body of the landfill. The amount of leachate seeping into the ground through the body of the landfill is not known, nor have subsequent hydro-geological and hydrological surveys been carried out at this location.

Figure 8.6: *Old landfill Vučjak*

During 2019, a temporary migrant centre was established on the location of this landfill, which was subsequently dislocated. The landfill area covers an area of about 7 ha.

Illegal landfill Bezdan (Međudražje) is a landfill with uncontrolled / illegal disposal of municipal waste located in the settlement Međudražje. The landfill is about 200 m away from the regional road and houses in the village. The landfill is a natural bay of approximately 20.0 x 2.5 m with a variable depth of 1.0 to 2.5 m. Mostly about 10 households dispose of municipal waste, glass, PVC, packaging and construction waste at this landfill. The intensity of waste disposal is low, because it is used by a small number of residents of the mentioned settlement.

Figure 8.7: *Wild landfill Bezdan in the settlement Međudražje*

During a field visit, the Bezdan landfill in Međudražje was identified as the only currently active illegal landfill in the catchment area of the water source Klokot, in Bosnia and Herzegovina.

Illegal landfill Baljevac - During the field inspection in 2003, larger quantities of various waste were found at the landfill. Among other things, there were bulky metal scraps such as car bodies, remnants of white goods, etc., but also smaller metal scraps such as cans. In addition, it was then recorded that organic waste from slaughterhouses and butchers, as well as remains of medical waste (substances and drugs of unknown origin and composition) were previously disposed of at this landfill.

Bulky metal objects were previously removed from the landfill, but the location is densely overgrown with low and high vegetation and it is impossible to identify it without prior cutting of vegetation.

Waste is no longer disposed of at the said landfill; however, the landfill was registered as a potential contaminant because at that time the origin and composition of the deposited waste could not be determined with certainty.

Figure 8.8*: Wild solid waste landfill at the Baljevac site (archive recording from 2003)*

Baljevac Military Landfill - In the vicinity of the aforementioned landfill solid waste, there is an old military landfill, which was used by the former Yugoslav army before the war. At the landfill, various types of waste were disposed of, primarily cans and waste from the logistics unit of the airport "Željava", which was located in Baljevac. During a field inspection in 2003, it was determined that the disposal of waste at this location was carried out without any control and compliance with sanitary principles, and can be considered an illegal / wild landfill.

As at the previously mentioned landfill in Baljevac, this military landfill no longer disposes of waste, it has completely grown into low and high vegetation, and the area around the landfill is not safe to access. Field identification of the landfill site is possible only with the prior removal of low and high vegetation.

Cemeteries

In the catchment area located on the territory of Bosnia and Herzegovina, there are only two registered cemeteries that are active, in the settlement Zavalje and settlement Izačić. The cemetery in the settlement Zavalje has been used for a long time, but only a few burials are performed during the year.

The cemetery in the area of Izačići has been used for the last 10 years, the capacity of the plot allows for about 250-300 burials. The cemetery is located on a plateau near BC Izačić, or 6 km northwest of the water source Klokot.

Figure 8.9: *Cemetery in the settlement Izačić*

Mine fields

Areas where the danger of landmines has been identified are located in the forest parts of the catchment area of the water source Klokot. The locations were identified and marked in the forest departments of the forest management unit "Plješevica". The area occupied by minefields is about 450 ha of forest area.

Public institutions

In the catchment area of the water source Klokot, in Bosnia and Herzegovina, apart from the border crossing BC Izačić, there are no other public institutions.

BC Izačić (border crossing Izačić) is located about 7 km northwest of the water source Klokot. It is one of the most important border crossings between Bosnia and Herzegovina and Croatia, through which intensive road traffic takes place. The crossing was built with a common infrastructure for the needs of BC Izačić (BiH) and BC Ličko Petrovo Selo (RH). In the complex of the border crossing there are parking lots for trucks and passenger motor vehicles, then the central border control facility, the facility for customs procedure and inspection, commercial facility, test hall, restaurant with public toilet, duty free shop and public toilet.

Collecting waste water takes place in a separate sewage system. Sanitary wastewater is delivered to a treatment plant (biorotor), where biological wastewater treatment is performed. The plant has a hydraulic capacity of 100 m^3 / day, and is dimensioned for an organic load of 283 equivalent inhabitants (ES). The designed effluent quality is 20-25 mg BOD5 / l and 0.3 ml / l suspended solids.

Rainwater is collected from the asphalted surfaces of the border crossing complex, whose area is 45,000 m^2. The collected rainwater is delivered to an oil and fat separator with a capacity of 60 l / s. The effluents from the treatment plant and the oil and grease separator are led to a common shaft, from where they are led to a nearby sinkhole through a 35-meter pipeline and discharged into the karstic underground.

During a field visit in February 2020 to the Izačić (BiH) / Ličko Petrovo Selo (RH) border crossing, it was determined that the installed wastewater treatment plant was not in function, which confirms the wastewater spill around the plant itself. Untreated wastewater is discharged directly into the karst underground. The condition of the oil and grease separator could not be determined because the whole plant is located in blackberry vegetation and gives the impression of very poor maintenance by the owner. Oil and grease separator represents another risk due to the possibility of direct discharges of oils and fats in the karst underground with potentially large consequences for water source Klokot. The Consultant informed the competent service for water, environmental protection, communal services and inspection affairs of the City of Bihać about this case in detail.

Figure 8.10: *Biological wastewater treatment plant at BC Izačić (BiH) / BC L. P. Selo (Cro)*

During the month of July, the bio rotor (WWTP) and the separator at BC Izačić were cleaned and the operation of the accompanying devices was checked. It is planned to perform periodic servicing and testing of the device by the equipment manufacturer ("Tehnix") with the issuance of a certificate of correctness of the device, however, due to the epidemiological situation with COVID, the listed activities were not carried out.

Tourist facilities and weekend resorts

There are no commercial tourist facilities in the catchment area of the water source Klokot, on the territory of Bosnia and Herzegovina. In the area of the settlements Zavalje and Međudražje, there are several smaller weekend settlements that are located within the urban parts of the settlement or in their immediate vicinity. Wastewater disposal for these settlements is described in the chapter "Permanently inhabited population".

Agricultural activities

The local population located in the catchment area of the water source Klokot is individually engaged in extensive agriculture, production and extensive livestock farming. The most important crops grown are corn and potatoes, as well as other vegetable crops on individual very small areas. Agricultural areas in the catchment area of the Klokot mainly refer to pastures, meadows and, to a lesser extent, orchards.

Although livestock farming in this area has not been pronounced since the war, it has declined significantly in the last ten years. There are no livestock farms, and the small number of livestock is raised by individual households. There are no exact data on the number of cattle, but it is considered that the number is very small.

Agricultural activities and livestock in the catchment area of the water source Klokot, in Bosnia and Herzegovina, and their impact on total pollution can be considered minor or negligible.

Forest exploitation

In the catchment area of the water source Klokot, on the territory of Bosnia and Herzegovina, the forests are managed by the Public Company SPD "Forests of Una-Sana Canton". The condition of forest ecosystems in a part of the catchment area is described in more detail in a special section "Analysis of the condition of forests and forest lands".

Permanently inhabited population

The catchment area of the water source Klokot in Bosnia and Herzegovina with an area of 90.5 km2 is very sparsely populated (5.6 inhabitants / km2), the area is inhabited by about 510 inhabitants, i.e. 153 households in the settlements Veliki Skočaj (part of the settlement), Mali Skočaj, Međudražje, Zavalje together with the weekend settlement on Vučjak, and part of the settlement Izačić.

These settlements do not have an organized system of wastewater collection and treatment, and septic tanks that are not properly built are used for wastewater disposal. It is estimated that in the catchment area of water source Klokot in Bosnia and Herzegovina there are between 110 and 130 septic tanks, of which only 10-15% are properly built.

Municipal waste collection from these areas is performed once a week by PUC " KOMRAD Ltd. Bihać.

Roads

As the most important road, it is important to mention the section of the main road M5 that leads from the direction of Bihać towards the border crossing Izačić (BiH) / Ličko Petrovo Selo (CRO). This road represents a regionally important communication, because this road route is used for road transport of goods from the direction of Croatia to B&H and vice versa. Also, this road continuously transports fuel (gasoline, oil, fuel oil and heating oil), as well as other hazardous substances.

The second road is the regional road R403a in the direction Bihać - Zavalje - Veliki Skočaj and the third road is the local road Zavalje - Vučjak - Baljevac. These roads do not transport dangerous goods and fuels.

Basic data on roads are listed in the following table.

Table 8.3: *Roads in the catchment area of the water source Klokot, in Bosnia and Herzegovina*

Label	Category	Direction
M5	Highway	Bihać - BC Izačić (BiH) / BC L.P. Selo (CRO)
R403a	Regional road	Bihać - Zavalje - Veliki Skočaj
--	Local road	Zavalje - Vučjak - Baljevac

All these roads are free drainage roads without built gutters and oil and grease separators. The preparation of project documentation is in progress, which envisages the collection and purification of rainwater from asphalt surfaces on the section of the main road M5 from BC Izačić to the settlement Kamenica at the entrance to the City of Bihać. The implementation of this project would significantly reduce the risk of pollution caused by traffic activities.

8.4 DESCRIPTION OF POLLUTERS IN THE REPUBLIC OF CROATIA

Quarries and material landers in the Klokot catchment area in the Republic of Croatia

In the part of the Klokot water source catchment area in the Republic of Croatia, a total of three quarries, one gravel pit and two material landers of materials have been identified, the most important of which are the Prijeboj quarry and the Frkašić gravel pit.

The Prijeboj quarry is located within the Plitvice Lakes National Park on the stretch from Prijeboj to Korenica, in the immediate vicinity of the D1 highway (approx. 300 m). The quarry is closed, access is blocked by placing embankments and concrete blocks on the access road. Although the exploitation of stone was stopped about ten years ago, the quarry has not been repaired. The area from which the stone was exploited is about 4.0 ha. The volume of excavated material is estimated at 350,000 m^3.

Figure 8.11: *Prijeboj Quarry*

Gravel pit Frkašić is a surface mine / borrow pit of a mixture of natural gravel (small pebbles) with a small additive of clay. Gravel exploitation has been active since the late 1980s. It is located 10 km southeast of Korenica on the road Korenica - Donji Lapac next to the D218 highway. The gravel pit is managed by the Korenica Forestry (UŠP Gospić) on the basis of a concession agreement. The area from which gravel is excavated covers an area of about 10.0 ha. The volume of excavated material is estimated at over 600,000 m^3.

Parts of the areas where excavation is no longer carried out have been properly prepared for sanitation but have not been repaired.

Figure 8.12: Gravel pit in Frkašić

In addition to the listed locations of stone and gravel exploitation in the area of the Plitvice Lakes municipality, two other smaller quarries have been identified that are occasionally used for the maintenance of forest roads (Homoljac and Rudanovac). These quarries are not significant pollutants in terms of their volume and manner of use.

In the area of the municipality of Udbina, three locations of material landers where gravel was previously excavated were identified (two locations in Tišmin Varoš and one in Jošani). These material landers of gravel are not in use, the locations have grown into low vegetation, and in terms of their size and area they do not represent significant polluters.

Landfills

Landfill Vrpile / Kalebovac - Korenica - is certainly the most important landfill for municipal waste in the Klokot catchment area in the territory of the Republic of Croatia. It is located at a distance of 2.5 km southwest of the city, in the locality Ljeskova poljana, Kalebovac. The landfill was closed at the end of 2019, it is fenced, and there is a gate with a lock at the entrance. Currently, municipal waste in a weekly production of about 50-60 m3 is collected in a container and taken to a landfill in Karlovac.

Figure 8.13: *Municipal waste landfill Vrpile (Korenica) in the sanation phase*

During the construction of the landfill, no protective foils were placed on the substrate, and waste disposal was performed with the stabilization of the layers with inert material. Also, the system of degassing, drainage and purification of leachate has not been built. The landfill area covers an area of 1.6 ha.

In the past two years, study-project documentation has been prepared for the sanitation of this landfill. According to the information of the representatives of the municipality of Plitvice Lakes, the project Recommendation for the sanitation of this landfill was submitted to the responsible Ministry and the Environmental Protection Fund of the Republic of Croatia. The municipality expects funding for the sanitation to be approved in 2020. Preparations for remediation works are underway, and remediation works should be completed by the end of 2022.

Landfill Prijeboj - the landfill is no longer active, and it was used for organized disposal of municipal waste primarily for the needs of the National Park "Plitvice Lakes". The landfill is located within the borders of the Plitvice Lakes National Park, in the immediate vicinity of the D1 road in the direction of Ličko Petrovo selo - Prijeboj. The landfill area covers an area of about 1.1 ha.

Figure 8.14: *Restored municipal waste landfill Prijeboj*

Remediation works were carried out at the landfill, which included the removal of complete landfilled waste with the remediation of the land surface, and in the last 5-6 years, the condition of the landfill and its impact on the environment has been monitored. The results of the monitoring so far have shown that the remediation works were carried out in accordance with international standards and that this location does not pose a danger to the environment.

Illegal landfill

Illegal landfills in the municipality of Plitvice Lakes have been identified by speleological associations of the Republic of Croatia and presented on the website: "Čisto podzemlje". These are mostly natural pits in which illegal disposal of municipal and bulky waste was carried out. The pits are located within and around the borders of the Plitvice Lakes National Park, and are presented below.

Rastovača pit

The pit is located a few hundred meters north of the village of Rastovače under Hrastovim vrhom. Large amounts of municipal waste were thrown into it. The dimensions of the entrance are 3 x 3 m, length 13 m and depth 34 m. Pollution was recorded in 2012.

Figure 8.15: *Illegal landfill in the Rastovača pit*

“Pony Kapitalac” pit

The pit is located along the forest macadam road that connects Rastovača and Ličko Petrovo Selo (within the Plitvice Lakes National Park). The entrance is smaller, and is covered with small amounts of municipal waste (about 1 m^3 of waste). The dimensions of the entrance to this pit are 1 x 0.6 m, length 5 m and depth 31 m. Pollution was recorded in 2019.

Figure 8.16: *Illegal landfill in the Pony pit*

Pit at the mouth of the Plitvice river into the Koran river

Significantly polluted pit in the settlement of Poljanak. At the bottom of the building there is a lot of waste (dozens of cubic meters) which directly endangers the river Plitvice near the mouth of the river Korana. Pollution is located along with the very fundamental phenomenon of the Great Waterfall in Plitvice. The dimensions of the entrance to the pit are 10 x 15 m with a depth of 25 m. Pollution was recorded in 2019.

Figure 8.17: *Illegal landfill pit near the mouth of Plitvice*

Right pit near Poljanka

The pit is located in the forest area of NP "Plitvice Lakes", about 250 meters southwest of the village Poljanak. It has two entrances, and the main one is covered with municipal waste. At a depth of 5 meters there is a false bottom of garbage, but below it the pit continues to a depth of about 50 meters, and the bottom is also covered with waste. The dimensions of the entrance are 1 x 1 m with an undetermined depth. Pollution was recorded in 2019.

Figure 8.18: *Illegal landfill pit near Poljanka*

Golubnjača pit

The pit is located in the Plitvice Lakes National Park, on the road leading from Homoljačko polje to the village of Jasenova Korita. At the bottom of the pit is a larger sloping cliff (sipar) covered with municipal waste and carrion. Sipar continues in a vertical jump of several meters, which is almost completely covered with tens of cubic meters of fresh waste. After a vertical jump, another 20 m3 of waste cubes bury a large sloping hall that leads to the horizontal parts of the building. The entrance to the pit measures 7.0 x 5.0 m, is 170 m long and 63 m deep. Pollution was recorded in 2019.

Figure 8.19: *Illegal landfill pit Golubnjača*

Note: Information on illegal landfills (pits) is taken from the website "Ćisto podzemlje", the authors of the text and photos are representatives of the volunteer initiative of the Zagreb Speleological Association.

<u>Cemeteries</u>

In the territory of the Republic of Croatia in the catchment area there are 38 registered locations with cemeteries (13 locations in the municipality of Plitvice Lakes and 25 locations in the municipality of Udbina). The most active is the city cemetery in Korenica, while most cemeteries in rural areas are completely inactive or with a minimum number of burials per year.

