PROLINE-CE

WORKPACKAGE T2, ACTIVITY T2.1

SET UP OF PILOT SCECIFIC MANAGEMENT PRACTICES

D.T2.1.4 DESCRIPTIVE DOCUMENTATION OF PILOT ACTIONS AND RELATED ISSUES

PILOT ACTION 2.2: *KOZŁOWA GÓRA*

September, 2017

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Date last release	25.09.2017

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1. Introduction

Within a year in Kozłowa Góra reservoir water quality parameters changing is observed. Preliminary results of field and laboratory investigations indicate that pollution loads, supplied mainly through inlets, cause yearly phytoplankton bloom.

In summer season, especially in June, sometimes July, algal bloom, cause decreasing in quality parameters, is reported. This condition entails difficulties in water treatment and clogging of filters by diatoms and radiators, and consequently, significant increase in treatment costs. For years the result has been closing the Water Treatment Plant up to stabilization of parameters and algal bloom disappearance. The closure of water treatment technological line is associated with additional expenditure spends on f.e. filters perfusion to keep their cleansing capacity.

The motivation to select Kozłowa Góra reservoir as a Pilot Action area was to identify possible sources of pollution and prepare plan of preventive measures and practises implementation.

2. Basic data about pilot action

2.1. Characteristic of the Kozłowa Góra reservoir

Kozłowa Góra is a dam reservoir located at km 28+000 of Brynica River watercourse in the area of Silesian voivodship (Southern Poland) (Figure 1).

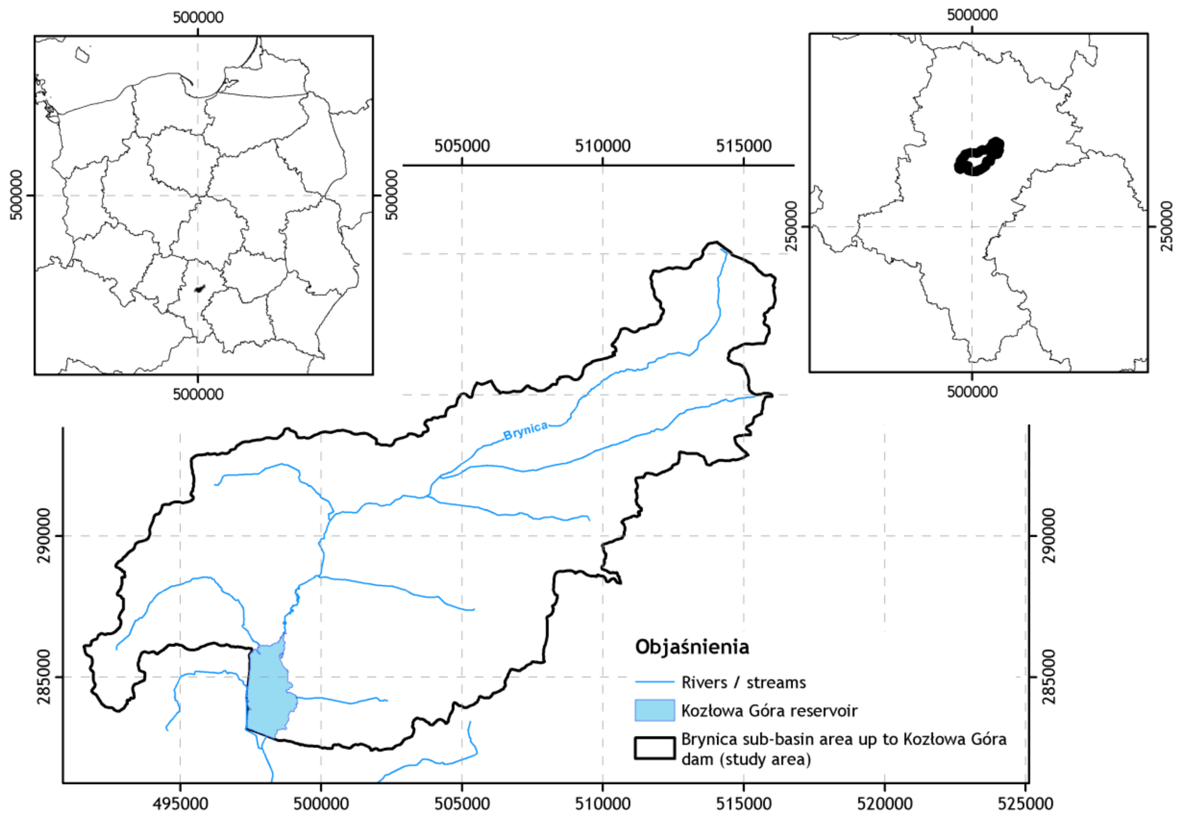


Figure 1. Location of Kozłowa Góra reservoir and Brynica River sub-basin upstream the Kozłowa Góra dam administration map of Poland.

Initially built for defensive-military purposes, the reservoir was placed into service in 1938. At present, it is administered by the Silesian Waterworks PLC in Katowice and serves mainly to provide water for the population. Its supply capacity is 50,000 m3/24h. The reservoir also serves as a flood protection of the areas located downstream of the dam.

The reservoir surface area varies from 1.765 km2 to 6.039 km2, depending on the water damming level. At normal water damming level – 278.08 m a.s.l., the reservoir surface area is 5.268 km2 (Bojarski A. et al., 2004).

Kozłowa Góra reservoir is fed mainly by Brynica waters. According to the hydrological data from 2007-2016, the inflow rates, determined by the water balance method, range from 0.011 m3/s to 32.446 m3/s (Table 1).

Table 1. The flows typical for Brynica at the inflow to Kozłowa Góra reservoir calculated by means of water balance method on the basis of data from 2007-2016.

Water flow	NNQ	SNQ	WNQ	NWQ	SWQ	WWQ	NSQ	SSQ	WSQ
Value [m^3/s]	0.011	0.054	0.15	4.4	13.208	32.446	0.533	0.89	1.608

NNQ – lowest discharge, SNQ – average low discharge, WNQ – highest low discharge, NWQ – lowest high discharge, SWQ - average high discharge, WWQ – highest discharge, NSQ - lowest average discharge, SSQ – average discharge, WSQ – highest average discharge,

Besides Brynica river, the reservoir is also fed by several smaller streams: Rów od Ossy, Potok Ostróżnica, Rów od Pomłynia, Rów od Kalinowej. The flows of these streams are not measured.

The main element of the reservoir is the frontal dam separating Brynica valley at the length of 1,300 m. The 8 m high dam is sealed with a clay screen with the thickness of 70 cm at the base and 18 cm in its upper part. A sheet pilling is placed into the foundation of the dam, and it joins the clay screen at the length of 600 m. There is also a 2,750 m long lateral dam running along the west bank. Its crest is 7 m wide.

The frontal dam has a bottom spillway consisting of 6 gates. The maximum discharge capacity of the bottom spillway ranges from 24.7 to 98.68 m3/s (Bojarski A. et al., 2004). The following characteristic flows were identified in the dam cross-section of Kozłowa Góra reservoir (Olbrych M., 2004):

- minimum acceptable flow (biological) Qbiol.= 0.15 m3/s
- minimum safe flow Qbezp=2.5 m3/s
- nondamaging flow (permitted) QN= 8 m3/s
- maximum allowable flow Qdop= 12 m3/s.

In the years 2007-2016 the extreme outflow values (idle outflow) ranged from 0.150 m3/s to 12 m3/s. In certain years, the average daily outflows varied from 0.387 m3/s to 1.381 m3/s.

The discharge water from the bottom spillways flows into the discharge canal with a trapezoid cross-section 3.0-3.5 wide at the bottom, 1.5 m deep at maximum fill and the slope inclination of 1:2. The northern side of the reservoir, in Niezdara, is formed by 500 m long protective embankment.

Kozłowa Góra reservoir is classified as a shallow reservoir. The reservoir depth, determined on the basis of the bathymetric model of the reservoir basin made in July 2016 by MaxiMapa® company (2016), varies from 0.0 to 4.75 m, with average 2.03 m, at the water damming level at 277.55 m a.s.l.

According to the regulations regarding the "Technical conditions of water management structures and their location" outlined in the resolution of the Minister of Environmental Protection, Natural Resources and Forestry of 20 December 1996 (at present: the Resolution of the Minister of the Environment of 20 April 2007 on technical conditions of hydro-technical structures and their location), Kozłowa Góra dam has been classified as grade II of importance. The type of Kozłowa Góra reservoir was determined according to the classification by Wiśniewolski and Prus (2009), that considers: the average terrain height (for Kozłowa Góra — 250 m a.s.l.), the average depth (2.4 m) (Table 2), the surface area (5.268 km2). The average annual flow SSQ (1.1 m3/s) was also assumed (Strzelecki T. et al., 2010). At the normal water damming level of 278.08 m a.s.l. and the capacity of 12.389 hm3, SSQ 1.1 m3/s, the reservoir residence time is 130 days. In the conditions defined above, Kozłowa Góra reservoir should be classified as Type 15.

The characteristics of Kozłowa Góra reservoir are presented in Table 2.

Table 2 . Characteristics of Kozłowa Góra reservoir (after: Bojarski A. et al., 2004 oraz Jaguś A. et al., 2003; MPHP10).

No.	Feature	Unit	Value
1	Kilometer of Brynica river in the dam cross-section	km	28+000
2	Sub-basin surface area to dam cross-section	km^2	193.93
3	Minimum water damming level (Min PP)	m a.s.l.	275.03
4	Minimum working level for Kozłowa Góra Water Treatment Plant (ZUW)	m a.s.l.	275.29
5	Normal water damming level (NPP)	m a.s.l.	278.08
6	Maximum water damming level (Max PP)	m a.s.l.	278.58
7	Exceptional water damming level (with forced flood reserve filled — Nad PP)	m a.s.l.	278.99
8	Total capacity at damming to the datum level Nad PP 278.99 m a.s.l.	hm^3	17.582
9	Capacity at minimum water damming level 275.03 m a.s.l.	hm^3	1.263
10	Capacity at normal water damming level 278.08 m a.s.l.	hm^3	12.389
11	Capacity at maximum water damming level 278.58 m a.s.l.	hm^3	15.175
12	Compensation capacity between levels 278.08 -275.03 m a.s.l.	hm^3	11.126
13	Flood capacity between datums 278.08 - 278.58 m a.s.l.	hm^3	2.786
14	Flood capacity between levels 278.08 - 278.99 m a.s.l. (with forced	hm^3	5.193

	flood capacity above Max PP)		
15	Surface area at damming to level 275.03 m a.s.l.	km^2	1.765
16	Surface area at damming to level 278.08 m a.s.l.	km^2	5.268
17	Surface area at damming to level 278.58 m a.s.l.	km^2	5.746
18	Surface area at damming to level 278.99 m a.s.l.	km^2	6.039
19	Average depth (at damming to level 277.55 m a.s.l.)	m	2.03
20	Maximum depth (at damming to level 277.55 m a.s.l.)	m	4.75
21	Datum of frontal dam crest	m a.s.l.	280.07
22	Frontal dam height	m	8.0
21	Width of frontal dam crest	m	8.0
22	Frontal dam length	m	1300

2.2. Water management system conducting on Kozłowa Góra reservoir

The description of the water management system in normal operation conditions was made on the basis of the Maintenance and Operating Instructions for the Kozłowa Góra Reservoir (in Polish, title: Instrukcja utrzymania i eksploatacji Zbiornika Wodnego Kozłowa Góra) (Bojarski A. et al., 2004).

The period of normal reservoir operation involves water management within the usable storage capacity of the reservoir – 11.126 hm3, ranging between reservoir water levels of 275.03 and 278.08 m a.s.l. The period of normal reservoir operation consists of three water management phases, depending on water reserves in the reservoir (Table 3).

Table 3. The mode of water management implemented during normal reservoir operation.

No.	Water damming level in the Kozłowa Góra Reservoir	The amount of water in the Kozłowa Góra Reservoir	Maximum water intake by the Kozłowa Góra Water Production Plant (ZPW)	Minimum acceptable flow (biological)
	[m a.s.l.]	[hm^3]	[m^3/s]	[m^3/s]
1.	277.05 - 278.08	5.0 - 11.126	0.58	0.15
2.	276.51 - 277.05	3.0 - 5.0	0.25	
3.	< 276.51	<3.0	0.16	

Flood event water management was detailed described in section 2.7.2 of the report.

2.3. Geographical description

The pilot site lies in the central part of Silesia region and covers the area of 193.93 km2 within the boundaries of the following districts: tarnogórski, będziński, myszkowski and lubliniecki. It is situated outside the territory of the Upper Silesia Conurbation and encompasses communes which are primarily of a rural or urban-rural nature. Administratively, it belongs to 10 communes, amongst which only one commune, i.e. Ożarowice, lies entirely within the confines of the sub-basin. The area of the other communes located within the boundaries of the sub-basin changes from 0.4% of the total area of Tarnowskie Góry to approx. 73% of the Świerklaniec commune. There is also a different share of the communes within the total area of the sub-basin – from 0.17% (Tarnowskie Góry) to 23.46% (Ożarowice).

The area of the Brynica sub-basin, upstream the Kozłowa Góra dam, is situated at the peripheries of three separated mesoregions as distinguished by Kondracki (2002): 318. 57 Opole Plain; 341.12 Tarnowskie Góry Hummock; 341.23 Woźniki Ledge. In the pilot area lowland landscape is dominating, where the lowest heights (in the area of the reservoir) reach 277 m a.s.l., while at the highest locations, the value slightly exceeds 300 m a.s.l. The elevation of the Opole Plain, within the pilot area, reaches to approximately 344 m a.s.l. in the north-western part. The north-eastern part of the sub-basin is located within the limits of Woźniki Ledge. It encompasses the upper course of the river from its beginning in the area of Pustkowie Mysłowskie to the area of Komorne referred to above. River valleys, as in the case of Brynica River, exhibit deeply-cut valley forms surrounded by Triassic hills (

Figure 2). The largest elevations of 368.9 m a.s.l. (Kosiowizna) and 363.8 m a.s.l. (Rudzica) are located to the east and north from the Huta Szklana village at the watershed of Brynica and Warta River.

The remaining part of the sub-basin, to the south and east from the Brynica Valley is located within the limits of the Tarnowskie Góry Hummock. It is a relatively narrow belt of hills, related to Triassic formations constituting the substrate of the northern part of the Silesian Upland, stretching from the culmination of Chełm through the Tarnowicki plateau up to Twardowicki plateau on the east. It is an upland area, diversified with small hills characterized by high relative elevations. The watershed dividing the Brynica sub-basin from the Czarna Przemsza sub-basin on the east runs from the Zabijak-Brudzowice region, through dune hills in the Szeligowiec forrest, between Brudzowice and Mierzęcice and further through Sadowie, Zawada and Nowa Wieś, reaching the highest point of the entire sub-basin - 398 m a.s.l. at a hill between the southern part of that village and Łubianki. Subsequently the watershed runs through the Korzystna Góra hill (381.6 m a.s.l.) in vicinity of Siemonia, where it reaches datum

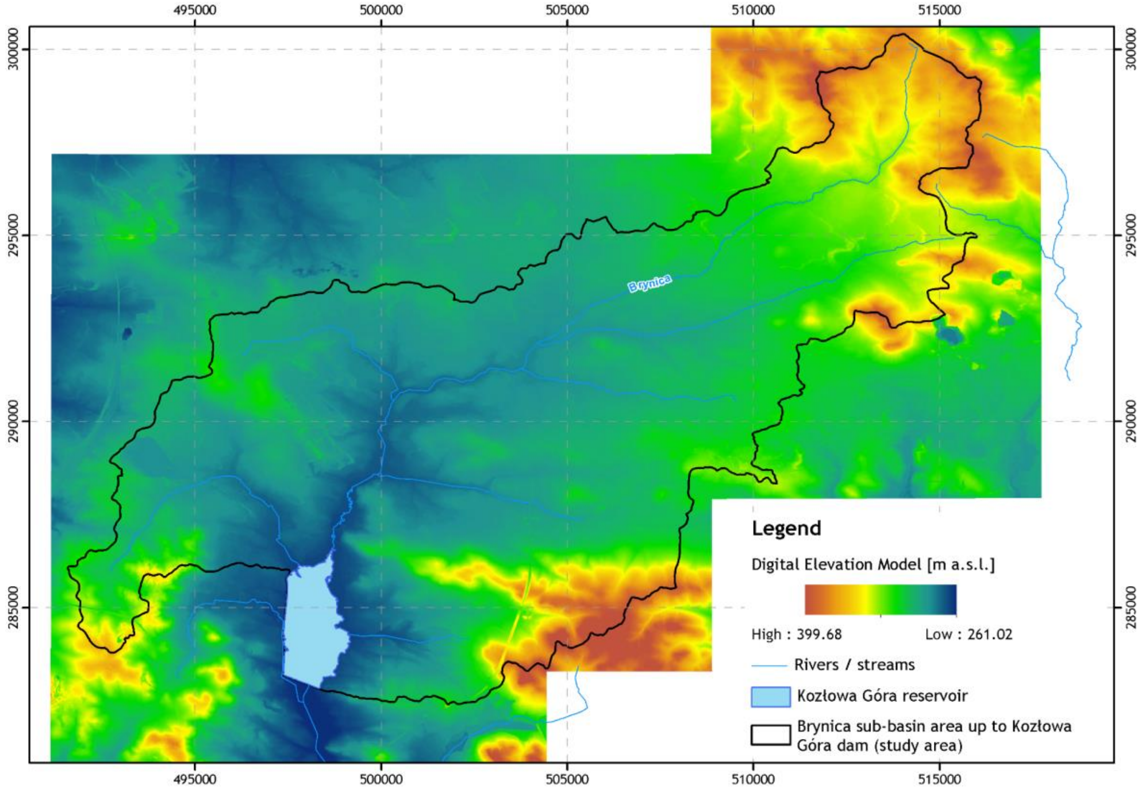


Figure 2. Digital Elevation Model of the study area

corresponding the datum of the area of the dam that is approximately 278 m a.s.l. The landscape of the Tarnowskie Góry Hummock is folded. Relatively large difference in height occur here – from 100 m in the Nowa Wieś area to approximately 0.5 m in the reservoir area (

Figure 2).

