HYDROCLIMATIC AND GEOLOGICAL CONDITIONS OF THE VARIABILITY OF FLUVIAL TRANSPORT RATE IN THE UPPER PART OF THE WIEPRZ RIVER CATCHMENT

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ABSTRACT: The article summarises the results of observations conducted in the periods 1989-1992, 1998–2000, and 2001–2003 in the catchment of the Roztocze section of the Wieprz River with an area of 404 km². The presented results of the study on fluvial transport document the response of an upland river to variable hydro-climatic conditions. Fluvial transport rate in periods extreme in hydrological terms was compared. In the conditions of low water stages (1989–1992) and mean annual discharges lower than the mean multiannual by 19%, the Wieprz River discharged an average of 13300 tonnes of solutions and 485 tonnes of suspensions annually. The unitary indices amounted to 32.7 and 1.2 t/km²/year, respectively. In the years 1998–2000, in the conditions of high water stages and mean annual discharges higher than the multiannual by 41%, the Wieprz River discharged approximately 22,800 tonnes of solutions and 981 tonnes of suspensions annually. The unitary indices increased proportionately to 56.2 t/km²/year and 2.4 t/km²/year, respectively. In the years 2001–2003, in the conditions of variable water stages and discharges higher than the multiannual by 12%, the Wieprz River discharged an average of approximately 17,500 tonnes of solutions and 441 tonnes of suspensions annually. The unitary indices reached the values of 43.3 t/km²/year and 1.1 t/km²/year, respectively.

KEY WORDS: hydro-climatic drivers, geological conditions, fluvial transport, Wieprz River catchment, Roztocze Region

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Introduction

Water and matter circulation, distinguished by high temporal variability and considerable spatial variability, determines the modern development of the natural environment of the temperate climate zone. The character, range, and functioning of the circulation depend on the properties of the natural environment, including among others: land relief, hydro-climatic conditions (particularly the course and rate of precipitation and variability of temperatures), lithology of surface formations, land use structure, and human activity (Kostrze-wski, Szpikowski 2003). The determination of the processes of water circulation and fluvial transport in relation to the variability of environmental conditions is one of the most important aspects of the identification of the rules of functioning of geoecosystems (Gregory and Walling 1973, Kostrzewski et al. 1994, Krzemień 1999, Kostrzewski, Szpikowski 2003). The geoecosystem of a river catchment is the most convenient spatial unit for the determination of water and matter circulation.

The Roztocze part of the Wieprz River catchment constitutes an important part in the water management system of the entire catchment.

The area of the catchment above Zwierzyniec, constituting 3.9% of the area of the Wieprz River catchment, provides 6% of fluvial discharge. It is distinguished by the low level of environment degradation, expressed in a low value of the complex pollution coefficient (Świeca 1998, Świeca, Kociuba 2007). In such conditions, the type and amount of transported river load can reflect the current geomorphological processes (Gregory, Walling 1973). The study on river load could therefore be conducted in reference to Cholley's concept of a denudational system. According to the concept, transport in the river channel is referred to the catchment as the basic spatial unit (Kostrzewski 1993), and the amount of discharged material is treated as the index of the area's morphological activity (Świeca 1998).

The objective of the study was to present the spatial variability of the dynamics of fluvial processes in the Roztocze part of the Wieprz River catchment, as well as the relations between the quantitative indices of fluvial transport and hydro-climatic and geological conditions.

Methods

The spatial and temporal dynamics of selected processes of water circulation and fluvial transport were analysed in direct relation to the assessment of the variability of the geological and hydro-climatic conditions of the upper Wieprz River catchment. The study on the complex and co-dependent processes of water and matter circulation in relation to the spatial diversity of the geographic environment of the upper Wieprz River catchment required observation of hydrometeorological phenomena. Out of four analysed water gauge/hydrometric profiles, the main one (closing the upper Wieprz River catchment) was located in Zwirzyniec (permanent water gauge station of IMGW-BIP), and three (closing the subcatchments) in the tributaries: the Kryniczanka (in Dominikanówka), Jacynka (in Kaczórki), and Świerszcz Rivers (in Sochy). The obtained hydrometric data include results of daily water level and discharge rate measurements in Zwierzyniec, and weekly measurements in the tributaries. The meteorological

conditions were analysed based on mean daily air temperatures and daily precipitation totals from the meteorological station of IMGW-BIP in Tomaszów Lubelski, located in the direct vicinity of the study area, approximately 36 km SE of Zwierzyniec.

