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HISTORICAL AND CONTEMPORARY TRANSFORMATIONS OF THE HYDROGRAPHIC CONFLUENCE AT SIELPIA

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Abstract. Making use of the cartographic-geomorphological method, a case study of the hydrographic confluence at Sielpia made it possible to identify changes in the river and hydrographic networks connected with the development and decline of the Old-Polish Industrial District (OPID), whose functioning relied on the use of hydropower in iron metallurgy. The formation and disappearance of artificial industrial reservoirs and canals, the drainage networks, and the appearance of catastrophic flash floods as a result of failures of hydrotechnical structures have been reflected in cartographic materials, relief, and sediments.

Keywords: river network changes, Czarna Taraska River, Czarna Konecka River, Sielpia, Old-Polish Industrial District

INTRODUCTION

The area discussed in this study lies within the Lesser Poland Upland (Solon et al. 2018), in the Świętokrzyskie region, in the middle Vistula basin (Majewski 2013). The hydrographic confluence at Sielpia is situated within the boundaries of the Old-Polish Industrial District (OPID) (Fig. 1), where iron ore was extracted and processed on a large scale in recent centuries (Chłopek 2017). The hydropower of the Czarna Konecka and Czarna Taraska Rivers was used at that time to power the iron works established along their banks. To meet the needs of this industry, an anthropogenic small water retention system (ASWRS) was built, comprised of numerous canals and stepped falls that created ponds which provided water for the hammer works (Kalicki et al. 2019a, b, c, 2020).

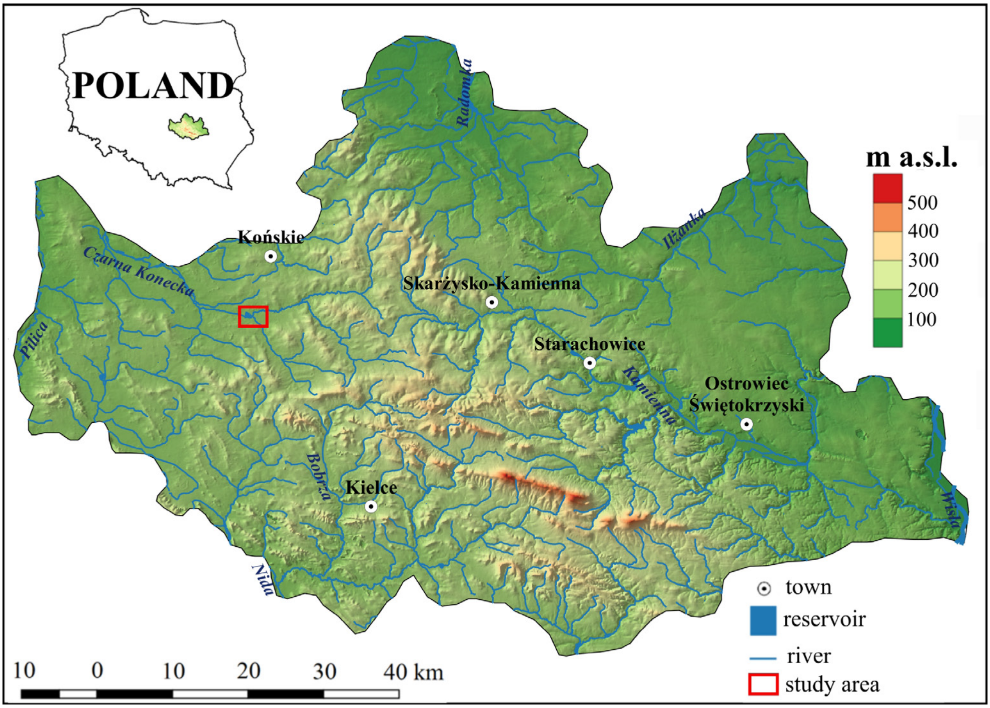

Fig. 1. The investigated area on a digital elevation model (DEM) of the OPID (boundaries after Zieliński 1965); (by K. Fularczyk based on gugik.gov.pl)

HISTORY OF THE OPID – AN OUTLINE

The first water-powered hammer mill in the Świętokrzyskie region was established as early as the 13th century (Kubicki, Saletra 2013). However, water-powered hammer works in the valleys of the Czarna Konecka and Czarna Taraska are not mentioned in the sources before the turn of the 15th and 16th centuries, as the earliest accounts refer to Wąsosz (1492) and Królewiec (1564) (Fajkosz 2010). Beginning from the 16th century, sources also record the development of settlements in the basins of the two rivers, connected with iron works that were opened on a large scale, accompanied by numerous dykes, canals, and ponds, as well as by workers' housing estates (Herbst 1951).

The economic crisis at the turn of the 17th and 18th centuries, caused by the consequences of the Swedish Deluge among other factors, inhibited the development of industry in the investigated area, as it did throughout Poland. In the second half of the 18th century, the OPID iron industry began to gain in importance for the economic development of the Polish-Lithuanian Commonwealth. The introduction of new technologies such as the blast furnace process significantly improved the efficiency of steel plants (Radwan 1963; Wikiera 1996). The first blast furnaces in the analysed area were built in 1739 in Stąporków on the Czarna Konecka and in 1779 in Kawęczyn on the Czarna Taraska (Krygier, Ruszczyńska 1958; Wikiera 1996; Kubicki, Saletra 2013). At the beginning of the 19th century, hammer works were transformed into more efficient plants using the Bessemer process, known as *fryszerki* (Krygier, Ruszczyńska 1958; Zieliński 1965; Fajkosz 2010; Chłopek 2017, 2019). The development of industry and the increase in production resulted in increased human interference in fluvial systems and the expansion of the ASWRS. For example, an 8-km-long canal was dug in 1821 for the needs of a rolling mill, and in 1821–1830 a water reservoir was created in Sielpia (Krygier, Ruszczyńska 1958). This reservoir was augmented by adding a southern reservoir in 1837, which is documented by a protocol drafted on 21 April 1848 in connection with the seizure of peasants' land for mining purposes. In this document, the villagers complain about the seizure of meadows for the construction of a newly arranged pond (Fajkosz 2010). In 1843, the first water turbine in the Kingdom of Poland was installed in Sielpia (Szot-Radziszewska 2009), which marks the beginning of automation in the OPID area in the second half of the 19th century (Chłopek 2017).

At the end of the 19th century, with the rise of the steam engine, hydropower ceased to be a decisive factor in the location of steel plants, and riverside blast furnaces began to be extinguished (Chłopek 2017), such as that in Kawęczyn in 1893 (Krygier, Ruszczyńska 1958). A socio-economic recession, unprofitable exploitation of low-grade ores, deforestation, and the development of iron metallurgy based on new technologies in other regions resulted in the decline of the mining and metallurgical industry in the valleys of the Świętokrzyskie region (Herbst 1951; Chłopek 2017, 2019). The cessation of production in the Sielpia plant in 1921 was caused by a deficit of forest resources and iron ore deposits (Szot-Radziszewska 2009). The regression of metallurgy in the OPID may have been accelerated by the floods that hit the region and damaged the hydrotechnical infrastructure in the 19th and early 20th centuries (Chłopek 2017, 2019).

The presented development of metallurgical technology in the investigated area, which determined the changes in the hydrographic network, correlates with the forging and blast furnace sub-periods distinguished by Radwan (1963) (Fig. 2).

