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WATER – AN UNDERESTIMATED RESOURCE OF THE LUBLIN REGION

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Summary. The Lublin Region, considered to be equivalent to the area of the Lublin Voivodeship, is an agricultural region characterised by varied geological structure, relief, soil cover, climatic conditions and hydrographic and landscape features. At the same time, it is an area where the territorial and climatic conditions of the water cycle are remarkably diverse. The specific runoff from the area of the Voivodeship varies between regions and amounts to an average value of 4.0 dm^3 s^{-1} km^{-2}, while the resources of surface water are low and seasonally changeable. Traditional farming methods and absence of large industrial plants or urban areas considerably affect the quality of the waters. High quality groundwater resources are used as a water supply for public utilities and industry. The degree of environment transformation in the Lublin Region is relatively low and this creates an opportunity to maintain the high quality of the water which remains an underrated resource of the region.

Key words: Lublin Region, water resources, surface waters and ground waters

INTRODUCTION

The Lublin Region is a geographic entity in centre-eastern Poland corresponding to the area of the Lublin Voivodeship and occupies 25,122.5 km^2 (approx. 8% of the area of Poland). In terms of hydrography, the Lublin Voivodeship is situated in the Vistula and Bug interfluve (Fig. 1), in the physiographic and cultural borderland between Eastern and Western Europe. The district comprises two geographic regions – the Lublin Upland and Polesie Lubelskie and the Polish part of Roztocze. Its boundaries also encompass small fragments of the Mazovian Lowland and Podlasie in the north, and of the Sandomierz Basin and Pobuże in the south (Fig. 1). The diversity of environmental features following the parallel system determines the division of the voivodeship into three parts: the northern lowland area, the central upland area and the southern