The measurements of fluvial transport rate in the upper Wieprz River catchment were performed in the hydrometric cross-section of IMGW-PIB in Zwierzyniec in intervals of two weeks (in the years 1989–1992) and one week (in the years 1998–2003). A total of 477 water samples were collected for the analyses of turbidity and determination of physical parameters, including 79 samples in the years 1989–1992, and 398 samples in the years 1998–2003. Samples for analyses of the concentration of suspention and dissolved material were collected by means of a bottle batimeter with a volume of 1 dm^3 more or less at half the depth of the current zone of the stream. The suspended load was calculated based on water turbidity measurements by means of the filter–weight method following Brański (1968), and water mineralisation by water specific electrical conductivity measurements with the application of a conductivity measure type MP-2 and OK. 102/1 by Redeliks. Water electrical conductivity (at a temperature of 25°C) was converted to dissolved material concentration (Krawczyk 1996).

The estimation of the values of the analysed fluvial transport components was based on the regression between discharge and concentration. In the conducted analysis of coefficients of determination for 5 applied regression models, the highest coefficients were obtained for the quadratic polynomial regression model. It was used for the determination of daily loads of mineralisation and turbidity (Świeca 1998, Świeca, Kociuba 2004). After statistical analysis, the collected data provided the basis for the assessment of the variability of fluvial transport in relation to the volume and character of fluvial discharge and geological conditions. The study applied the results of research conducted in the years 1989–1992 (Świeca 1998), 1998–2000 (Rodzik, Świeca 2001), and 2001–2003 (Kociuba et al. 2003, Świeca, Kociuba 2004).

Environmental conditions of fluvial transport in the upper Wieprz River catchment

In geomorphological terms (Maruszczak 1972), the catchment of the upper Wieprz River above Zwierzyniec, with an area of 404.0 km², is located in the Roztocze Tomaszowskie sub–region (Fig. 1).

The analysed part of Roztocze is distinguished by a considerable diversity of geological-geomorphological conditions. Late Cretaceous rocks are of importance in morphological terms. They are varied in lithostratigraphic terms, including gaizes and margle gaizes, opokas and margle opokas, and margles (Cieśliński et al. 1996, Maruszczak, Świeca 2004). Late Cretaceous rocks (particularly Maastricht) are locally covered by patches of Early Neogene rocks represented by Miocene limnic and marine formations – loamy, sandy, sandy-carbonate, and carbonate (Musiał 1987). Neogene rocks (Baden) are deposited under a discontinuous Quaternary sediment cover (aeolian sands and loesses).

The basic features of the relief are related to Laramian tectonics, and its secondary features are determined by the arrangement and lithological properties of surface rock outcrops (Maruszczak, Świeca 2004). The landscape of the catchment features plateaus cutting Upper Cretaceous and Early Neogene rocks: the upper one reaches 320–350 m a.s.l., and the lower one 300–330 m a.s.l. In the landscape of the southern watershed zone, inselbergs are observed. One of them – Wapielnia – reaches 386 m a.s.l.

The Wieprz River is the main river of the analysed part of Roztocze. Its length from the source to Zwierzyniec amounts to 44.1 km (13.6% of its total length). The source of the Wieprz River is located in a peatland area in the vicinity of the village of Wieprzów Tarnawacki at an altitude of 273.5 m a.s.l. The lowest point in the water gauge profile closing the catchment is located at an altitude of 219.2 m a.s.l. The mean inclination of river channel is 1.23‰. It is within the range of inclinations typical of upland rivers (1–3‰).