Figure 8.20*: City cemetery in Korenica*

Military facilities (Željava and Udbina Airport, and other military complexes)

Željava Airport was built in 1968 as a very important military strategic facility in the former Yugoslavia. As it was considered an important strategic facility, the public in the former state did not have access to information on facilities at the airport and surrounding military quarters and other military facilities. Therefore, data on devices and the impact of devices at the airport on the source of Klokot could not be obtained on the basis of official documentation, but information was collected from persons who worked at the airport until the outbreak of war in the Republic of Croatia and Bosnia and Herzegovina. The information gathered relates to the condition and status of the airport and its facilities until 1992, when the airport was operated by units of the former JNA. With the outbreak of war activities, it is estimated that the former army took out all significant equipment from the airport, while the airport itself was mined when leaving the former army.

Most of the vital contents of the airport were buried in the limestone massif of the Plješevica mountain. On the outer surfaces along the mountain, only runways and taxiways have been built, and a number of ancillary facilities of less significant logistical content. A total of two runways and three runways were constructed, which are directly connected to the entrances to the underground facility "Klek". The underground facility has four entrances, of which entrance number 4 is on the territory of BiH, while the remaining three entrances are located on the territory of the Republic of Croatia. During the inspection of the terrain during the month of February 2020, visits of the airport and the abandoned military quarters in the settlement of Željava were All four entrances to the underground airport were significantly damaged. The State Border Service of the Republic of Croatia patrols the area every day, covering all four entrances, while the Border Police patrols the area up to the fourth entrance made.

Figure 8.21: *Access to entrance 4 and inside the entrance*

Before the war, the airport had a power supply, but it also had two high-power diesel generators (DIT) with their own fuel tanks. The power of the aggregate is not known. One DIT was placed next to entrance 2, and the other next to entrance 3. The delivery of diesel fuel for the units was done by tanks to the entrance number 3, where the transfer to the tanks was done.

Kerosene for airplanes was delivered by pipeline from the main warehouse in the settlement of Pokoj near Bihać to the kerosene outlet near the so-called "Triangle" at the airport. The main kerosene tank was located outside the mountain range. The route of the transport pipeline is not known, during the inspection of the terrain it was not possible to identify the route or inspection shafts due to the overgrown vegetation. According to previously available information, there is no kerosene in the pipelines, because it was extracted during the 1992-95 war years.

Figure 8.22: *Inspection shafts on the route of the pipeline for the transport of kerosene to the airport Željava (Archive photo from 2003)*

In the underground part of the airport, there was a workshop in which the highest level of maintenance of airplanes and aircraft engines was performed with the use of large quantities of lubricants. Waste oils and lubricants were stored in oil barrels. In addition to lubricants, alcohol and liquid nitrogen were used to maintain the material resources. In addition, the reconnaissance squadron owned aero-photo equipment, and films were developed using classic equipment with silver bromide, thinners, and other chemicals. The procedure for disposing of this waste is unknown.

Of the other facilities, there was a battery station at the airport, but it is not known what chemicals were used. There was an elevator in the building that led to the meteorological station and the air traffic control tower.

In addition to the airport building itself, in its complex there is also the "Željava" military quarters, which housed about 250 soldiers, with the reserve accommodation capacity for an additional 1000 soldiers.

The military quarters included other ancillary facilities, such as:

- restaurant with a capacity to serve up to 1,500 soldiers,
- motor vehicle maintenance workshop,
- gas station with 5 tanks whose capacities are unknown.
- boiler room on solid and liquid fuels.

In the period from 1990-1991. in the area of the military quarters, a wastewater treatment plant "Emsher Chamber" was built. The capacity and functionality of the plant are unknown. The access road and the location of the abandoned military quarters are overgrown with low and high vegetation. The entrance gate is locked with a restraining order warning.

After the war, Zeljava Airport was not used for either military or civilian purposes, as its maintenance was extremely expensive. By mining the underground facility while leaving the former army, the airport was severely damaged, including the protective concrete lining of the underground tunnels and facilities. The internal damage to the "Klek" building has not been investigated in detail to date. Despite the stated contents of this military facility, it is not known what material and technical means and equipment were taken from the airport before its mining, i.e. what equipment, means and waste were left inside the massif (oils, lubricants, radioactive substances and other harmful substances matter).

The airport and military quarter in Udbina is a military facility that is active. The military quarter has an internal sewerage network with a septic tank that is periodically emptied. The facility has an approval in terms of meeting water requirements. The spatial coverage of the airport and military quarter is about 75 ha. The space is completely fenced, there are no fuel tanks or gas stations inside the space. Fuel for the regular needs of the military facility is delivered by tank.

Figure 8.23: *Spatial coverage of the military quarter and Udbina airport*

Minefields

Uncleaned minefields in the Klokot water source catchment area are located in the forest parts of the Plitvice Lakes municipality. Mined areas have been identified at a total of 23 locations located in the database of the Plitvice Lakes Municipality.

In the area of Udbina municipality a total of 6 locations with minefields were identified, which have been completely cleared in the last decade.

Livestock farms

Livestock production in the catchment area is particularly pronounced in the municipality of Udbina, where 14 livestock farms are registered. In the area of the municipality of Plitvice Lakes (Korenica) only one cattle farm is registered.

On farms in the Klokot water source catchment area in the Republic of Croatia, a total of around 1,050 head of cattle and 7,400 heads of small cattle are raised.

Devices for collecting low tide and wastewater treatment have not been built or installed on these farms. Farm manure is used as organic fertilizer in agricultural production, although most of the manure remains on pastures. Most livestock move to areas with a more temperate climate during the winter months.

The following table shows the farms with the maximum number of livestock.

Table 8.4: *Farms with the number of livestock in the Klokot and Privilica catchment area in the territory of the Republic of Croatia*

Name of the farm	Location	Number and type of livestock
Korenica	Korenica	50-60 cattle
Natura BIF	Udbina / Rebić	300 cattle
Plitvice BIF	Udbina / Rebić	400 cattle
OPG Gučanin	Udbina / Krbavsko polje	1.000 sheep
Šolaja	Udbina / Jošani	300 sheep
Bioplod-Lika	Udbina / Krbavsko polje	1.000 sheep
OPG Ljubica Amić i OPG Paulina Amić	Udbina / Krbava	500 sheep, 200 cattle and 100 horse
OPG Dejan Dragaš i OPG Saša Dragaš	Udbina / Bunić	1.500 sheep
OPG Milan Knežević	Udbina / Bunić	500 sheep
OPG Jovica Čortan	Udbina / Bunić	300 sheep
OPG Vojvodić Dušan	Udbina / Grabušić	500 sheep
OPG Delić Saša	Udbina / Grabušić	600 sheep
OPG Bioplod	Udbina / Klašnjca	400 sheep
OPG Škorić Stevo	Udbina / Frakašić	400 sheep
OPG Ćuprija Milan	Udbina / Frakašić	400 sheep

During the year, the number of listed cattle varies. In addition to the number of heads on registered farms, it is estimated that in this area there are between 100-150 head of cattle, 300-400 sheep and 100-200 pigs individually owned by the population.

Gas stations (GS)

In the catchment area of the Klokot water source in the Republic of Croatia, there is only one commercial gas station in the municipality of Plitvice Lakes, i.e. in the urban zone of Korenica (GS "INA"). Fuel is stored in underground tanks that are isolated. Sanitary wastewater is disposed of in a properly constructed septic tank that is periodically emptied. Rainwater is collected and treated through oil and grease separators. The facility has a work permit.

In addition to the gas station in the catchment area of the Klokot water source in the Republic of Croatia, i.e. in the municipality of Plitvice Lakes, there are two other internal gas stations with smaller fuel tanks, but there is no accurate record of the amount of fuel stored here annually. These are GS Mukinje (for the needs of NP "Plitvice Lakes") and GS of the company "Knežević prijevoz" on Prijeboj.

In the area of the top of Plješevica, according to the information of the representatives of the municipality of Plitvice Lakes, there are fuel tanks that are not in use and were used by the former Yugoslav army. The storage has a capacity of 100 tons of diesel fuel and was used for the needs of providing electricity for radar and meteorological equipment, as well as for the needs of heating and motor vehicles.

Public institution

In the area of the municipality of Plitvice Lakes, there are several public institutions such as the Korenica Health Centre, which provides emergency, family and dental services to the citizens of Korenica, Plitvice Lakes and Udbina. The capacities of the Health Centre are very small and limited. In addition to the Health Centre in the area of Korenica, there is one primary school and one secondary school with a total of 630 students. Wastewater is discharged from public institutions into the public sewerage system of Korenica.

Tourist capacities in the Klokot catchment area in the Republic of Croatia

Plitvice Lakes National Park (NP) - is the most significant tourist potential in the catchment area of the Klokot water source in the Republic of Croatia with a total area of about 29.7 km2.

NP "Plitvice Lakes" in its tourist offer has several hotel facilities with a capacity of over 400 rooms. Wastewater from the area of the national park is collected through a built sewerage network that includes the area from the settlements of Jezerce, Mukinje, Plitvice and Rastovaca. Wastewater is delivered to the settlement of Rastovača where there is a temporarily built wastewater treatment plant with a capacity of 2,000 PE. It should be noted that in the summer period, when the largest and most intensive visit of tourists to the NP "Plitvice Lakes", wastewater comes to the plant for 2,500 PE.

The most important tourist settlements in the catchment area are the motel "Borje" with a camp and the camp Korana (Čatrnja). From the motel and auto camp Borje, wastewater is treated with a wastewater treatment plant (II stage of treatment), capacity 460 ES, which is in operation. Wastewater from the Korana campsite is collected in a collection pit with a sedimentation tank. Maintenance and pumping of wastewater is regularly performed by the utility company from Rakovica. In addition to those listed within the NP "Plitvice Lakes", hotel facilities also exist in the settlement of Ličko Petrovo selo (hotel Lyra) as well as in hotel Macola in Korenica.

One of the greatest potentials in terms of tourist capacity is private accommodation, apartments and rooms, which are experiencing their expansion, especially in recent years. According to the data on the number of overnight stays in the municipality of Plitvice Lakes in 2019, a total of 445,247 overnight stays were recorded, which is an increase of almost 50% in the last 5 years.

According to the data on the number of overnight stays in the municipality of Plitvice Lakes in 2019, a total of 445,247 overnight stays were recorded, which is an increase of almost 50% in the last 5 years.

The following table presents data on the number of overnight stays in hotel facilities, campsites and private apartments.

Table 8.5: *Number of realized tourist nights in the period 2015 – 2019*

Year	Private accom-modation	Hotel accom-modation	Camp accom-modation	Total
2015.	121.799	161.854	16.910	300.563
2016.	156.476	156.853	16.837	330.166
2017.	211.725	176.443	23.526	411.694
2018.	228.565	179.280	24.976	432.821
2019.	243.681	178.411	23.155	445.247

In the next period, it is planned to expand privately owned apartment capacities, as well as build a new hotel in Korenica, which in case collection and wastewater treatment is not carried out according to existing regulations will further affect the quality of groundwater and surface water in the catchment area of Klokot.

Tourist capacities and their further expansion in the area of the municipality of Plitvice Lakes have and will have a great impact on the groundwater of the catchment area of the Klokot water source in the coming period.

Agricultural activities

According to the indicators from the Spatial Plan of Lika-Senj County from 2002, which is still current, agricultural areas make up about 50% of the total area (2,675 km2) of the county. Of that number, about 42% are arable land (1,123 km2), and the remaining about 58% are other areas mostly unsuitable for cultivation (karst pastures).

In the Klokot water source catchment area in the Republic of Croatia, intensive agricultural production has been significantly declining in the last decade, especially in the area of Krbavsko and Koreničko polje. More intensive agricultural activities are carried out only in the area of Lički Petrovo Selo, where agricultural land has been cultivated for several years on an area of about 100 ha. Corn and fodder plants are mainly grown in this area. Manure is mainly used as fertilizer, which is brought from other parts of Lika-Senj County, especially from the farm in Sadilovac. Data on the type and amount of use of pesticides or any other fertilizers are not known. These agricultural areas are located only 8.5 km northwest of the water source of Klokot. The application of any types of fertilizers and pesticides for agricultural purposes in this area have a direct impact on the water quality at the source of Klokot.

Forest exploitation

In the territory of the Republic of Croatia, forest exploitation takes place within the forestry company UŠP Gospić, which is part of the business company "Croatian Forests". More detailed descriptions of forest management and exploitation are discussed in a separate chapter.

Permanently inhabited population

About 6,247 people live in the catchment area of the Klokot water source in the Republic of Croatia. According to the 2011 census, the area of the municipality of Plitvice Lakes (including Korenica) has 4,373 inhabitants in 41 settlements, and the area of the municipality of Udbina has 1,874 inhabitants.

Collection and treatment of wastewater of permanently inhabited population and tourist facilities

In the area of the Klokot spring basin in the Republic of Croatia and in Lika-Senj County in general, wastewater collection and treatment is not at a satisfactory level and is below the national average, which is especially pronounced in the municipality of Udbina. In the area of the Klokot water source catchment in the Republic of Croatia and in Lika-Senj County in general, wastewater collection and treatment is not at a satisfactory level and is below the national average, which is especially pronounced in the municipality of Udbina.

The sewerage system of the municipality of Udbina includes only parts of the narrower central part of the city and consists of several smaller pipelines of negligible length with a mixed collection system and with direct discharge of wastewater into the karst underground. Only 21 households and 3 legal entities are connected to this sewerage system. The population uses septic tanks that do not meet the water tightness requirements for wastewater disposal. Out of a total of 303 septic tanks registered, only about 10% were properly built.

In the area of the municipality of Plitvice Lakes, a sewerage system over 12.5 km long has been built, which includes the settlements of Jezerce, most of Mukinje, Plitvice and Rastovac, which covers over 50% of the population together with tourist facilities. Wastewater from these settlements and the tourist complex of the national park is delivered to the "Temporary assembly-disassembly device for wastewater treatment" with a capacity of 2,000 ES. According to the information of the representatives of NP "Plitvice Lakes", during the summer period when the highest intensity of tourist visits of the mentioned WWTPs, it treats wastewater up to 2,500 PE. The treated wastewater is discharged from the WWTP into the natural sinkhole "Rastovača", which according to the tracing of groundwater has a direct connection with the source Klokot.

The installed wastewater treatment plant is of MBR (membrane biological reactor) technology, it was put into operation in November 2018 and is currently in function as a temporary solution. A permanent solution for the part of the agglomeration (Plitvice Lakes 1) that covers the area of NP "Plitvice Lakes" is planned to be solved by a new sewage pipeline to the settlement of Čatrnja where a new WWTP with a capacity of 9,400 PE should be built at the location of Čatrnja with III stage of treatment wastewater. The study-project documentation for the project of wastewater collecting and treatment from this area has been completed and the construction of this device is expected in the coming years, which will be mostly financed by European funds.

The technological characteristics of the MBR wastewater treatment plant are shown in the following table.

Table 8.6: *Indicators of permissible limit values and the possibility of cleaning the installed device*

Indicator	Measuring unit	Limit value	Possibility of treatment
BOD_5	mg O/l	25	< 2
COD_5	mg O/l	125	< 30
Total N	mg N/l	10	< 10
Total P	mg P/l	1	< 1
Suspended substances	mg/l	60	< 2
Intestinal enterococci	cfu/100 ml	400	0
Escherichia coli	cfu/100 ml	1000	0

Figure 8.24: *Temporary WWTP (MBR type) and discharge pit " Rastovača "*

The existing sewerage network is of a mixed type, about 2.5 km long, and mainly collects wastewater from the urban part of the settlement, to which about 530 households are connected. Wastewater is fed to the central septic tank (underground multi-chamber facility) through the sewerage network and the main collector. After settling, the water from the multi-chamber septic tank overflows into the Matica stream, which ends in the Korenički abyss. For the discharge of water from the multi-chamber septic tank into the Matica riverbed, the Korenica water company has a discharge permit. By tracing the underground flows from the location of the Korenički abyss, the direct connection of this abyss with the source of Klokot was proven.

The rest of the households use individual septic tanks to dispose of wastewater. According to the estimates of the water company in the area of Korenica, there are about 840 septic tanks, of which about 70% are improperly built. Small number of septic tanks have a recorded database of this company.

Collection and treatment of wastewater in the second part of the agglomeration (Plitvice Lakes 2), i.e. the area of the settlement Korenica is planned to be realized in the next few years. Study and project documentation have been prepared for the entire area of the Korenica settlement. In the following period, the construction of a sewerage network and another wastewater treatment plant is planned for the Korenica area. The projected capacity of the WWTP is 4,850 PE. Most of the permits for undisturbed construction have already been obtained for the construction of certain sections of the sewerage system in Korenica.