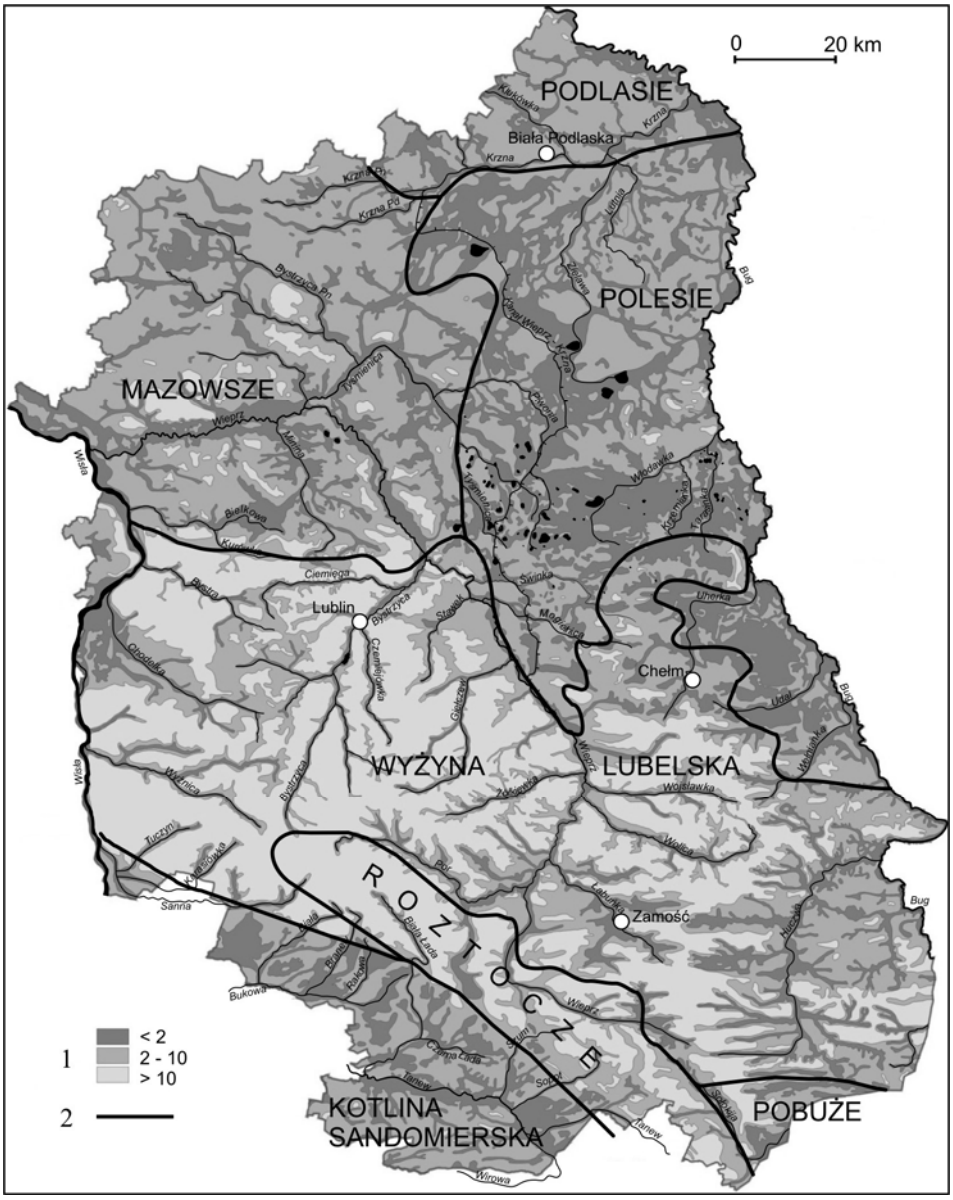

Fig. 1. Depth of the groundwater table [Michalczyk *et al.* 2008] in the Lublin Voivodeship against the background of the physiographic division: 1 – depth of the groundwater table in metres, 2 – region boundaries

lowland part. The parts differ in terms of geological structure, relief features and soil cover, as well as climatic and hydrological conditions and plant cover, which is reflected in the structure of land use and in the landscape and water resources of the voivodeship. A map of groundwater depth provides a synthetic

overview of those properties (Fig. 1). The two most abundant rivers flowing northwards mark the western and eastern boundaries of the voivodeship, yet their resources and regime are determined outside of the area of the Lublin Region. The Wieprz River, which is the main river in the Lublin Voivodeship, cuts centrally across the interfluve and its entire drainage basin is comprised within the studied area (Fig. 1). This creates conditions favourable to good organisation of water economy and the protection of the high quality water resources.

The structure of land use in the Lublin Region, which greatly affects the directions of the water cycle, is dominated by agricultural land – 71.15% (of which cropland – 53.46%), followed by forests – 22.6% and land under water – a mere 0.8% of the area of the voivodeship (Environmental Protection 2008). The biggest forest complexes are to be found on the sandy plains of the Sandomierz Basin, in Central Roztocze and in the Bug-adjacent part of Polesie. Forests are the most scarce in the Lublin Upland, mainly due to the presence of very good soils which developed on loess and loessial deposits and limestone. Protected areas account for 22.7% of the area of the district. The population of the Lublin Voivodeship in 2009 was 2,160,400 (6% of the population of Poland), of which 1,061,000 people inhabited the 41 towns of the district, and 1,124,000 – the 4207 villages, resulting in a mean population density equal to 87 persons/km^2 [Ochrona środowiska 2008].

Apart from hard coal and carbonate rocks, there are no mineral resources in the Lublin Voivodeship. The biggest resource of the region consists in the preservation of a relatively natural functioning of the environment: forests, meadows, cropland and surface and ground waters. Traditional farming methods and the presence of forest areas, coinciding with a lack of large industrial plants, favour the preservation of natural properties in the waters of the Lublin Region.

RESEARCH MATERIAL AND METHODS

The study was carried out using field material collected by the Department of Hydrography of the UMCS and observation and gauging records provided by the IMGW. The evaluation of water resources was based on analysis of the volume and variability of precipitation, evapotranspiration and runoff. Apart from the gauging records, a lot of cartographic material illustrating the condition of the individual components of the geographic environment was used and analysed in terms of the water cycle conditions. The collected information referred to the density of the river network, lakes, ponds, water bodies, springs, physical, chemical and bacteriological properties of the water, and its economic use in the Lublin Region. All the data were analysed with reference to the conditions of the geographic environment and to its economic utility. A map of groundwater depth in the Lublin Voivodeship, compiled at the Department of Hydrography of the UMCS to illustrate the retention capacity of the soil in individual physi-

ographic regions, is presented. Compilation of all the material testifies to a profound significance of water for the environment, landscape and economy.

EVALUATION OF WATER RESOURCES

Conditions of water resources formation

In the nature-cycle water is constantly moving – falling down in the form of precipitation, absorbed by soil and transferred to groundwater resources, returning to the atmosphere during the process of evapotranspiration, and flowing into rivers on the land surface. In the Lublin Region water resources are mainly alimented from precipitation and come from the upper parts of the Vistula and the Bug catchments. By the standards of the country, it is a region of low precipitation, lower than the mean value in Poland. Roztocze is watered most abundantly, as the mean annual precipitation totals exceed 650 mm [Kaszewski 2008]. The northern lowland part and the upland area near the Bug river are characterised by precipitation below 550 mm. The amount of evaporated water in the studied area is estimated at about 450 mm [Jaworski 1968]. In the northern part, approx. 400 mm of water returns to the atmosphere, while in the upland part – it is 475 mm. Out of the mean amount of about 470 mm, 112 mm of water evaporates in the winter half-year and 358 mm in the summer half-year.