Almost the entire analysed catchment (more than 85% of its area) is under various forms of na-
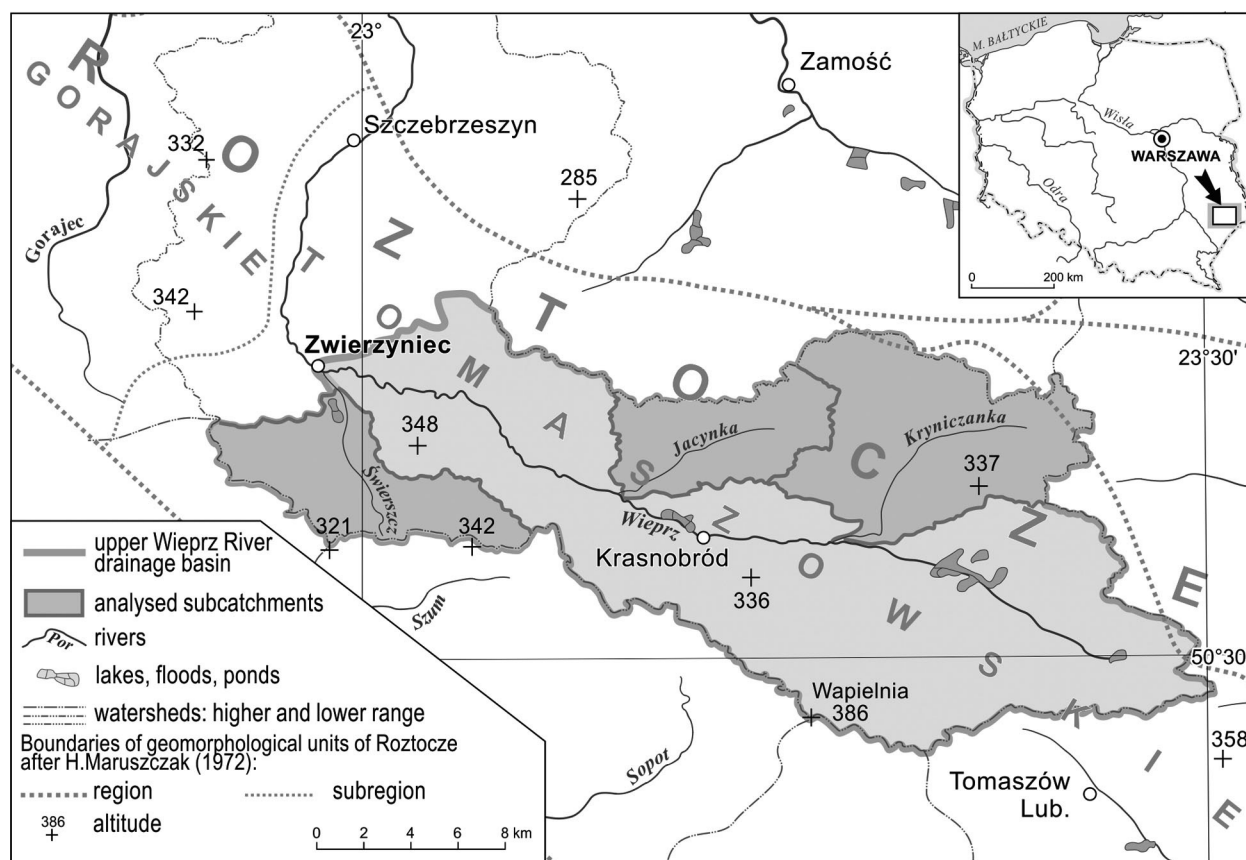

Fig. 1. Location of the upper Wieprz River drainage basin (with subcatchments) in relation to the gomorphological regions

ture protection due to the low level of its anthropogenic transformation, and high environmental values. The catchment is distinguished by relatively high forest cover (42.1% of the catchment area), and relatively low contribution of agricultural land (51.4%) (Świeca et al. 2004).

Hydro-climatic conditions in the study periods

The outflow differences in the hydrometric profiles suggest the domination of nival-precipitation fluvial regime in the upper part of the Wieprz River catchment, with a slight prevalence of supply and runoff in the cold half year. The assessment of the catchment's hydrological conditions emphasises the regulating role of the bedrock in the development of fluvial runoff. The contribution of groundwater supply in the total fluvial runoff amounts to 83% (Michalczyk 2004). Hydro-climatic conditions are largely respon-

sible for the character and course of the fluvial transport processes in this river catchment. They determine their occurrence and intensity. The field research in periods 1989–1992, 1998–2000, and 2001–2003 was conducted in conditions considerably differing from mean multiannual values in hydro–climatic terms (Fig. 2; Table 1).