The conditions of the relief of the Brynica sub-basin upstream the Kozłowa Góra dam are related to the geological structure of the substrate, the tectonics and the geomorphological processes that took place from Paleogene to Holocene.

2.4. Geological description

The sub-basin area of the Brynica River, upstream the Kozłowa Góra dam, falls within the boundaries of the northern part of the Upper Silesian Depression and the Silesia-Cracow Monocline. In the geological profile identified, there are formations from the Devonian, the Carboniferous, the Permian, the Triassic, the Jurassic and the Quaternary Period (Figure 3). Except for the Permian, formations from these periods are also visible on the ground surface.

In the geological cross-section, formations of the Lower, Middle and Upper Devonian Period were identified to occur under the overburden of Triassic and Quaternary rocks. Their thickness exceeds 1,000 m. The Lower Devonian formations occur as quarzitic sandstones (Wyczółkowski, 1968). The deposits of the Middle and Upper Devonian are represented as carbonate rocks: dolomites and limestones. The deposits of the (Middle) Devonian become exposed only in the area of the Dziewki village near Siewierz (Figure 3).

In the pilot area, there are Lower and Upper Carboniferous formations. In its northern part, the Lower Carboniferous formations occur as alternate clayey-sandy shales and sandstones. A series of carbonate rocks, i.e. dolomites and limestones, was found over the clay-sandstone series (Wyczółkowski J., 1960 b). The higher-lying formations of the Upper Carboniferous have assumed the form of clayey shales, clayey-sandy shales and fine-crystalline sandstones.

In the southern part of the area, within the reach of the Upper Silesian Coal Basin, the Lower Carboniferous formations are classified as Culm facies, while the Upper Carboniferous formations are represented by shales (classified as Paralic series), sandstones and coal of the Poręba, Grodziec and Flora beds. Their outcrops become exposed over small surfaces in the area of Kozłowa Góra (Figure 3).

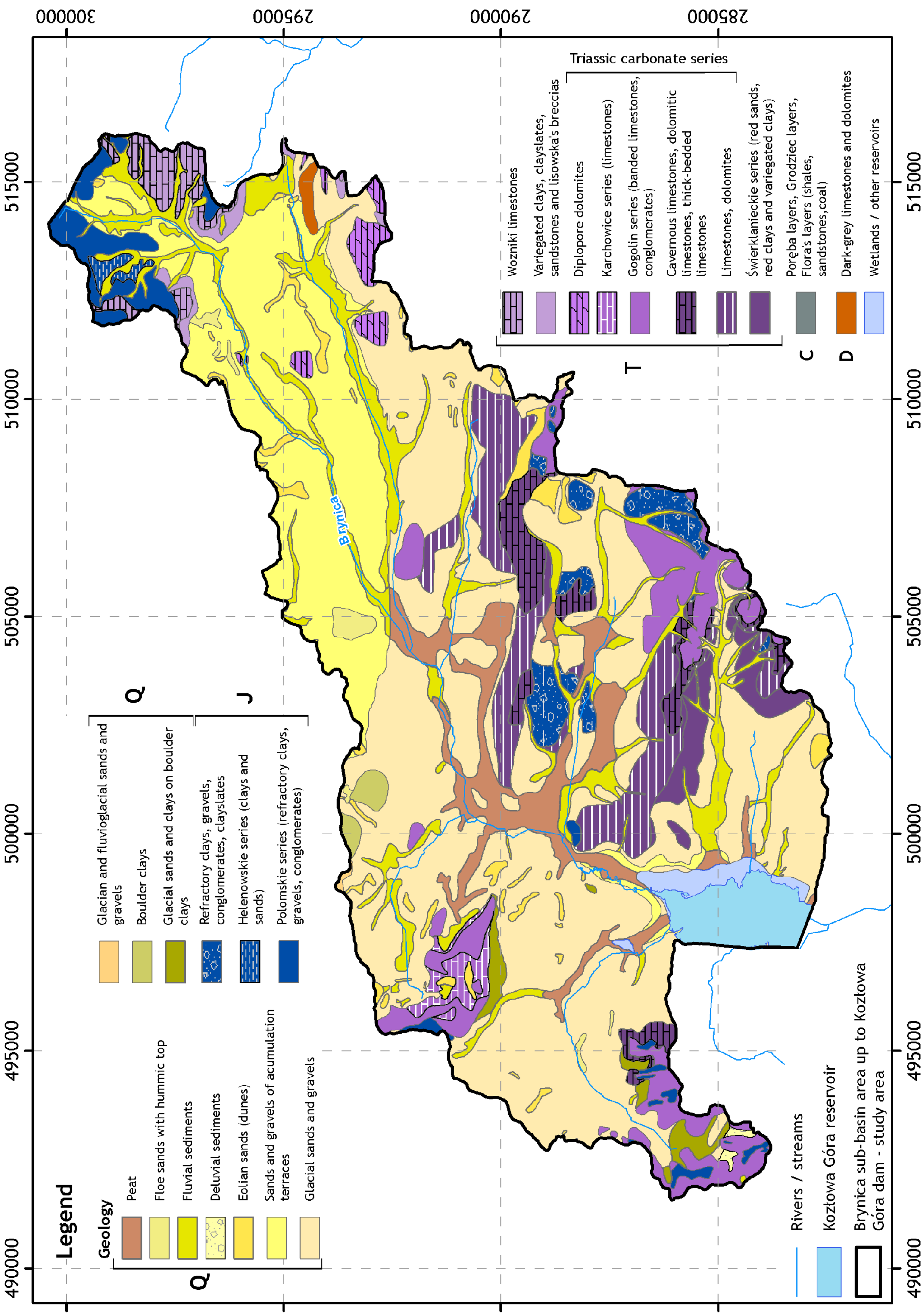


Figure 3. Geological map of the study area (after Biernat S., 1954; Biernat S., 1955; Wyczółkowski J., 1960 ab)

There is little knowledge about the occurrence of Permian formations in the area under scrutiny (Żero E., 1968). No outcrops of these formations are present within the boundaries of the pilot area. The formations from this period, classified as conglomerates and sand-clay-gravel deposits, were identified in boreholes in the area of Świerklaniec, Żyglin, Miasteczko Śląskie and Bibiela (Żero E., 1968).

The geological cross-section of the Triassic Period contains almost all the divisions. The middle lower Bunter sandstone has taken the form of sands, sandstones, conglomerates and mottled clays. In the area under scrutiny, these deposits become visible in the slops of the hills from Piekary Śląskie through Kozłowa Góra to Świerklaniec and Orzech, as well as in the area of Tąpkowice – Podsączów – Myszkowice – Siemonia (Figure 3). The thickness of the middle Bunter sandstone deposits amounts to approximately 25 m (Żero E., 1968).

Higher in the geological cross-section, there is a series of marine sediments from the upper Bunter sandstone (the Rhaetian), reaching the thickness of 50–60 m. The lower part of the Rhaetian is represented by marly dolomites and sandy limestones (Żero E., 1968), which are covered by thick bedded limestones, dolomitic limestones and cavernous limestones. They become exposed in the following regions: Tąpkowice – Myszkowice, Rędzina – Siemonia, Kolonia Podłączna – Pyrzowice – Zadzień, Zendek and Świerklaniec (Figure 3).

The shell limestone formations, lying higher in the geological cross-section, are represented by the so – called Gogolin layers, formed as platy limestone, wavy-bedded, conglomerate and cellular limestones. The outcrops of these formations can be found in the south-eastern part of the Brynica sub-basin: in the area of Żyglin, Bibiela, Świeklaniec, Nakło, Siemonia, Myszkowice and Nowa Wieś, as well as to the north of the Łubne–Niwiska road.

Another division within the shell limestone includes the Górażdże beds formed as limestones, ore – bearing dolomites and Karchowice beds (also formed as limestones). From amongst the above – mentioned formations, it is only the ore-bearing dolomites that appear on the surface, with their outcrops in the area of Żyglin. In the area of Brudzowice, their thickness amounts to approx. 80 m (Wyczółkowski J., 1968 b). In the north-west part of the area analysed, in the vicinity of Brudzowice, Młynek and Podżarze, there are outcrops of diplopore dolomites. Their thickness is approx. 40 m.

The formation of the upper shell limestone (beds from Tarnowice and Wilkowice), classified as limestones and dolomites, were identified in the profiles of most boreholes made within the reach of the Koziegłowy sheet. The thickness of upper shell limestone deposits ranges from 0 to 36 m (Wyczółkowski J., 1968 b).

Higher in the geological cross-section, there are Rhaetic-Keuper formations, which are composed of mottled clays, clay-slates and clay-stones with sandstone and conglomerate insertions. Their thickness reaches several dozen metres. They become exposed in the neighbourhood of Brudzowice, Winowno and Pińczyce (Figure 3). In the uppermost part of the Rhaetic-Keuper profile, there are the Woźniki limestones. Their outcrops in the area under analysis can be found in the vicinity of Winowno, Huta Szklana, Pińczyce and Markowice. They do not form a single, regular level. The boreholes made indicate that there are at least two levels of limestones separated from each other by a thick layer of clays. The maximum thickness of the Woźniki limestones, amounting to more than 24 m, was determined in the nearby Woźniki village.

The Jurassic formations within the area described occur locally and are represented by lias. They are classified as refractory clays, conglomerates, clay-slates and sands. Superficial Lias formations can be found in the following areas: Ożarowice, Zawada and Mierzęcice, Pyrzowice, Markowice, Łazy, Pustkowie Mysłońskie and Zabijak (Figure 3).

The surface of the area described is dominated by Quaternary formations. Besides the area of fluvial valleys in its southern and central parts, there are glacial sands and gravels, deposited during the Mid-Poland Glaciation. Between Zendek and Winowno, there is a wide zone covered with sands and gravels of the accumulation terraces deposited during the Baltic glaciation. In watercourse valleys, there are fluvial deposits and peat formations.

2.5. Pedology

In the analysed area, 8 types of soils were distinguished based on the agricultural-maps of the IUNG. In agricultural areas, brown soil and podzolic soils are the dominating types, comprising 50% of the area. Moreover, quite fertile soils, namely black earths and rendzinas exhibit a significant share in the studied area, corresponding to 20 and 15%, respectively (Table 4).

Table 4. Soils types in agricultural areas

Soil type	Black earths	Bogged soils	Podzolic soils	Brown earths	Postmurhic soils	Soils unfit for agriculture	Peat soils	Fluvisols	Redzinas
Percentage share [%]	19.8	7.2	24.1	25.4	5	0.3	2.1	1.2	15

The individual types of soils occur in relatively high dispersion in the studied area, with the exception of a significant uniform area of occurrence of podzolic soils in the north-eastern part of the area and a relatively large area of black earths in the central part (Figure 4).

The occurrence of the individual types of soil is dependent on the texture in the entire soil profile. In the analyzed area, the dominating type is constituted by sandy soils, including mostly sands. Another type of soils that commonly occurs in the studied area is rendzinas. Their distribution is related to carbonate rocks occurring at low depths near the surface. The remaining types of soils take a much smaller part in the studied area (Figure 5).

The formation of soil is a very slow process and thus its proper use and protection is extremely important. The greatest threats related to degradation of soil in the pilot area include the sealing of soil in urbanized areas and areas covered by communication infrastructure, which may lead to a complete loss of soils. Soil sealing which means the covering of the ground by an impermeable material poses one of the main causes of soil degradation in the EU. Soil sealing cover about 3.5 % of the study area and occurs in central and southwestern part. In the pilot area, where over 40% of the area is constituted by agricultural lands, the soils may be endangered by improper agricultural activities leading to the impoverishment of soil. Agricultural practices which may have a negative impact on the quality and quantity condition of soils is related i.e. to the liquidation of waterholes and field-swamps, mechanical and chemical devastation of natural vegetation including woodlots, thus promoting water and aeolian erosion of soil. The contamination of soil is also related to the developed industrial activities in the vicinity of the analysed sub-basin. This promotes increased concentration of trace elements in soil, including heavy metals. For that reason, the area of the Świerklaniec municipality was included as an agricultural problem area. The pollution of soil with metals was also found in remaining municipalities. The most common values of heavy metals which were exceeded in soils include the presence of cadmium, zinc and lead. The main sources of this contamination are constituted by the zinc mill operating in Miasteczko Sląskie, combustion of solid fuels and the use of sludge and sewage. The greatest hazard of pollution of soils with heavy metals occurs in areas with acid soils – in such case the elements become mobile and may easily reach surface and underground waters as well as the tissues of plants and animals.