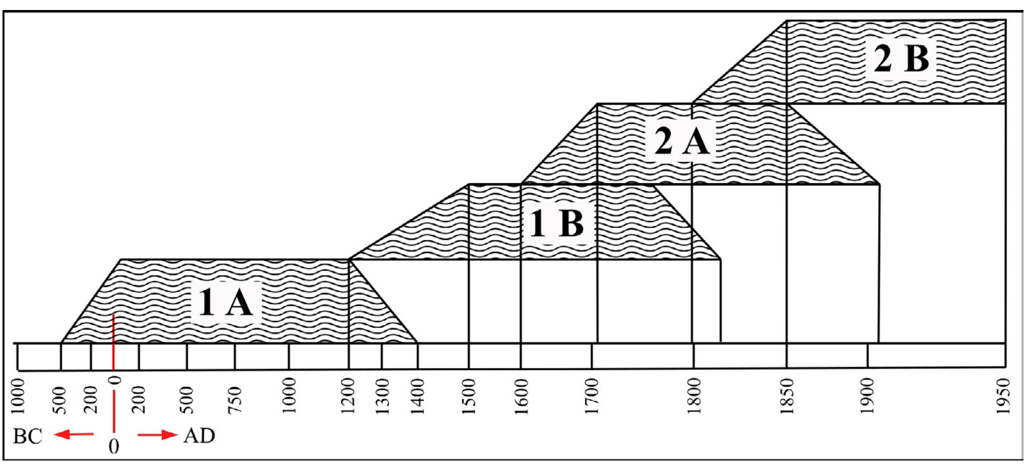

Fig. 2. Periods and sub-periods of metallurgical technology development in Poland (Radwan 1963) 1 – period of direct iron extraction from ores: 1A – rudnica sub-period, 1B – hammer works subperiod; 2 – period of indirect iron extraction from ores; 2A – blast furnace sub-period, 2B – coke blast furnace sub-period

After the collapse of the metallurgical industry in the valleys of both rivers, milling based on water energy developed, but on a smaller scale (Fajkosz 2010). These changes led to the abandonment of numerous industrial ponds and canals, which over the years became partially or fully terrestrializated, and thus the ASWRS fell into disuse in the OPID (Kalicki et al. 2019a, b, c, 2020). Previously unknown in the Holocene, great catastrophic flash floods occurred in the Świętokrzyskie valleys in the 20th century (Kalicki et al. 2019c). They were caused by breaches of neglected dams and runoff from overfilled reservoirs during intense and prolonged rainfall or thaw. Water reservoirs in the Czarna Konecka and Czarna Taraska valleys ceased to be dredged, and after failures of damming devices, most of the sediments accumulated in them eroded, to be subsequently transported by the rivers and accumulate in the Sielpia reservoir (Kalicki et al. 2021).

STATE OF RESEARCH

The analysis of changes in a river network based on cartographic materials (Plit 2006, 2007) is a frequently used and long-established method, known both from Polish literature (e.g. Bąkowski 1902; Falkowski 1971; Trafas 1975, 1992; Plit 2002, 2004, 2010; Skrycki 2003; Bogucka-Szymalska 2006; Lenar-Matyas et al. 2006; Graf et al. 2008; Śmielak 2008; Zawiejska, Wyżga 2010; Kałmykow-Piwińska, Falkowski 2012; Tobiasz 2012; Nawieśniak et al. 2014; Ostrowski, Kaszyński 2014; Goraj 2015; Noszczyk et al. 2015) and from studies published abroad (e.g. Schirmer 1983; Petts et al. 1989; Strasser 1990, 1992; Yang et al. 1999; Gregory 2006; James et al. 2009; Martinson 2010; Radoane et al. 2013; Podobnikar, Lamovec 2015; Salit et al. 2015; Dixon et al. 2018; Lestel et al. 2020). This analytic method, especially when verified by geomorphological field research, provides a good tool for tracing changes in fluvial environments over recent centuries (e.g. Kalicki, Plit 2003; Krupa 2013; Kalicki, Fularczyk 2018, 2019; Fularczyk et al. 2020a, b).

The issues related to the OPID have been repeatedly addressed in various historical studies (e.g. Radwan 1963; Zieliński 1965; Kubicki, Saletra 2013; Chłopek 2017, 2019; Chłopek, Sim 2020). Much less attention has been given so far to the impact of the OPID on the natural environment (e.g. Rutkiewicz, Malik 2019) and the transformation of the fluvial environment (e.g. Kłusakiewicz et al. 2016; Chrabąszcz et al. 2017; Przepióra, Kalicki 2018; Kalicki et al. 2019c; Przepióra et al. 2019; Fularczyk et al. 2020a, b; Kalicki et al. 2020). In previous publications concerning the reservoir in Sielpia (Aksamit et al. 2019; Kalicki et al. 2021), the cartographic-geomorphological method, which would allow capturing changes in the hydrographic network in this area, has not been applied (see Kalicki, Plit 2003).

OBJECTIVES AND METHODS

The aim of this study is to present the historical and contemporary transformations of the hydrographic confluence at Sielpia. The presented case study identifies the impact of the development and decline of the OPID on the transformation of the area's river network.

Changes within the area of the hydrographic confluence at Sielpia were analysed using historical sources and cartographic materials from the 19th–21st centuries (Table 1, Figs 3–5).

The results of the analytical studies were verified in the field. Two sites were selected for detailed research: the Sielpia reservoir (I in Fig. 6) and the palaeochannel of the Czarna Taraska (II in Fig. 6). The field work included photographic documentation, digging a test pit in the central-western part of the Sielpia reservoir (P1 in Fig. 6), drilling a geological borehole in the Czarna Taraska palaeochannel (P_2 in Fig. 6), and documenting a schematic cross-section through this valley (A-A' in Fig. 6).

The collected sediment samples were subjected to granulometric analysis using the sieve or laser method (Racinowski et al. 2001), the grain size distribution parameters of Folk and Ward (1957) were calculated, and the content of organic matter was determined by the loss on ignition method (Łądkiewicz et al. 2017). The results are presented graphically using GRANULOM, INKSCAPE and QGIS programs.

Table 1. Cartographic materials used in the study

Map name	Sheet	Cartographic actuality	Year of publication	Scale
West Gallizien	–	1801–1804	–	1:28 800
Topograficzna Karta Królestwa Polskiego	Końskie (Kol. III, Sek. VI)	1822–1831	1843	1:126 000
Mapa Sztabu Generalnego Armii Czerwonej Robotników i Chłopów	Końskie (M-34-29)	1893–1898	1940	1:100 000
West Osteuropa	Gruppe Warschau (XXVII-7-F)	1914–1915	1915	1:25 000
Mapa Taktyczna Polski	Końskie (Pas 44, Słup 31)	1937–1938	1938	1:100 000
Szczegółowa Mapa Geologiczna Polski	Radoszyce M-34-29-D	1945*–1953	1967	1:50 000
Mapa topograficzna	Końskie (133.4)	1974	2000	1: 50 000
Mapa topograficzna	Nowy Dziebałtów (133.434)	1985	–	1:10 000
Ortofotomapa	–	2003/2004	–	–
Ortofotomapa	–	2010	–	–
Ortofotomapa	–	2018	–	–
Ortofotomapa	–	2019/2020	–	–

* it has been assumed in this study that the map was created after WWII

RESULTS

The cartographic materials illustrate changes in the river network from the beginning of the 19th century to the present day (Figs 3–5).