Industrial polluters

There are no significant industrial companies in the catchment area of the Klokot water source in the territory of the Republic of Croatia. The most important economic and industrial plants such as Likagraf - Korenica, Invaplast - Udbina, Sait - Udbina, Likaplast - Udbina, Wood processing - Korenica, Asphalt base Rudanovac - Korenica, as well as a number of smaller industrial companies are no longer working.

The wood industry and wood processing in the catchment area of the Klokot spring in the Republic of Croatia has been significantly declining in the last decade. Wood processing is performed only by the pellet production plant "Moderator" in the municipality of Udbina. The sawmill in Korenica is no longer active and is currently undergoing bankruptcy proceedings.

Municipal development plans

The most significant activities that are planned to be realized in the catchment area of the Klokot water source refer to the municipality of Plitvice Lakes. The development plan of the municipality of Plitvice Lakes plans to build a business zone in the settlement of Prijeboj primarily for the needs of NP "Plitvice Lakes" with the construction of 16 new buildings (a single warehouse for the needs of the NP with laundry, bakery, butcher, administration, office space, gas station and other facilities laundry, bakery, butchery, administration, office space, gas station and other facilities service) pump as well as other facilities). There is no information whether this business zone will be connected to the existing sewerage system and WWTP managed by NP "Plitvice Lakes" or a special sewerage system will be built for this business zone and connected to a new wastewater treatment plant in Čatrnja (part of Plitvice Lakes agglomeration 1). In addition to the business zone, the expansion of tourist capacities, especially private accommodation, is expected in the coming period. It is expected that the implementation of the development plan of the municipality of Plitvice Lakes and the construction of a business zone on Prijeboj will have a significant impact on the water source of Klokot.

Roads in the area

There are several state roads in the territory of the Republic of Croatia, which have a very heavy traffic. In addition to the state road 1 (D1), the section Karlovac - Plitvice Lakes - Korenica - Udbina, the catchment area of the Klokot water source is intersected by other state roads that intersect with the state road D1.

The following table shows all the roads located in the Klokot catchment area.

Table 8.7: *Highways of the Republic of Croatia in the Klokot catchment area*

Label	The length of the road in the catchment area	Direction
D1	86,0 km	Karlovac - L. P. Selo - Prijeboj - Korenica - Udbina
D504	2,5 km	L. P. Selo – border crossing with BiH
D217	3,5 km	Rakovica - L. P. Selo – Border crossing Izačić (BiH)
D218/i D506	29,0 km	Korenica - Frkašić - Donji Lapac - Srb
D25	27,0 km	Korenica - Lički Osik
D52	23,5 km	Borje - Babin potok – Otočac
D42	13,5 km	Plitvice – Saborsko

These roads are roads with free drainage, without built-in grease and oil separators, and are a significant subject of interest and attention in order to protect the source of Klokot. These roads are used, among other things, for the transport of tanks for the transport of fuel and other dangerous and harmful substances. There are no signs (traffic signs) on these state roads warning that traffic is passing through the protected area of the Klokot water source.

Traffic on these roads is a constant potential source of pollution, which can occur at sources in the event of excessive overturning of tanks and leakage of pollutants into groundwater. In addition, various pollutants accumulate on the impermeable surfaces of roads, which are washed away from the asphalt surfaces during precipitation, from where they mostly reach the groundwater.

8.5 ESTIMATION OF POLLUTION LOADS IN CATCHMENT AREA OF WATER SOURCE KLOKOT

The estimation of the pollution load in catchment area of water source Klokot was made based on the collected data on polluters in catchment area and unit pollution per population equivalent (PE).

Overview assessment of pollution load for the largest polluters in catchment area of water sources Klokot is shown in Table 8.8.

Table 8.8: *Estimation of the pollution loads generated in catchment area of water source Klokot*

Polluters		Unit	Quantity	Unit load (PE)	Total load (ES)
Bosnia and Herzegovina					**12.885,00**
Quarry Željava/Baljevac 1		ha	0,4	500	250
Quarry Baljevac 2		ha	0,1	500	50
Quarry Baljevac 3		ha	0,6	500	300
Quarry /material lenders Zavalje		ha	1,6	500	800
Quarry Međudražje		ha	4,6	500	2.300
Landfill Vučjak		ha	8,0	870	6.960
Landfill Mali Baljevac		t	17,5	2,5	44
Landfill "Bezdan" Međudražje		t	10,5	2,5	26
Border crossing Izačić		PE	283	1	283
Permanently inhabited population		person	510	1	510
Forest exploitation		km^2	40,4	30	1212
Roads (No. of vehicles / day)		vehicles	do 500	0,8	400
Croatia					**(28.187,00)**
Quarry Prijeboj		ha	2,2	500	1.100
Gravel Frkašić		ha	10,3	500	5.150
Landfill Vrpile / Kalebovac		ha	3,34	870	2.906
Wild landfills (karstic pits)		t	54	2,5	135
Livestock farms	Cattle	livestock	1.050	0,83	871
	Small cattle	livestock	7.400	0,08	592
Permanently inhabited population		person	6.247	1	6.247
Agriculture (tillage)		ha	100	4,5	450
Tourist capacities of NP "Plitvice Lakes" and private offer		tourists employees	1.220 90	0,08 0,42	98 38
Forest exploitation		km^2	220	30	6600
Roads (state road D1)			do 5.000	0,8	4.000
				Total (B&H and Cro):	**41.072,00**

9 VEGETATION CHARACTERISTICS OF THE SOURCE BASIN

The catchment area of the Klokot spring is to a lesser extent located in Bosnia and Herzegovina (only 9.51% of the total catchment area, i.e. 90.5 km^2), while the larger part of the catchment area is in the territory of the Republic of Croatia (90.49%, i.e. 861, 0 km^2).

Vegetation cover of the entire catchment area consists of significant areas of karst pastures that are particularly pronounced in the catchment area in the Republic of Croatia, then arable and uncultivated agricultural land (meadows, orchards, etc.), and the most important areas - forest ecosystems that are the main determinant of the stability of the recharge of the Klokot spring with drinking water.

9.1 ANALYSIS OF THE CONDITION OF FORESTS AND FOREST LANDS IN THE KLOKOT SPRING CATCHMENT AREA

Forest areas in the entire catchment area of the Klokot spring cover an area of a total of 51,833.2 ha (BiH and the Republic of Croatia), which represents 54.46% of the total catchment area. The total mass of the forest ecosystem in the spring basin is estimated at about 9.75 million m^3 of wood mass with an average stock of 188 m^3 / ha.

Table 9.1 *Overview of forest management with wood stocks and catchment areas*

Forest ecosystem	**Ownership**	**Average stocks**		**Area**	**Representation of forests in the basin**
		MIL (m^3)	(m^3/ha)	(ha)	(%)
Bosna i Hercegovina	Forest company „Una-Sana Forests“ (ŠPD Unsko-sanske šume)	1,115	199,6	5.589	5,87
Republic Croatia	Hrvatske šume d.o.o.	5,737	186,8	30.714	32,27
	Šume NP Plitvička jezera (Plitvice Lakes National Park)	2,900		15.530	16,32
Total:		**9,753**	**188,1**	**51.833**	**54,46**

Further in text is in more detail described the forest ecosystems of the basin in BiH and the Republic of Croatia.

9.2 FORESTS AND FOREST LAND IN FEDERATION OF BOSNIA AND HERZEGOVINA

Forest wealth in the area of Una-Sana Canton (BiH) is managed by the Forest Company SPD "Una-Sana Forests" (ŠPD "Unsko-sanske šume").

In the catchment area of the Klokot spring in BiH, the forest ecosystem occupies an area of 5,589.20 ha, which is about 5.9% of the total catchment area. The catchment area includes parts of economic units of MU Plješevica with an area of 5,506.8 ha and MU Gata with an area of 82.4 ha.

MU Plješevica covers a much larger part of the catchment area (98.5%), however, MU Gata differs a lot according to the category of forest species and stocks. Based on the data on wood mass stocks by management units, the average stocks of MU Plješevica are 217.50 m^3 / ha, while for MU Gata only 57.30 m^3 / ha.

According to forest categories, on an area of 5,159.70 ha there are high forests, forest crops and coppice forests. Shrubs, bare and unproductive forests are located on an area of 298.50 ha, and the rest of 131.00 ha are areas of other forest land.

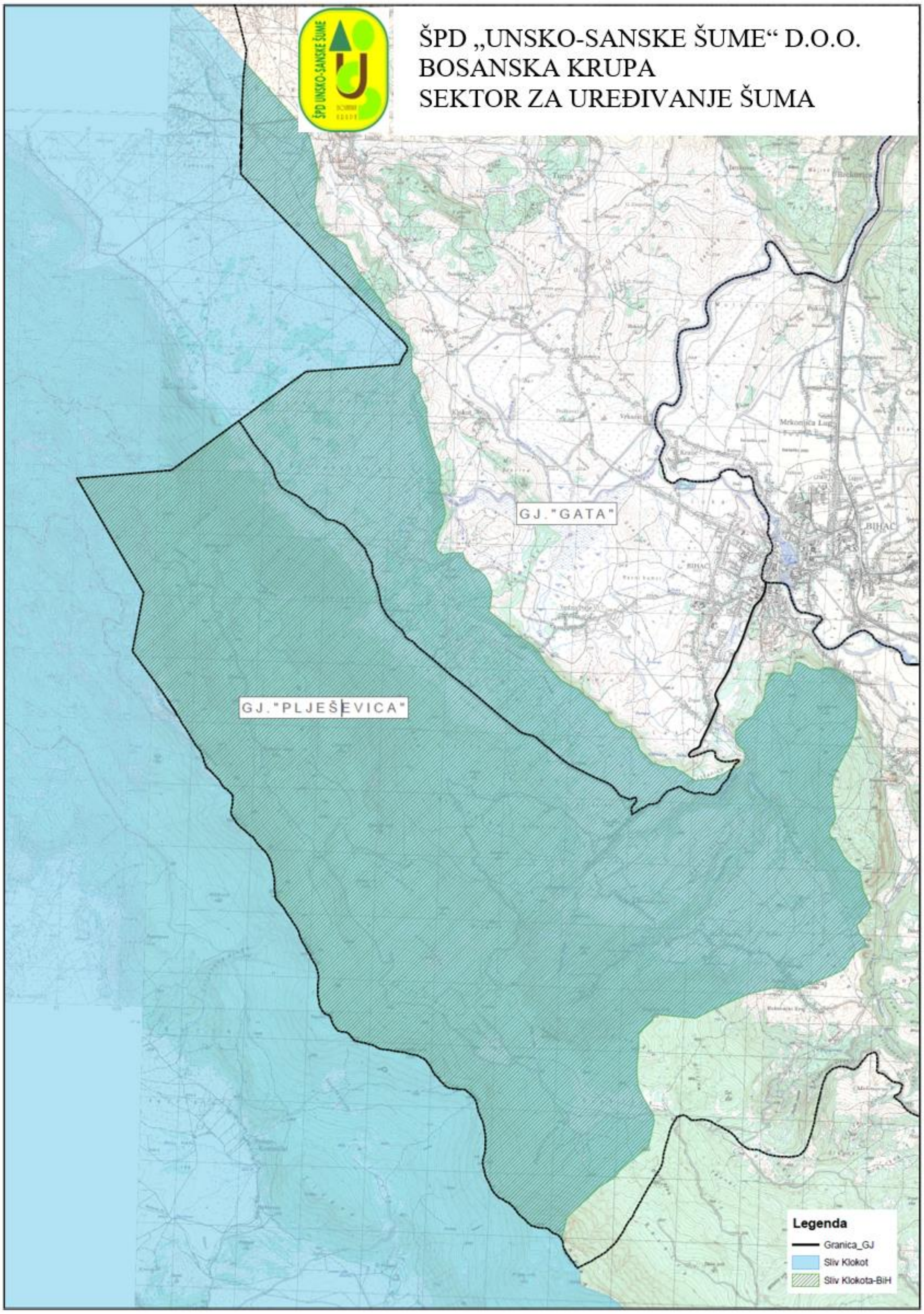


Figure 9.1 *Overview of the forest ecosystem area in the Klokot spring basin in BiH*

According to data from 2019, the total wood stock in the catchment area is estimated at 1,115,599.50 m^3. Basic data on forest areas, categories and timber stocks for both economic units are shown in the following table.

Table 9.2 *Overview of forest categories, areas and stock masses of MU Plješevica and MU Gata*

Category	Code	Total area	Stock of wood mass	
		(ha)	(m^3/ha)	∑ (m^3)
High forests with natural regeneration	1000	3.589,50	275,17	987.718,50
Forest crops	3000	396,00	54,06	21.406,20
Coppice forests	4000	1.174,20	90,68	106.474,80
		5.159,70		
Shrubs and bare	5000	289,40		
Unproductive forests	6000	9,10		
Other forest land	7000	131,00		
Total:		**5.589,20**		**1.115.599,50**

Within the forest area there are unsafe areas with minefields that cover an area of 1,118.70 ha. No forest exploitation activities are carried out in these insecure areas.

Forest logging (deforestation) is carried out on an area of 4,041 ha, the annual average forest logging (2009 - 2019) in the catchment area is 9,300.10 m^3. According to the average increase in forest wealth of 5.49 m^3 / ha, deforestation accounts for 41.87% of the annual increase, or 2.3 m^3 / ha, which allows rational forest management on long term.

In the forest ecosystem of this part of the basin, natural forest growth is particularly pronounced, and covers about 99% of forest areas, while afforestation cultivates about 1% of forest areas. Basic data on stocks, felling ratio and growth of forest ecosystem are shown in the following table.

Table 9.3 *Overview of areas, stocks, increments and felling of timber in the BiH basin (2009-2019)*

Forests areas	Total stocks of wood mass		Annual increase		Annual logging		Logging in relation to increment
(ha)	(m^3)	(m^3/ha)	(m^3)	(m^3/ha)	(m^3)	(m^3/ha)	(%)
4.041,00	1.115.600	276,00	22.211	5,49	9.300	2,3	41,87

The improvement of the forest ecosystem is certainly contributed by the fact that in the last 15 years there has been a progressive succession of forest vegetation in this part of the basin, i.e. there is a natural expansion of forests on previously cultivated areas, which significantly increases wood mass and stocks.

In the economic area of ŠPD " Unsko-sanske šume " in the basin area there are about 131 ha of wooded areas, meadows, pastures and barren lands. These areas provide the possibility, in addition to the progressive succession of forest vegetation, and the progression of vegetation by artificially increasing the growth of the forest ecosystem by additional afforestation.

Erosive processes in this part of the forest ecosystem are not pronounced due to the planned deforestation and maintenance of forest roads. There are certain damages caused by weather conditions, which are manifested by breaks and eruptions of trees, after which they are removed according to the plan of sanitary logging.

In the next period, within the forest ecosystem in the basin, apart from the planned logging, the construction of new forest roads or other infrastructure is not planned until 2021, when a new Forest Management Plan for the forests of Una-Sana Canton will be developed.

In general, compared to the situation in 2004, a significant improvement of the forest ecosystem in the spring basin is evident. This situation is partly due to the previous Decisions of the City of Bihać on the protection of the Klokot spring and strict restrictions on deforestation in protected areas.

9.3 FORESTS AND FOREST LANDS IN THE REPUBLIC OF CROATIA

Forest wealth in the catchment area of the Klokot spring in the Republic of Croatia is managed by the company "Hrvatske šume" d.o.o. Zagreb (except for a part of the forests in the national park managed by the Plitvice Lakes National Park). Forest management is divided into several Forest Administrations - subsidiary, FAS Gospić manages forests in the municipalities of Plitvice Lakes and Udbina, while smaller parts of the forest area in the catchment area of the source Klokot in Rakovica municipality is managed by FAS Karlovac, and in Saborsko forests by FAS Ogulin.

The area of the forest ecosystem and the territorial affiliation of the forest ecosystems are shown in the following figure.