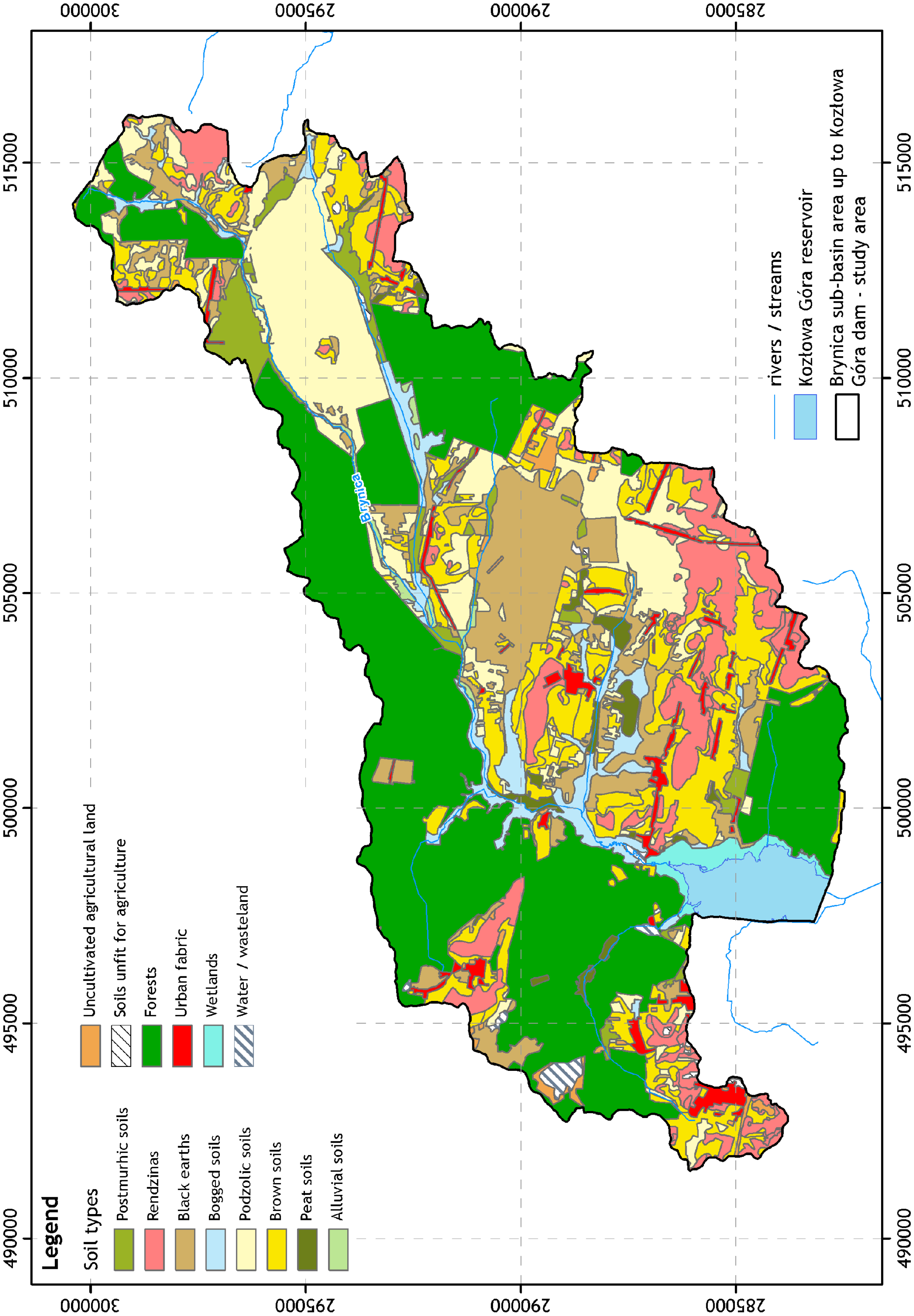


Figure 4. Soil types in the study area

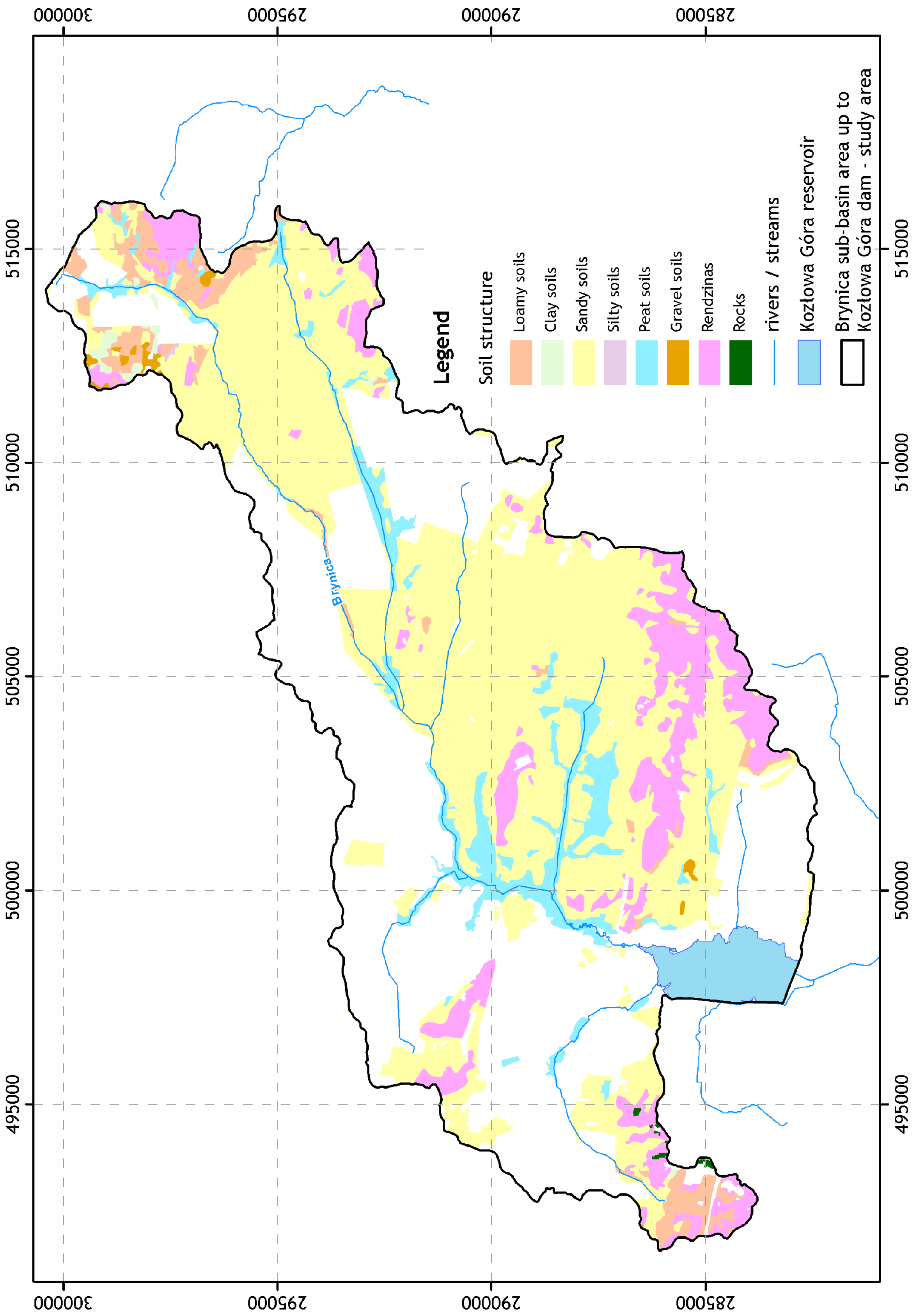


Figure 5. Soil species based on soil texture in the studied area

2.6. Climate characteristics

The climatic conditions of the Kozłowa Góra reservoir and its surroundings are determined by 3 main climate driving factors including the circulation of atmosphere, astronomical factors which determine the amount of solar radiation reaching earth and local conditions including mostly topography, exposure or altitude.

In line with the Woś's classification (2010), the area of the Kozłowa Góra reservoir lies within the Upper-Silesian Climatic Region (No. 26). In the region, the annual number of sunny hours reaches 1427 (589 in the summer and 133 in winter) and is the lowest in the country. The mean daily sunshine time varies from 6.3 h in June to 1.1 h in December. The mean annual air temperature is 8.1°C. The monthly maximum is in July (17.8°C) while the minimum is in January (-2.4°C) which results in the amplitude of 19.9°C.

In the pilot area the mean annual air temperature was 7.9°C and varied in individual years between 9.9°C (2014) and 6.3°C (1996). As in the entire Europe, summer is the warmest season with a mean temperature reaching +17.1°C. In autumn and spring, the air temperature difference is slight (8.2°C and +7.9°C, respectively) and decreases below zero only in winter (-1.4°C). In the winter, the range of air temperature variability in the period in concern was higher than in any other season. During the warmest winter (2006/07), the mean temperature reached up to +2.4°C, while in the coldest winter season, it dropped below -7.9°C (1962). In case of the remaining seasons, the variability range of the mean air temperature did not exceed 5°C. Within a year, the highest air temperature is exhibited by July (17.9°C) while the lowest is in January (-2.3°C). The lowest mean temperature of January, -10.7°C, was noted in 1987, while the highest temperature of July, namely 21.5°C occurred in 2006.

Annually, 719 mm of precipitation is noted in the area of the Kozłowa Góra reservoir. The highest annual sum of precipitation, exceeding as much as 1024 was noted in 2010; the lowest sum of less than 500 mm occurred in 1982, which results in a wide range of variability amounting to 524 mm. Precipitation in the warm half of the year, reaching a mean amount of 450.7 mm, constitute approximately 63% precipitation of the cold half of the year, amounting on average to 268.7 mm. The amount of precipitation in the warm half of the year may however vary in a wide range from 727.8 mm to 269.4 mm. The range of variability in case of the cold half of the year was significantly smaller – from 391.2 mm to 155.8 mm.

In the area of the Kozłowa Góra reservoir, the mean monthly total precipitation varied from 35.4 mm in February to 100.1 mm in July. The highest monthly sum of precipitation in the period in concern, however, was noted not in July, but in May of 2010 – 269.1 mm, when the high precipitation in the second half of the month led to the flood which covered the Central Europe.

2.7. Hydrology

2.7.1. Surface waters

The entire sub-basin area of the Kozłowa Góra Reservoir is located in the left-side catchment area of the Vistula River and is supplied with water from the Brynica River (a tributary of the Przemsza River) along with its tributaries. The watersheds separating the sub-basins of the Przemsza River's tributaries belong to class III, while the sub-basins of the Brynica River's tributaries – to class IV. In the vast majority of cases, the watersheds have a stable course and demonstrate an unstable course only in built-up areas and lands with clearly anthropogenic transformations of the surface. Across the entire sub-basin, there are also no-outflow areas, mainly in the abandoned extraction sites of building minerals. Moreover, in many parts of the area, there are absorptive and evapotranspirational no-outflow depressions.

The Brynica River starts its course at the foot of the Woźniki ledge at the altitude of approximately 340 m a.s.l. and after overcoming the elevation difference of 100 m at the distance of 54.9 km, it flows into the Czarna Przemsza River.

The main left-bank tributaries of the Brynica River at the upstream section from the reservoir include: Trzonia, Czeczówka and Potok Ożarowicki along with Rów z Siedlisk. The only right-bank tributary at this section is the Dopływ spod Żyglinka. The Kozłowa Góra Reservoir is directly fed by: Dopływ z Siemoni (left bank) and Potok spod Nakła (right bank). The Rów Świerklaniecki ditch flowing towards the reservoir from the west was diverted and now enters the Brynica River downstream from the reservoir.

The surface watercourses in the neighbourhood of the Kozłowa Góra Reservoir – except for the Brynica River – are characterised by a short length and flow rates ranging from a few to several dozen dm3/s. In estuary cross-sections, they can reach a few hundred dm3/s at the maximum (Budzyńska A. et al., 1999). The greatest number of small watercourses flow directly into the reservoir on its eastern side. The east bank of the reservoir is visibly waterlogged, while the west bank is encircled by an embankment wall. Oftentimes, small watercourses are periodic or episodic in nature (Figure 6). They carry water during the snow-melt season and in the periods of heavier rains (Jaguś A., Rzętała M., 2003).

A relatively large amount of water is carried in the watercourse that flows into the Kozłowa Góra Reservoir on its north-west side. It consists of two watercourses and a large part of the tributaries are formed by drainage ditches.

In the sub-basin of the reservoir, the Brynica River and its tributaries lie in the bottoms of flat waterlogged valleys. Some watercourses are formed by drainage ditches permanently or periodically filled with water. The Brynica River, at the section of 10 km from its springs, was regulated as a result of land improvement works on the agriculturally active meadows and farmlands and it further flows along its natural bed (often meandering) through afforested areas as well as meadows and farmlands (Strzelec M. et al., 1999). The width of the Brynica River bed oscillates between 0.5–1.0 m in the source section and 5 m before reaching the estuary (Jaguś A., Rzętała M., 2003). Its left-bank tributaries are more numerous and have significantly longer valleys than their left-side counterparts.

Many streams and rivers have been equipped with infrastructural developments of the banks, which – along with the system of weirs and gates – are mainly used for proper drainage and irrigation of agricultural and forest areas. Such infrastructural developments of river banks are also present in urbanised areas.

In the close vicinity of the Kozłowa Góra Reservoir, there are several other small reservoirs, e.g. the reservoir in Ostrożnica and the reservoir in the palace-park complex. In the neighbourhood of the build-up area in Kozłowa Góra, there are numerous tiny reservoirs in rock excavation pits (Jaguś A., Rzętała M., 2003). The area of the Kozłowa Góra Reservoir's basin amounts to 193.93 km2 (MPHP13).

The hydrological characteristics of the area are based on the data from 2 gauge stations of the Institute of Meteorology and Water Management (Polish: IMGW) – Brynica on the Brynica River (upstream of the reservoir) and the Brynica Namiarki (downstream of the reservoir). Characteristic monthly discharges have been summarised in Table 5, and their course within a hydrological year has been presented in Figure 7.

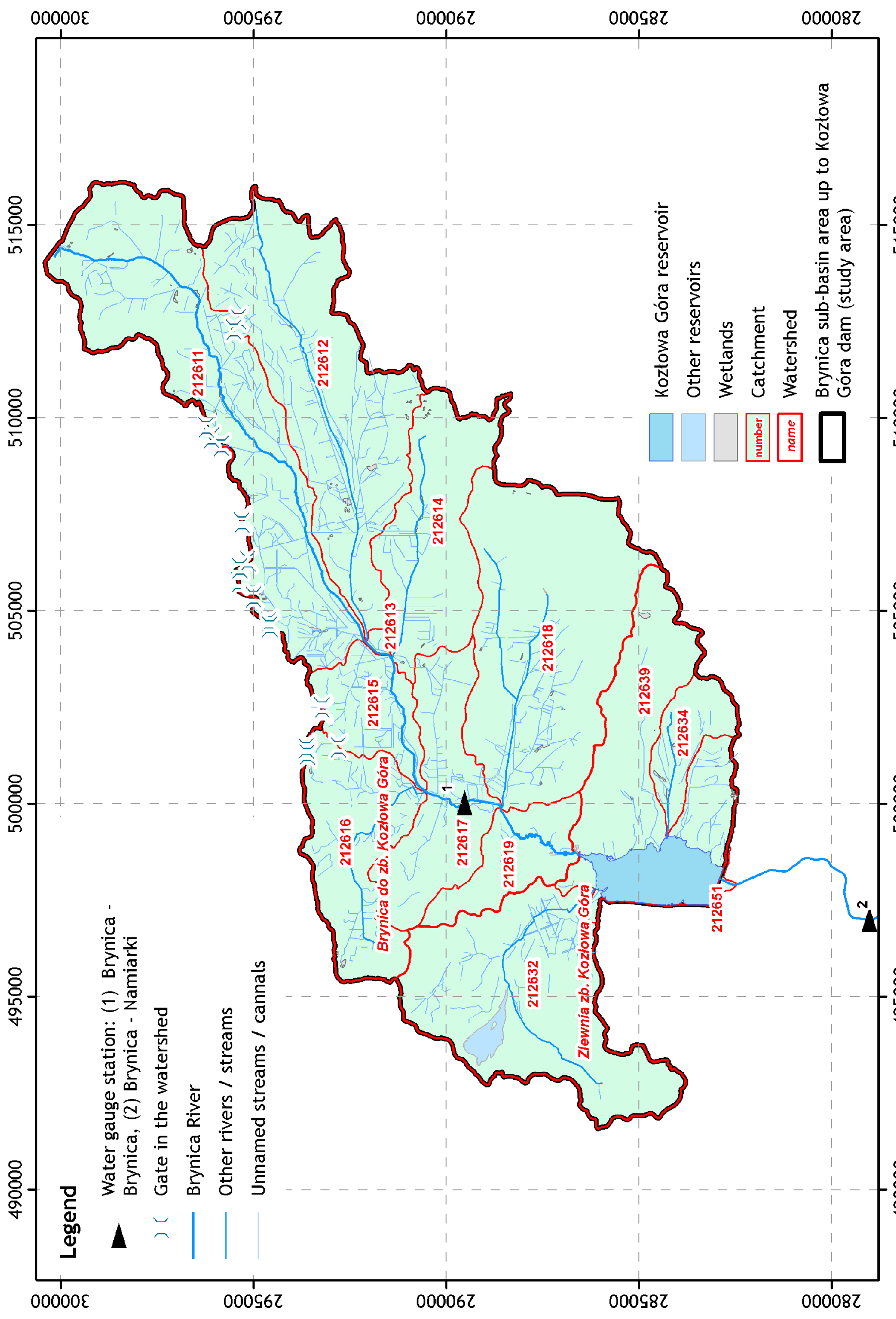
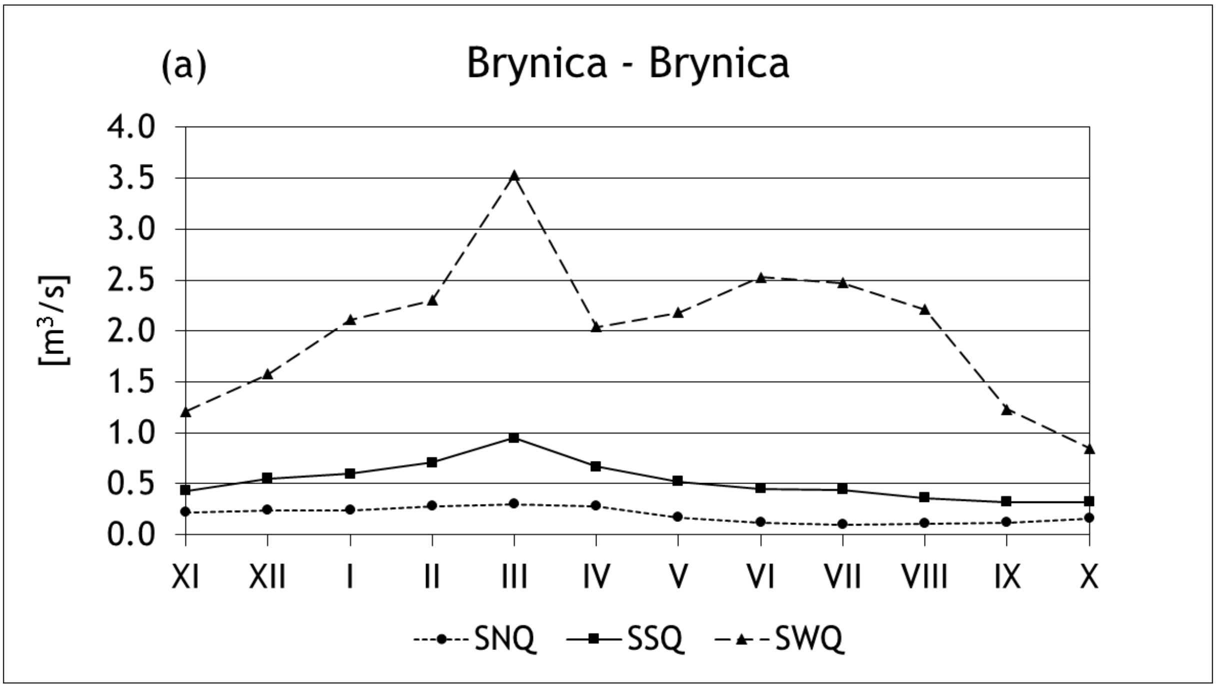