Good permeability of the surface deposits is conducive to the retention of precipitation water in the soil and to the formation of abundant groundwater resources. In the Lublin Region, deposits of very high permeability occupy 19.7%, of high permeability – 23.1%, and medium permeability – 27.7% of the area, while 8.7% is low-permeability area and as much as 20.8% – the river valley zones – area of varied permeability [Michalczyk *et al*. 2008]. Good permeability of the surface deposits is reflected both in the large resources of groundwater and in the large and even share of groundwater alimentation in the total runoff. Its size determines the durability of low-water discharge in the rivers of the region.

The deliberate or unconscious undervaluation of the natural resources and processes results in reinforcing of the stimuli which lead to incorrect use of the environment and, in turn, to the destruction of natural resources. The use of the natural environment should be based on maintenance of the process of self-regulation, which ensures a relative stability and resistance of ecosystems and the biosphere. Economic activity has changed the conditions of water movement and the recharge of groundwater resources by removing the natural plant cover, swamp and bog draining, separating rivers from their flood area and solidification of land. The preservation of the natural environmental processes, including the quality and quantity of water, is beneficial to the health of the population.

Ground waters

According to the Hydrogeological Atlas of Poland [Paczyński 1995], the Lublin Voivodeship lies within three hydrogeological regions: the Lublin Cretaceous, Podlaski and Podkarpacki. In terms of utility, waters in carbonate rocks from the Upper Cretaceous are of the biggest significance, followed by those in Tertiary and Quaternary deposits (Tab. 1), while waters in Jurassic deposits have only a local importance.

Table 1. Exploitable groundwater resources in the Lublin Voivodeship [Ochrona środowiska... 2005]

Specification	Exploitable resources in hm^3 from geologic deposits				
	Total	Quaternary	Tertiary	Cretaceous	Older horizons
Resource state (31st December, 2007)	1.160.6	188.3	108.8	856.5	7.1
Share (%)	100.0	16.2	9.4	73.8	0.6

Ground waters of the functional level are present in sediments of various age and lithology. They practically form one continuous water table whose altitude reflects the land relief and which generally inclines following the topographic features of the area. The depth of the groundwater table of the main horizon is determined by the topographic features. In most of the area of the district it reaches the depth of 5 m, both in Polesie and in valley floors of the Lublin Upland (Fig. 1). In hilltop areas in the northern Lublin Upland the thickness of the aeration zone is 20–40 m, and in the southern part – 40–70 m. Comparatively rich water resources of high quality are to be found in the fissured and layered Upper Cretaceous deposits [Michalczyk 1986, Michalczyk and Wilgat 1998]. The deeply incised Vistula Valley which, together with the Bug River, collects water from most of the Lublin Voivodeship, is a regional drainage base for the district's groundwater. Table 2 presents the volume and exploitation of the resources in four different areas of the voivodeship.

Table 2. Renewable and available water resources in catchment basins of the main rivers in the Lublin Voivodeship [Program… 2003]

Catchment basin	Area	Renewable resources	Exploitation	Available resources
	km^2	thousand m^3/d		
San and Sanna	2.746	701	No data	335
Wisła	2.989	925	No data	589
Wieprz	10.415	2.615	204	1.482
Bug	8.982	1.670	73	785

Ground waters come to the surface in springs, understood as natural, spontaneous and concentrated groundwater outflows. In the area of the Lublin Voivodeship,

about 1.700 springs have been recorded, 1.500 of which are functioning [Michalczyk 2001]. Their density varies, as they are unevenly distributed – there are about 1,400 springs in the upland region (Lublin Upland and Roztocze) and only about 100 in the lowland part (Sandomierz Basin, Polesie Lubelskie, Podlasie, part of Mazovia). Small outflows are the most numerous, more than half of them giving a yield lower than 1 $dm^3 s^{-1}$ – nearly all springs in the lowland part of the district belong to this group. The yield of the 13 biggest outflows ranges from 100 to 300 $dm^3 s^{-1}$ [Michalczyk 2001].

Springs are an important natural element and arouse widespread interest. Many of them are very precious and unique due to their hydrological, hydrochemical, landscape, cultural or other properties. Some of them have been given the status of nature monuments, and the water from a dozen springs is believed to have miraculous properties. Spring waters, usually of high quality, determine the water volume in the streams and rivers of the upland part of the Lublin Region and are of high scenic and tourist value.