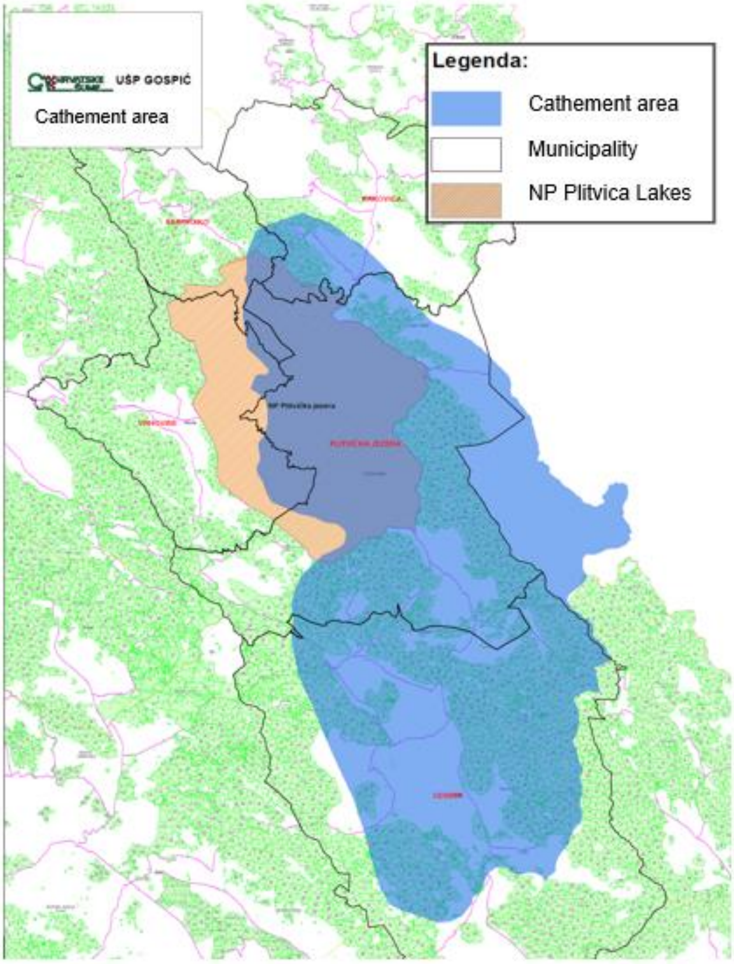


Figure 9.2 *Overview of the forest ecosystem in the Klokot spring basin in the Republic of Croatia*

The total area of the forest ecosystem in the catchment area of the Klokot spring in the Republic of Croatia is 46,244 ha. All forest areas are systematized into commercial, protective and special purpose forests. Data on forest management and areas are shown in the following table.

Table 9.4 *Overview of forest ecosystem areas in the Klokot spring basin in the Republic of Croatia*

Forest administration - subsidiary	Territory	Area (ha)
FAS Gospić	Municipality Plitvička Jezera	12.512,0
	Municipality Udbina	16.372,0
FAS Karlovac	South part of Rakovica municipality	1.420,0
FAS Saborsko	South-east part of Saborsko municipality	410,0
NP Plitvička jezera	Central and east part of National Park	15.530,0
	Total (ha):	**46.244,0**

The total mass of the forest ecosystem in the basin on the territory of the Republic of Croatia is estimated at about 8.6 million m3 of wood mass reserves (including the forests of the Plitvice Lakes National Park), with an average stock of 185.7 m3 / ha.

In the area covered by forests of 30,714 ha managed by the company Hrvatske šume (does not include the forests of NP "Plitvice Lakes"). The total mass of the forest ecosystem is estimated at 5.74 million m3, 81,645 m3 of wood is been cut annually, of which about 4.5% is sanitary and 95.5% is rows.

As in the part of the catchment area in BiH, the forest ecosystem is dominated by high forests with natural regeneration with a significant share of coppice forests. In addition, there is a natural increase in forest, which is almost 97%, while afforestation accounts for about 3% of the increase. According to the ten-year average growth of forest wealth, deforestation covers 70.2% of the annual growth.

Basic data on stocks, increments and felling are shown in the following table.

Table 9.5 *Overview of areas, stocks, increments and felling of wood mass in the basin of the Republic of Croatia (2009-2019)*

Forests area	Total stocks of wood mass		Annual increase		Annual logging		Logging in relation to increment
(ha)	(m^3)	(m^3/ha)	(m^3)	(m^3/ha)	(m^3)	(m^3/ha)	(%)
30.894	5.737.668	185,72	116.282	3,78	81.645	2,66	70,3

In addition to the above, the improvement of the forest ecosystem is also contributed by the fact that in the last ten or more years there has been a progressive succession of forest vegetation (natural expansion of the forest on previously cultivated areas).

In the economic scope of Croatian Forests, there are about 4,500 ha of unforested areas, meadows and pastures, mosaically distributed throughout the forest complex. These areas, as previously mentioned, provide an opportunity to increase the growth of the forest ecosystem through afforestation.

In addition to the natural growth of forests, the improvement of the forest ecosystem is certainly contributed by forest areas with special purposes such as the forests of NP "Plitvice Lakes" whose area in the basin covers about 15,530 ha, with an estimated stock of about 2.9 million m^3 of wood. In accordance with international standards, deforestation in the area of NP "Plitvice Lakes" is not carried out and it is left to natural regeneration processes.

Erosive processes in this part of the forest ecosystem are also not pronounced due to planned logging activities and maintenance of forest roads. Any damage (fractures, eruptions, etc.) is periodically repaired.

In the period from 2010 to 2020, a total of 94 km of forest roads were built. In the following period until 2026, the construction of new forest roads in the total length of about 35 km is planned within the forest ecosystem. The realization of other infrastructure projects is not planned until 2026, when a new Forest Management Plan will be developed.

9.4 DEFORESTATION ALONG THE BORDER BETWEEN FBIH AND RC

The exception to planned logging on the territory of the Republic of Croatia is certainly logging carried out by the company "Croatian Forests" in the border area with BiH in order to establish a zone to control and prevent illegal entry of migrants from BiH into the Republic of Croatia. The logging works were carried out during the months of May and June 2020 in the area of the Plješivica Mountain, above Baljevac and the Željava military airport. The logging is so controversial, because part of the logging was carried out in the economic unit (MU) Plješivica in Bosnia and Herzegovina, more precisely on the stretch Željava - Kurića vrh, as shown in the following figure.

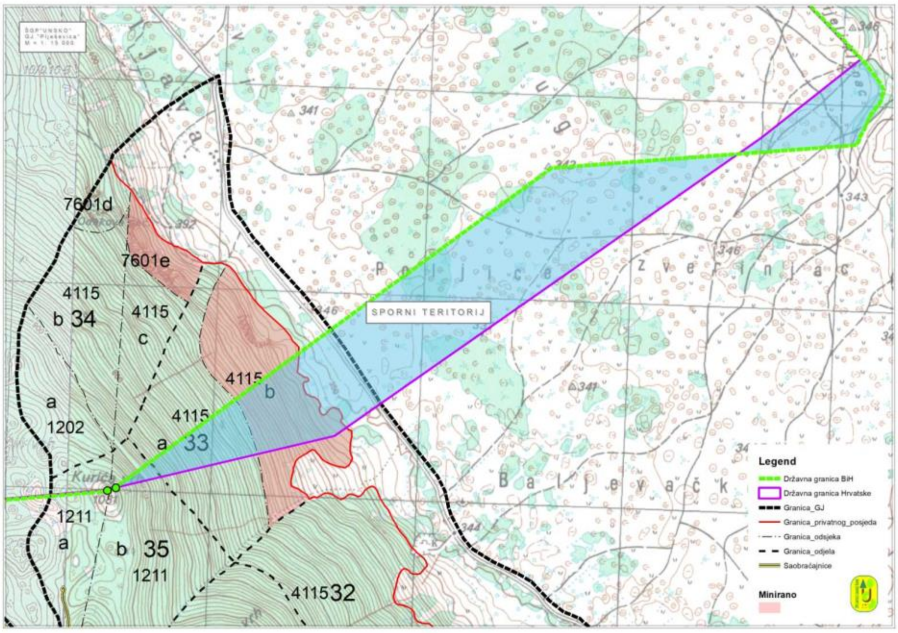


Figure 9.3 *Overview map of the disputed territory where deforestation is carried out (source: Association of the Association of Forestry Engineers and Technicians of FBiH)*

According to available information, logging is planned on the intersection of the corridor about 8 kilometres long and 100 meters wide (80 ha), but the situation on the ground can determine that the area of felled forest is much larger, and is estimated at an area of about 150 ha.

Figure 9.4 *Deforestation on Plješivica mountain*

In addition to the above, what is worrying additionally, is the logging in the area of the Plješevica rainforest. The rainforest is located on the territory of both countries and covers an area of about 500 ha. Rainforests are a special value of forests and forest ecosystems, which enjoy the highest degree of protection in the world compared to other ecosystems.

According to the International Union for Conservation of Nature (IUCN), signed by BiH and the Republic of Croatia, rainforests are in the first category of protection (Ia and Ib), which means:

- Ia - Strictly protected areas for the purpose of scientific research;
- Ib - Strictly protected wilderness areas.

This example of deforestation can be characterized as a very gross violation of European nature protection directives and international environmental standards by the competent institutions of the Republic of Croatia.

The previously described deforestation on the Plješevica corridor will in any case cause changes and disturbances in the biological balance of the forest ecosystem at this locality, which will result in pronounced negative impacts of biotic and abiotic factors in the form of wind and snow, disturbances of the general forest condition, the occurrence of erosive process, etc., which will eventually be reflected in the qualitative and quantitative characteristics of the water at the source of Klokot.

9.5 CONCLUSION

Taken as a whole, except for deforestation on the Plješevica border corridor, a significant improvement of the forest ecosystem in the catchment area has been achieved compared to 2004 when the project for the protection of the Klokot and Privilica springs was developed. The improvement is particularly pronounced in the development of high forests with natural regeneration, increasing natural forest growth and increasing wood stock in forests.

In addition to the evident progress of forest ecosystems in the catchment area of the Klokot spring in both countries in the period 2004-2019, and the unplanned crossing of the corridor, the habitat potential provides exceptional conditions for further improvement and enhancement of forest quality.

In order to improve and maintain the stability of the forest ecosystem of the catchment area and the water supply of the Klokot spring, the main recommendations are certainly:

- prevent any form of further reduction of areas with forest cover;
- implement measures to protect the forest ecosystem, especially for protected areas (rainforests and special purpose forests);
- plan to carry out deforestation that is in accordance with the norms of deforestation according to the natural and artificial growth of the forest ecosystem;
- enable the expansion of forest areas with the establishment of better quality cover, either by direct conversion (logging of existing low forests and introduction of coniferous tree species) or gradual transfer of low forests to a higher cultivation form, and
- plan afforestation in order to create a better structure of the catchment area, with indigenous tree species, in accordance with the protection of biotopes and the return of the value of the landscape, as well as the use of habitat potential
- Stop deforestation along the border between the Republic of Croatia and Bosnia and Herzegovina, as well as intensive construction of forest roads, otherwise this activities will lead to a significant deterioration in the quality of surface and groundwater in the catchment area of the Klokot spring.

10 CHARACTERITICS OF EROSION PROCESSES IN THE CATCHEMENT AREA

In general, the effect of erosion processes in the catchment area is the production of sediment, which occurs by undermining torrents and soil washing, with its transfer to river flows and pits with consequences of their backfilling, eutrophication and in the end, the transported sediment reaches groundwater, where sedimentation occurs. and deposition of part of the sediment in the system of karst conductors, which is manifested by the turbidity of groundwater.

The largest part of the Klokot spring catchment area is built of carbonate rocks, which are mostly overgrown with vegetation (forests, karst pastures and meadows), and on the other hand some smaller parts of the catchment area are completely bare where the erosion process has ended. Based on that, the erosive processes in the Klokot catchment area can be characterized as weak.

Referring to the previous process from 2004, the estimated total annual sediment production in the catchment area is stated, with the important note that - given the karst characteristics and the sinking of groundwater - only part of the sediment is deposited. in a system of underground fissures.

There is practically no drawn sediment in the area of the Klokot spring, and the results of erosion processes in the influential Klokot catchment area are manifested as floated (dispersed) sediment or suspended and colloidal particles, respectively as occasional turbidity of water at its source. Turbidity at the source of Klokot was measured on individual days in the period from March 27, 2006 to May 21, 2020, and a total of 514 measurements were performed. It is important to note that in the past almost 15 years, the sampling intensity at Klokot spring was not at a satisfactory level. The analysis of water quality was conducted twice on average, which is insufficient for the water supply system that supplies water to about 50,000 inhabitants of the City of Bihać.

Data of the turbidity measurement ***M***, with the adopted turbidity limit of 1,0 NTU, jointly with the corresponding water flows ***Q***, are given in the table 9.1.

Table 10.1 *Overview of turbidity measurement of Klokot in the Klokot profile (27. 3. 2006.-21. 5. 2020.)*

Date	***Q*** **(m^3/s)**	***Turbidity*** **(NTU)**	**Date**	***Q*** **(m^3/s)**	***Turbidity*** **(NTU)**	**Date**	***Q*** **(m^3/s)**	***Turbidity*** **(NTU)**
(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
27.3.2006.	32,5	1,84	3.12.2012.	25,5	1,68	6.9.2017.	6,6	1,4
29.3.2006.	39,3	1,74	7.12.2012.	24,9	1,66	8.9.2017.	5,9	1,1
20.4.2006.	39,7	3,18	17.12.2012.	48,5	1,69	**12.9.2017.**	**20,4**	**5,1**
6.6.2006.	28,4	2,5	**21.1.2013.**	**58,7**	**10,6**	14.9.2017.	15,2	2,5
4.1.2007.	**16,3**	**5,03**	4.2.2013.	27,3	1,65	18.9.2017.	23,9	3,2
8.1.2007.	14,7	1,3	1.4.2013.	61,8	2,54	22.9.2017.	18,7	1,5
8.6.2007.	11,1	1,86	11.11.2013.	39,1	1,93	**7.11.2017.**	**33,0**	**4,1**
12.9.2007.	**25,4**	**10,0**	15.11.2013.	27,3	1,66	10.11.2017.	21,1	3,3
17.9.2007.	8,8	1,66	26.11.2013.	44,5	1,67	27.11.2017.	23,7	1,1
23.10.2007.	**19,4**	**4,16**	10.2.2014.	36,4	1,57	1.12.2017.	47,5	2,3
29.10.2007.	21,9	1,36	24.2.2014.	37,3	2,2	4.12.2017.	25,2	1,5
1.11.2007	**38,4**	**14,1**	28.4.2014.	36,5	1,3	**13.12.2017.**	**50,8**	**5,1**
5.11.2007.	20,0	1,04	**5.5.2014.**	**59,1**	**13,0**	19.12.2017.	40,2	1,7

9.1.2008.	29,1	2,28	7.5.2014.	38,2	3,1	19.3.2018.	74,4	3,7
25.3.2008.	59,3	1,63	9.5.2014.	29,6	2,3	26.3.2018.	29,3	1,2
26.3.2008.	49,3	1,46	19.5.2014.	44,7	1,7	7.5.2018.	20	2,1
7.11.2008.	**28,4**	**9,26**	**1.8.2014.**	**28,8**	**5,0**	18.6.2018.	15,4	2,0
11.11.2008.	18,6	2,5	15.9.2014.	56	1,9	25.6.2018.	12	1,1
5.12.2008.	37,4	2,31	27.10.2014.	32	2,4	2.7.2018.	17	1,6
22.12.2008.	42,9	1,93	26.1.2015.	23,7	1,1	30.7.2018.	6,5	1,8
3.4.2009.	**47,5**	**6,23**	2.2.2015.	31,9	1,2	6.5.2019.	25,7	1,1
6.4.2009.	47,3	1,33	23.2.2015.	33,3	3,0	**16.5.2019.**	**67,1**	**26,0**
28.12.2009.	58,1	3,63	28.9.2015.	16,3	1,4	20.5.2019.	24,3	1,9
18.5.2010.	38,1	3,91	**12.10.2015.**	**45,3**	**4,6**	27.5.2019.	15	1,1
1.6.2010.	22,9	1,62	19.10.2015.	32,3	1,9	3.6.2019.	25,2	1,1
28.6.2010.	14,3	1,4	**11.1.2016.**	**29,7**	**4,1**	28.10.2019.	4,1	1,1
21.9.2010.	**17,3**	**4,57**	22.2.2016.	30,3	2,9	4.11.2019.	15,8	1,6
21.9.2010.	17,3	3,72	2.3.2016.	37,2	1,2	**11.11.2019.**	**34,6**	**5,4**
24.9.2010.	10	1,67	21.3.2016.	18,8	1,2	18.11.2019.	51,4	2,3
4.10.2010.	10,4	1,39	9.5.2016.	20,4	1,2	9.12.2019.	25,5	1,3
27.10.2010.	15,8	2,76	9.11.2016.	32,7	3,0	16.12.2019.	23,8	1,5
7.12.2010.	58,5	1,56	14.11.2016.	25,6	2,4	**23.12.2019.**	**63,5**	**8,2**
20.12.2011.	21,3	1,45	6.3.2017.	38,7	2,4	30.12.2019.	22,1	1,3
5.3.2012.	17,3	1,07	12.4.2017.	17,4	1,1	27.4.2020.	6,48	1,6
16.4.2012.	16,3	1,65	**4.9.2017.**	**14,9**	**4,1**	**21.5.2020.**	**22,3**	**7,7**
21.5.2012.	25,9	1,34						

In the figure 10.1, the turbidity levels are provided 1,0 NTU and 4,0 NTU. The total of 106 measured data over the limit were considered ***M*** = 1,0 NTU and 20 data above the limit ***M*** = 4,0 NTU.