Figure 6. Hydrological map of the study area



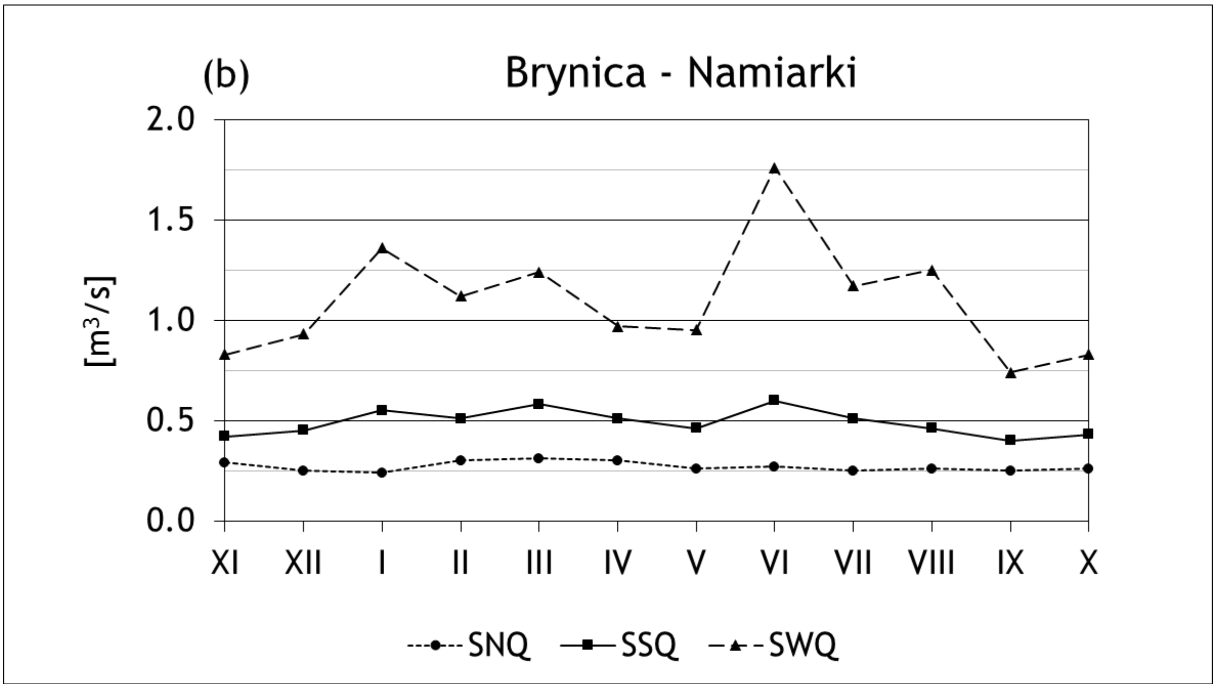


Figure 7. The course of outflow within a hydrological year for water gauge station (a) Brynica – Brynica in the long-term period of 1961- 2015 and (b) Brynica – Namiarki in of 1961-1999 (Absalon D. i in., 2001 ab).

SNQ – average low discharge, SSQ – average discharge, SWQ – average high discharge.

Table 5. Average monthly discharge coefficients and irregular runoff coefficients (λ) (Absalon D. et al., 2001ab, daily data IMGW).

River - water gauge	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	λ
Brynica - Brynica	0.81	1.04	1.13	1.34	1.79	1.26	0.98	0.85	0.83	0.68	0.60	0.60	-*
Brynica - Namiarki	0.86	0.92	1.12	1.04	1.18	1.04	0.94	1.22	1.04	0.94	0.82	0.88	370

* available daily data, in the long-term period of 1961-2015, do not allow to estimate irregular runoff coefficients

The sub-basin area upstream of the reservoir shows a slight domination of the winter half-year runoff, which constitutes 62% of the annual runoff. The annual course of runoff demonstrates one distinct spring high water stage with the maximum level in March, when the flow rate reaches 179% of the average annual flow. The period of increased flows begins as early as in December and ends in April (the Brynica River). The minimum flow occurs in the autumn period (September - October) when the average flow amounts to 60% of the value of the average annual flow. A period of reduced flows lasts from June to November. A similar regime is demonstrated by the minimum and maximum flows.

The regime of the Brynica River outflow downstream from the reservoir (the Namiarki water gauge) is considerably shaped under the influence of the Kozłowa Góra Reservoir, which leads to the adjustment of the flows (the maximum flows in particular). It should be remembered that the data come from the period of intensive water intake from the reservoir.

This sub-basin shows a slight domination of the winter half-year runoff, which constitutes 52% of the annual runoff. The annual course of runoff demonstrates three distinct high water stages: The first can be observed in January, the second occurs during the spring snow-melt season, while the third – being the highest – reaches its maximum level in June, when the average flow rate amounts to 122% of the average annual flow. The minimum flow occurs in September when the average flow amounts to 82% of the value of the average annual flow (Table 6). A period of reduced flows lasts from August to December.

The effect of the functioning of the Kozłowa Góra Reservoir (water intake, evaporation) is a very low average specific runoff, which is equal to only 2.26 dm3/s*km2, thereby constituting 43% of the specific runoff value in the Brynica profile, situated upstream from the reservoir.

Table 6. The extreme statuses observed (cm), the extreme and average discharges (m^3/s) and the corresponding specific discharges ($dm^3/s*km^2$).

River	WWW date		SSW period		NNW date	
Water gauge	WWQ date	WWq	SSQ period	SSq	NNQ date	NNq
Brynica	292 15.05.1996		-		108 14.07.1995	
Brynica	17.8 2.06.1962	181	0.53 1961-2015*	5.40	0.007 14.09.1992	0.07
Brynica	310 22.07.1997		167 1961-1995		122 16.11.1956	
Namiarki	14.8 12.06.1968	68.2	0.49 1961-1999	2.26	0.047 18.03.1964	0.18

WWW – highest water level, WWQ – highest discharge, WWq – highest specific discharge, SSW – average water level, SSQ – average discharge, SSq – average specific discharge, NNW – lowest water level, NNQ – lowest discharge, NNq – lowest specific discharge

Surface water resources, in the Brynica section are determined by average discharge (data in the long-term period of 1961 – 2015) which is 0.53 m3/s, corresponding to outflow index H=169 mm and specific discharges at 5.40 (dm3/s*km2).

The human economic activities in the area under examination result in far-reaching transformations of the natural environment, particularly the area surface and hydrographic conditions (Absalon D. et al., 2001ab). They involve, amongst others:

- changes in the hydrographic network layout;
- water quality degradation;
- interference with the natural water cycle;
- changes in the groundwater table levels.

2.7.1.1. Surface water quality

The quality assessment of water bodies was prepared on the basis of the data from the Provincial Environment Protection Inspectorate (WIOŚ) (assessment of the ecological and chemical statuses as well as the quality of the water bodies in 2015, taking into account the results of the assessments for the years 2011 – 2014). The assessment was performed for 3 surface water bodies (SWB), located in the study area: The Brynica River from its source to the Kozłowa Góra Reservoir PLRW20005212619, the Kozłowa Góra Reservoir PLRW20000212639, Potok spod Nakła PLRW20006212632 (Figure 8). They are part of Catchments of Integrated Water Bodies (CIWB): Brynica River from its source up to Kozłowa Góra reservoir MW0202 and Brynica River from Kozłowa Góra Reservoir up to the estuary, includes Kozłowa Góra Reservoir MW0203, where only the northern part covers the study area (Figure 9).

The Brynica River from its source to the Kozłowa Góra Reservoir PLRW20005212619 is classified as an abiotic surface water body (SWB) type 5 (upland silicate stream with fine-grained substrate – western). Potok spod Nakła PLRW20006212632, as an abiotic type 6 (upland carbonate stream with fine-grained substrate on loess and loess-like rocks). Ecological status is determined for abiotic types 5 and 6. The Kozłowa Góra Reservoir PLRW20000212639 is classified as type "0" – severely changed body of water for which the ecological potential is determined.

The Brynica River, from its source to the Kozłowa Góra Reservoir, and Potok spod Nakła are characterised by the 2nd class of biological elements. The Kozłowa Góra Reservoir, on the other hand, by the 3rd class due to the FLORA indices (the total assessment class for the diatom and phytoplankton indices).

The SWB Brynica River from its source to the Kozłowa Góra Reservoir and the Kozłowa Góra Reservoir correspond to the 1st class of hydromorphological elements. Potok spod Nakła corresponds to 2nd class hydromorphological elements.

The class of physicochemical elements, including: oxygenation conditions, salinity, acidification and biogenic substances, made it possible to classify the SWB Brynica River, from its source to the Kozłowa Góra Reservoir, and Potok spod Nakła to class II. The SWB Kozłowa Góra Reservoir was classified below the good potential due to the parameter which determines the oxygenation conditions, namely ChZT-Cr, which amounted to 30.42 mgO2/L in 2015.

The SWB Brynica River from its source to the Kozłowa Góra Reservoir and the Kozłowa Góra Reservoir in the class of physicochemical elements – specific synthetic and non-synthetic contaminations – were qualified as class II, while the Potok spod Nakła – as class I. The following substances determined the classification into the 2nd class: barium, aluminium, copper and phenols.

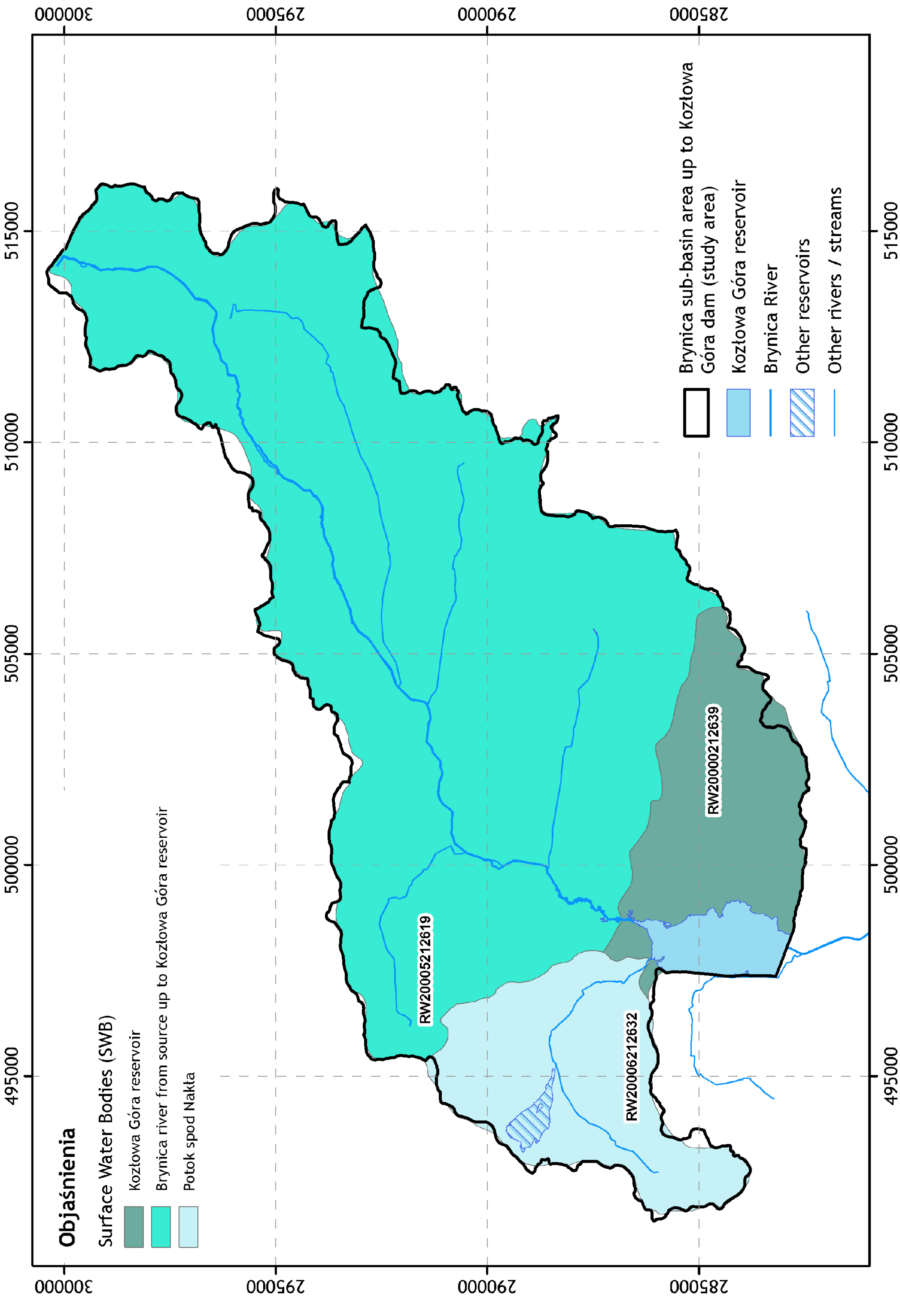


Figure 8. Location of the study area on the background of Surface Water Bodies (SWB) borders.