In terms of temperatures, the period 1989–1992 was considerably warmer, and in terms of precipitation – similar to the mean multiannual value. The mean annual temperature in Zwierzyniec was higher by 1.0°C than the multiannual. The mean annual precipitation total was lower by only 1.6% than the multiannual (Table 1). Years 1998–2000 were warmer and considerably more humid than the mean annual values. The mean annual temperature in Zwierzyniec was higher than the multiannual by 0.6°C (Table 1). The mean annual precipitation total in the years 1998–2000 was higher than the multiannual by 24%. In terms of temperatures, years 2001–2003 were warmer, with a lower mean precipitation
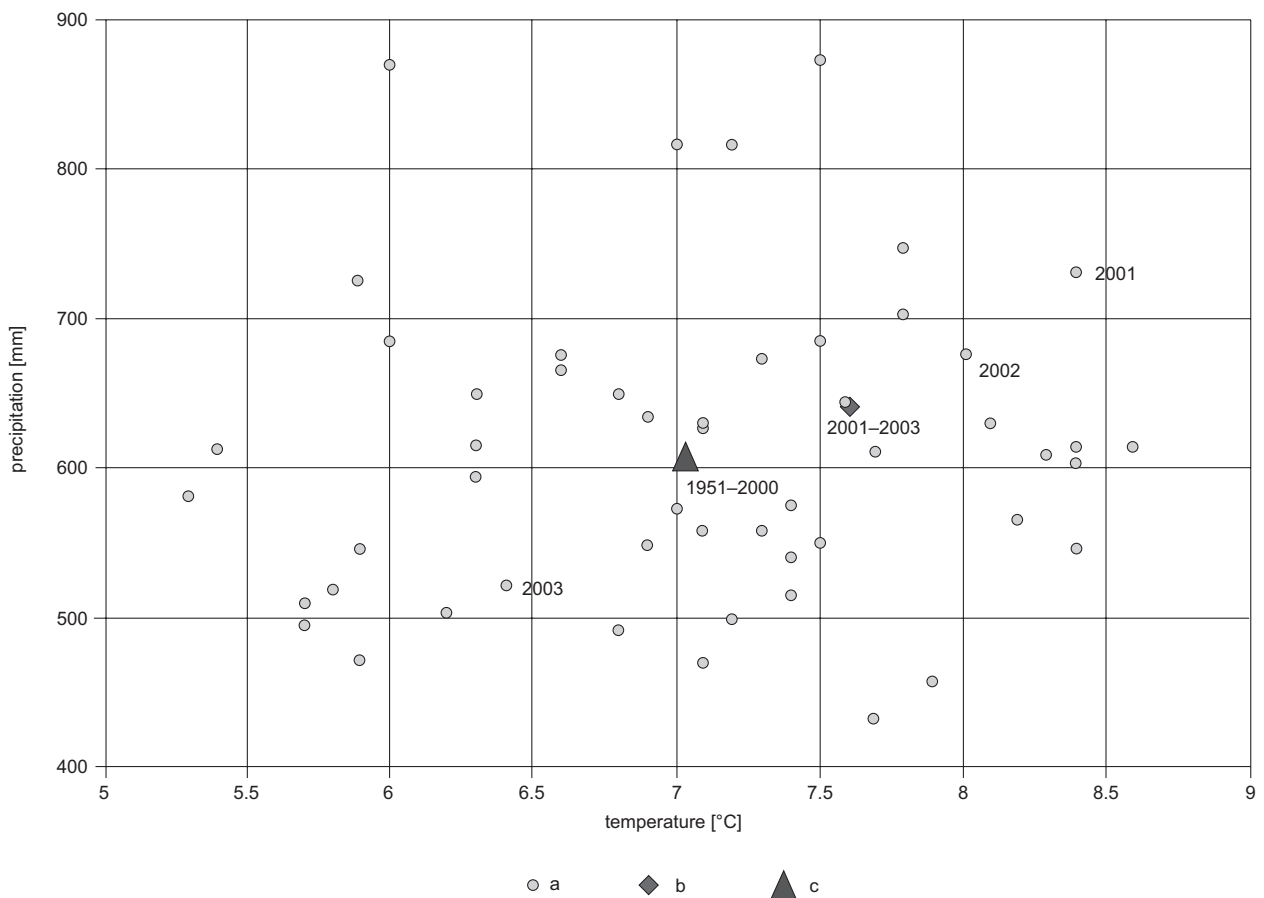