Analyses of water quality at the Klokot spring showed that the increase in turbidity parameters above the maximum allowable concentrations (MAC) was recorded mostly in spring (combination of rain and snowmelt) and in autumn (long-term rains of higher intensity).

In the considered period (27. 3. 2006. - 21. 5. 2019.) the turbidity of Klokot water above M = 2,0 NTU does not occur until Klokot flow does not pass over the limit of ***Q*** = 15,0 m^3/s. However, at the flows higher than 15,0 m^3/s there is a danger of crossing the limits of ***M*** = 4,0 NTU. For example, on 4. 1. 2007. at the flow ***Q*** = 16,0 m^3/s the recorded turbidity was ***M*** = 5,03 NTU, on 21. 5. 2020. at the flow ***Q*** = 25,0 m^3/s the recorded turbidity was ***M*** = 10,0 NTU. During the time of high water appearance 16. 5. 2019. at the flow ***Q*** = 67,1 m^3/s the turbidity reached the maximum value: M_{max} = 26 NTU.

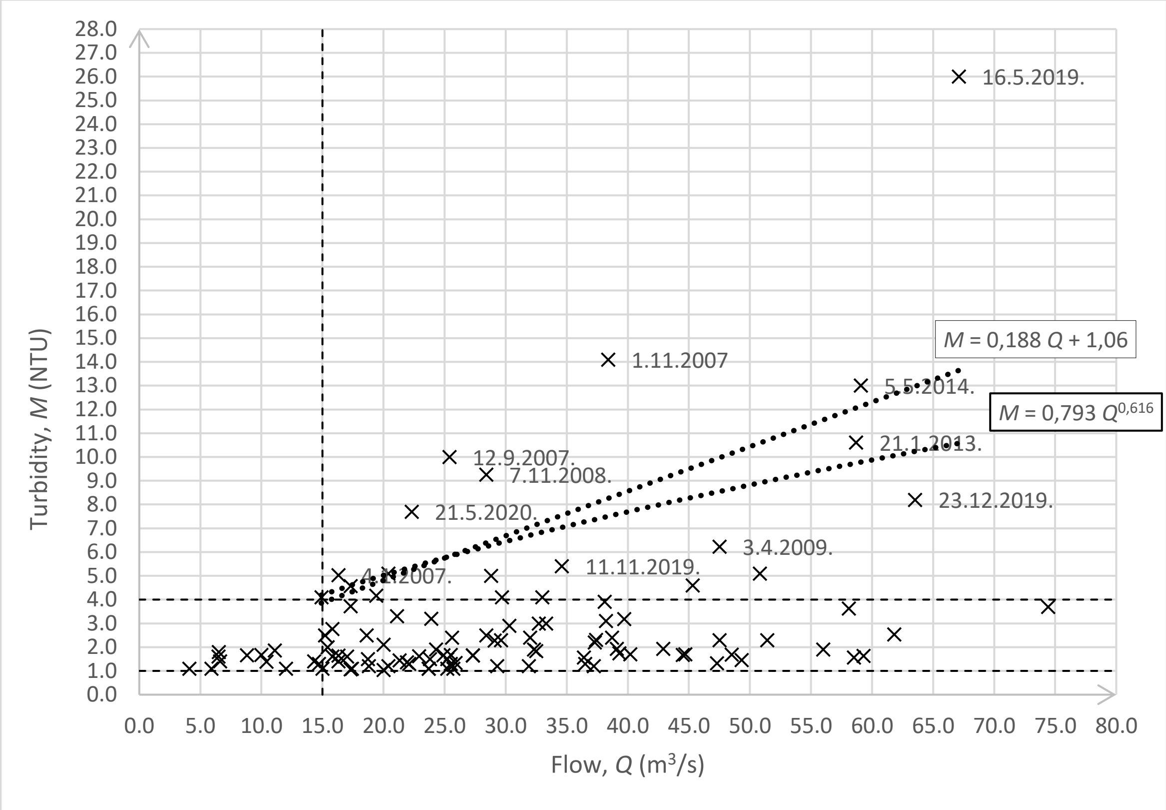


Figure 10.2** Water turbidity measurements **M** > 1,0 NTU at the Klokot spring depending on the flow **Q

The figure 10.3 shows the water turbidity measured at the Klokot springs in the period (27. 3. 2006. - 21. 5. 2020.) above ***M*** = 1,0 NTU sorted by size.

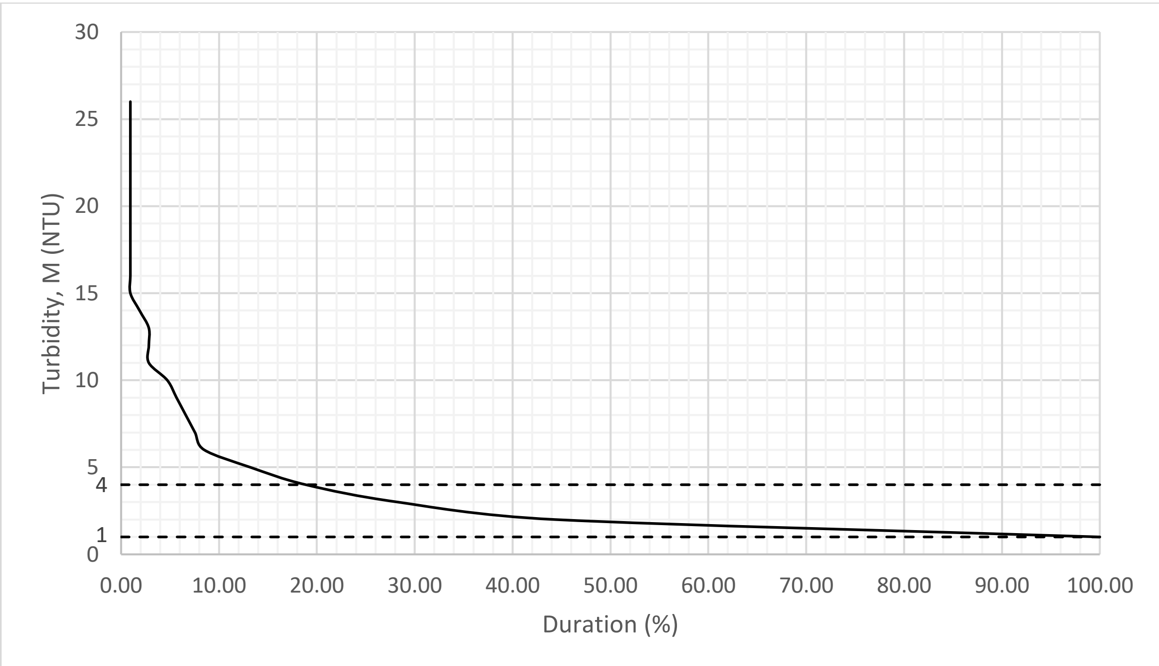


***Figure 10.3** Values of turbidity of the Klokot spring water **M** > 1,0 NTU in the period (27.3.2006.-21.5.2020.) sorted by the size*

Based on the data from the table 10.1 the linear and nonlinear regularities between the flow **Q** and turbidity **M** are defined, first with the adopted turbidity limit of 4.0 NTU (number of pairs of values **n** = 20), and then with the turbidity limit of 1.0 NTU (**n** = 106). The following expressions were obtained:

$$\boldsymbol{M} = 0{,}188\ \boldsymbol{Q} + 1{,}06 \qquad \boldsymbol{n} = 20; \quad \boldsymbol{r} = 0{,}60$$

$$\boldsymbol{M} = 0{,}793\ \boldsymbol{Q}^{0{,}616} \qquad \boldsymbol{n} = 20; \quad \boldsymbol{r} = 0{,}58$$

$$\boldsymbol{M} = 0{,}0845\ \boldsymbol{Q} + 0{,}493 \qquad \boldsymbol{n} = 106: \quad \boldsymbol{r} = 0{,}39$$

$$\boldsymbol{M} = 0{,}5463\ \boldsymbol{Q}^{0{,}4377} \qquad \boldsymbol{n} = 106; \quad \boldsymbol{r} = 0{,}38$$

Figure 10.2 shows the direction and curve for ***n1*** = 20 considered cases, when the turbidity is ***M***> 4.0 NTU. For these cases, based on the magnitudes of the correlation coefficients ***r***, it is concluded that the correlations are weak - according to the usual criterion that the correlation is weak, if: **|** 0.75 **|** > ***r***> **|** 0.50 **|**. However, due to the large scatter of the input calculation data around the direction, respectively the curve, none of the derived expressions is suitable for conclusions on the turbidity ***M*** based on the flow rates ***Q***.

For cases when the turbidity is ***M***> 1.0 NTU, the correlation relations, defined on the basis of 106 pairs of values (***Q, M) -*** $\boldsymbol{n_2}$ = 114, are only indicated, so the derived rules of connections are not suitable for further application.

Measurements carried out over a period of almost 15 years show that at the source of Klokot comes a certain amount of suspended sediment (suspended and colloidal particles) which, depending on the size of the water flow, relatively often causes turbidity above the maximum allowable concentrations (MAC). In the measurement period (March 27, 2006 - May 21, 2020), it was established that the turbidity of the water at the Klokot spring out of a total of 516 sampling 106 times exceeded the limit of 1.0 NTU (22%), and 20 times the limit of 4.0 NTU (4%). In the last three and a half years (January 1, 2017 - May 21, 2020), the limit of 1.0 NTU was exceeded 36 times, and the limit of 4.0 NTU even 8 times, which indicates a deteriorating water quality trend at the Klokot spring in the several past years. Therefore, in terms of the production of suspended (dispersed) sediments, the conditions in the basin are deteriorating. Deteriorations may be due to natural processes such as the influence of climate on the frequency and amount of precipitation in the catchment area or anthropogenic factors such as deforestation and changes in the use of certain areas in the catchment area, etc. Regardless of the cause, the occurrence of turbidity at the sources in the Dinarides karst is difficult to control in the catchment areas.

In terms of transport and the amount of floating and drawn sediment, almost identical conditions were recorded in similar large Dinaric karst catchment areas where water predominantly comes to the springs by underground.

Such phenomena cannot be prevented by appropriate interventions in the catchment area. In a fissure system in karst, in which it is partially filled with sediments of clay dimensions or fine-grained sediments of clay dimensions, sediments are regularly removed and / or deposited, depending on hydrological conditions. When the flow velocities are higher, the sediment is transferred to the place where it deposits with decreasing velocities, and then in some other flow conditions it is restarted, and its washing occurs.

Due to the very frequent occurrence of turbidity in relation to the number of samples, which significantly disrupts the regular supply of drinking water, it is necessary to propose appropriate measures to improve water quality at the project at the water source Klokot. In turbid water, colloidal (floating) particles include bacteria as well as number of other inorganic and organic contaminants, thus preventing the mentioned bacteria from being removed from the water by chlorine disinfection.

For this reason, very often in the last 15 years, in periods of significant increase in turbidity in the water distributed to service users, representatives of PC "Vodovod" Bihac through public advertising channels reported to their service users to boil water before using it in the household.

It should be added that the representatives of PHI USC stated that they recorded that analyses of raw water quality at the source Klokot and analyses of raw water quality at the source Zdena from which the municipality of Sanski Most is supplied are almost identical in terms of turbidity, respectively its occurrence, frequency and value in relation to precipitation and recorded flows. However, a drinking water treatment plant was built at the Zdena spring in Sanski Most, primarily with the aim of regulating the values of turbidity and microbiological load of raw water.

In accordance with all the above, in the coming period at the Klokot spring it is necessary to establish regular and continuous monitoring of water quality, and according to its results to define key input parameters for selecting technology (sedimentation method, filtration, disinfection, etc.) of drinking water treatment at the future plant.

11 SPATIAL MODELLING - VULNERABILITY AND RISK OF POLLUTION

The Vulnerability Map and the Pollution Risk Map developed within the Project are the result of digital modelling based on the collected relevant data in the area of the Klokot Basin in the Republic of Croatia and Bosnia and Herzegovina. They have not been used in defining the sanitary protection zones of the Klokot Spring. Nevertheless, this chapter was prepared in the framework of this Study because the Consultant considers the information useful for the overall management of the catchment area.

Esri ArcGIS Desktop software with 3D Analyst and Spatial Analyst extensions was used in the development. Preparation of the necessary layers, digitization and attribution of vector data was performed according to the standard and the needs arising according to the selected method of modelling vulnerability and risk of pollution in the Klokot source basin.

11.1 PREPARING DATA LAYERS

The input data for spatial modelling are organized in the form of a GIS database. The catchment area of the Klokot spring, with an area of 950 km2, was determined, for which the following thematic data were prepared:

1. Hydrogeological units
2. Land use
3. Digital terrain model
4. Hydrographic network
5. Geomorphological objects
6. Average precipitation
7. Potential polluters

1. Polygons of hydrogeological units were made by digitization of the Basic Geological Map of the Republic of Croatia and Bosnia and Herzegovina M 1: 100 000 and were supplemented by field reconnaissance and hydrogeological processing. The attributes porosity and permeability were added to the polygons.
2. Spatial data of land use in the form of polygons were made by interpreting multi-channel satellite images of LANDSAT ETM with a resolution of 25m. The nomenclature of interpretation of the vector polygon layer is defined by the CORINE program and contains 44 classes that are grouped into three levels. The basic, first level contains five categories: artificial areas (urban zones), agricultural areas, forests and semi-natural areas, water surfaces and water bodies, and the second and third levels are developed according to the stated standard.
3. Digital terrain model was made on the basis of topographic maps 1:25 000. Using digitized altitude elements of these maps, a raster with a resolution of 20 m with values of absolute height in their cells.
4. The hydrographic network consists of two layers. It is digitized from topographic maps 1:25 000 and contains rivers, streams and ravines in the form of lines, and standing water (lakes) and large rivers in the form of polygons.
5. Geomorphological objects are shown in the form of a point and are digitized according to topographic maps 1:25 000 or generated based on coordinates. They are classified by type into swallow holes, pits and caves and contain relevant attribute data. In addi-

tion to the listed objects, and for the purpose of assessing the permeability of the deposits, sinkhole locations were used. A map of their density was made, which indicates increased karstification, ie increased permeability of the area.

6. The map of average precipitation was digitized according to the "Map of average precipitation in the period 1930-1960" of the former Federal Meteorological Institute of the SFRY. Precipitation isohyets form polygon boundaries in the range of 1250-1750 mm of the annual average.
7. Potential polluters in the Klokot Basin were collected by field visit and processed into three spatial data layers. In the form of a point, objects and smaller areas (quarries, cemeteries, illegal landfills, farms, etc.), line roads, and as polygons larger areas (areas without drainage, agricultural areas, airports, minefields, etc.) Potential polluters are categorized. and determined by weight according to Hazards Analysis and Mapping - COST Action 620 (D. De Ketelaere, H. Hötzl, C. Neukum, M. Civity and G. Sappa).

11.2 DIGITAL SPATIAL MODELLING

11.2.1 Pollution vulnerability

The pollution vulnerability map was prepared according to the COP method (J. Ma Vias, B. Andreo, M.J. Perles, F. Carrasco, I. Vadillo and P. Jimenez). The method uses three basic factors: C (flow concentration) - flow concentration, O (overlaying layers) - aquifer cover and P (precipitation) precipitation. The prepared data in vector form (hydrogeological units, land use, relief, hydrography, geomorphological objects and precipitation) were processed and spatially overlapped, supplemented with the necessary attributes and classified. According to the numerical values of the parameters, the vector layers were converted into a raster format with a cell resolution of 100 m. Map algebra (raster calculator) with a combination of rasters gave the result Map of pollution hazards.