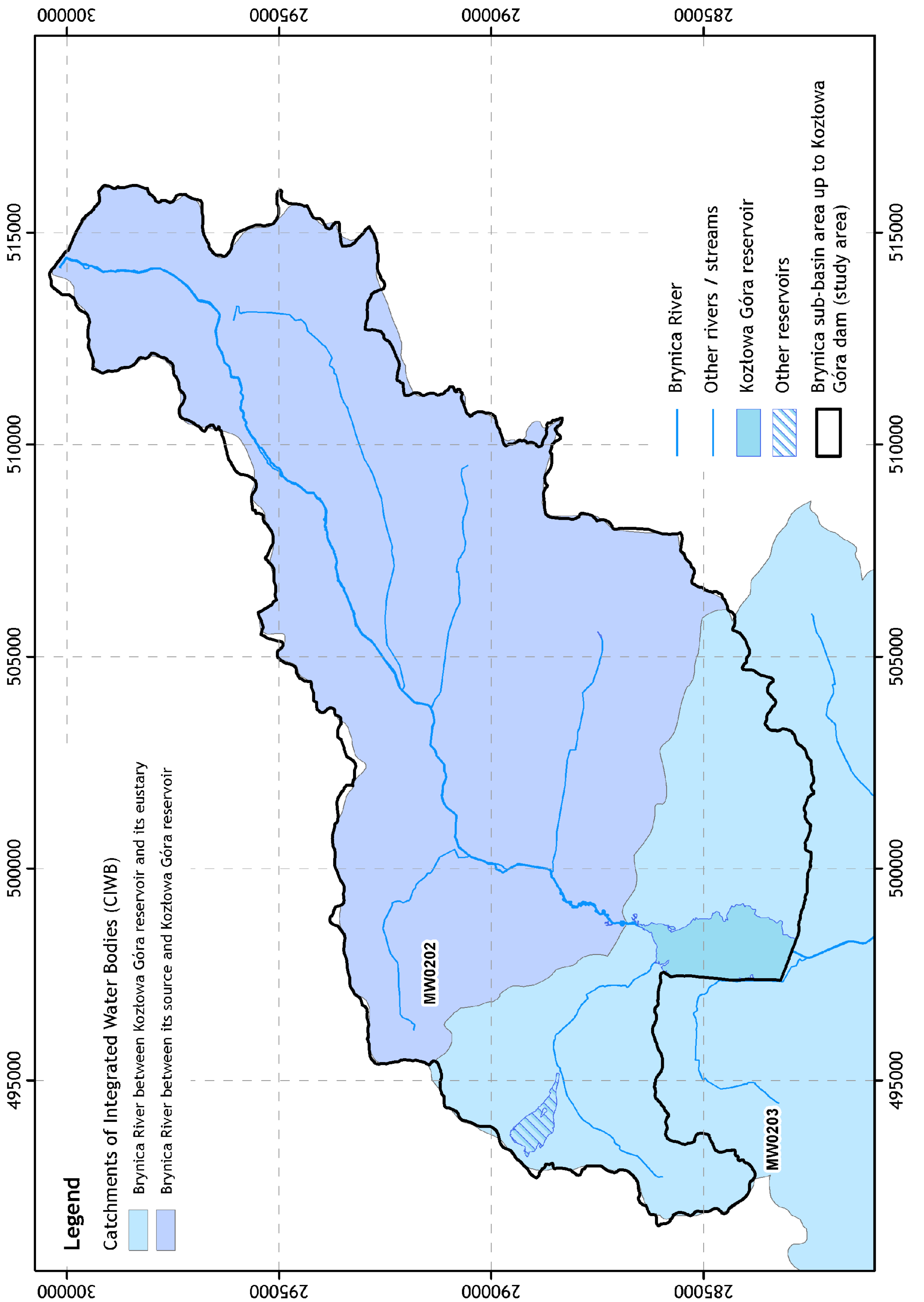


Figure 9. Location of the study area on the background of the Catchments of Integrated Water Bodies (CIWB) borders.

Table 7. Results of the Operational Monitoring (MO) of SWB.

SWB	Code of SWB	Code of monitoring point	Name of the nearest water table gauge	Abiotic type	Strongly modified or artificial SWB (Y / N)	PrMonitoring porgramme	Biological elements class	Hydromorphological elements class	Physicochemical Elements Class (Group 3.1 - 3.5)	Physicochemical elements - specific synthetic and non-synthetic impurities class (3.6)	Ecological status / potential	Chemical status	Does SWB occur in the protected area? (Y/N)	Have all additional requirements been met? (Y/N/NA)	STATUS
Brynica od źródeł do zbiornika Kozłowa Góra	PLRW20005212619	PL01S1301_1698	Brynica - powyżej zb. Kozłowa Góra	5	N	MO	II	I	II	II	GOOD	PSD_sr	Y	N	BAD
Zbiornik Kozłowa Góra	PLRW20000212639	PLO1S1302_0703	Zbiornik Kozłowa Góra - w rejonie zapory	0	T	MO	III	I	PSD	II	MODERATE	GOOD	Y	N	BAD
Potok spod Nakła	PLRW20006212632	PL01S1301_2147	Potok spod Nakła - m. Ostrożnica	6	N	MO	II	II	II	I	GOOD	PSD	Y	N	BAD

Table 8. Results of the Monitoring for Protected Area (MPA) of SWB.

SWB	Code of SWB	Code of monitoring point	Name of the nearest water table gauge	Abiotic type	Strongly modified or artificial SWB (Y / N)	PrMonitoring porgramme	Biological elements class	Hydromorphological elements class	Physicochemical Elements Class (Group 3.1 - 3.5)	Physicochemical elements - specific synthetic and non-synthetic impurities class (3.6)	Ecological status / potential	Chemical status	Protected area code	Evaluation of meeting requirements	STATUS
Brynica od źródeł do zbiornika Kozłowa Góra	PLRW20005212619	PL01S1301_1698	Brynica - powyżej zb. Kozłowa Góra	5	N	MOEU	II	I	II	II	DOBRY	PSD_sr	PLRW20005212619	T	BAD
Zbiornik Kozłowa Góra	PLRW20000212639	PL01S1302_073	Zbiornik Kozłowa Góra w rejonie zapory	0	T	MOPI	III	I	PSD	II	UMIARKOWANY	DOBRY	PLDW20000212639	N	BAD
Potok spod Nakła	PLRW20006212632	PL01S301_2147	Potok spod Nakła - Ostrożnica	6	N	MOEU	II	II	II	I	DOBRY	PSD	PLRW20006212632	T	BAD

Legend for Table 7 and Table 8:

CLASS OF BIOLOGICAL QUALITY ELEMENTS			
ECOLOGICAL STATUS		ECOLOGICAL POTENTIAL OF ARTIFICIAL WATER BODIES	ECOLOGICAL POTENTIAL OF HEAVILY MODIFIED WATER BODIES
I	HIGH ECOLOGICAL STATUS/ MAXIMUM ECOLOGICAL POTENTIAL	I	I
II	GOOD ECOLOGICAL STATUS/ GOOD ECOLOGICAL POTENTIAL	II	II
III	MODERATE ECOLOGICAL STATUS/ MODERATE ECOLOGICAL POTENTIAL	III	III
IV	POOR ECOLOGICAL STATUS/ POOR ECOLOGICAL POTENTIAL	IV	IV
V	BAD ECOLOGICAL STATUS/ BAD ECOLOGICAL POTENTIAL	V	V
CLASS OF HYDROMORPHOLOGICAL QUALITY ELEMENTS			
ECOLOGICAL STATUS		ECOLOGICAL POTENTIAL OF ARTIFICIAL WATER BODIES	ECOLOGICAL POTENTIAL OF HEAVILY MODIFIED WATER BODIES
I	HIGH ECOLOGICAL STATUS/ MAXIMUM ECOLOGICAL POTENTIAL	I	I
II	GOOD ECOLOGICAL STATUS/ GOOD ECOLOGICAL POTENTIAL	II	II
CLASS OF PHYSICO-CHEMICAL QUALITY ELEMENTS			
ECOLOGICAL STATUS		ECOLOGICAL POTENTIAL OF ARTIFICIAL WATER BODIES	ECOLOGICAL POTENTIAL OF HEAVILY MODIFIED WATER BODIES
I	HIGH ECOLOGICAL STATUS/ MAXIMUM ECOLOGICAL POTENTIAL	I	I
II	GOOD ECOLOGICAL STATUS/ GOOD ECOLOGICAL POTENTIAL	II	II
PSD	BELOW GOOD ECOLOGICAL STATUS / POTENTIAL	PPD	PPD
ECOLOGICAL STATUS/ POTENTIAL			
ECOLOGICAL STATUS		ECOLOGICAL POTENTIAL OF ARTIFICIAL WATER BODIES	ECOLOGICAL POTENTIAL OF HEAVILY MODIFIED WATER BODIES
VERY GOOD	HIGH ECOLOGICAL STATUS/ MAXIMUM ECOLOGICAL POTENTIAL	MAXIMUM	MAXIMUM
GOOD	GOOD ECOLOGICAL STATUS/ GOOD ECOLOGICAL POTENTIAL	GOOD	GOOD
MODERATE	MODERATE ECOLOGICAL STATUS/ MODERATE ECOLOGICAL POTENTIAL	MODERATE	MODERATE
POOR	POOR ECOLOGICAL STATUS/ POOR ECOLOGICAL POTENTIAL	POOR	POOR
BAD	BAD ECOLOGICAL STATUS/ BAD ECOLOGICAL POTENTIAL	BAD	BAD

CHEMICAL STATUS		
GOOD	GOOD CHEMICAL STATUS	
PSD_sr	BELOW GOOD CHEMICAL STATUS	AVERAGE ANNUAL CONCENTRATION EXCEEDED
PSD_max		MAXIMUM CONCENTRATION EXCEEDED
PSD		AVERAGE ANNUAL AND MAXIMUM CONCENTRATION EXCEEDED

STATUS OF SWB	
GOOD	GOOD STATUS
BAD	BAD STATUS

Based on the classes described above, it was determined that the ecological status of the SWB Brynica River from its springs to the Kozłowa Góra Reservoir and of Potok spod Nakła is good. The SWB Kozłowa Góra Reservoir is characterised by moderate ecological potential.

The chemical status of the SWB Kozłowa Góra Reservoir was determined as good. The status of the other SWB under analysis was below good. In the case of Potok spod Nakła, this was due to the cadmium and its compounds, while in the case of the Brynica River from its springs to the Kozłowa Góra Reservoir – benzo(g,h,i)perilen and Indeno(1,2,3-cd)pyren.

The final assessment of the SWB under analysis indicates that the quality of water is poor (

Table 7).

The SWB in question are located in protected areas. The SWB Kozłowa Góra Reservoir is covered by the operational monitoring programme of surface waters used as a source of potable water for inhabitants, implemented in special control measurement sites (MOPI). In accordance with the results, the SWB does not comply with the additional requirements for surface waters used as a source of potable water for inhabitants. The failure to comply with the requirements (except for A3) is due to the ChZT-Cr (mg/L) value being exceeded.

The SWB Brynica River, from its springs to the Kozłowa Góra Reservoir, and Potok spod Nakła are covered by the monitoring programme of SWBs sensitive to eutrophication caused by contaminants from municipal sources (MOEU). In both cases, the requirements for water bodies sensitive to eutrophication caused by municipal contaminants have been met (Table 8).

2.7.2. Flood issues

Kozłowa Góra reservoir is not only drinking water source, but also meets function of flood mitigation in Brynica River catchment. Generally it is characterized by relatively high flood capacity.

The biggest flood event so far was observed in May 2010. For the very first time observed water inflow, to the reservoir, exceeded 48,39 m3/s. The flood event estimated probability was 0.22% - 1 in 450 years' flood. The flood was completely reduced to discharge up to 12m3/s (maximum discharge value for the Kozłowa Góra reservoir) (Figure 10).

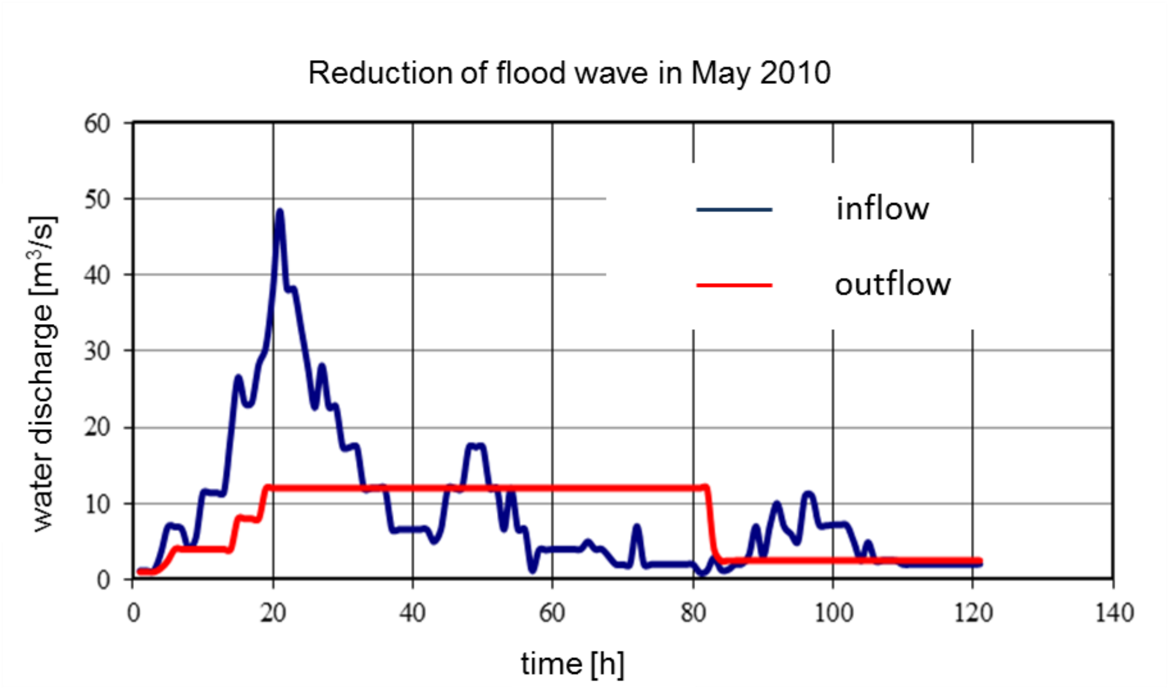


Figure 10. Flood event in May 2010.

The description of the water management during flood events was made on the basis of the Maintenance and Operating Instructions for the Kozłowa Góra Reservoir (in Polish, title: Instrukcja utrzymania i eksploatacji Zbiornika Wodnego Kozłowa Góra) (Bojarski A. et al., 2004) and takes into account two flood cases:

The management of water during periods of flooding involved water management activities within the flood control storage capacity and the forced flood reserve, i.e. the reservoir capacity between the normal water level NPP=278.08 m a.s.l. and the exceptional water level NadPP=278.99 m a.s.l. The flood control procedures are commenced when the normal water level (NNP) has been exceeded and the inflow to the reservoir is higher than 2.5 m3/s. Such procedures are conditional upon the volume of inflow to the reservoir and the fill level of the flood control storage capacity. Flood control measures include the following:

- Determining the volume of outflow which may not exceed the volume of inflow to the reservoir
- After the flood warning level has been exceeded on the Brynica water gauge, instructing that water be discharged from the reservoir at the rate of 2.5 m3/s
- After filling the usable storage capacity of the reservoir, that is to say after exceeding the level of 278.08 m a.s.l., instructing that water be discharged at the rate of up to 8.0 m3/s
- Water inflow to the reservoir exceeding 30.0 m3/s, increasing the water discharge rate up to 10.0 m3/s, and – where rising tendencies are forecast – up to 12 m3/s

- Exceeding the water damming level of 278.90 m a.s.l., it is important to regulate the outflow through a bottom outlet so as not to exceed the maximum water damming level at forced overdamming, i.e. 278.99 m a.s.l.
- High water stage is over, it is necessary to immediately restore the flood control storage capacity by means of a non-damaging outflow (QN=8.0 m3/s).

The management of water during failures of the damming structure, in the event of danger necessitating that the reservoir should be emptied, it is important to discharge water at the level of the harmless outflow, i.e. 8 m3/s with a simultaneous notification to relevant authorities, and it is necessary to adhere to the instructions in the case of dam failure.

2.8. Hydrologeology

Within the described Brynica sub-basin including the Kozłowa Góra reservoir, three multi-aquifers may be distinguished: Quaternary, Triassic and Carboniferous.

The ***Quaternary aquifer*** occurs in sands and gravels characterized by variable thickness. These formations are divided by marginal lake muds, clays and loamy sands. Such development of the quaternary formations causes the aquifers to be discontinuous, often isolated. The water table is located at the depth from approximately 1 meter to approximately 15 meters. The shape of the older bed is determining the thickness and the development of the water-bearing formations. The most favourable hydrogeological parameters are exhibited by formations in the areas of deposition of sand and gravels of terraces in the Brynica buried valley, where the thickness of the water-bearing formations reaches 20 meters. At the left-side areas of the Brynica sub-basin, the quaternary is characterized by worse parameters. The thickness reaches 10 meters, the cover is non-continuous and formations of the older bed exhibit outcrops on the surface. In the profile, glacial and fluvioglacial sediments are predominant. Sands and gravels with a smaller amount of finer fractions are most common. The depth to the water table in that region varies from 1.5 m to maximally 6 m. The groundwater levels are from, approximately, 280 m a.s.l., at the mouth to the Kozłowa Góra reservoir to approximately 340 m a.s.l. by the source of the river (Figure 11). The drainage mostly occurs through the Brynica River. The hydraulic connection between Quaternary and deeper aquifers are observed in the area where permable quaternary sediments are deposited.