Fig. 2. Hydrological years 2001, 2002, and 2003 in the diagram of annual precipitation totals (mm) and mean air temperature (°C) in consecutive years 1951–2003 in Tomaszów Lubelski [a]; additionally the mean from the period 2001–2003 [b] and multiannual mean from the period 1951–2000 [c]

Table 1. Hydro-climatic indices of solution and suspension outflow in the years 1989–1992, 1998–2000, and 2001–2003 in relation to the multiannual 1951–2000 in the water gauge cross-section in Zwierzyniec

Indices				Years			
				1989–1992	1998–2000	2001–2003	1951–2000*
hydro-climatic conditions	temperature		[°C]	8.2	7.8	7.6	7.2
	precipitation		[mm]	693	876	643	704
	discharge		[m³/s]	1.68	2.94	2.33	2.08
	water outflow		[million m³]	53.07	91.49	73.59	–
outflow of solutions	total mineralisation		[mg dm⁻³]	252	250	238	–
	outflow of solutions		[t]	13 273	22 783	17498	–
			t km⁻² y⁻¹	32.7	56.2	43.3	
		contribution in total load	[%]	96.5	95.9	97.5	–
outflow of suspensions	turbidity		[mg dm⁻³]	9.7	11.0	5.9	–
	outflow of suspensions		[t]	485	981	440.6	–
			t km⁻² y⁻¹	1.2	2.4	1.09	
		contribution in total load	[%]	3.5	4.1	2.5	–

*temperature data for the multiannual 1951–1980.
The meteorological conditions was characterized based on mean daily air temperatures and daily precipitation totals from the meteorological station of IMGW-BIP in Tomaszów Lubelski.

total (Table 1). The mean annual temperature in Zwierzyniec was higher than the multiannual by 0.4°C. The mean annual precipitation total was lower than the mean multiannual by 8.7%. Based on the analysis of the temperature and precipitation conditions, the study periods can be respectively described as: warm and moderately humid in the years 1989–1992; exceptionally humid and moderately warm in the years 1998–2000; and moderately warm and moderately dry in the years 2001–2003.

Discharges of the Wieprz River in Zwierzyniec developed accordingly to the temperature and precipitation conditions. Mean annual values in the study periods were considerably varied, amounting to 1.68 m³ s⁻¹ (1989–1992), 2.94 m³ s⁻¹ (1998–2000), and 2.33 m³ s⁻¹ (2001–2003). These values corresponded to the specific runoff of 4.1, 7.3, and 5.8, respectively at a mean annual of 5.1 dm³ s⁻¹ km⁻². The mean annual discharge in Zwierzyniec in the years 1998–1992 was lower than the multiannual by 19.2%, and in the years 1998–2000 and 2000–2003, higher than the multiannual by 41.3 and 12.0%, respectively (Table 1).

In the three discussed study periods, the mean monthly, seasonal, and annual discharges usually showed high variability in relation to the corresponding values from the years 1951–2000. In the period 1989–1992, in particular years, mean annual discharges changed inconsiderably, and were usually lower than the mean multiannual values. In the remaining two periods, i.e. 1998–2000 and 2001–2003, annual discharges were usually higher.

Concentration of dissolved material and dynamics of transport of solutions

In the Roztocze part of the Wieprz River catchment, water physical parameters are particularly determined by geological conditions (Świeca 1998). In the upper Wieprz River in Zwierzyniec, relatively low variability of total mineralisation indices was recorded: from 228 to 265 mg dm⁻³ (mostly between 241 and 260 mg dm⁻³). The mean annual index showed a slight variability from 238 to 252 mg dm⁻³ (Table 1).