Ground waters contain an abundance of dissolved minerals, usually beneficial to living organisms. The medicinal properties depend on hardly discernible differences in the chemical composition. The waters vary considerably in chemical composition, which results from the geological structure of the area. They are usually of high quality that meets the requirements of drinking water, and are used in the production of mineral table water and in medicine. The waters in the functional water-bearing horizons are poorly mineralised, as the dry residue is 200–500 mg dm^3. They are two-ion waters of the HCO_3-Ca type (rarely – three-ion HCO_3-Ca-Mg waters), slightly alkaline or neutral. The total hardness is 4–7 mwal dm^3 and the alkalinity – 4–6 mwal dm^3. In the natural chemical composition of the waters, only a few milligrams/litre of chlorides and sulphates and trace amounts of manganese are found [Chmiel 2005]. The general quality of ground waters meets the physicochemical and bacteriological standards for public utility waters.

Spring waters met the physicochemical standards set for drinkable water and the norms of high quality water classes [Raport… 2009]. The only criterion most spring waters failed to satisfy was the bacteriological requirements, yet in some springs the contamination was only periodical [Strupieniuk 2007].

Surface waters

In respect of the density of surface waters, the Lublin Voivodeship is one of the most varied regions in the country. In the Lublin Upland and Roztocze, the surface water network is the thinnest in the country, whereas in Polesie – the densest. The presence of permanent wetlands and lakes, such as the Łęczna-Włodawa Lake District in Polesie, is a peculiarity of the surface waters of the region. The Lake District is made up of small or medium-sized lakes, of which Lake Uściwierz is the biggest (284 ha) and Lake Piaseczno – the deepest

(38.8 m). What with the small surface area and depth, the lakes do not contain much water. Two of them – Białe Włodawskie and Piaseczno – have a capacity bigger than 10 mln m^3 each [Wilgat 1954, Harasimiuk *et al*. 1998], while most do not even contain 100.000 m^3 of water. The total capacity of natural lakes approximates 80 mln m^3, and together with lakes converted into storage reservoirs – over 100 mln m^3. According to GUS [Ochrona…. 2005], surface waters occupy an area of 21.081 ha, 10.089 ha of which is flowing water and 10.992 ha – stagnant water (ponds – 4.775 ha). Ditches occupy a similar area – 12.114 ha. In 2001–2006, the employees of WIOŚ in Lublin evaluated the purity of 39 lakes in the Łęczna--Włodawa Lake District. Lake Piaseczno was found to have Class I water purity, 23 lakes were classified in class II, and 15 – in class III [Grzywna 2007].

There are no large water reservoirs in the Lublin Voivodeship. The Nielisz reservoir, with a volume of 19.5 mln m^3, is by far the biggest. Some reservoirs are former lakes adapted to store water during the implementation of the Wieprz-Krzna Canal project. Small reservoirs, used for recreation, are the most numerous. An analysis carried out by the District Authority for Water Melioration and Water Appliances (*Update of the Small Retention Programme for the Lublin Voivodeship*) showed a demand for 679 bodies of small retention (including 287 storage reservoirs), where 128.56 mln m^3 of water will be stored.

All types of wetland play an important role in water storage. Their common feature is very shallow occurrence of water at a small depth under the surface. According to the data published in *The Programme of Water Economy in the Lublin Voivodeship*, fishing ponds in the district occupy the area of 6.604 ha: 4.513 ha in the Wieprz drainage basin, 516 ha in the San and Sanna basin, 659 ha in the Bug basin, and 916 ha in the direct catchment area of the Vistula.

Runoff volume and water quality

The evaluation of quality of the water running off from the Lublin part of the interfluve was based on published and archive hydrometric materials of IMiGW [Michalczyk and Wilgat 2008]. Apart from border rivers, the Wieprz River drains the biggest amount of water – its mean discharge in Kośmin in 1951–2006 was 36.0 $m^3 s^{-1}$. Other rivers in the region are poorer in water: the Tanew discharge is 12.3 $m^3 s^{-1}$, the Krzna – 10.4 $m^3 s^{-1}$, the Tyśmienica – 8.5 $m^3 s^{-1}$. Medium-sized rivers, which carry about 5 $m^3 s^{-1}$ of water, include the Bystrzyca and the Bukowa. The Huczwa and the Zielawa carry approximately 4 $m^3 s^{-1}$ each, and the Por, Bystrzyca Północna and Włodawka rivers – about 2.5 $m^3 s^{-1}$ each. The mean discharge in other rivers is smaller than 2 $m^3 s^{-1}$ [Michalczyk and Wilgat 1998]. The rivers are characterised by even flow, largely due to a big share of groundwater in the runoff. An average amount of water discharged from 1 square kilometre (specific runoff) varies from 3.3 $dm^3 s^{-1} km^{-2}$ in the Huczwa basin and in the Bug-adjacent area to 7 $dm^3 s^{-1} km^{-2}$ on the south rise of Roztocze.