Water of the quaternary are not exploited at the area of the described part of the sub-basin. The nearest wells are located to the west of the Kozłowa Góra reservoir in Nowe Chechło and Kozłowa Góra. There are, however, numerous wells driven for domestic purposes.

Triassic multi-aquifer

Two aquifers constitute this multi-aquifer: Triassic carbonate series and the Świerklaniec beds.

The aquifer complex of the Triassic carbonate series is related to Muschelkalk and Reoethian dolomites and limestone. These are fissure-karstic-porous aquifers. The aquifer complex of the Triassic carbonate series is comprised of two Muschelkalk and Reoethian limestone aquifers which are divided with marl formations of the Upper Gogolin beds. In many areas the Muschelkalk and Reoethian limestone were combined into a single aquifer called the aquifer complex of the Triassic carbonate series.

The thickness of that aquifer complex varies from several meters on the south in the outcrop area to over 200 m in the north (Lubliniec – Koszęcin area). The aquifer complex of the Triassic carbonate series is characterized by very good, variable hydrogeological parameters. The values of hydraulic conductivity vary from 0.1 to 85 m/24h and the transmissivity is from approximately 100 to 1000 m2/24h. The operating wells are usually characterized by high exploitation efficiencies varying from 4.5 to 257 m3/h. The recharge is through filtration at outcrops or indirectly through permeable overlaying formations. At short sections of Brynica or Mała Panew, inflow from rivers has also been noted. The groundwater flow direction in that complex is the buried Odra valley, which is the regional base of drainage. Currently, in the hydrodynamic field local flow systems are noted, which are caused by intensive exploitation of waters by means of large underground water intakes. At the area of the Triassic carbonate series, where very good hydrogeological conditions are observed, Major Groundwater Basin (MGB) have been established. At the area of the Silesian Triassic aquifer complex, 5 major groundwater basin have been distinguished. Most of all, within the characterized Brynica sub-basin a fragment of the Lubliniec – Myszków 327 MGB is present (

Figure 12). It stretches from the outcrops of the carbonate formations of the Muschelkalk and Reoethian limestone at south to Brudzowice, Winowo at north. The water table in that part of the aquifer is unconfined or slightly confined and is at the level of 300 – 315 m a.s.l. (Figure 13). The aquifer complex is supplied in the region of direct outcrops located in the Żyglin-Mierzęcice-Brudzowice area and the drainage occurs through the wells of the largest intake in the region – Bibiela and large dolomite quarries in the Siewierz area.

The aquifer of the Świerklaniec beds, occurs in the formations of lower Buntsandstein, is located at the area of direct outcrops or is under thin carbonate formations of Reoethian. The aquifer is constituted by a continuous layer of gravels, sands and loamy sands with variable thickness. The thickness of the water-bearing formations falls within the range of 10 — 27.5 m. The depth of the top of this level is up to approximately 40 m. The groundwater table mainly unconfined, confined water table is observed when covered by overlaying isolating layers. The table of water is at the level of 310 m a.s.l. - 280 m a.s.l.. The aquifer is recharged through outcrops and the drainage occurs in the Brynica valley. There are over a dozen exploitation wells at the area of the Świerklaniec beds aquifer, out of which only several are operational. The potential efficiencies of the wells are small and vary in the range of 10 - 30 m3/h.

Carboniferous multi-aquifer

The multi-aquifer is constituted by several separate fissure-porous aquifers. These aquifers are related to sandstones of the paralic series beds of the Upper Carboniferous. The sandstones of the aquifers occur under a layer of claystones and mudstones. The depth of the aquifers is small - from several to over a dozen meters. In the Kozłowa Góra reservoir region, these formations are away from the effects of mining-induced drainage, caused by hard coal exploitation (Kropka J. et. al., 1998). In the pilot area, the aquifer is exploited only by means of one well in Dobieszowice.

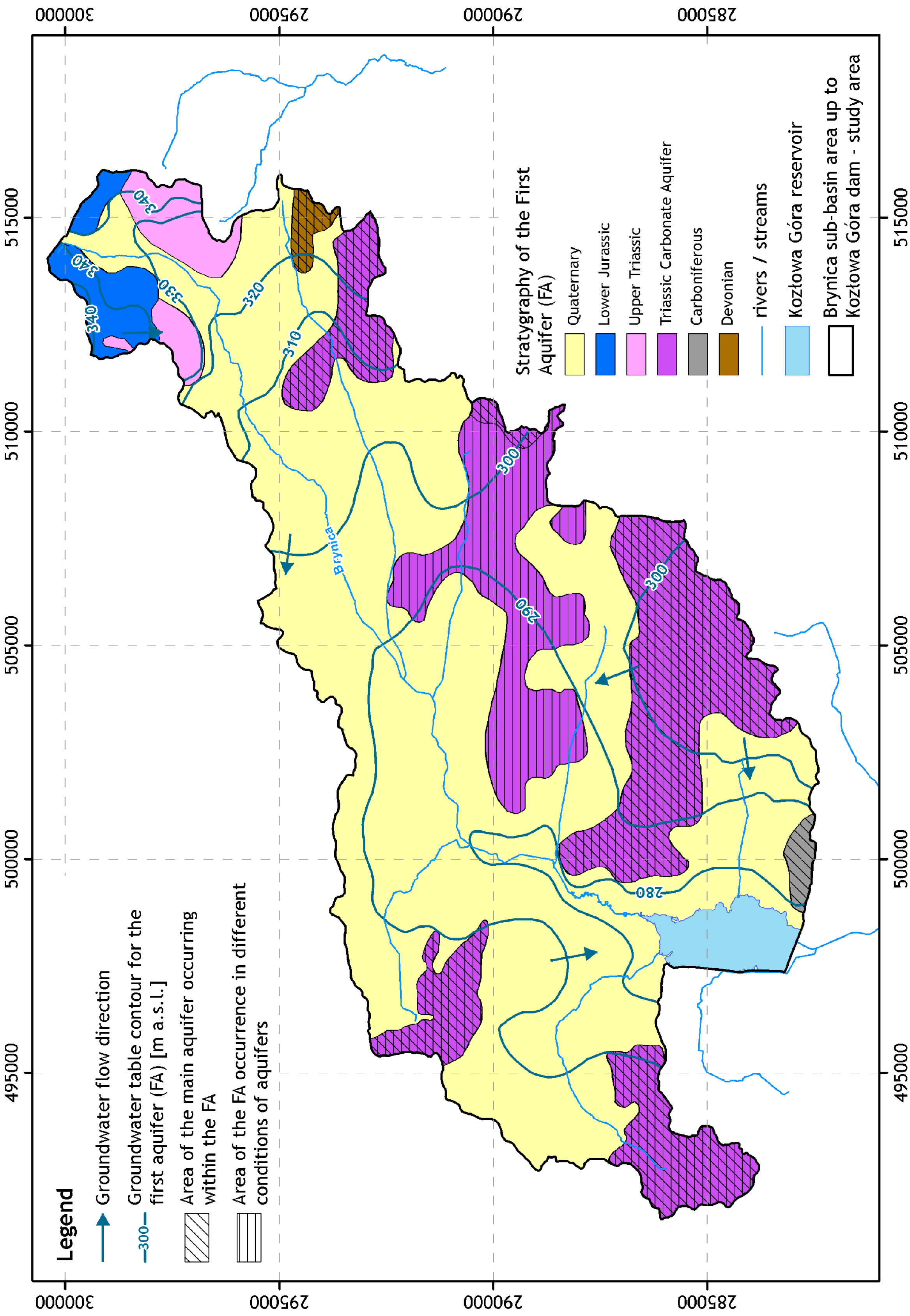


Figure 11. Hydrogeological map of the first aquifer (after Rodzoch et al., 2012).

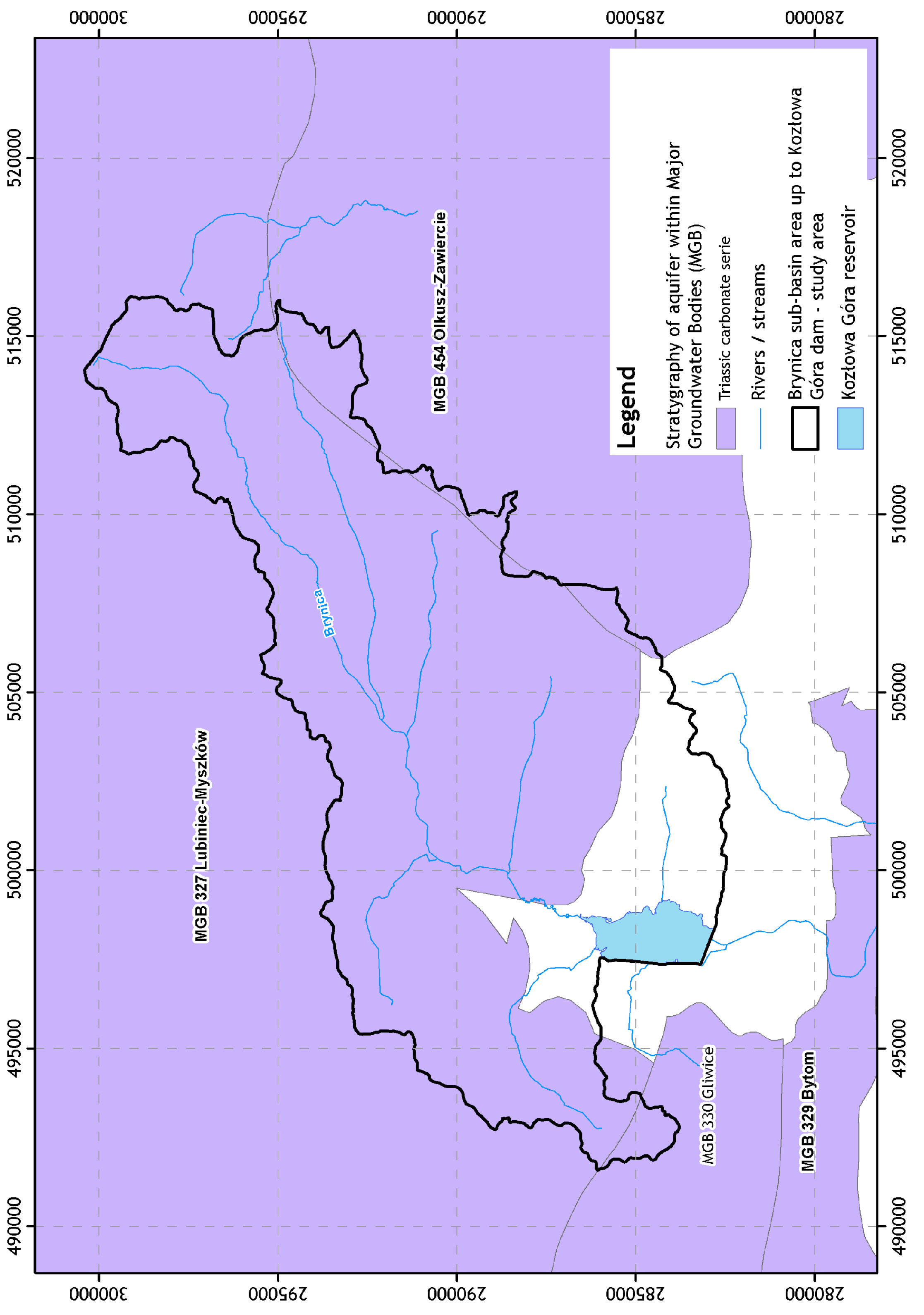


Figure 12. Map of the Major Groundwater Basin (MGB).

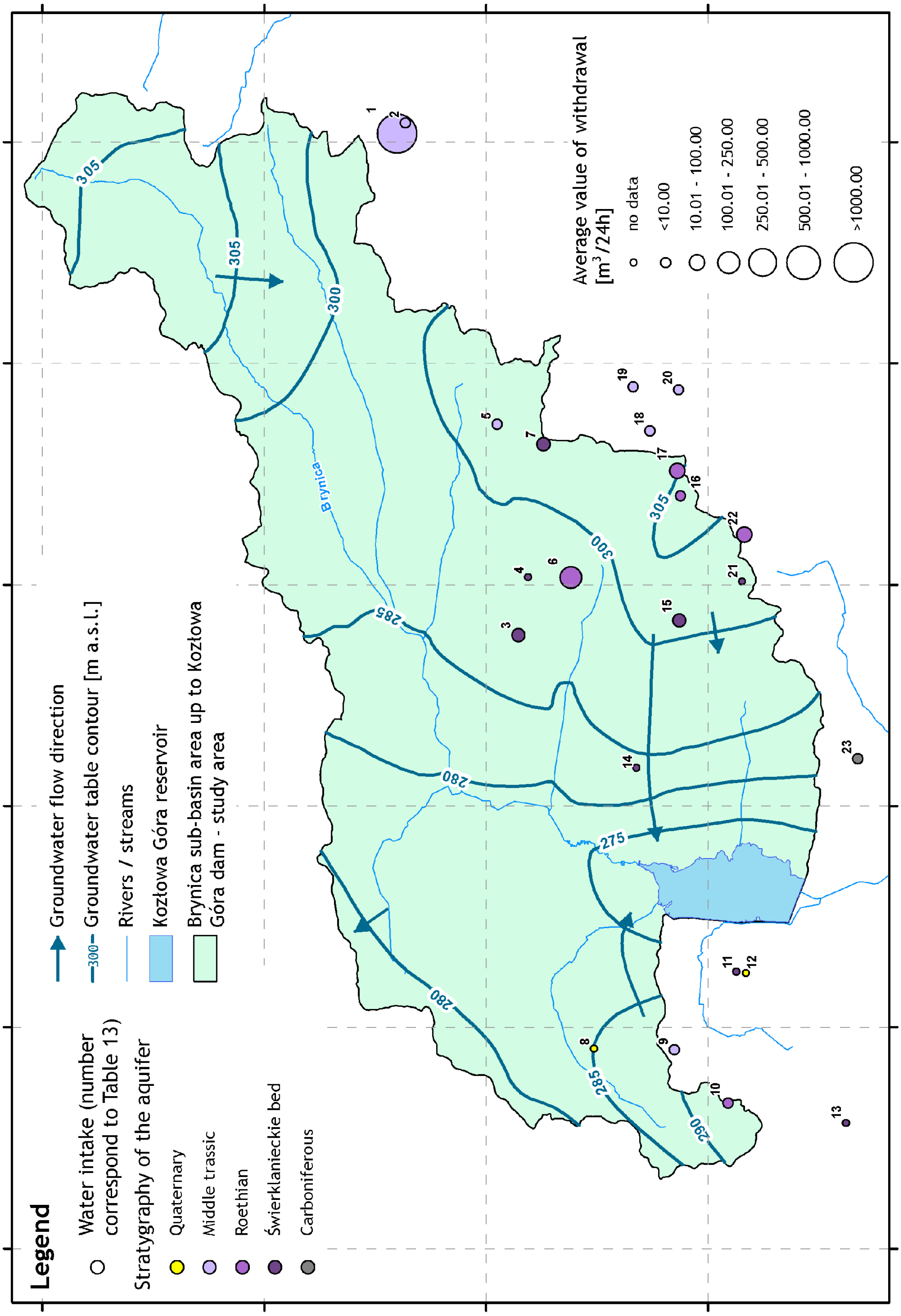


Figure 13. Hydrogeological map of Triassic multi-aquifer and groundwater exploitation (after Rodzoch i in., 2012).

2.8.1.1. Groundwater quality

The water of the Quaternary multi-aquifer most often exhibits the HCO3-SO4-Ca and HCO3-SO4-Ca-Mg hydrogeochemical type. The mineralization of water varies from approximately 300 to over 800 mg/L, which results from the variable anthropopressure. The quality of this water is largely dependent on the content of nitrites, which locally exhibit concentrations exceeding 50 mg/L – the limit of the good groundwater chemical status water (2016 Journal of Laws Pos. 85). The increased concentrations of nitrates are the reason for classifying a part of the water of the Quaternary aquifer as unsatisfactory (4th quality class), exhibiting evident human influence.