Around 1800, the reservoir in Sielpia did not yet exist (Fig. 3A) and, over a section 1.5-km long before connecting with the Czarna Taraska, the meandering Czarna Konecka flowed through many channels, revealing an anastomosing pattern. At that time, there was a reservoir in Świnków on the Czarna Taraska, which powered five water wheels in a scythe factory established at the end of the 18th century (Chłopek, Sim 2020). The river flowed out of the reservoir through three weirs, forming three branches that soon flowed together, creating at a point about 0.5 km downstream of the dam a single, strongly meandering channel flowing SE-NW. The Czarna Taraska met one of the side branches (the southernmost) of the anastomosing Czarna Konecka in Sielpia, and after another 200 m it flowed into the main, northern channel of that river.

The collapse of the scythe factory, which was already in ruin in the 1830s (maleniec.pl), resulted in the disappearance of the pond in Świnków as early as the 1810s.

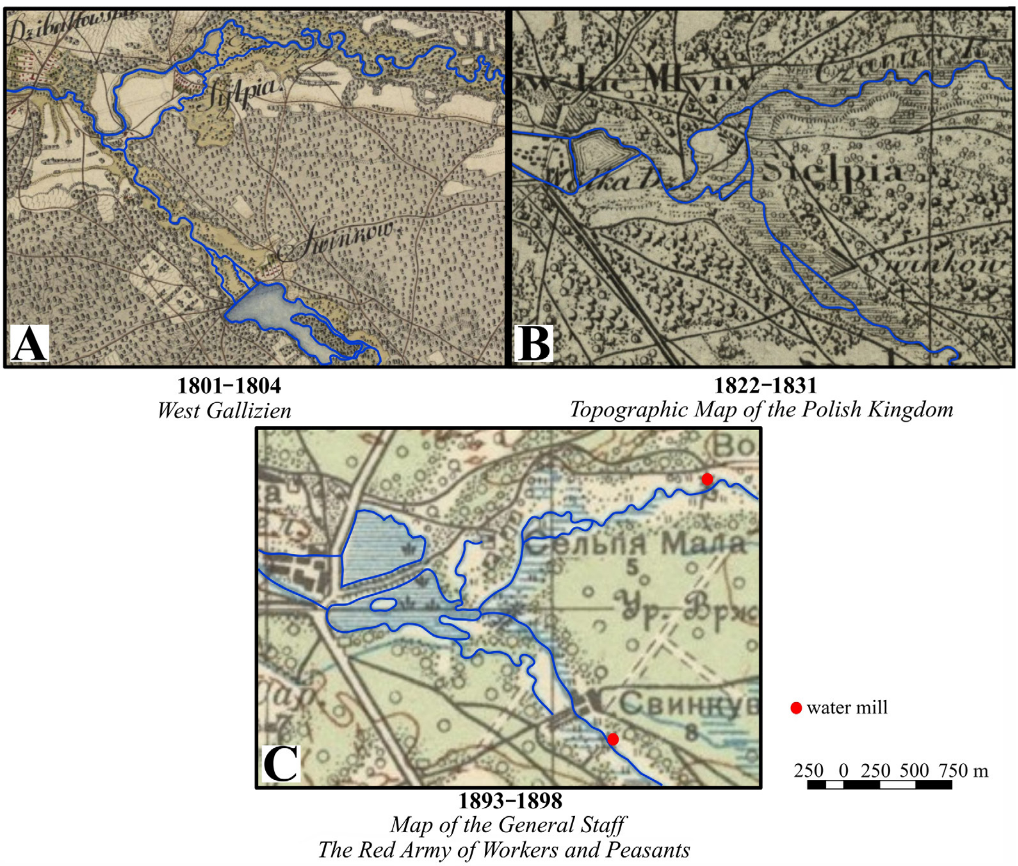

Fig. 3. Changes in the hydrographic network in the vicinity of Sielpia in the 19th century; (by K. Fularczyk based on mapire.eu, igrek.amzp.pl)

Within the drained bottom, and downstream of a water-damming dyke still visible in morphology (G in Fig. 6), a two-channel anastomosis developed over a section of about 1 km (Fig. 3A-B). The estuary section of the Czarna Taraska also changed completely. Rather than to the north-west the river was now flowing to the north in a straight, probably anthropogenic channel, and it flowed into the southern side branch of the Czarna Konecka more than 0.5 km upstream of what was its natural mouth at the beginning of the 19th century. The natural, meandering Czarna Taraska channel is not marked on the map of the Kingdom of Poland. Its absence does not stem from the map's inaccuracy, but from the fact that the channel was probably dry at that time, and the entire flow was directed to an anthropogenic channel diverting water to the north. The shifting of the Czarna Taraska channel may have been connected with the start of the works on the construction of the reservoir in Sielpia in 1821 and was meant to facilitate construction works.

The reservoir in Sielpia was not built until the 1820s (Krygier, Ruszczyńska 1958). In 1837, the reservoir was extended to include a southern reservoir, which was separated from the previously existing lake by a causeway (Fajkosz 2010). At the end of the 19th century, there was an island in the centre of this southern reservoir, and an elongated peninsula in the eastern part (Fig. 3C). The Czarna Konecka and Czarna Taraska flowed into a small bay to the north of the peninsula, while the natural, old, meandering channel of the Czarna Taraska was linked with a bay to the south of it. This old channel started at the dyke of the drained pond in Świnków and was filled with water. The fact that this oxbow lake was filled up with water again was probably related to the fact that the dyke had a regulating system which allowed for distributing water between the old, natural channel and/or the new, anthropogenic channel. This situation continued until World War I (see Fig. 4A). The anastomosing section of the Czarna Konecka upstream of the reservoir in Sielpia was regulated: the northern channel became an oxbow lake, and the southern one was straightened. Regulatory work also brought an end to the anastomosis of the Czarna Taraska near Świnków. The bottoms of both valleys became swamped.

By the outbreak of World War I, the northern bay in the Sielpia reservoir, into which both rivers flowed forming an inland delta, became completely terrestrializated. The southern bay, on the other hand, remained unchanged (see Figs 3C and 4A), which proves that the old meandering channel of the Czarna Taraska was filled with water, but the flows must have been low and human-regulated. At the beginning of the 20th century, a mill and a small pond were built on the Czarna Konecka. This was short-lived, however, because already in the interwar period the pond disappeared, and the river upstream of the Sielpia reservoir flowed in one channel which gradually decreased in sinuosity until the middle of the 20th century (Fig. 4A–C).

In the interwar period, probably after the collapse of the plant in Sielpia in 1921 and the resulting neglect of the technical infrastructure, the southern body of the reservoir in Sielpia silted up significantly, and three islands emerged there. This was probably also the cause of the final "draining" of the old Czarna Taraska channel (Fig. 4B, II, Fig. 6). The area covered by wetlands also diminished significantly (see Fig. 4A–B).