Among the conditions controlling physical and chemical properties of waters, the hydrological conditions are considered as the most important (Gregory, Walling 1973; Kostrzewski et al. 1994). A significant correlation was determined between total mineralisation (C_d) and discharge

(Q) C_d=f(Q). In the analysed periods (1989–1992, 1998–2000, and 2001–2003), the highest coefficients of correlation (*r* from 0.508 to 0.620) were obtained for the quadratic polynomial regression model (C_d=aQ²+bQ+c), represented by a parabola. For the study periods the arms of the parabola are directed downwards. The course of the function suggests an increase in the concentration of dissolved material along with discharge until a certain threshold value. After exceeding the threshold value, the concentration decreases. At low discharges, relatively low concentration of dissolved material is related to the prevalence of groundwater supply and leaching of the underground catchment. Along with an increase in discharge, total mineralisation also increases. In Zwierzyniec, a discharge of 2 m³ s⁻¹ constitutes the threshold value. After its exceeding, with growing discharge and contribution of surface flow, the concentration decreases. This may be related to higher dilution of solutions caused by water flowing through strongly leached near–surface soil layers.

In the waters of the upper Wieprz River, the quadratic polynomial regression models of the correlation between total mineralisation and discharge were used for the determination of mineralisation for everyday discharges. Based on this, the daily, monthly, and annual load and transport of solutions were calculated. The volume of outflow of solutions was determined to be dependent on the volume of fluvial discharges. This is a proportionate correlation with relatively high coefficients of correlation (*r* from 0.906 to 0.935).

In the upper Wieprz River, the transported material was dominated by solutions. Their contribution varied from approximately 96.5% in the years 1998–2000 to approximately 97.5% in the years 2001–2003 (Table 1). In Zwierzyniec, in the cross–section closing the studied part of the catchment, the amount of transported solutions particularly reflected the environmental conditions. In the years 1989–1992, the river transported approximately 13,300 tonnes of solutions annually. In the years 1998–2000 and 2001–2003, the values amounted to 22,783 and 17,498 tonnes, respectively. It should be emphasised that the study on fluvial transport in the years 1989–1992 was conducted at considerably lower, and in the years 1998–2003 at considerably higher discharges than mean multiannual values.

Concentration of suspended material and dynamics of transport of suspensions

In comparison with dissolved material, transport of suspensions is considerably more varied. The content of suspensions in fluvial waters is so variable – irrespective of the discharges themselves – that even daily measurements do not ensure accurate results.

In the hydrometric cross–section on the Wieprz River in Zwierzyniec, turbidity indices in the study periods varied from 0.1 to 24.3 mg m⁻³ (in the years 1989–1992), from 0.3 to 77.5 mg m⁻³ (in the years 1998–2000), and from 0.7 to 24.1 mg m⁻³ (in the years 2001–2003). Mean annual values in the three study periods varied from 5.9 to 11.0 mg m⁻³ (Table 1).

The determined regression model between concentration of suspended material and water discharge with the application of the quadratic function (polynomial function of the second degree) suggests a very weak relationship, often at an insignificant level with very low coefficients of correlation (*r* from 0.092 to 0.256). A much stronger correlation with water discharge was determined for suspension load (*r* from 0.377 to 0.676).

In reference to the results of research on fluvial transport, it should be emphasised that the catchment of the upper Wieprz River is distinguished by a relatively low concentration of suspensions in fluvial transport (Świeca 1998, Rodzik, Świeca 2001, Kociuba et al. 2003, Świeca, Kociuba 2004, Stępniewski, Rodzik 2008). In the three study periods, transported suspensions constituted from 2.5 to 4.1% of annual fluvial discharge (Table 1).

In the conditions of low human influence, a strong relationship between transport of suspended load and discharge values was observed. In the years 1989–1992, the Wieprz River discharged an average of approximately 485 tonnes of suspensions annually. In the years 1998–2000, at an almost double increase of discharge in the river, transport of suspensions was also doubled to a value of 981 tonnes. Lower discharges in the years 2001–2003 caused a decrease in the weight of transported suspensions to 441 tonnes. The mean annual unitary outflow amounted to 1.2, 2.4, and 1.1 t km⁻² y⁻¹, respectively.