The water of the carbonate series complex is mostly of the HCO3-Ca-Mg type. The Muschelkalk limestone groundwater, especially in uncovered areas, indicates an increase in the concentration of sulphates, sometimes chlorides, which may be decisive for the hydrochemical type of these waters. The water mineralization of the Muschelkalk limestone aquifer is usually at the level of 500 mg/L. Slightly lower values of approximately 400 mg/L are observed in case of the Reoethian aquifer. The Triassic carbonate series groundwater is classified as waters of good quality (class 2) or satisfactory quality (class 3) (Table 9, Figure 14). Good quality waters (class 2) were noticed in two regional network monitoring points: Mierzęcice and Rogoźnik. Nitrites were the main decisive parameter for the groundwater classification into the 3rd quality class (in two monitoring points: Zendek, Świerklaniec). This concerned monitoring points located in rural residential areas or sparse urban areas, where the aquifer is not isolated. In case of the monitoring point located in a forested area (Żyglin), the decisive factor for including the waters in the 3rd class of quality was the content of zinc and oxygen.

The Świerklaniec beds aquifer waters mostly represent the HCO3-Ca-Mg type, however in the outcrop area increased contents of sulphites and chlorides are noted, which impacts the hydrochemical type. Mineralization value is increased to 500 mg/L. These waters exhibit a good chemical condition and are usually classified to be of the 2nd quality class.

The quality of the Carboniferous multi-aquifer waters in the area of the Brynica sub-basin may be characterized based on analysis conducted in monitoring point in Dobieszowice. The type of water is HCO3-Cl-SO4-Ca-Mg and the mineralization is low - 250 mg/L. The chemical condition was appraised as good. The final quality class in that point was determined to be class 2, although the content of manganese reached the range related to class 3. This increased manganese content, however, is caused by natural processes.

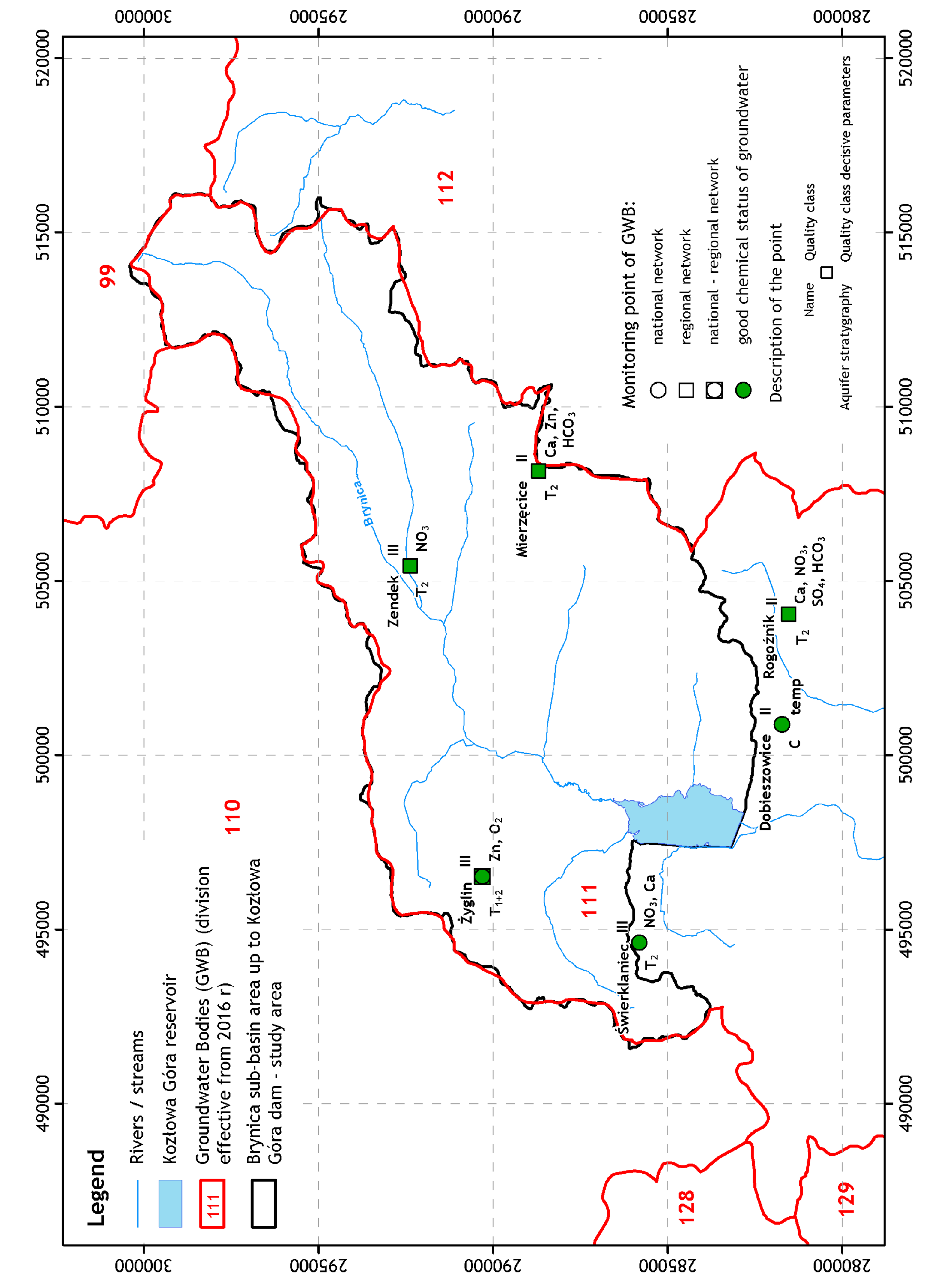


Figure 14. Map of groundwater bodies with monitoring point locations.

Table 9. List of national and regional groundwater monitoring points with the water quality class assessment (as of 2016).

Point number according to MONBADA	Point number according to SOH	Point number according to WIOŚ	Coordinates		Name	Monitoring network	Stratygraphy of aquifer	Aquifer top depth [m a.s.l.]	Screen depth range [m]	Water table	Water quality class*	Parameters referring to certain quality classes			
			X	Y								II	III	IV	V
1899	II/941/1	0001/R	496514	290305	Żyglin	K, R	T1+2	22.7	55.0-65.0	U	III	Fe, temp, HCO_3, Ba, Ca, Mo	Zn, O_2		
2677			494627	285807	Świerklaniec	K	T2	14	22.0-33.0	U	III	SO_4, PEW, HCO_3	NO_3, Ca		
2684			500880	281718	Dobieszowice	K	C	54.7	57.0-86.5	C	II	temp	Mn		
		0002/R	508151	288694	Mierzęcice	R	T2	10.7		U	II	Ca, Zn, HCO_3	temp		
		0006/R	504043	281528	Rogoźnik	R	T2	n.d.			II	Ca, NO_3, SO_4, HCO_3			
		0081/R	505437	292369	Zendek	R	T2	n.d.			III	temp, Ca, HCO_3	NO_3		

* Evaluation based on Rozporządzenie Ministra Środowiska z dnia 21 grudnia 2015 r. w sprawie kryteriów i sposobu oceny stanu jednolitych części wód podziemnych (Dz.U.2016, poz. 85).

K - national monitoring network, R - regional monitoring network, U - unconfined groundwater table, C - confined groundwater table

2.9. Land use

The description of the spatial management in the sub-basin in question was prepared on the basis of the CORINE Land Cover 2012 map analysis (

Figure 16) as well as the data from environmental protection programmes and implementation reports for the particular communes.

The largest part of the sub-basin is covered by forest areas – 47.8% of the land area, including forests – 46%. The remaining surface (1.8%) is covered by forest areas in the process of changes (forest nurseries, tree clearance) (Figure 15). There is a wide belt of forests in the western, northern and eastern parts of the sub-basin. Large forest areas also extend east of the Kozłowa Góra Reservoir. Forest areas have definitely dominated the right-side part of the Brynica River sub-basin. In the dominant part the area, the forests are administered by the Świerklaniec Forest Inspectorate, with only the eastern part being under the Siewierz Forest Inspectorate. They are part of the Forest Protective Belt of the Upper Silesian Industrial Region (GOP). The forests are dominated by coniferous trees – nearly 74%. The share of mixed and deciduous forests is considerably smaller, i.e. 20% and 6% respectively. The tree species composition is markedly dominated by the pine (70 – 80%).

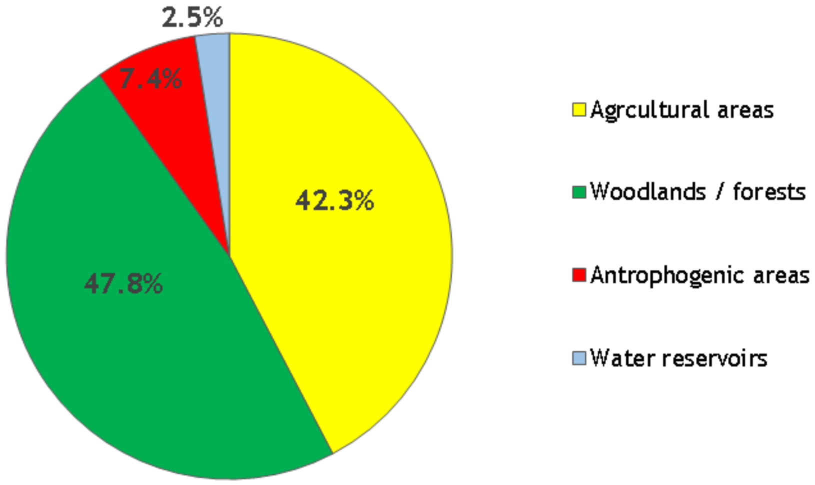


Figure 15. The main forms of land use in the sub-basin of the Brynica River sub-basin upstream the Kozłowa Góra dam

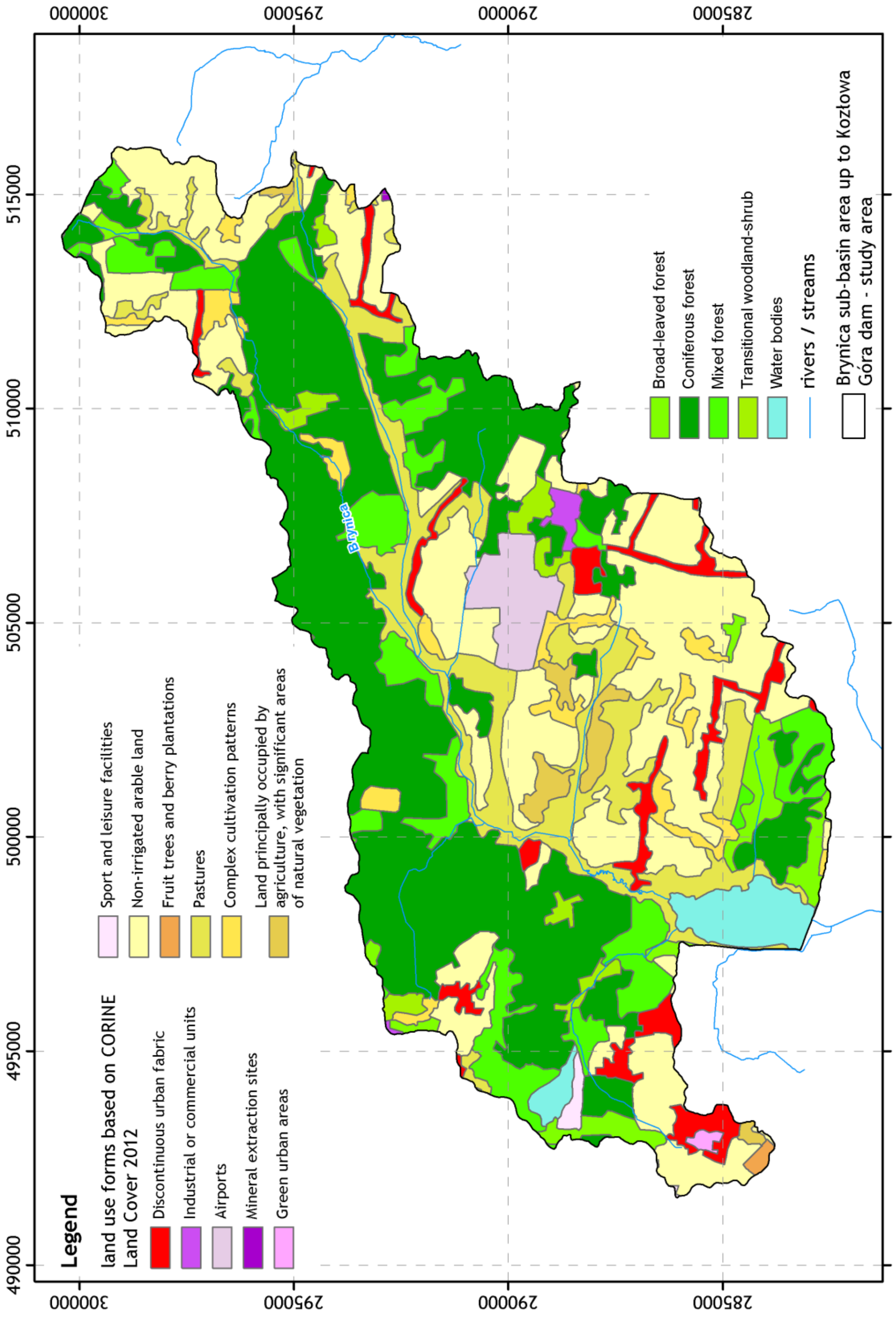


Figure 16. The land-use forms within the confines of the Brynica River sub-basin upstream the Kozłowa Góra dam (based on CORINE Land Cover 2012)

Agricultural lands cover the area of 82 km2. This constitutes 42.3% of the total sub-basin area. They include arable lands, areas occupied by permanent crops (orchards and plantations), meadows and pastures as well as areas of mixed farming. Agricultural lands usually occur in the central and north east part of the sub-basin, in the area of the Ożarowice, Mierzęcice, Bobrowniki, Siewierz and Koziegłowy communes. Arable lands under regular tillage make up more than half of these areas (60.3%) (Figure 17). Meadows and pastures have a considerably smaller share – 28%, while the smallest share is demonstrated by orchards and plantations, occupying merely 0.35% of the agricultural land area.

Regions occupied mostly by agriculture with a large share of natural plants and allotment cultivation, which together make up the so-called areas of mixed farming, cover respectively: 3.6 and 7.8% of the agricultural areas within the sub-basin.

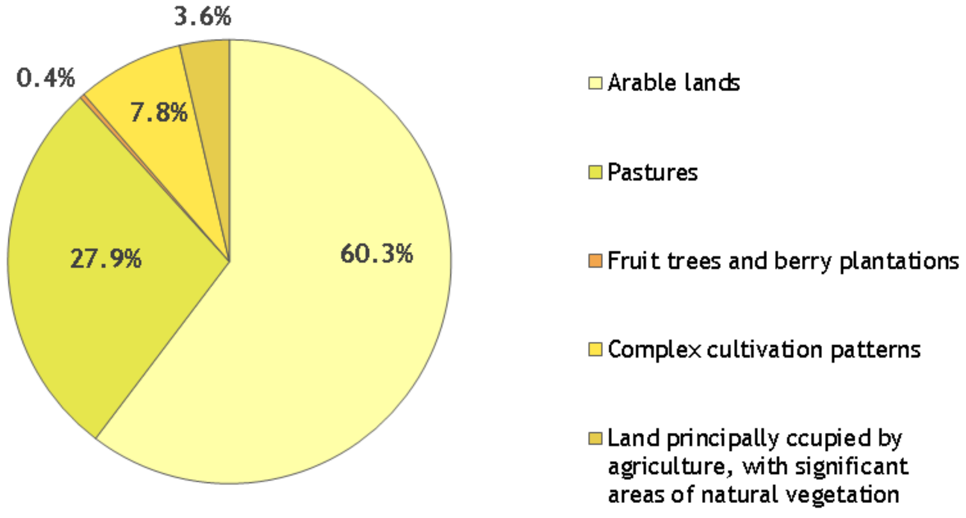


Figure 17. The agricultural land use structure in the Brynica River sub-basin upstream the Kozłowa Góra dam

Due to the dominant nature of the communes making up the sub-basin, anthropogenic regions constitute a small percentage of this area, with merely 7% (Figure 15). More than a half of the surface (58.7%) is covered by residential buildings (Figure 18). The largest built-up areas located in the western part of the region include the villages (sołectwa) in the Tarnogórski district, namely: Świerklaniec, Nakło, Nowe Chechło and Miasteczko Śląskie. These areas are characterised by condensed single-family residential housing and location of basic service facilities. Furthermore, in the central part of the area, in the Mierzęcice commune, there is a typically urban housing estate along with infrastructure (the Mierzęcice Osiedle village).