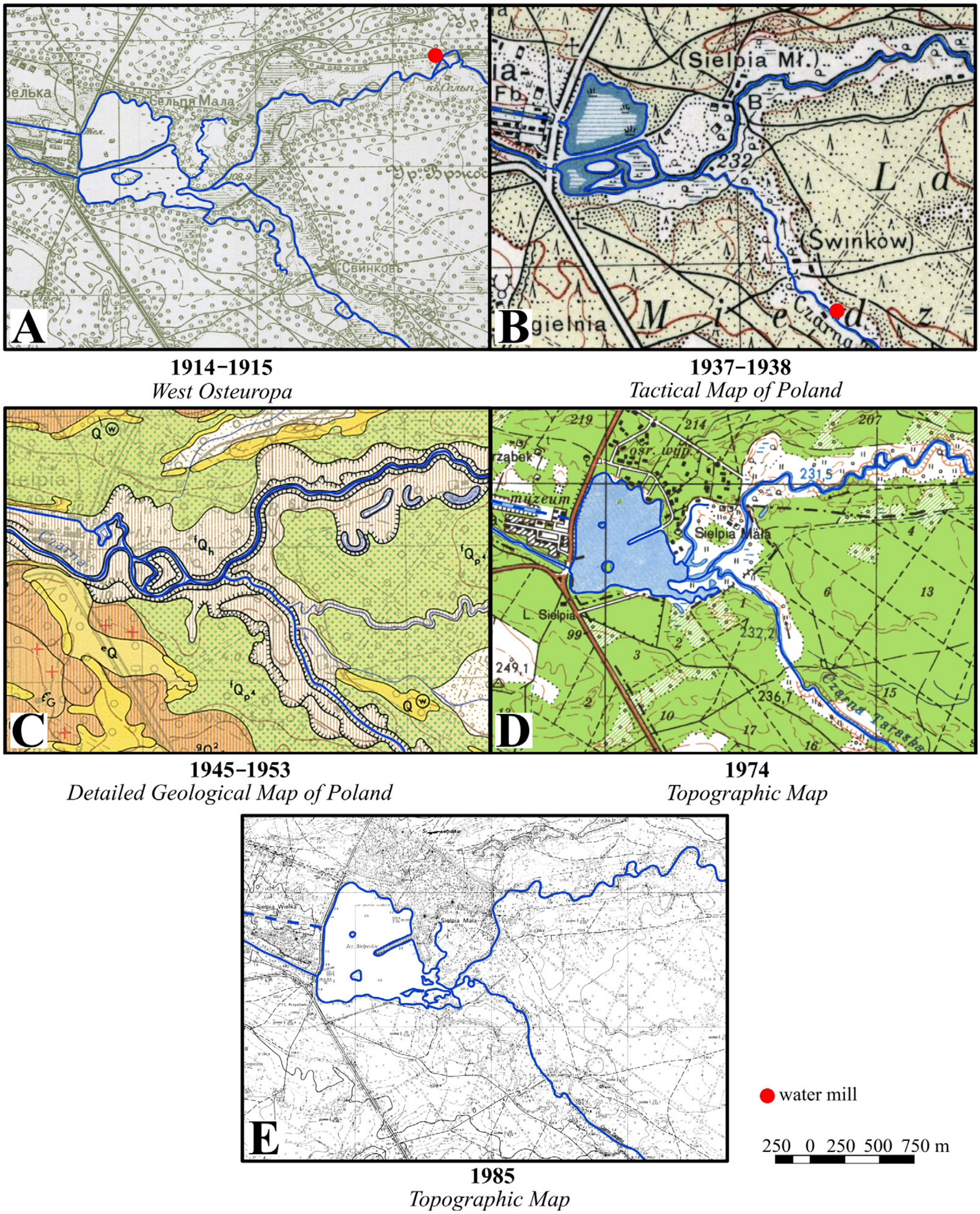

Fig. 4. Changes in the hydrographic network in the vicinity of Sielpia in the 20th century; (by K. Fularczyk based on mapire.eu, igrek.amzp.pl, pgi.gov.pl)

Even before the outbreak of World War II, the reservoir in Sielpia had ceased to exist, because the flood from 11–15 May 1939 (Suligowski 2013) destroyed both reservoirs, and in September that year the retreating Polish army demolished the bridge with the drain (Jedynak 1993). A multi-channel system developed in the drained basin of the reservoir, with the course of individual channels conforming to the morphology of the bottom (islands, delta) and being conditioned by the location of two damaged weirs which the water flowed towards. The main Czarna Konecka channel flowed through the southern weir, and there was a small pond at the northern one (Fig. 4C).

A new reservoir (I in Fig. 6, Fig. 4D) was built in 1962 (Jedynak 1993). It was a single body of water with two small islands, and the dyke, which in the previous reservoir separated the northern and southern bodies, was only fragmentarily preserved, forming a peninsula in the eastern part of the pond. The 8-km-long canal (built along with the northern body of the older reservoir in 1821–1830 (Krygier, Ruszczyńska 1958) draining the reservoir's waters through the northern weir was active only at higher floods and functioned as a relief channel, as it did in the interwar period after the collapse of the metallurgical plant in Sielpia in 1921 (see Fig. 4B and D).

Cartographic materials from the times of the Peoples Republic of Poland (Fig. 4C–E) show the gradual and slow development of the Czarna Konecka delta in the SE part of the reservoir. They also show that one of the meanders of that river, approx. 0.5 km upstream of the former mill pond from the early 20th century, was cut off (see Fig. 4A).

The situation must have changed in the 1990s, because by 2003 the entire eastern part of the reservoir in Sielpia had been filled by a vast inland delta (Fig. 5A). The delta must have been dredged in the following years, as in 2010 it occupied an incomparably smaller area (see Fig. 5A–B). In the past decade, the reservoir has become silted again, although the size of the delta is much smaller than in 2003 (Fig. 5C). In 2019, works on the dredging of sediments and revitalization of the reservoir resumed (Fig. 5D), and for the last two years revitalization works have been carried out, including on the dredging of the youngest alluvial cone at the mouth of the Czarna Konecka. Both rivers have a single-channel arrangement. The Czarna Konecka meanders do not show significant changes in the last three decades, while the lowest section of the Czarna Taraska has become more and more winding as a result of natural fluvial processes leading to the transformation of a straight, anthropogenic artificial channel into a natural meandering channel (Fig. 5).

Detailed research was carried out on two sites (Fig. 6).

Site I – Sielpia reservoir

During the 200 years of its existence, the reservoir in Sielpia (I in Fig. 6) underwent numerous changes in terms of its size, including a complete disappearance and recreation (Figs 3–5) caused by various natural and anthropogenic factors. One natural factor of the last half-century were flash floods after failures of hydrotechnical structures on the Czarna Konecka and the Czarna Taraska (Fig. 7). As a result, large amounts of sediment from the banks and bottoms of the channels, as well as from former ponds, were deposited into the Sielpia reservoir (Aksamit et al. 2019; Kalicki et al. 2019a, b, c, 2020, 2021), forming a high-energy sub-aquatic cone in its eastern parts, near the mouth of the Czarna Konecka River. At the beginning of the 21st century, this resulted in the complete terrestrialization of this part of the reservoir and its shallowing (Fig. 5A, Fig. 7A).