Diversity of geoecosystems in the upper part of the Wieprz River catchment

Partial catchments of three tributaries of the Wieprz River were selected for the determination of the diversity of the natural conditions and degree of anthropopressure in the upper part of the Wieprz River catchment, namely those of the Kryniczanka (66.7 km²), Jacynka (30.2 km²), and Świerszcz Rivers (45.4 km²) (Fig. 1; Table 2).

In geological terms, the Kryniczanka River catchment stands out among the Lower Maastricht marl opokas and margles, covered by loesses and loess-like formations (80.0% of the catchment). The catchment is distinguished by the lowest extreme denivelation, the lowest relief ratio, and the highest catchment elongation index. The valley shape coefficient and the edge sinuosity index are the same as in the Świerszcz River catchment (Table 2). The catchment is relatively strongly affected by economic activity. Agricultural land constitutes approximately 83% of the catchment area (including 67% of cultivated land), with the highest contribution of meadows and pastures (17%). The mean discharge of the Kryniczanka River in its mouth section amounts to approximately 250 dm³ s⁻¹. The waters of the Kryniczanka River show a relatively high level of mineralisation (270 mg dm⁻³).

In relation to the Kryniczanka River catchment, the Jacynka River catchment is distinguished by its geological conditions with the prevalence of loesses and loess-like formations and sands, and deluvial loams. Due to this, index values describing relief features (extreme denivelation and relief ratio) are higher and respectively lower valley shape coefficient (the lower the index value, the deeper the river valley is indented). Here, the catchment elongation index reaches the lowest value among all of the three analysed catchments (Table 2). It has the highest contribution of agricultural land (67%, including 57% of cultivated fields), and the lowest forest cover (26%). The mean discharge of the Jacynka River in its mouth section is approximately five times lower than for the Kryniczanka River, and amounts to approximately 50 dm³ s⁻¹. The waters of the Jacynka River are less mineralised (186 mg dm⁻³).

The Świerszcz River catchment is distinguished by the highest diversity of geological conditions (Lower Maastricht gaizes and margle gaizes; Upper Baden detritic and algal reef limestones; deluvial, aeolian, and alluvial fan sands), and consequently orographic conditions (highest extreme denivelation and relief ratio) (Table 2). The catchment has the highest forest cover (61%) and the lowest contribution of agricultural land (35%, including 34% of cultivated fields). The mean discharge of the Świerszcz River is almost 2.5 times lower than that of the Kryniczanka River, and amounts to approximately 100 dm³ s⁻¹. The waters of the Świerszcz River are the least mineralised (177 mg dm⁻³).

In the analysed partial catchments, the volume of transported solutions and suspensions reflects the natural conditions and degree of anthropopressure. In the analysed catchments, the material transported in the river beds is dominated by solutions. Their contribution varies from approximately 80 to 97%. The Kryniczanka River, the largest tributary of the upper Wieprz River, transports approximately 1,950 tonnes of dissolved material annually. The value for the Świerszcz River is approximately 950 tonnes, and for the Jacynka River – approximately 250 tonnes. The unitary solution outflow indices for the catchments amount to 29, 20, and 8 t km⁻² y⁻¹.

Suspensions constitute from approximately 3.5 to 20.5% of the transported material. Low contributions of suspensions (approximately 3.5–4.0% of the total load) are recorded in the catchments of the Świerszcz (forested catchment) and Kryniczanka Rivers (extensive meadows in the valley bottom). The contribution is considerably higher (approximately 20.5%) in the Jacynka River catchment, distinguished by high expansion of loess formations, lower forest cover, and the highest contribution of cultivated fields.