O factor - is a protective factor in terms of aquifer pollution. Classified data according to lithology, permeability and cover (soil) were used in the construction of raster O (Figure 13.1). The range of raster cell values ranges from 1 - 15 (1 - very small, 2 - small, 2-4 medium, 4-8 large, 8-15 very large).

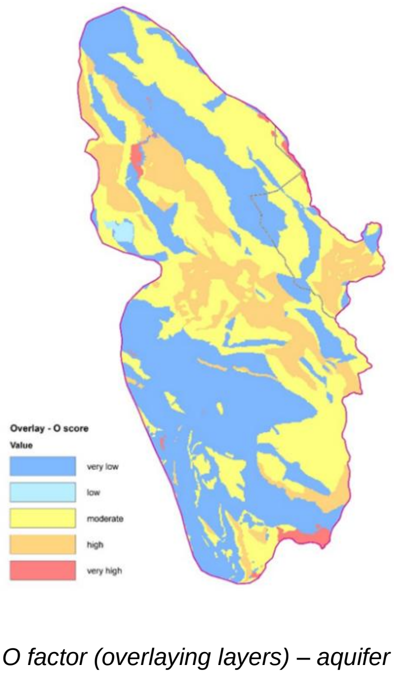


***Figure 11.1**: O factor (overlaying layers) – aquifer protective cover*

C factor - is a reduction factor of protection and depends on the distance from concentrated flows (rivers, swallow holes), the slope of the terrain (relief) and vegetation (land use). When determining the C factor, we worked according to two scenarios, namely: a.) In the area up to 100 and 250 m from the concentrated flows, according to the slope (<8%, 8-31%, 31-76%,> 76%) and the associated vegetation gave factors of 1 - 0.75 and b.) in the rest of the area (karst) according to karst characteristics and inversely proportional factors depending on slope and vegetation (0.75 - 1) (Figure 13.2).

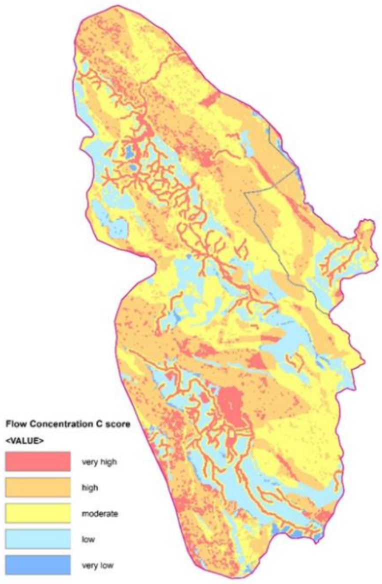


***Figure 11.2**: C factor - flow concentratio*

P factor - is a reduction factor of protection and depends on the amount and intensity of precipitation. Raster cells were calculated values according to the precipitation map for <1250 - 0.8, 1250-1750 - 0.7 and> 1750 mm - 0.8. (Figure 13.3)

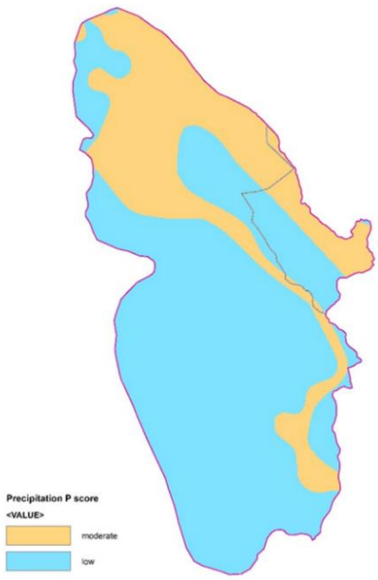


***Figure 11.3:** P factor (precipitation) amount and intensity of precipitation*

The final calculus multiplication of C * O * P (Figure 13.4) yielded a raster with cell values of 0–15, which reclassified into five classes show a very large (0–0.5), large (0.5–1) mean 2) low (2-4) and very low risk of pollution (4-15). (Figure 13.5)

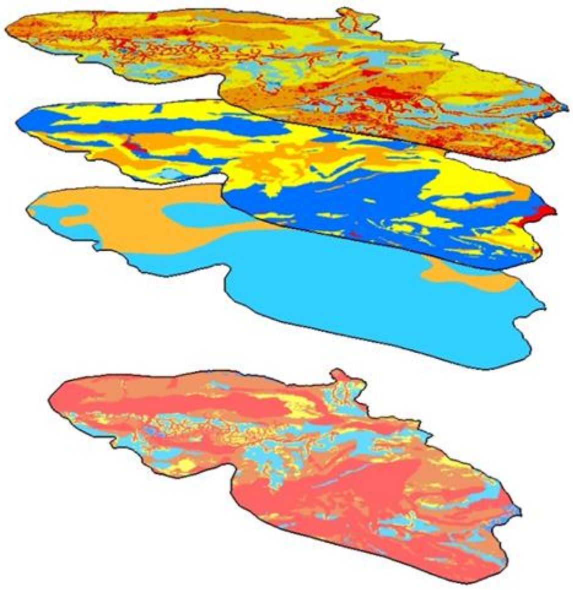


***Figure 11.4**: Raster multiplication C * O * P*

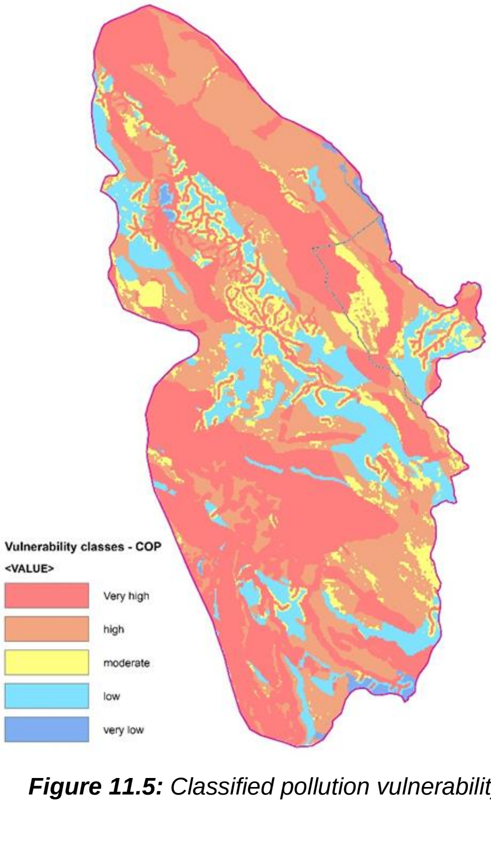


***Figure 11.5:** Classified pollution vulnerability*

11.2.2 Potential polluters

Vector layers of data on potential polluters are classified by type of display (point, line, and polygon) and classified by type into the corresponding layers (quarries, gas stations, cemeteries, minefields, roads etc). Each potential pollutant was determined with a weight value (H), a ranking factor (Qn) and a reduction factor Rf. Using the above parameters, the hazard index (HI) was calculated for each pollutant according to the formula: HI = H * Qn * Rf. The created spatial layers are shown in the figure 11.6.

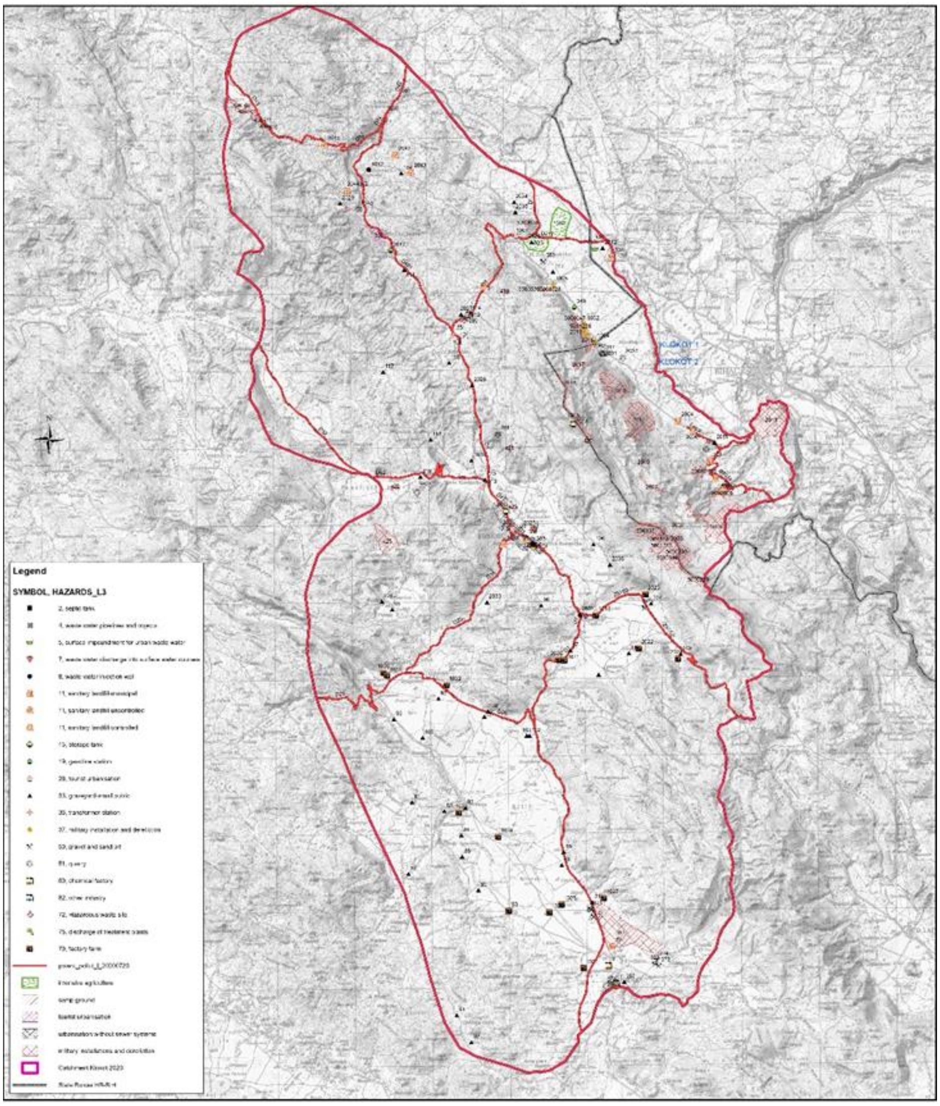


Figure 11.6: *Potential polluters*

The vector layers were then converted into raster (3 rasters) with a cell size of 100 * 100 m and cell values according to the hazard index. Rasters were summed and a raster with a total cell value was obtained. The specified raster was then reclassified into 5 classes according to the hazard index, as follows:

Hazard index	Hazard class	Hazard level
0-24	1	No or very low
24-48	2	Low
48-72	3	Moderate
72-96	4	High
>96	5	Very high

The result is a classified hazard index raster (Figure 11.7)

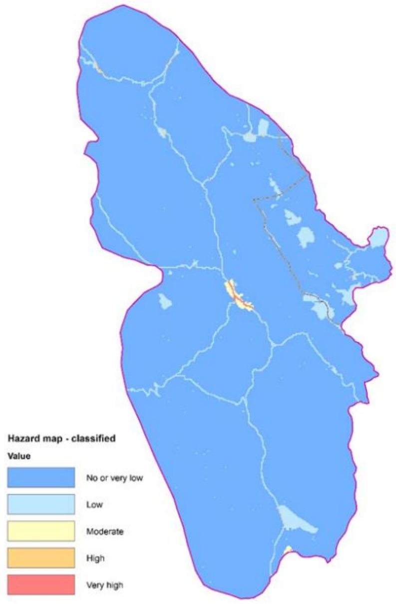


***Figure 11.7**: Classified pollution hazard - raster*

Risk Map

By combining the raster with classes determined according to the degree of vulnerability to pollution and the hazard raster, ie the raster of classified hazard (Figure 13.8) and using a raster calculator and the formula COP-raster * 1 / HI raster, a raster with reclassified cell values is obtained. (Figure 11.9).

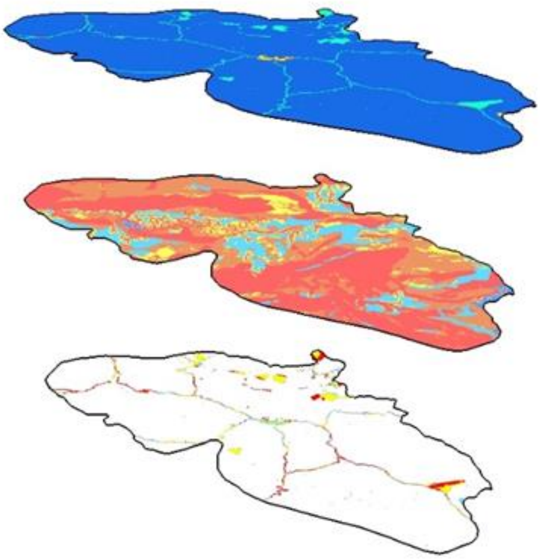


***Figure 11.8:** A combination of pollution hazard raster and classified vulnerability*

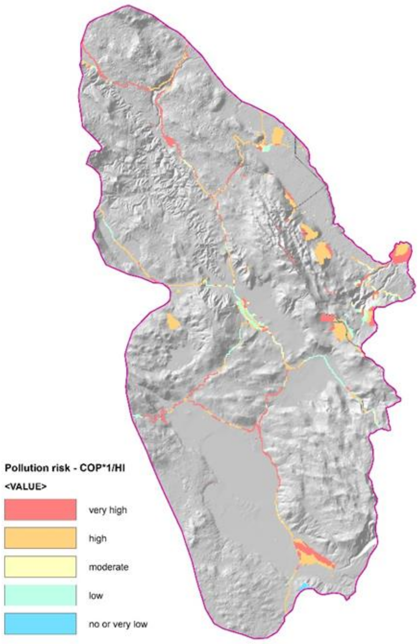


Figure 11.9: *Raster classified according to pollution risk*

11.3 CONCLUSION

Vulnerability map and pollution risk map of karst aquifer are very useful in considering the natural and anthropogenic risk of pollution of springs in the karst area. They indicate critical places that should certainly be avoided when planning the use of space. They have not been used in defining the sanitary protection zones of the Klokot spring, but we believe that they will serve in the implementation of the development of the area in the basin. Moving potential polluters from high-risk areas, defined by these models, and / or planning some activities outside of them, can enable activities and life with almost no restrictive restrictions in the area of sanitary protection zones.

12 RECOMMENDATION OF MEASURES TO ENSURE WATER QUALITY

12.1 GENERAL

Klokot and Privilica springs are used to supply drinking water to the Bihac Municipality. The development of sanitary protection zones is relevant to protect the groundwater that is taken from Klokot spring. However, the experience has shown that protection zones set up in karstic area prove to be not effective enough in making it possible to permanently guarantee the distribution of water respecting quality limits about turbidity or bacteriology. Therfore, the Consultant has developed the following approach to address this issue in an overall perspective:

- On the one hand, the groundwater in the catchment shall be protected from contamination with contemporary measures to ensure best-possible utilization of the water at Klokot
- On the other hand, the water that is used as drinking water shall be treated with an effective purification system

Therefore, the focus is on the following:

- ➢ Define measures to directly address mitigation/elimination of polluters according to chapter 8. See chapter 12.2.
- ➢ Develop an overall long-term planning approach (e.g. in form of a masterplan) in the different fields to address problems of contamination from an overall perspective. See chapter 12.3.
- ➢ Develop measures to contain hazards on karstic waters (like accidents, littering etc.). See chapter 12.4.
- ➢ Set up a groundwater monitoring system to control the performance and ensure sustainability of the measures. See chapter 12.5.
- ➢ Determine the adequate drinking water treatment for Klokot spring water. See chapter 12.6.

Limits of effectiveness of Sanitary Protection Zones in karstic areas

It is commonly accepted that karst aquifers are very vulnerable to contaminants of all kinds, due to the low filtering power of the infiltration zone, the low dispersion effect and the dilution of the contaminants linked to the organization of flows. and generally short water residence times. The purification processes within the aquifer are limited.

Therefore, in karstic environment, protection zones over the large and very reactive karstic environment does not guarantee the distribution of water whose characteristics permanently meets the quality limits of water intended for human consumption because of turbidity and bacteriological contamination.