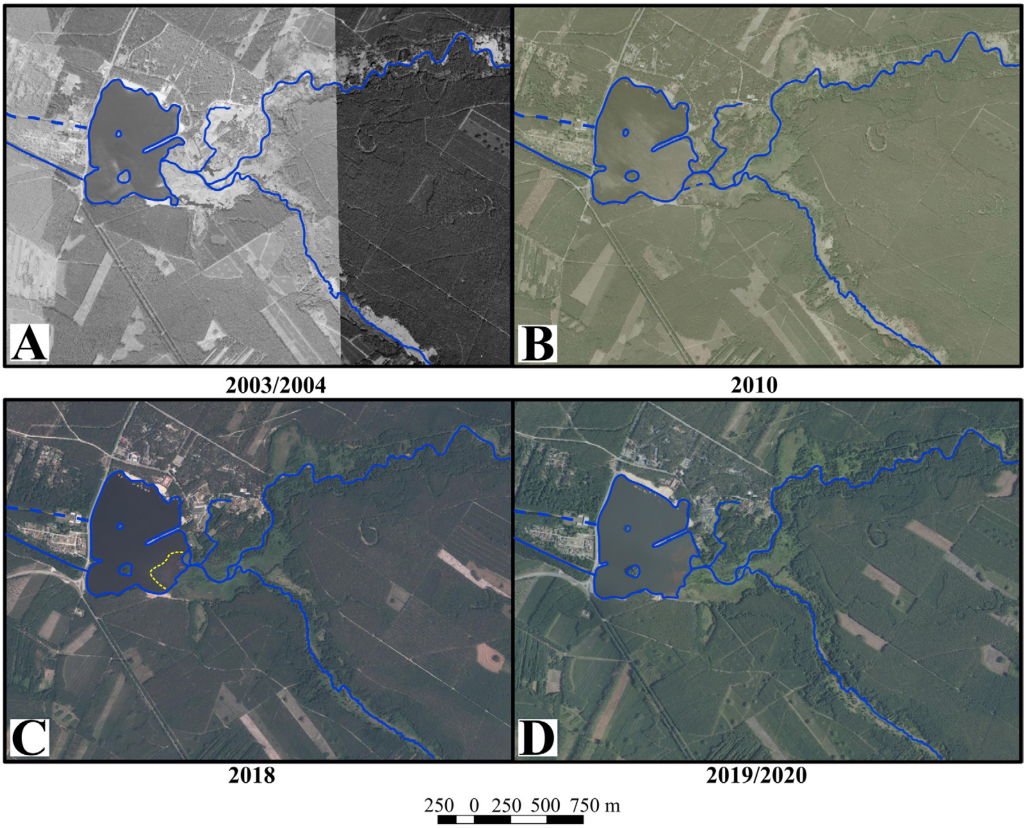

Fig. 5. Changes in the hydrographic network in the vicinity of Sielpia in the 21st century. Dashed yellow line marks the front of the inland delta; (by K. Fularczyk based on mapy.geoportal.gov.pl)

After it was dredged, it silted up again in the last two decades. However, the reason for the development of the next delta (D in Fig. 6, Fig. 7B) was not dam failures and catastrophic flash floods, but secular processes related to floods caused by long lasting rains, such as in 2010 and 2016. Since 2019, the reservoir has been seasonally drained and dredged again, which made it possible to conduct field research in its basin in 2020. Using cartographic and field materials, the bottom relief was mapped, the course of the channels within the basin in different seasons was reconstructed, and samples were taken for sedimentological analyses (Fig. 8).

The anastomosis in the basin of the Sielpia reservoir in 1939–1962 (1 in Fig. 8A) consisted of several channels, the course of which was related to the relief of the basin (see Figs 4B and C). In the eastern part of the basin, the channels encircled the former delta and the island, met in the central part, and then diverged again to the north-west and the south-west, towards the north and south weirs (J_N and J_S in Fig. 8A). Just before the northern weir, there was a small pond where rainwater was retained in 2020 (Fig. 8A). In 2019, after the deliberate drainage of the basin in Sielpia, a channel functioned within its borders (2 in Fig. 8A), its course partly conforming to one of

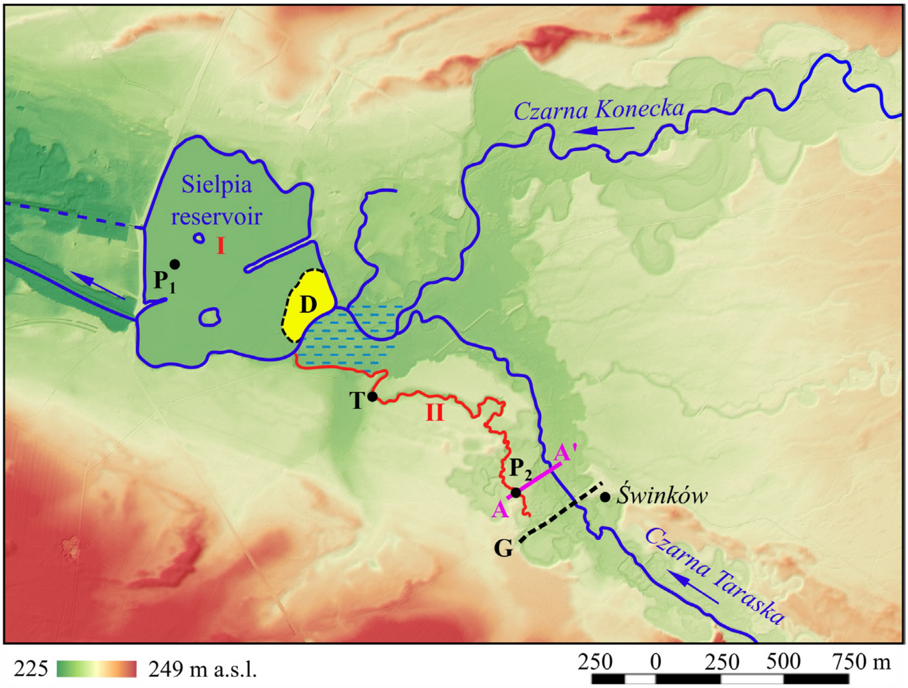

Fig. 6. Digital elevation model (DEM) of the investigated area. I – research site Sielpia reservoir; II – research site old, meandering channel of the Czarna Taraska; D – contemporary inland delta; G – dyke of the old pond in Świnków; T – beaver dam; A-A' – geological cross-section (see Fig. 9); P_1 – geological outcrop (see Fig. 8); P_2 – geological borehole (see Fig. 10); (by K. Fularczyk based on gugik.gov.pl)

the branches of the former anastomosis (see 1 in Fig. 8A). After the reservoir was drained again in 2020, the channel running through the basin was straightened (3 in Fig. 8A), and the place where it divided towards the weirs was located approximately 100 m south of the P1 geological outcrop. In the eastern part of the reservoir basin, the inland delta created in the previous decade (Figs 7B, 4 in Fig. 8A) and deposited on lake sediments in three phases (Kalicki et al. 2021) was evident in the relief of the reservoir's bottom. Small retention "pools" functioned before its front (Fig. 8C), as well as in other depressions of the basin's bottom.

Two sediment members (Fig. 8B) can be distinguished in the P1 outcrop: one lower and fluvial (I), the other upper and lacustrine (II). The sands of the lower member are probably channel sediments of the Czarna Konecka floodplain from the time before the reservoir was built. From these sediments, the Subatlantic subfossil oak trunks ("black oack") and the trunk of a subfossil fir tree have been dredged in the eastern part of the lake basin, felled from the La Tène to the end of the Middle Ages (*cf.* Kalicki et al. 2021). The upper member, silty-clay and about 40-cm thick, is the filling of the basin. It has a 3-cm sand layer in its upper part, which can be associated with a large flood, which also washed these coarse-clastic sediments to parts of the reservoir distant from the mouth of the Czarna Konecka.