Waters in the Lublin Region are mainly exposed to contamination with organic and microbiological substances [Miazga and Parcheta 2007]. Monitoring tests carried out at 97 gauging-control points [Stan czystości rzek w 2007] showed that in most cases the river water was of unsatisfactory quality. The criteria of water quality assessment included colour, COD, Kjeldahl nitrogen and the presence of coliform bacteria. Contamination with nitrogen compounds, including the concentration of nitrates, was relatively low and was not the biggest threat to water quality. In some points, mainly below the sewage disposal site, excessive concentrations of phosphates were found in some periods. River waters contained a low concentration of chlorides, sulphates and fluorides and were not contaminated with heavy metals. The salinity indexes (dissolved substances) corresponded to class I or II of water quality.

CONCLUSIONS

The distribution of the surface water and groundwater resources in the Lublin Region is uneven, which is due to territorial and climatic conditions. Mean runoff index in the lowland part of the region amounts to approx. 100 mm, and in the upland part – to nearly 130 mm. In the entire region runoff is much lower than the mean value for Poland, which is indicative of water scarcity [Michalczyk and Wilgat 2008]. Small water resources should be used sensibly and protected against qualitative changes, particularly in the case of ground waters. Moreover, extremely valuable peatbog areas, lakes, springs and river valleys are present in the region.

The extent of transformation of the region's hydrosphere is relatively small, which is a chance for preserving the high quality of the water. Other factors which argue for this include the comparatively natural conditions of water occurrence and the high quality of physicochemical and bacteriological parameters in the utility water horizons. River valleys, in particular, should be protected from ill-considered transformations of the water relations. It is necessary to supply water to the Wieprz-Krzna Canal and to reduce the rate of water circulation, mainly by constructing small retention reservoirs and correction steps – beginning in the spring courses of the rivers. Resolute countermeasures against the pollution of surface and ground waters and their quantitative protection are a prerequisite for the maintenance of the high value of the environment, including water resources, which remain an undervalued resource of the Lublin Voivodeship. The resources decide about the environmental and scenic attractiveness of the region and are fundamental as a water supply for the population and a basis for the economy of the district.

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WODA – NIEDOCENIANE BOGACTWO LUBELSZCZYZNY

Streszczenie. Lubelszczyzna jest regionem geograficznym terytorialnie utożsamianym z województwem lubelskim. Pod względem hydrograficznym jego obszar położony jest na międzyrzeczu Wisły i Bugu, Rozmieszczenie zasobów wód powierzchniowych i podziemnych jest nierównomierne, co wynika z czynników terenowych i klimatycznych. Średni wskaźnik odpływu z niżowej

części Lubelszczyzny wynosi około 110 mm, a z części wyżynnej prawie 130 mm. Odpływ z całego obszaru Lubelszczyzny jest zdecydowanie niższy od wartości średniej dla Polski, co jednoznacznie podkreśla ubóstwo wodne regionu. Stopień przekształcenia środowiska regionu lubelskiego jest jeszcze stosunkowo niewielki, co stwarza szansę zachowania wysokiej jakości wód regionu. Przemawiają za tym względnie naturalne warunki występowania wód i wysoka jakość parametrów fizykochemicznych i bakteriologicznych użytkowych poziomów wody, źródeł i jezior. Konieczne są działania na rzecz zmniejszenie tempa obiegu wody, głównie przez wybudowanie zbiorników małej retencji i progów korekcyjnych – już od źródłowych biegów rzek. Zdecydowane przeciwdziałanie zanieczyszczeniu wód podziemnych i powierzchniowych oraz ich ochrona ilościowa warunkują dalsze utrzymanie wysokich walorów środowiska, w tym również zasobów wody, stanowiących ciągle niedoceniane bogactwo województwa lubelskiego. Zasoby te decydują o atrakcyjności przyrodniczej i krajobrazowej regionu oraz stanowią podstawę zaopatrzenia w wodę mieszkańców i gospodarki województwa.

Słowa kluczowe: Lubelszczyzna, zasoby wodne, wody podziemne i powierzchniowe