Final remarks

The results obtained based on the regression between discharge and concentration of the analysed river load components reflect the estimated values. Following Stach (2002, 2008), the method of load estimation adopted in the study does not consider the strong temporal autocorrelation of concentrations and discharges. The results of the study of fluvial transport in the upper Wieprz River catchment document the response of

Table 2. Indices of solution and suspension outflow in the years 2001–2003 in catchments of the tributaries of the upper Wieprz River in relation to hydrological descriptions and geological-morphometric parameters

	Kryniczanka River	Jacynka River	Świerszcz River
Geological descriptions (based on: Musiał 1987; Cieśliński et al. 1996)			
Maastricht rocks [% of the catchment area]	Lower Maastricht margle opokas and margles; loesses and loess-like formations 80.0	Lower Maastricht margle opokas and margless 9.0	Lower Maastricht gaizes and margle gaizes
Miocene rocks [% of the catchment area]			Upper Baden detritic and algal reef limestones
loesses and loess-like formations [% of the catchment area]		48.1	
sands and deluvial loams [% of the catchment area]		27.3	
sandy formations [% of the catchment area]			deluvial, aeolian, and alluvial fan sands 47.0
Morphometric descriptions			
extreme denivelation [m]	72.7	79.0	111.8
relief ratio (Rh = H/L, Schumm 1954; Strahler 1954)	0.009	0.014	0.020
catchment elongation ratio (Re = 2(A/п)$^{0.5}$/L, Schumm 1954)	0.97	0.72	0.73
valley shape coefficient (Vf = 2Vfw/[(Eld−Esc) + (Erd−Esc)], Bull, Mc Fadden 1977)	0.4–0.9 1.0–3.2 3.7–22.9	0.6–0.9 1.0–3.3	0.4–0.9 1.0–3.2 3.7–22.9
edge sinuosity index (S = Lmf/Ls, Bull 1977)	1.1–1.4	1.0–1.1	1.0–1.1
Hydrological descriptions			
discharge [m^3 s^{-1}]	0.21	0.04	0.16
water outflow [million m^3]	6.71	1.19	5.05
Solution outflow indices			
total mineralisation [mg dm^{-3}]	270	186	177
outflow of solutions [t]	1934.0	234.4	932.5
Unit outflow of solutions [t km^{-2} y^{-1}]	28.56	7.71	20.32
contribution in total load [%]	96.0	79.5	96.7
Suspension outflow indices			
turbidity [mg dm^{-3}]	8.1	22.2	5.9
outflow of suspension [t]	81.3	60.4	32.2
Unit outflow of suspension [t km^{-2} y^{-1}]	1.20	1.98	0.70
contribution in total load [%]	4.0	20.5	3.3

H – Difference of extreme elevations; L – Maximum catchment length; A – Total area of catchment;
Vfw – Valley floor width, Eld – Elevation (m a.s.l.) of the left valley divide, Erd – Elevation (m a.s.l.) of the right valley divide, Esc – Elevation (m a.s.l.) of the valley floor.
Lmf – Length of the mountain front along the foot of the mountain, Ls – Straight line length of the mountain.

an upland river to changes in hydrological conditions. Periods 1989–1992 and 1998–2000 can be considered extreme in hydrological terms.

The four-year period from 1989 to 1992 was distinguished by low water stages. Mean annual discharges were lower than multiannual values by 19%. On the average, the Wieprz River discharged approximately 13 300 tonnes of solutions and 485 tonnes of suspensions annually from the catchment with an area of 404 km^2. Unitary indices amounted to 32.7 and 1.2 t km^{-2} y^{-1}, respectively. In the years 1998–2000, in the conditions of high water stages, mean annual discharges were higher than the multiannual values by 41%. The Wieprz River discharged an average of approximately 22 800 tonnes of solutions and 981 tonnes of suspensions annually. Along with an almost triple increase in discharges in relation to the dry years 1989–1992, also the solution (56.2 t km^{-2} y^{-1}) and suspension transport index (2.4 t km^{-2}

y^{-1}) almost doubled. In the years 2001–2003, in the conditions of varied water stages, discharges were higher than the multiannual values by 12%. In such conditions, the Wieprz River discharged an average of approximately 17,500 tonnes of solutions and 441 tonnes of suspensions annually, and the unitary indices reached 43.3 t km^{-2} y^{-1} and 1.1 t km^{-2} y^{-1}, respectively.

The lithological diversity of surface formations and their use have a considerable effect on the intensity of geochemical processes in the analysed catchments. This is reflected in the values of fluvial transport indices. No significant correlation was determined between relief diversity expressed in the analysed morphometric indices and the values of fluvial transport indices.

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