The protection zones are not the zones the only health barrier between the water collected and the consumer. It is therefore not a question of "expecting everything" from the protection zones.

12.2 PROPOSED IMPROVEMENT MEASURES FOR IDENTIFIED POLLUTERS

The table below indicates the measures to directly address mitigation/elimination of polluters, which can be initiated at short notice. In addition, it also mentions the mid-term/long-term measures, which need to be planned and implemented in the framework of the overall protection approach concerning the whole region.

Federation of Bosnia & Hercegovina

Polluter with ID	Zone	Importance category	Proposed improvement measures	Cost estimates (€)
Quarries				
Željava/Baljevac (347) Baljevac 2 (2001) Baljevac 3 (2002) Zavalje (2005)	**II**	**3** **3** **2** **3**	**Short-term Measures:** • Blocking access roads to the quarry to prevent uncontrolled entry and waste disposal; • Placement of warning boards (prohibition of access and waste disposal); • Integration of polluters in a groundwater quality monitoring system; • Establishment of inspection supervision.	30,000 €
			Mid-term/Long-term Measures: • Professional closure of the sites on the basis of a project design. Attention: For the location of the Baljevac 3 quarry located above the Klokot water source, the proposed measures need to be implemented at first and soon. Only a very rough cost estimate can be provided for theses measures at this stage.	(0.7 Mio. €)
Međudražje (2007) (part of the quarry that is not used)	**III**	**2**	**Short-term Measures:** • Blocking the access road to the part of the quarry that is not used to prevent uncontrolled access and waste disposal; • Placement of warning boards (prohibition of access and waste disposal) on the part of the quarry that is not used; • Integration of polluters in a groundwater quality monitoring and control system; • Establishment of inspection supervision.	30,000 €
			Mid-term/Long-term Measures: • Professional closure of the site that is not used on the basis of a project design. Only a very rough cost estimate can be provided for theses measures at this stage.	(0.1 Mio. €)

Landfills				
Vučjak landfill (2006)	**II**	**2**	**Short-term Measures:** • Blocking the access road to the landfill; • Placement of warning boards (prohibition of access and disposal); • Carrying out hydrogeological and other exploration works in order to determine the condition of the landfill in terms of wastewater seepage and the impact on the water source of Klokot; • Integration of polluter in a groundwater quality monitoring system;	50,000 €
			Mid-term/Long-term Measures: • Preparation of study-project documentation for landfill sanitation; • Landfill sanitation with disposal of landfilled waste. Only a very rough cost estimate can be provided for theses measures at this stage.	(1.2 Mio. €)
Landfills with uncontrolled waste disposal Baljevac (JNA), (2004) Međudražje (Bezdan), (2008)	III II	**2** **1**	**Short-term Measures:** • Securing the passage for the Baljevac landfill (clearing bushes and shrubs); • Waste removal and sanitation of the landfill surface; • Establishment of monitoring of rehabilitated areas (landfills, sinkholes, etc.) • Placement of warning boards (prohibition of access and waste disposal); • Intensification of work with citizens for the purpose of raising awareness (sensitization) • Establishment of inspection supervision. The Baljevac landfill has been registered as a potential polluter, because the composition and origin of the deposited waste (organic and medical waste) have not been determined with certainty since 2003. The "Bezdan" landfill in Međudražje needs to be rehabilitated as soon as possible, in order to stop further disposal of construction and municipal waste. It is necessary that the competent services of the city of Bihać organize the removal of waste from the area of the settlements of Mali and Veliki Skočaj, Međudražje, Zavalje and Vučijak in a more efficient way. In addition, it is necessary for the communal inspection to ensure that the disposal of the mentioned waste is stopped at this location. Cost estimation was made with the coverage of sanitation works on the landfills.	60,000 €

Border crossing				
GP Izačić (BiH) / L. P. Selo (RC), (2010)	**III**	**1**	**Short-term Measures:** A WWTP has been installed at the Izačić border crossing, where overhaul and servicing works are currently being carried out. • Conducting a test run with monitoring of the parameters of the discharged water; • Introduction of regular monitoring of the quality of discharged water after treatment; • Establishment of a reporting system to the competent institutions; • Integration of polluter in a groundwater quality monitoring system; • Establishment of inspection supervision.	40,000 €
Roads				
Main road (M5) Regional road (R403a) Local road	**III** **II / III** **II**	**2** **2** **2**	**Short-term Measures:** Roads in the Klokot water source catchment area are roads with free drainage without built gutters and oil and fat separators. • Marking of the sanitary protection zone of the water source with traffic signs; • Establishment of an alert system in case of incidental pollution (M5).	30,000 €
			Mid-term/Long-term Measures: • Modernization of roads (M5) in the water source protection zone: it is necessary to plan the construction of facilities for collection and treatment of surface water from traffic areas.	n.A.
Settlements in the catchment area				
V. Skočaj M. Skočaj Međudražje Zavalje (Vučjak) Izačić	**III** **III** **III** **II** **III**	**1** **1** **1** **1** **1**	**Short-term Measures:** Settlements in the catchment area of the Klokot water source do not have an established system of organized wastewater collection and treatment. • Record wastewater infrastructure and collection from existing facilities; • Develop a strategic plan on how to collect and treat wastewater; • Adopt municipal Decisions according to which existing and future wastewater treatment facilities will use watertight septic tanks or will discharge wastewater into the sewage system whose wastewater is to be treated at the constructed wastewater treatment plants.; • Establish inspection and control system for wastewater collection and treatment.	100,000 €
			TOTAL (Short-term Measures):	**340,000 €**

Republic of Croatia

Polluter with ID	Zone	Importance Category	Proposed improvement measures	Cost estimates (€)
Quarries and gravel pits				
Prijeboj (1011) Frkašić (1023)	**III**	**2**	**Short-term Measures:** • Placement of warning boards (prohibition of access and waste disposal); • Integration of polluters in a groundwater quality monitoring system; • Establishment of inspection supervision.	30,000 €
			Mid-term/Long-term Measures: • Professional closure of the sites on the basis of a project design. Only a very rough cost estimate can be provided for theses measures at this stage.	(3.8 Mio. €)
Landfills with uncontrolled waste disposal				
Rastovača pit (2042) Pony pit (2043) Plitvice water source pit(2044) Poljanak pit (2045) Golubnjača pit (20_)	**III**	**2**	**Short-term Measures:** • Sanitation of landfills with extraction and removal of waste; • Establishment of monitoring of rehabilitated areas (landfill, pit, etc.) • Placement of warning boards (waste disposal bans) • Intensification of work with citizens for the purpose of raising awareness (sensitization); • Establishment of inspection supervision. These pits / landfills need to be rehabilitated as soon as possible, in order to stop further waste disposal and prevent groundwater pollution. It is necessary that the competent services of the municipality of Plitvice Lakes efficiently organize the extraction and removal of waste from the pits, and that the municipal inspection / wardens, ensure that further disposal of waste is stopped at this location.	100,000 €

Military facilities				
Aerodrom i kasarna Željava (1001, 1002, 1003, 1004, 1005)	**II**	**1**	**Short-term Measures:** • Conduct detailed research of the interior of the facility from the point of view of identifying the type of pollution, with special reference to storage facilities and contents in them; • Examine for the presence of radiation in and around the building; • Establish continuous groundwater monitoring and provide access to monitoring results to the competent institutions in both countries; • Establish an alert system in case of incidents.	200,000 €
Livestock farms				
Municipality Udbina (14 livestock farms) (1024 – 1032) (2020 – 2024) Municipality P. Jezera (1018)	**III**	**1**	**Short-term/Mid-term Measures:** • Establish accurate records of the characteristics of all farms (number and type of livestock, barn capacity, manure production, livestock health surveillance, as well as other relevant data) in the catchment area of the Klokot water source.; • According to the valid regulations of the Republic of Croatia, in the next 5-7 years on the mentioned farms to ensure the construction of devices for collecting low tide and wastewater treatment; • Establish supervision and control over the collection and use of manure on agricultural land; • Establish inspection supervision.	300,000 €
Tourism and tourist facilities				
NP Plitvička jezera (302) Korenica (1015) Ličko Petrovo Selo (1007)	**III**	**1**	**Short-term/Mid-term Measures:** • Establish accurate records of existing tourist facilities (hotels, motels, restaurants, camps, private apartments, etc.); • Establish records on the manner of collection and treatment wastewater of existing tourist facilities with records of constructed septic tanks (improperly constructed - watertight and properly constructed - watertight); • Adopt municipal Decisions or Decisions at the level of NP "Plitvice Lakes" according to which the construction of new tourist facilities can be done exclusively by collecting wastewater in watertight septic tanks or in the sewer system whose wastewater is treated at wastewater treatment plants	400,000 €

Agriculture				
Ličko Petrovo Selo (100 ha), (1001)	**III**	**1**	**Short-term/Mid-term Measures:** • Recording of locations and areas with intensive agricultural activities; • Registration of quantities and periods of use of pesticides and fertilizers on agricultural land; • Educating and informing farmers about alternative phyto-sanitary products; • Establish a ban on the storage of fertilizers, insecticides and pesticides in the catchment area; • Establish monitoring of fertilizer use and monitor groundwater quality; • Establishment of inspection supervision	100,000 €

Roads				
Highways in the catchment area (D1, D504, D217 D218/D506, D25 D52, D42)	**III**	**1**	**Short-term Measures:** Roads in the catchment area of the Klokot water source in the Republic of Croatia are roads with free drainage without built gutters and oil and grease separators, the Recommendations of basic protection measures are:: • Marking of the sanitary protection zone of the water source with traffic signs;; • Establishment of an alarm system in case of accidental (incidental) pollution.	70,000 €
			Mid-term/Long-term Measures: Modernization of roads (M5) in the water source protection zone: it is necessary to plan the construction of facilities for collection and treatment of surface water from traffic areas.	n.A.

Inhabited places				
Udbina Korenica Prijeboj P. Jezera L. P. Selo	**III**	**1**	**Short-term/Mid-term Measures:** In the area of the Klokot spring basin on the territory of the Republic of Croatia, most settlements do not have an established system of organized wastewater collection and treatment. • Record wastewater infrastructure and collection from existing facilities; • Develop a strategic plan on how to collect and treat wastewater in the catchment area; • Adopt municipal Decisions according to which existing and future wastewater treatment facilities will use watertight septic tanks or will discharge them into the sewage system whose wastewater is treated at wastewater treatment plants • Establish inspection and control system for wastewater collection and treatment	500,000 €
			Mid-term/Long-term Measures: • Build planned sewerage systems and wastewater treatment plants in the agglomeration of Plitvice Lakes 1 and 2 as well as in the catchment area as needed.	n.A.
			TOTAL (Short-term Measures):	**1,700,000 €**

Recapitulation of costs for the implementation of proposed short-term improvement measures:

Catchment area	EURO (€)
Bosnia and Herzegovina	340,000
Republic of Croatia	1,700,000
TOTAL:	**2,040,000**

12.3 MEASURES IN THE FRAMEWORK OF THE OVERALL PROTECTION APPROACH

12.3.1 Legislation

EU legislation applies in the Republic of Croatia as EU member state. The legislation of the Federation of Bosnia and Herzegovina is aligned on EU legislations. Therefore, in addition to the legislation specific to the protection of karstic areas detailed in Chapter 6 of this Study, the following European Union directives are considered.

- Directive 91/271/EEC of 21 May 1991 relative to the treatment of urban wastewater introduces the concept of 'sensitive areas': areas in which urban wastewater discharged must undergo treatment against phosphorus and/or nitrogen.
- Directive 91/676/EED of 12 December 1991 on the protection of waters against pollution by nitrates from agricultural sources aims at reducing the pollution of water caused or induced by nitrates from agricultural sources and to prevent any new pollution of this type, by implementing action plans on vulnerable areas (ie feeding waters contaminated with nitrogen) previously identified and the establishment of monitoring programs to assess their effectiveness.
- Directive 2000/60/EC called "European Water Framework Directive"(WFD) adopted on October 23, 2000 defines the framework for the management and protection of water by large hydrographic basins. The current hydrographic basins therefore constitute the level of implementation of the directive and the basin committees are responsible for defining environmental objectives in the context of updating water development and management master plans (called 'River Basin Management Plan'). This directive gives priority to the protection of the environment and commits Member States to achieve good general conditions for both ground and surface water. Any further degradation of the environment should be prevented, the condition of the aquatic ecosystems preserved and improved, allowing sustainable use of water, based on the long-term protection of available water resources. This directive specifies that the Member States must provide the necessary protection for the identified bodies of water to "prevent the deterioration of their quality to reduce the degree of purification treatment necessary for the production of drinking water. The directive foresees:
    - the establishment of an inventory of hydrographic districts (sets of hydrographic basins) to account for the various uses of water and their impacts on the state of the waters;
    - the establishment of a register of protected areas to identify all the bodies of water subject to special protection (including the abstraction of drinking water).
- Urban Wastewater Treatment Directive (UWWTD) obliges the EU member states to collect wastewater and install treatment plant in agglomerations with more than 2,000 people equivalent (2,000-10,000 PE). Moreover, agglomerations with less than 2,000 people which already have a collection system must set up appropriate treatment. Appropriate treatment is defined as primary and secondary treatment (removal of organic matter: BOD, COD, SS), nutrient removal as tertiary treatment only required in case of eutrophication. Microbiological parameters are not considered. Agglomerations of more than 10,000 PE discharging to sensitive areas should on top of this remove nutrients Nitrogen, Phosphorus. Agglomerations with less than 2,000 have no requirement. See Table 12.1.

	Agglomerations with up to 2,000 PE	Agglomerations with up to 2,000 PE having a wastewater collection system	Agglomerations with 2,000-10,000 PE	Agglomerations with 2,000-10,000 PE discharging to sensitive areas
Urban Wastewater Treatment Directive *applies*	*no*	*yes*	*yes*	*yes*
Requirements		*Provision of a wastewater treatment system*	*Provision of a sewerage and wastewater treatment system*	*Provision of a sewerage and wastewater treatment system*
		Removal of organic matter (BOD, COD, SS)*	*Removal of organic matter* (BOD, COD, SS)*	*Removal of organic matter* (BOD, COD, SS) Nutrients ** (N, P)*
Water Framework Directive applies	*yes*	*yes*	*yes*	*yes*
Requirements	*Setting up measures to achieve a good water and groundwater status to protect drinking water, implying provision of sanitation and wastewater treatment for communities*			
	* BOD_5=25 mg/l O_2 (70-90% reduction) COD=125 mg/l O_2 (75% reduction) SS=35 mg/l (90% reduction)		** Total phosphorus=2 mg/l (80% reduction) Total nitrogen=15 mg/l (70-80% reduction)	

Table 12.1: *WFD requirements depending on the size and situation of each agglomerations.*

12.3.2 Implementation strategy for wastewater management

In less densely populated area, centralized wastewater management presents disadvantages: cost/benefit ratio is not very favorable, and leaks can cause contamination of the soil and groundwater. On-site treatments present advantages: better adjustment to individual situation, more flexibility and adjustability to changing conditions (tourism etc.). They also better fit the landscape, allow to re-use treated water and nutrients (Nitrogen, Phosphorus). There are different criteria that need to be considered (see Figures 12.1). In addition, there is a need for education to allow their correct usage and qualified personal for operation/maintenance.

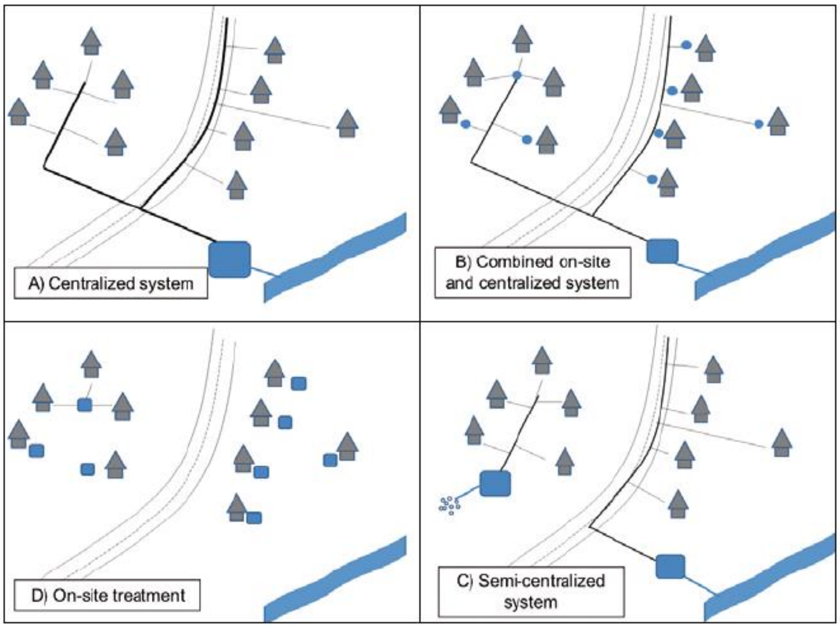


Figure 12.1: *Different wastewater treatment systems*

All in all, based on Table 12.1 and the evaluation of the different options related to wastewater management (Fig. 12.1), it is required to design, construct and operate Wastewater Treatment Plants for the agglomerations with more than 2'000 Person Equivalent (PE) in the Klokot catchement area of Republic of Croatia.