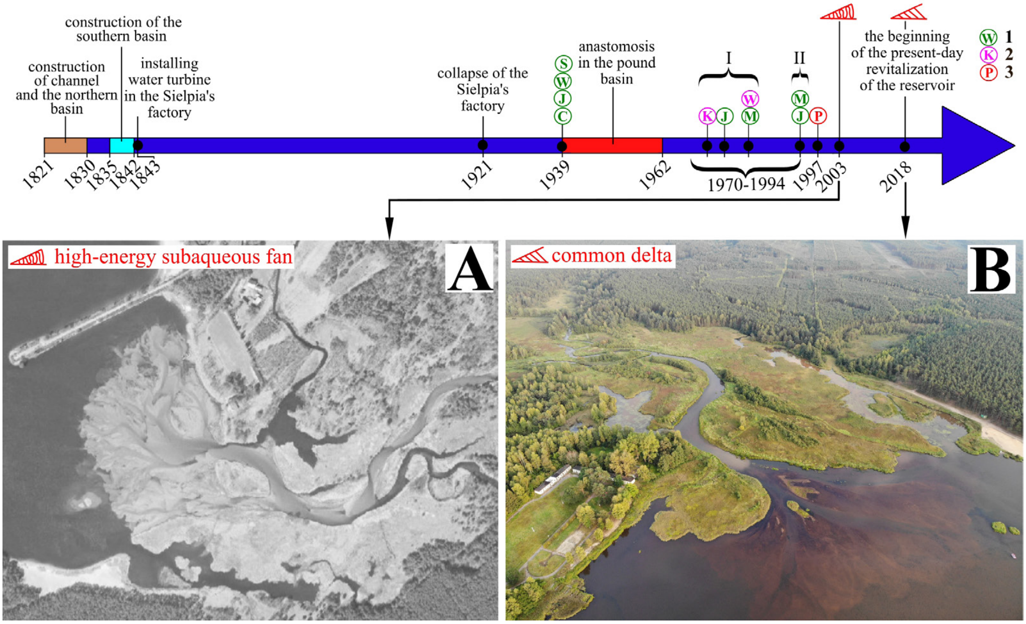

Fig. 7. Evolution of the reservoir in Sielpia and selected causes of changes in the retention/river network. 1 – failures of dams on the Czarna Konecka in Sielpia (S) and upstream of the Sielpia reservoir in Wąsosz (W), Janów (J), Czarna (C) and Małachów (M), 2 – failures of dams on the Czarna Taraska in Kawęczyn (K) and Wólka Smolana (W); 3 – large rainfall flood; I – the first series of dam failures, II – the second series of dam failures. A – inland delta in 2003 (geoportal.gov.pl), B – inland delta in 2018, probably built after the dredging of the earlier delta (aerial UAV photo from K. Ociepa 2018); (by K. Fularczyk based on Krygier, Ruszczyńska 1958; Jedynak 1993; Szot-Radziszewska 2009; Fajkosz 2010; Aksamit et al. 2019; Kalicki et al. 2020c)

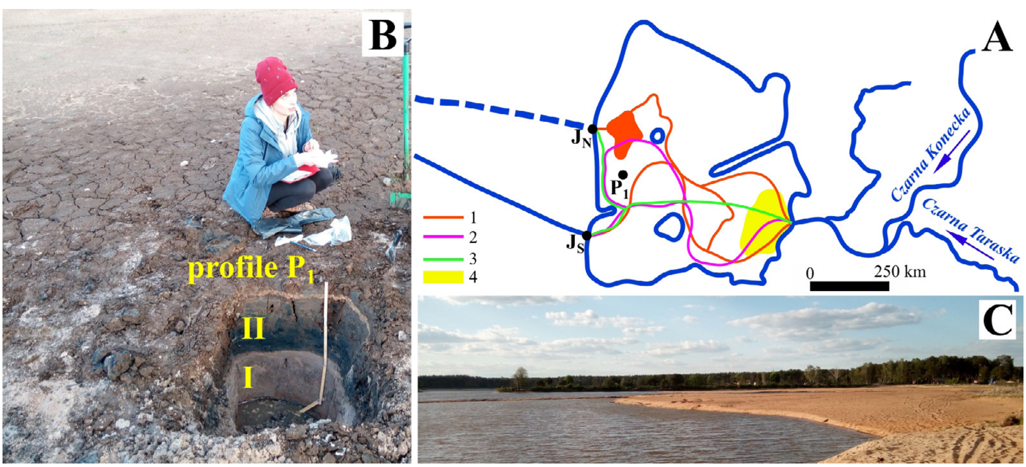

Fig. 8. River network (A), sediments (B) and contemporary inland delta (C) in the drained basin of the Sielpia reservoir. 1 – river network in 1939–1962, 2 – river network in 2019, 3 – river network in 2020, 4 – range of the contemporary inland delta, J_N – northern weir, J_S – southern weir, I – fluvial member; II – lacustrine member; (developed by K. Fularczyk, photo by P. Kusztal, May 2020)

Site II – old meandering channel of the Czarna Taraska

The site covers the former meandering channel of the Czarna Taraska, running approximately parallel to its contemporary course (II in Fig. 6). In the initial and final courses, this system of inactive bends winds through the floodplain, while in the middle course it cuts through a terrace. At the beginning of the 19th century, this branch was an active riverbed of the Czarna Taraska, which flowed from the pond in Świnków (Fig. 3A). The later disappearance of this pond and the redirection of the river's waters to the anthropogenic, straightened artificial canal mentioned above caused this natural channel to become an abandoned channel, initially a dry one (Fig. 3B), and then filled with water until the outbreak of World War I (Figs 3C, 4A). For the next 100 years, the palaeochannel was a dry landform (Fig. 4B-E, 5), clearly legible in the field and marked on a detailed geological map as being of the Holocene date (see Fig. 4C). In recent years, this form has been inhabited by beavers. Their dams (T in Fig. 6) have dammed up rainwater, flooding parts of the oxbow lake.

The cross-section (Fig. 9) of a fragment of the Czarna Taraska valley (A-A' in Fig. 6) includes its contemporary channel, former canals on the floodplain, which drained water from the then existing pond in Świnków and were marked on the map from the beginning of the 19th century (Fig. 3A), and the abandoned channel (II in Fig. 6). The bottoms of these canals, and of the former Czarna Taraska channel, are located about 1 m higher than the bottom of the present-day active riverbed (Fig. 9).

A geological borehole was drilled in the Czarna Taraska abandoned channel (P_2 in Fig. 6). Two members have been distinguished in the profile: lower and upper (Fig. 10). The lower member (20–15 cm) is made of different-grained (Mz = 1.2φ), well-sorted (δ_I = 0.4) channel sediments, while the upper one (15–0 cm), which represents the filling of the palaeochannel, consists of clayey, organic sands (15–5 cm) and detritus with sands (5–0 cm). The accumulation of sediments forming this filling took place after the former riverbed was cut off in the interwar period (see Figures 5A and B).

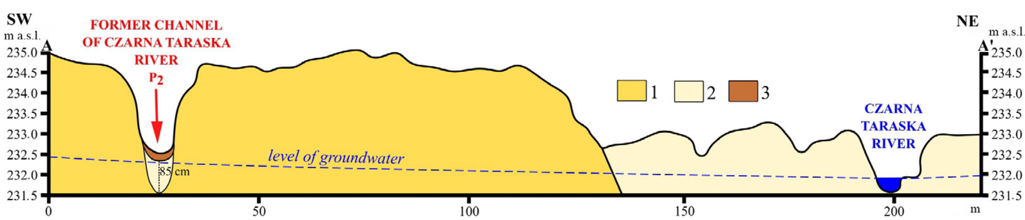

Fig. 9. Cross-section through a fragment of the Czarna Taraska valley (A-A'). 1 – alluvial deposits of the Pleistocene terrace, 2 – alluvia of the old, meandering channel and Holocene floodplain deposits, 3 – organic-rich deposits filling the old meandering channel (by K. Fularczyk)