It constitutes an autonomous urban entity arising out of the revitalisation of the remnants of the former military unit. In this area, thanks to the direct vicinity of the airport, there are several hotels as well as hotel & catering companies. The remaining villages are of typical rural nature with buildings located along a single street.

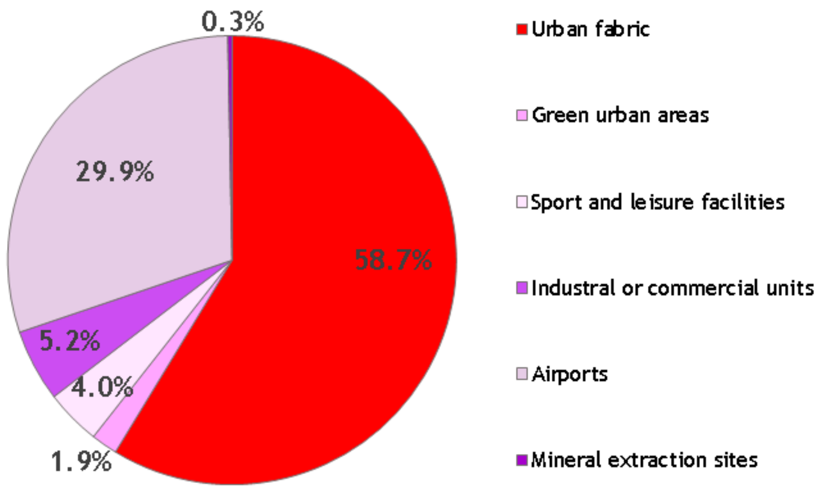


Figure 18. The structure of using the anthropogenic regions in the area of the Brynica River sub-basin upstream the Kozłowa Góra dam

Urban green and relaxation areas constitute less than 6% of the anthropogenic areas, including sports and recreation grounds with a 4.0% share. They encompass, amongst others, the centres at the Nakło-Chechło artificial lake which offer weekend or holiday recreational activities for the local inhabitants. Green areas, such as parks and squares, constitute merely 1.9% of the total sub-basin area (e.g. the Świerklaniec Park and the manor park in Nakło Śląskie).

The anthropogenic regions include industrial, commercial and traffic areas. Industrial and commercial buildings occupy 5.2% of the anthropogenic areas. It consists of buildings related to the transportation activities as well as the scrap trade and processing sector in the central part of Mierzęcice, and just outside the sub-basin – industrial sites of the Huta Cynku "Miasteczko Śląskie" zinc smelter. A considerable share in the surface of the anthropogenic areas, reaching as much as 29.9%, is held by the territory of the Katowice International Airport in Pyrzowice. It is located in the area of two communes, namely Ożarowice and Mierzęcice. In the southern part, which is more developed, there is a complex of three passenger terminals, cargo, ramps and car parks, as well as the administration buildings and hangars. The central part consists of the runway with its navigational facilities and taxiways. In the northern part – which is the least developed region – there is the approach radar and the patrol road around the fencing of the airport. These are the airport's back-up lands for investments.

Within the sub – basis area, there is a complex system of road infrastructure. In the southern part of the area runs a section of the A1 motorway with the "Pyrzowice" interchange and of the S1 expressway linking the airport in Pyrzowice with the Upper Silesian Agglomeration. There is the west – east national road no. 78 spanning Chałupki-Gliwice–Zawiercie–Chmielnik, while the easternmost part of the sub-basin is intersected by the national road no. 1 Zwardoń – Częstochowa – Łódź – Gdańsk. Moreover, the road network includes provincial roads: 913 (an alternative route to the S1 road), the provincial road no. 912, 908 running in the westernmost part of the sub-basin and the system of local roads.

In the middle part of the area, there is the eastbound railway line no. 182: Tarnowskie Góry – Zawiercie, open only for freight traffic from Zawiercie to Siewierz. It is currently planned for revitalisation and reconstruction. It is intended to become part of a fast railway link connecting Katowice with the Pyrzowice airport and Zawiercie. In the south-westernmost part of the sub-basin runs a section of the coal trunk-line: Gdynia – Herby Nowe – Tarnowskie Góry – Chorzów Batory, which links Upper Silesia with the Baltic coast. Right at the western border of the sub-basin, there is one of the largest marshalling yard in Europe, the length of which amounts to a few kilometres from the station in Miasteczko Śląskie to the station in Tarnowskie Góry.

Mines, post – mining pits and construction sites represent nearly 0.3% of the anthropogenic regions. At the borderland of the sub-basin, in its eastern part, there is a working of the "Brudzowice" dolomite mine of the Górnicze Zakłady Dolomitowe S.A. [Dolomite Mining Works, Joint-Stock Company] seated in Siewierz.

East of Żyglin, by the road leading to the Brynica River, there is a private limestone quarry covering an area of several hectares. Across the entire sub-basin area, there are numerous small sites of active or abandoned aggregate exploitation. Moreover, in the central part of the sub-basin, among Pyrzowice, Zendek and the Polski Las farmstead, there are ongoing works related to the construction of another section of the A1 Pyrzowice–Częstochowa motorway.

Water areas consist of inland waterways, which are composed of watercourses and reservoirs. The former group includes the Brynica River along with its tributaries: Trzonia, Czeczówka, Potok Ożarowicki and the tributary from Żyglin, while the latter – the Kozłowa Góra Reservoir and the Chechło-Nakło Reservoir formed in a former sand excavation site. In total, they represent 2.5% of the area of the sub-basin in question.

2.10. Protected areas

Within the Pilot area there are no protected areas defined.

3. Water supply in the pilot action

3.1. Drinking water sources

Surface water

Kozłowa Góra reservoir itself is drinking water source. It supply capacity is 50,000 m3/24h. The raw water is taken from Kozłowa Góra reservoir outflow weir and flows by gravity to the Water Treatment Plant.

Kozłowa Góra reservoir and WTP is a part of the Water Supply Ring System operating by GPW and supplying Upper Silesia Industrial Region.

Groundwater

The part of the Brynica sub-basin in concern falls under the GL-IIIB unit of water balance distinguished in the documentation providing the available groundwater resources of the Biała Przemsza and Przemsza sub-basins (Rodzoch A. et. al., 2012). At the same time it is the area of the Groundwater Body No. 111 (GWB 111), distinguished for the needs of the water management plan for river basins in line with the Water Framework Directive (WFD 000/60/EC, 2000). In case of the GL-IIIB Brynica unit of water balance, the available resources were determined to be 70,000 m3/24h and the estimated intake of groundwater (without the mining drainage) is 11,134 m3/24h. In the part of the Brynica sub-basin in concern - from the source up to the Kozłowa Góra reservoir, the size of the current intake of groundwater is estimated to be approximately 8,800 m3/24h, out of which approximately 85% is the drainage of the Middle Triassic formations by the "Siewierz" dolomite mine (Table 10).

Generally in the inventory of the described area 23 active intakes of groundwater were evidenced with variable intake values: from 0.03 thousand m3/24h (Pyrzowice airport), up to 2,692 thousand m3/24h (Siewierz, dolomite mine). Nearly half of the intakes (43%) are intakes with low consumption, not exceeding 10 m3/24h. Larger intakes with consumptions in range of 200-600 m3/24h are organized for the municipal services in Myszkowice, Sadowie and Pyrzowice. The largest number of intakes uses the waters of the Triassic carbonate series (52%), the part of the intakes of water from Świerklaniec beds is also large (35%). The remaining intakes exploit the water of the Quaternary and Carboniferous stages. The most intensive exploitation is conducted in relation to the complex of the Triassic carbonate series, providing for approximately 95% of the total intake of underground water from the area in concern. 4.6% of exploited water is acquired from the Świerklaniec beds while only 0.4% is acquired from Quaternary and Carboniferous formations.

Table 10. Comparison of groundwater intake volumes

Number referring to Figure 13	Well location			Basic information about well and it user		Stratygraphy of the aquifer	Water permit	Actual annual groundwater intake volume	
	Coordinates (1992)		Location	Well name	User				
	X	Y					[m^3/24h]	[km^3/a]	Year
Quaternary aquifer									
8	494520.71	287573.05	NOWE CHECHŁO	NOWE CHECHŁO - LEŚNA	ZAKŁAD WODOCIĄGÓW I KANALIZACJI	Quaternary	96.0		
12	496226.43	284144.28	KOZŁOWA GÓRA	ZAKŁ.DOSWIAD-CZALNY		Quaternary			
Middle Triassic aquifer									

1	515195.83	292006.40	BRUDZOWICE	KOPALNIA DOLOMITU "SIEWIERZ "	GÓRNICZE ZAKŁADY DOLOMITOWE S.A	Middle Triassic	16800.0	2692.42	2010
2	515436.52	291823.82	BRUDZOWICE	KOPALNIA DOLOMITU "SIEWIERZ "	GÓRNICZE ZAKŁADY DOLOMITOWE S.A.	Middle Triassic		7.87	2009
5	508626.46	289752.38	ZADZIEŃ	ZADZIEŃ	GMINNY ZAKŁAD GOSPODARKI WODNEJ i KOMUNALNEJ	Middle Triassic	208.0	0.00	2010
9	494496.14	285761.11	ŚWIERKLANIEC	OGRÓD ŚLĄSKI	CENTRUM OGRODNICZE "OGRÓD ŚLĄSKI"	Middle Triassic		6.05	2011
18	508470.74	286306.67	MIERZĘCICE	OŚRODEK ZDROWIA	GMINNY ZAKŁAD GOSPODARKI WODNEJ I KOMUNALNEJ	Middle Triassic	152.0	0.90	2010
19	509467.78	286685.38	MIERZĘCICE	ZAKŁAD RZEŹNICZO-WĘDLINIARSKI "BARA"	ZAKŁAD RZEŹNICZO-WĘDLINIARSKI "BARA" Jacek Bara	Middle Triassic	80.0	5.78	2010
20	509407.95	285662.33	TARGOSZYCE	TARGOSZYCE	GMINNY ZAKŁAD GOSPODARKI WODNEJ i KOMUNALNEJ	Middle Triassic	98.0	2.41	2010
Roethian aquifer									
6	505164.21	288088.81	PYRZOWICE	WODOCIĄG GRUPOWY	ZAKŁAD GOSPODARKI KOMUNALNEJ	Lower Triassic - Roethian	2760.0	213.80	2010
10	493283.36	284552.59	NAKŁO ŚLĄSKIE	WAPIENNIKI	ZAKŁAD WODOCIĄGÓW I KANALIZACJI	Lower Triassic - Roethian	2.5	0.40	2011
16	507006.63	285615.94	ZAWADA	WODOCIĄG GRUPOWY ZAWADA 1	GMINNY ZAKŁAD GOSPODARKI WODNEJ I KOMUNALNEJ W MIERZĘCICACH	Lower Triassic - Roethian	214.0	5.79	2010
17	507574.46	285690.83	SADOWIE	WODOCIĄG GRUPOWY SADOWIE	GMINNY ZAKŁAD GOSPODARKI WODNEJ i KOMUNALNEJ	Lower Triassic - Roethian	576.0	99.10	2010
22	506132.72	284175.96	NOWA WIEŚ	WODOCIĄG GRUPOWY NOWA WIEŚ	GMINNY ZAKŁAD GOSPODARKI WODNEJ I KOMUNALNEJ W MIERZĘCICACH	Lower Triassic - Roethian	200.0	10.76	2010
Świerklanieckie bed aquifer									
3	503854.49	289273.38	OŻAROWICE	PRZETWÓRNIA	ZAKŁAD UBOJU I PRZETWÓRSTWA MIĘSNEGO H.A.M.	Lower Triassic Świerklanieckie bed		27.01	2009
4	505177.03	289055.31	PYRZOWICE	PORT LOTNICZY	PETROLOT SP. Z O.O.	Lower Triassic Świerklanieckie bed		0.03	2009

7	508169.04	288712.37	ŁUBNE	(JEDNOSTKA WOJSKOWA 4043) ŁUBNE	GMINNY ZAKŁAD GOSPODARKI WODNEJ I KOMUNALNEJ	Lower Triassic Świerklanieckie bed	448.0	31.88	2010
11	496254.20	284360.40	ŚWIERKLANIEC	ZAKŁ.DOŚWIAD-CZALNY	AGRO-SAD. SP. Z O. O. PPUH	Lower Triassic Świerklanieckie bed			
13	492838.00	281894.40	RADZIONKÓW		4 WOJSKOWY ODDZIAŁ GOSPODARCZY JEDOSTKA WOJSKOWA 4217	Lower Triassic Świerklanieckie bed		1.58	2008
14	500859.57	286613.79	TĄPKOWICE	UJĘCIE TĄPKOWICE	ZAKŁAD GOSPODARKI KOMUNALNEJ	Lower Triassic Świerklanieckie bed	200.0	7.97	2010
15	504196.46	285640.75	MYSZKOWICE	WODOCIĄG GRUPOWY S-1	ZAKŁAD GOSPODARKI KOMUNALNEJ	Lower Triassic Świerklanieckie bed	289.0	77.80	2010
21	505073.40	284232.49	ŁUBIANKI	UJĘCIE ŁUBIANKI	ZAKŁAD GOSPODARKI KOMUNALNEJ	Lower Triassic Świerklanieckie bed	160.8	0.46	2010
Carboniferous aquifer									
23	501066.00	281624.30	DOBIESZOWICE	CENTRUM MIĘSNE "MAKTON"	CENTRUM MIĘSNE MAKTON S.A.- ODDZIAŁ W DOBIESZOWICACH	Carboniferous	331.2	1.43	2008

3.2. Drinking water protection

The basis for establishing a Drinking Water Protection Zone (DWPZ) is act from 20 July 2017 r. - the Water Law (Journal of Laws 2017, item 1566).

Kozłowa Góra reservoir currently has no DWPZ established.

4. Main identified problems / conflicts

Solutions leading to the elimination of poor quality of water require a comprehensive approach to the analysis of the causes behind that state. The DPSIR analysis (Driver – Pressure – State – Impact – Response) is the cause-and-effect analysis that is recommended (by the European Environment Agency EEA, among others) and that comprehensively describes the problems, indicates their sources, and suggests corrective actions.

The application of this approach during the analysis contributes to the increased objectivity of the assessment as well as to the optimisation of the remedial actions that take into account the anticipated environmental changes.

It is estimated that the main source of pollution of the Kozłowa Góra reservoir are the surface waters flowing into the reservoir. This is a result of presence of agricultural holdings in the sub-basin area, as well as farms, industrial plants, wild dumps, and intensive land and air transportation. The Brynica River, due to the value of its flow, has the biggest impact when it comes to the pollution in the reservoir. The second source of pollution is the Ostróżnica stream, flowing directly into the reservoir. These are mainly the diffuse pollutants from the agricultural areas. At the current stage of analysis it is difficult to define the role of waste treatment plants in the sub-basin area, particularly in the overall context of impact on the sub-basin and reservoir waters. This includes both new and relatively efficient waste treatment plant in Ożarowice, which should significantly improve the quality of purified water, and numerous mechanical waste treatment plants with a rather negligible impact on improvement of physiochemical parameters of water. Status of the waste management in the sub-basin also requires a thorough research, although in the last decade substantial investments have been made in this area. The sources of local pollution may also involve "wild" dumps and pollution from malfunctioning septic tanks. Pollution from these two sources may seep into the reservoir through superficial runoffs or shallow groundwater runoffs.

Detailed DPSIR analysis was presented in D T 2.1.1.

Summarizing main identified problems and conflicts in reference to drinking water reservoir are: agricultural character of land use, high degree of urbanisation of the sub-basin (land transport, processing plants) and various, mainly poor, degrees of development and efficiency of the sewage network and waste treatment plant.

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