12.3.3 Overall planning approach

The above mentioned "European Water Framework Directive" (WFD) adopted in 2000 by the European Union defines the framework for the management and protection of water by large hydrographic basin. The measures taken to protect the Klokot and Privilica springs catchment area should be inserted in this wider strategic planning.

This directive foresees for EU member states the development of 'River Basin Management Plan' for each catchment basin. 'River Basin Management Plan' includes an Environmental Report, and a Program of Measures which defines the measures to be taken to reach a good ecological condition of the water bodies.

'River Basin Management Plan' applied to wastewater implies to define a Wastewater Strategic Planning: i.e. a common strategic vision for wastewater management, at the level of the catchment area. Regions or municipalities should then take this plan into account (Strategic Direction and Action Plan) with a long-term vision, at the scale of the whole catchment area, considering also neighboring regions, actors with diverging interests, and exploring all scenarios and options (at organizational and technical levels). Environmental as well as socio-economic aspects should be considered to develop 20-30 years development scenarios.

Key elements for a successful River Basin Management are:

- a long-term vision for the catchment area, agreed to by all the major stakeholders
- integration of policies, decisions and costs across sectoral interests such as industry, agriculture, urban development
- strategic decision-making at the river basin scale, which guides actions at sub-basin or local levels
- effective timing, taking advantage of opportunities as they arise while working within a strategic framework
- active participation by all relevant stakeholders in well-informed and transparent planning and decision-making
- adequate investment by governments, the private sector, and civil society organisations in capacity for river basin planning and participation processes
- a solid foundation of knowledge of the river basin

River Basin Management is generally understood as a spiral process (see figure below); each cycle of the spiral comprises several steps. It is expected that the next cycle of the spiral will be better managed than the previous one, after evaluation and lessons learned.

Figure 12.2: *River Basin Management Plan Process cycle.*

A cycle may reasonably cover a period of 6 years. The most important key of success is the strong commitment of all the actors (institutional, private, NGOs, and Civil Society) at all stage of the process. Coordinating this commitment among the stakeholders is sometimes called "Water Dialogue". It is generally admitted that it is necessary to have an institutional body for maintaining this dialogue and establishing rules for making it transparent, fair and constructive.

Trans-national management is adding challenges in comparison with basin being entirely comprised in one state. The challenges are essentially to:

- extent the multi-stakeholders dialogue (Water dialogue) to higher level of institutions (Regional and National);
- coordinate a planning process to be inserted into several decentralized socio-economic development plans
- find the way within different political, legal and institutional frameworks

Plitvice Lakes National Park and UNESCO

As the Pritvice Lakes National Park is within the catchment basin of the Klokot and Privilica springs, it is also part of the same hydrographic basin. Some studies, plans and measures developed in this zone by the Pritvice Lakes National Park Authorities can be of interest for the protection and mitigation measures in the Klokot and Privilica springs catchment area. The UNESCO Pritvice Lakes National Park report of 2018 on the conservation of the park mentions:

- wastewater management
- water infrastructures
- management of chemical leakages to the environment
- common national and EU investments and funding
- water monitoring
- emergency contamination alert system
- support to local and environmentally sensitive agriculture
- road management, development and bypass
- traffic study, etc

12.4 MEASURES TO CONTAIN HAZARDS ON KARSTIC WATER

The high speeds of underground water in karstic aquifers means that accidental pollution affecting the underground drainage network can be quickly evacuated in springs such as Klokot and Privilica. Following an accident, the pollution arrives quickly at the source, and disappears also relatively quickly compared to non-karstic aquifers.

Therefore, specific actions should be taken to prevent negative impacts of an accidental pollution. The inventory and monitoring of potential polluters within the catchment area enable to set up an alert network system. In case of an accidental contamination, the local authorities can be warned in time. Thus, the authorities can immediately contact the water utilities so that they suspend the water intake and rely on other sources or their water storage to supply water to the population. This chain of alert should be effectively set up in order to function quickly in case of a contamination accident. One of the potential sources of accidental contamination is the spill of contaminating substance (such as oil or petrol) on the roads, therefore information for the alert system should be visible on the roads in the catchment basin.

An effective alert system includes the setup of signs indicating the presence of a sanitary protection zone. In the Klokot and Privilica springs catchment area, the proposed locations for signs within the protection zones are shown on the map in Annex 18 Map of Proposition of Locations for Marks of Sanitary Protection Zone.

12.5 SURFACE AND GROUNDWATER QUALITY MONITORING SYSTEM

Surface and groundwater quality monitoring is of high importance. The locations need to be carefully selected under consideration of the expected results and of the overall strategy. The planning and implementation of such a surface and groundwater monitoring system is a key for a sustainable solution. The goal of this monitoring system is to track changes in the water quality at these different points and to analyse its evolution in link with the hydrology and the changes in the water usage and in the management of the potential polluters identified in the catchment area. Thus, it will be possible to see if the mitigation measures taken have an impact on the water quality at the different monitoring points and ultimately at Klokot spring.

The first step of the surface and groundwater monitoring system will therefore be a continuation of the analysis performed during the study, especially at Klokot spring.If more funds become available, a second step of the surface and groundwater monitoring system can be to develop new ground water monitoring points by drilling bore holes at strategic points.

Therefore, the Consultant suggests as a first step to continue with the collection of the water analyses as it is summarized in the table below:

Responsible	Type	Locations	Parameters	Frequency	Remarks
Water utility Bihac	Multiprobe	Water Quality Measurement at Klokot (fixed station)	10 parameters*	Online	System in place and in operation
Water utility Bihac	Laboratory	Klokot spring	Basic**/ Microbiology***	Weekly	Water spring
Water utility Bihac	Laboratory	Klokot spring	Periodic**	Monthly	Water spring
Water utility Bihac	Laboratory	Klokot spring	Extended**	Seasonal (every 3 months)	Water spring
Water utility Bihac	Multiprobe/ Laboratory	Privilica (BiH)	10 parameters*/ Microbiology***	Every month	Water spring
Water utility Bihac	Laboratory	Privilica (BiH)	Extended**	Seasonal (every 3 months)	Water spring
Cantonal Ministry	Multiprobe	Vučjak (BiH)	10 parameters*	Every month	Sink
Cantonal Ministry	Laboratory	Vučjak (BiH)	Extended**	Seasonal (every 3 months)	Sink
Croatian Water	Multiprobe/ Laboratory	Rastovača (RC)	10 parameters*/ Microbiology***	Seasonal (every 3 months)	Absorbent pit
Croatian Water	Laboratory	Rastovača (RC)	Extended**	Twice a year	Absorbent pit
Croatian Water	Multiprobe/ Laboratory	Prijeboj (RC)	10 parameters*/ Microbiology***	Every month	Sink
Croatian Water	Laboratory	Prijeboj (RC)	Extended**	Twice a year	Sink
Croatian Water	Multiprobe/ Laboratory	Korenički potok (RC)	10 parameters*/ Microbiology***	Every month	Sink
Croatian Water	Laboratory	Korenički potok (RC)	Extended**	Twice a year	Sink
Croatian Water	Multiprobe/ Laboratory	Vidrovac (=Krbavsko) (RC)	10 parameters*/ Microbiology***	Every month	Sink
Croatian Water	Laboratory	Vidrovac (=Krbavsko) (RC)	Extended**	Twice a year	Sink
Croatian Water	Laboratory	2 Bore holes near the border in the former military airport Zeljava (RC)	Extended**	Twice a year	Bore holes

***10 parameters:** Dissolved oxygen, pH, Redox, temperature, turbidity, ammonium, nitrate, chloride, TDS, specific conductivity

******The parameters analysed respectively in the Basic, Periodic and Extended analysis are listed in the subchapter 7.1 of this report.

***Microbiological sampling according to regulations

12.6 SELECTION OF AN ADEQUATE WATER TREATMENT

Sanitary protection zones in karstic area prove not to be effective enough to permanently guarantee the distribution of water respecting quality limits about turbidity and bacteriological contamination for human consumption.

Therefore, a water treatment plant is required for the water supply of Bihac. It is important to focus on the turbidity parameter to determine the means of treatment to be implemented to respect the limit value imposed by the legislations. There are different technologies which can be used for the purification of carstic water. Ideally, the operator should test the effectiveness of the technology with a pilot treatment plant during a full calendar year in order to receive results from different seasons. The implementation of a pilot plant project would also allow to validate the expenses of such a treatment process and eventually to adapt it to best fit to the characteristics of Klokot and Privilica springs water.

In Switzerland, ultrafiltration has become the most common technology used for the treatment of karstic waters over the last 15 years. The Consultant has already designd and build several of such plants and is convinced that such a treatment of the Klokot water would fullfil the expectations.

The cost estimate of a water treatment plant following the treatment steps described below is around € 6 Millions assuming a population of 70.000 inhabitants (calculated with 150 liters per capita per day) in Bihac in 2040.

Ultrafiltration

Ultrafiltration (UF) can be used to remove particles and macromolecules from raw water to produce potable water. UF processes are currently preferred over traditional treatment methods for the following reasons:

- No chemicals required, aside from cleaning
- Constant product quality regardless of feed quality
- Compact plant size
- Capable of exceeding regulatory standards of water quality

The most important part of the ultrafiltration system is the membrane. The water to be cleaned is pressed through the membrane using pressure while particles and organisms bigger than the pores of the membrane are kept back. This way only clean and safe water can pass and be used right away or stored for later use.

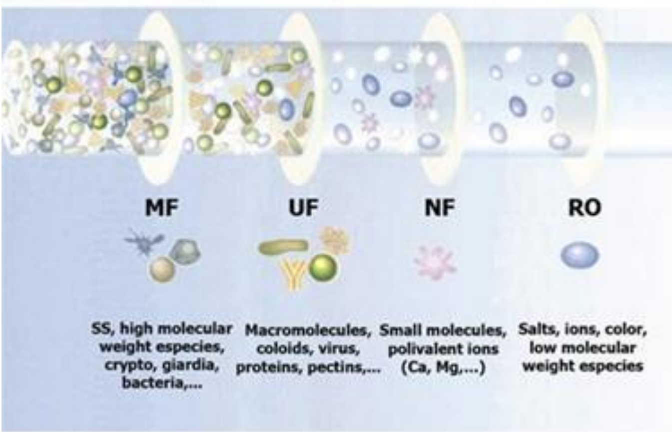


Figure 12.4: *Ultrafiltration (UF) processes utilize a semi-permeable membrane to separate microcontaminants from a water stream.*

Legend:

MF = Microfiltration, UF = Ultrafiltration, NF = Nanofiltration, RO = Reverse Osmosis

UF membranes are specially engineered for drinking water treatment. With its pore size of as small as 0.02 microns it provides more than enough purification performance:

Charge	leaning performance
Bacteria, Viruses	99.999 %
Suspended solids and turbidity	00 %

12.7 SUMMARY OF RECOMMENDATIONS

The table below recapitulates the recommendations for the key measures within the catchment area in function of their impact on drinking water quality.

Impact on drinking water quality at Klokot	Type of Contamination	Recommendations for Measures
Wastewater	Microbiological and chemical contamination	• Develop and operate wastewater collection and treatment in accordance with EU Urban Wastewater Treatment Directive (UWWTD). It implies to design, construct and operate Wastewater Treatment Plants for the agglomerations in the catchement area in Republic of Croatia. • Existing septic tanks and wastewater systems shall be checked on functionality and water tightness. • New septic tanks and on-site treatment systems shall be designed, constructed and operated in a professional way according to standards. • No new settlement should be built in Zone 2 (exceptions are possible with additional protection measures). • Surface and groundwater quality monitoring. • Etc.
Farming	Pesticides, fertilizers, chemical and microbio-logical contamination	• EU and national legislation regarding agriculture shall be respected. • Quantity, places and time of use of pesticides and fertilizers shall be registered by farmers. • Fertilizer and pesticide storage are forbidden in the protection zones. • Regular information should be provided to farmers regarding alternatives to phytosanitary products, which are forbidden. • Alert System with phone number to call in case of an accident and/or other incidents with contaminated underground. • Surface and groundwater quality monitoring. • Etc.
Roads	Chemical (especially petrol) contamination	• No new roads shall be built in zone 2. Exceptions are possible with additional protective measures. • Use of phytosanitary products to treat weed along the roads should be forbidden in Zone 2 and avoided in Zone 3. Information about alternatives to phytosanitary products shall be distributed. • At the boundaries of the catchment basin and at strategic places within the protection zones, the sanitary protection zone should be very clearly and visibly marked at key locations, especially along the roads. • An alert phone number to call in case of an accident and of contaminated underground (oil accident with spilling oil on the ground for instance) shall be available. • Surface and groundwater quality monitoring. • Etc.

Military infra-structure and waste landfills	Chemical contamina-tion	• Potential for contamination should be analysed and dangerous substances should be removed (e.g.: engine oil). • An alert phone number to call in case of incidents with regard to contamination shall be available. • Surface and groundwater quality monitoring. • Etc.
Others: quarries, public places, tourism	Microbiological and chemical contamination	• Sensibilisation of company staff shall be regularly performed (once a year). • Warning boards shall be placed, and access should be blocked to prevent uncontrolled waste disposal in old quarries. • Regular inspection visits of the active and inactive quarries as well as public places shall be organized. • An alert phone number to call in case of incidents with regard to contamination shall be available. • Surface and groundwater quality monitoring. • Etc.
Waste landfills	Microbiological and chemical contamination	• New landfills shall be forbidden in the protection zones. • Surface and groundwater quality monitoring. • Warning board should be placed, and access should be blocked to prevent uncontrolled waste disposal. • Regular inspection visits of the active and inactive waste landfills should be organized. • Etc.

Zurich/Bihac/Zagreb, 09/09/2020, HOLINGER; UNA CONSULTING; HIDROINZENJERING

ANNEX 1
Overview Map of the Catchment Area

ANNEX 2
Hydrogeological Map

ANNEX 3
Table of the Conducted Groundwater Flow Tracings

ANNEX 4
Map of Protection Zones – General with Tracings

ANNEX 4.1

Map of Protection Zones – Zones III and IV

ANNEX 4.2

Map of Protection Zones – Detail Zone II

ANNEX 4.3
Map of Protection Zones – Detail Zone I: Klokot

ANNEX 4.4
Map of Protection Zones – Detail Zone I: Privilica

ANNEX 4.5
Map of Protection Zones – Detail Zone I: Vucjak

ANNEX 5

Process of Development of Interstates Documents

ANNEX 6
Review and Analysis of the existing Legal Framework

ANNEX 7
Klokot Comparison of Rulebooks FBiH and RC Legal part

ANNEX 8

Klokot Comparison of Rulebooks FBiH and RC Technical part

ANNEX 9

Proposal for the Development of Rulebook on Water Protection Zones joint BiH and RH

ANNEX 10

Proposal for the Development of Protection Methods and Survey

ANNEX 11

Proposal for the Development of Decision on Source Protection BiH-RC

ANNEX 12

Proposal for the Development of Treaty on Protection of Karst Aquifers Joint BiH RC

ANNEX 13

Tables of Results of Physical and Chemical Analysis at Klokot Spring Water between 2004 and 2020

ANNEX 14

Overview Table of all Physical and Chemical Parameters which value is over Maximum Authorized Concentration

ANNEX 15

Tables of Results of Microbiological Analysis of Water Quality at Klokot between 2004 and 2020

ANNEX 16

Overview Table of all Microbiological Parameters which Value is over Maximum Authorized Concentration

Annex 17
Map of potential polluters

Annex 18

Map of Proposition of Locations for Marks of Sanitary Protection Zone