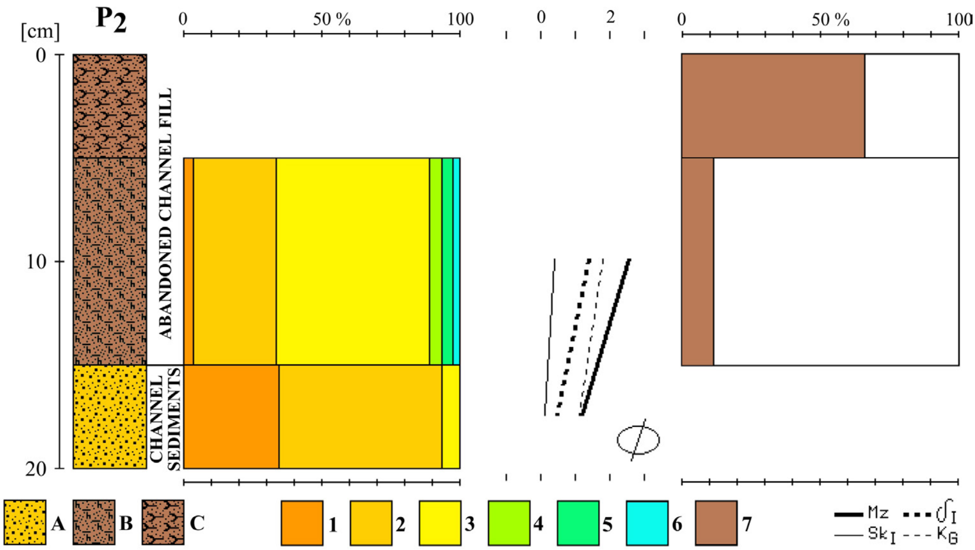

Fig. 10. Grain size of sediments and statistical grain size distribution parameters in profile P_2. Lithology: A – mixed sands, B – clayey, organic sands, C – detritus with sands. Fractions: 1 – coarse-grained sands (-1–1φ), 2 – medium-grained sands (1–2φ), 3 – fine-grained sands (2–4φ), 4 – coarse and medium-grained silt (4–6φ), 5 – fine-grained silt (6–8φ), 6 – clays (over 8φ), 7 – organic matter content (%). Grain size distribution parameters of Folk-Ward: Mz – mean diameter, δ_I – standard deviation, Sk_I – skewness, K_G – kurtosis

DISCUSSION

Over the last 200 years, the hydrographic confluence at Sielpia has undergone major changes caused by various natural and anthropogenic factors. These changes include the layout and length of the river and hydrographic networks, as well as the number and size of dam reservoirs. These hydrographic transformations resulted in changes to other environmental components and processes taking place in this area.

Anthropogenic causes were related to the development and subsequent decline of industrial plants of the OPID. The central point of these changes, and at the same time the driving force behind them, was the reservoir in Sielpia. Its emergence and disappearance entailed an anthropogenic reconstruction of the river network, and resulted in the transformation of natural fluvial processes and, consequently, changes in valley geosystems.

The construction of the first reservoir in Sielpia and the disappearance of the pond in Świnków correlating to the decline of the scythe factory in the 1820s caused the regulation of both rivers. The anastomosing sections of both rivers near Sielpia and Świnków disappeared at that time and, probably as a result of construction works, the Czarna Taraska River downstream of Świnków was anthropogenically diverted into a new artificial channel (Fig. 3B–C). The disappearance of the pond in Świnków and the concentration of the flows of the Czarna Taraska into one straightened channel triggered the deep erosion and increased lateral stability, as was the case of the Czarna Konecka section in the Małachów region after reservoir retention was abandoned (see Kalicki et al. 2019c), and of rivers in Upper Silesia after the degradation of artificial barrages (Ciszewski et al. 2005).

Another consequence of this erosion was the draining (Fig. 3B) and the contemporary "suspension" (about 1 m) of the natural, meandering palaeochannel of this river (Fig. 9). In the following decades, probably until the collapse of the plant in Sielpia in the interwar period, the abandoned channel was probably anthropogenically filled with water to be used to extinguish charcoal mounds, which may be indicated by numerous charcoal hearth remnants (CHRs) in its immediate vicinity (see Rutkiewicz, Malik 2019). However, the flows within it had to be low and regulated, as evidenced by the lack of a delta at its outlet to the reservoir in Sielpia (Fig. 3C). The collapse of the plant in Sielpia caused the "drainage" of the meandering Czarna Taraska palaeochannel, in which clayey sands with a large amount of organics were accumulating over the next 100 years (Fig. 10). The nature of the sediments and their small thickness (15 cm) confirm the autogenous nature of sedimentation, with a large share of transverse transport (sand supplied by mass movements) and no flow. Nowadays, the activity of beavers causes this form to be submerged in certain sections (T in Fig. 6), which in the following years may lead to morphological changes, similarly to the situation in the middle section of the Czarna Taraska (*cf.* Fularczyk et al. 2020b). A separate and unresolved issue remains the age and genesis of this form, which cuts the sandy terrace. It is possible that this is a remnant of analogous meandering systems visible on the higher, sandy levels of the Czarna Konecka, described near Czarniecka Góra (Kalicki, Zaborska 2020), which are also visible on these levels near Sielpia, together with a system of braided palaeochannels (Fig. 6).

The construction of the dam and reservoir in Sielpia altered the erosion base and the longitudinal profile of the rivers (decreased slope), raised the groundwater level, and, as a result, bogged down the bottoms of both valleys in the estuary sections over a length of about 1 km (Fig. 3C).

During the heyday of the OPID, the silting of the Sielpia reservoir was a very slow process. This was due to the existence of a highly developed anthropogenic small retention system (ASWRS) in both river basins, comprised of numerous ponds and canals (*cf.* Kalicki et al. 2019a, b, c, 2020). As a result, even the flood of 1903, disastrous for the OPID in the Kamienna and Czarna Konecka basins, did not cause any further growth of the delta in the Sielpia reservoir, as only a small bay (300 m long, 100 m wide) to the north of the peninsula had disappeared from the reservoir by the beginning of World War I (Fig. 4A). However, this flood, which damaged up to 20 dams on the Czarna Konecka, of which only some were rebuilt (Radwan 1954), resulted in a drastic reduction of the ASWRS. With the shuttering of subsequent OPID plants, including the steel plant in Sielpia in 1921 (see Szot-Radziszewska 2009), and the destruction of their hydrotechnical infrastructure, the system practically ceased to exist. This entailed enormous changes in the intensity of erosion and accumulation processes in the fluvial systems. Changes in land use after the collapse of the OPID industry and agricultural exploitation of the deforested areas in the interwar period only compounded the problems (Goska 2018). This triggered accelerated soil erosion, especially in the Czarna Taraska basin, as the Czarna Konecka basin is heavily forested.

In a relatively short period of time, in the interwar period, the revival of deep erosion levelling the longitudinal profile of the Czarna Konecka led to the almost complete terrestrialization of the southern basin of the Sielpia reservoir (Fig. 4B). The intense dynamics of fluvial processes was favoured by major floods in 1923 (Herbst 1951) and 1939, although the largest flood, in 1934, did not affect the two river basins (Suligowski 2013). The floods caused further damage, similarly to the military operations in 1939 (Herbst 1951), as a result of which the bridge with the outlet of the Sielpia reservoir was torn down (Jedynak 1993). All this led to the disappearance of the reservoir in Sielpia for about 20 years (Fig. 4C).

After the collapse of the OPID and the ASWRS, there was a drastic reduction in the number and area of water reservoirs, river channels were straightened, the river network became shorter (the disappearance of anthropogenic anastomoses and channels), and the hydrographic network was extended due to the intensification of melioration works in the 20th century. A better melioration system led to the drainage of valley bottoms and the disappearance of wetlands (Nowak et al. 2021). The local situation in Sielpia partially differs from this general picture. There, a system of anastomosis channels developed in the Czarna Konecka River at the bottom of the drained reservoir, which resulted in the lengthening of the river network. The arrangement of the channels conformed to the relief of the reservoir basin on the one hand, but on the other it was determined by anthropogenic factors such as the location of the weirs and how the system was regulated. This situation repeated, although for a very short time, in the periods when the reservoir was drained for the needs of hydrotechnical works in the 21st century. The river network in the basin of the Sielpia reservoir became concentrated each time the reservoir was drained, while in Furmanów the natural processes leading to the disappearance of the pond did not result in the development of a channel system within the its dry basin (Fularczyk et al. 2020a). This indicates a significant diversity of trends in the post-industrial evolution of the OPID industrial ponds. The concentration of flow in the channels, better drainage, and the disappearance of the reservoir in Sielpia resulted in a reduction of wetlands in the bottoms of the valleys of both rivers (Fig. 4C), which is in line with the general tendency (see Nowak et al. 2021).

The reservoir in Sielpia was rebuilt in 1962 (Jedynak 1993). The "suspension" of the rivers and the reduction of their slope resulted in intensive meandering of the riverbed of the Czarna Taraska in the estuary section, while no such tendency occurred on the Czarna Konecka, which may be due to the difference in the size of the two rivers. Over the next 20 years, the reservoir became only slightly terrestrializated, as a small delta formed (Fig. 4D–E). It was the effect of secular processes, and the material for the build-up of the delta could have come mainly from the agriculturally exploited basin of the Czarna Taraska. The high mean slope of that river (65% greater than that of the Czarna Konecka), lower permeability of the geological substrate in the catchment area, and the predominance of arable land and built-up areas (contrasting with the forested Czarna Konecka basin), favours the transportation of greater amounts of sediments (Popek, Wasilewicz 2019) through the Czarna Taraska river-canal both in its lower (Fig. 3B–4E) and middle courses (Fularczyk et al. 2020b).

The situation changed in the last thirty years of the 20th century, when catastrophic processes started to be recorded in the valleys, unheard of in the previous Holocene periods. They were caused by dam failures (Kalicki et al. 2019a, b, c, 2020). The first series of catastrophic flash floods took place in the 1970s and 1980s (I in Fig. 7), coinciding with the decline of waterwheel-based milling (oral information from the local population). The result was the silting of the reservoir in Sielpia, which was then dredged before the 1990s (https://konecki24.pl).

The second series of such events (II in Fig. 7) was connected with flash floods and large rainy floods (e.g. in 1997) that occurred in the Świętokrzyskie region at the turn of the 20^{th} and 21^{st} centuries (see Suligowski 2013). In the Czarna Konecka valley, an erosive section developed, with indented meanders and very strong lateral erosion of the riverbed (see Kalicki et al. 2019b, c), from which material was transported to accumulate in the Sielpia reservoir (Grzyb et al. 1995). At the mouth of the river, an extensive, sloping, high-energy sub-aqual cone (see Zieliński 2015) formed in the reservoir, discernible on an orthophotomap from the beginning of the 21^{st} century (Fig. 5A). It was dredged before 2010 (see Fig. 5A–B).

However, in the 2010s the reservoir in Sielpia became silted again, this time as a result of secular processes. Their intensity increased during the periods of high floods in 2010 and 2017 (echodnia.eu, Nowak 2017), which changed the morphology of the riverbed upstream of Sielpia (Fig. 11) and led to the formation of an inland delta (Aksamit et al. 2019) which accumulated in several phases (Kalicki et al. 2021) and is visible on the

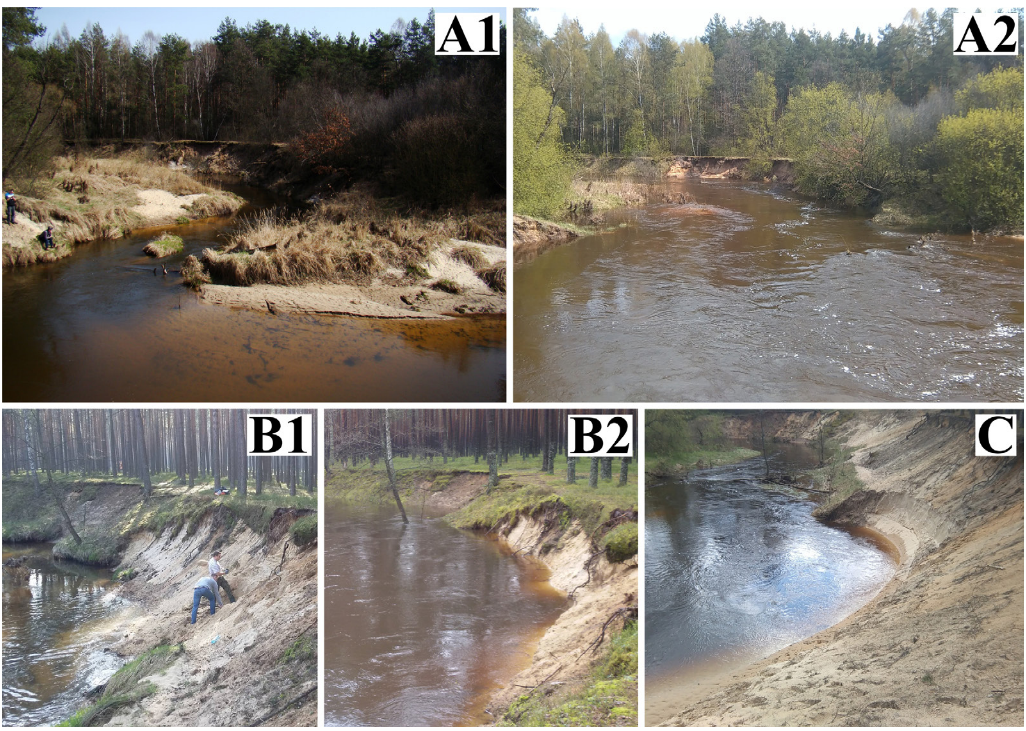

Fig. 11. Flood of 2017 and its morphological effects on the Czarna Konecka, upstream of the Sielpia reservoir (photo by M. Nowak, D. Zaborska, P. Kusztal); A1, B1 – water level before the flood; A2, B2 – water level during the flood; C – riverbank undercut by the flood (the loss of sediment is visible)

orthophotomap (Fig. 5C) and in the field (Fig. 7B, 8C). The delta covered older lacustrine sediments rich in organic matter. The delta sands are very young, as evidenced by a bottle cap from 2007 found in them. A major flood was recorded in Świętokrzyskie that year, although its effects were most intensely felt in another part of the region (*cf.* Suligowski 2013).

CONCLUSIONS

1. The analysis of historical and cartographic data in conjunction with the field prospection allows us to determine with great accuracy the time and causes of changes in the river network that have occurred in the last 200 years in the hydrographic confluence at Sielpia, and compare them with other areas studied using an analogous cartographic-geomorphological method (Fularczyk 2017; Kalicki, Fularczyk 2018, 2019; Kalicki et al. 2019a; Fularczyk et al. 2020a, b; Kalicki et al. 2020).
2. In the last two centuries, the hydrographic confluence at Sielpia has undergone transformations connected with the development and decline of the hydropower-based metallurgy and later milling industries of the Old-Polish Industrial District (OPID) and the accompanying anthropogenic small water retention system (ASWRS).
3. The erosion and accumulation processes in the riverbeds were most intense after the abandonment of reservoir retention along the entire Czarna Taraska River (Fularczyk et al. 2020b) and on a 10-km-long section of the Czarna Konecka upstream of Sielpia (see Kalicki et al. 2020), i.e. in the final decades of the 20th century, which corresponds to the period of the Anthropocene "Great Acceleration" (*cf.* Downs, Piegay 2019).

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