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Original article

Hydrological effects of the hydraulic structures constructed in the valley of the River Little Vistula in Poland from the mid-18th century to the present

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ABSTRACT

This study of the hydraulic structures constructed in the River Little Vistula (Mała Wisła) valley covers its western reach from the village of Strumień (Schwartzwasser) to the mouth of the River Przemsza. Its purpose was to assess the impact of these structures on changes in the conditions of runoff formation within the valley from the mid-18th century to the present. Historical materials (maps, sketches and plans) collected in the State Archives in Opole and Katowice were used in the study. Analyses of Austrian plane-table maps from the years 1763–1764 and 1861–1862 (1:28 800 scale) and of Prussian maps from the years 1827–1828 and 1881–1883 (1:25 000 scale) were also conducted. As a result of the study, the type and rate of hydraulic works were determined along with the techniques and methods used when constructing these structures in the 18th and 19th centuries. It was found that during the last 260 years, the main channel of the River Little Vistula moved within the meandering zone. Within the area of the Zarzecze and Mała Wisła settlements, a "new" River Vistula channel was formed during the flood in 1736, which shifted ca. 0.5–1.0 km to the south. The hydraulic structures which were constructed, mainly levees, caused water levels to rise excessively in the area during high water stages and the swollen waters often causing the levees to cave in, or to breach them. The river engineering work which was conducted also affected the formation of runoff in the valley of the River Little Vistula. It has been found that both anastomosis processes and river meandering were inhibited. In some channel reaches, temporal activation of deep erosion processes as well as channel shallowing were observed. Deep erosion reached up to 2 metres and channel shallowing up to 1 metre. These processes took place during river engineering work and the River Vistula bed took around a dozen years to stabilise following the completion of the work.

KEY WORDS: Little Vistula Valley, human impact, hydraulic structures

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1. Introduction

The purpose of this study was to assess the effects of hydraulic structures on river runoff formation in the valley of the Little Vistula (Mała Wisła) river from the mid-18th century to the present. The valley reach which was studied is situated in the western part of the Oświęcim Basin between the village of Strumień and the mouth of the River Przemsza. The entire length of the Oświęcim Basin is a latitudinal depression filled with areno-argillaceous Miocene sediments that are overlain with formations associated with Quaternary glaciations. During the last glaciation, this area was under the influence of periglacial climate, which resulted in the strong development of solifluction and slopewash processes. At that time, intensive accumulation of sediments from the Middle Polish Glaciation period occurred in the valley of the River Little Vistula. Those were Pleistocene alluvial soils, silts, sands and gravels, which formed one or two terrace levels in the valley of the River Vistula. The study area covers the valley reaches situated within the zones of maximum flooding observed until the end of the 19th century. The surface area of the valley reach studied is 87.3 km^2 and its length is around 41.0 km. In the second half of the 18th century, the River Vistula channel was around 87.1 km long, whereas today it is 52.8 km long (Fig. 1).

The transformation of the natural environment (and thus the surface hydrographic network) within the valley of the River Little Vistula began at a time when humans became interested in developing that area. At that stage, human activity focused on finding and adapting sites that were suitable for permanent settlement. This clearly took place at the very beginning of the Polish statehood. In subsequent years, the focus was on land use, mainly for cattle grazing (meadows and pastures), fish farming (pond complexes) and the construction of water wheels to drive mills, sawmills, iron smithies and fulling mills (using dykes, weirs, groynes). Agriculture only emerged in the River Little Vistula valley in the late Middle Ages when farmers mastered cultivation techniques suitable for the area's soils, which were very fertile, but also heavy and wet. Primeval riparian forests, which dominated the valley until the end of the 17th century, only accounted for 10.2% of its area by the mid-18th century. Wet meadows and pastures accounted for 37.3%, and a similar area was occupied by arable land with a percentage share of the total valley area of approximately 36.5%. Huge complexes of fish ponds that occupied about 12% of the valley formed an important part of the landscape. Built-up land, which was dispersed over the entire valley, only occupied ca. 2 km^2 in the mid-18th century, i.e. 2.3% of the total river valley area (WIELAND, 1736, PLAN VON SITUATION..., 1754).

From the end of the 18th century onwards, the River Vistula channel formed the border between the Austrian Empire and the Kingdom of Prussia within the reach studied. Frequent natural changes in the main (border) channel of the river resulted in meanders being cut off, which altered the territories of the two neighbouring countries.

Fig. 1. Map of the River Little Vistula valley from the late 19th century with the natural flooding zone marked (after Lageplan..., 1895, original scale: 1:75,000, State Archives in Opole)

2. Source materials

The study used historical plans and sketches as well as large-scale topographic maps, which were produced in the first half of the 18th century. The oldest known cartographic materials include a map of the Duchy of Racibórz (with a scale of ca. 1:106,000), developed and published by Wieland in 1736, and a plan of the River Little Vistula valley (with a scale of ca. 1:4200, drawn up in 1754 under the supervision of the Prussian engineer Neüwertz, who was appointed Inspector for Hydraulic Structures and Levees). The plan included a valley reach almost 22 kilometres long from Strumień to Czechowice and the mouth of the River Biała (CZAJA & RAHMONOW, 2016). The cartometric analyses conducted for Wieland's and Neüwertz's maps indicated significant angle distortions, but those maps still enabled the location of certain common points and comparisons of 3–5 km long reaches of the Vistula Valley with the content present on later topographic maps.

A study by KONIAS (2000) shows that Austrian topographic maps of this area that were drawn up from 1763 to 1764 and in 1780 (with a scale of 1:28 800), as well as Prussian topographic maps (*Urmesstischblatt*) with a scale of 1:26 000 that were drawn up from 1821 to 1831, were more accurate (in cartometric terms) and exhibited similar accuracy to today's maps. Therefore, they allowed the verification of map contents from the first half of the 18th century. The first plans to regulate the River Little Vistula valley were made from 1794 to 1796 (PLANY REGULACJI..., 1796), and subsequent ones were drawn up from 1820 to 1860 and in 1885–1886 in connection with measurements of the border between Prussia and Austria (BODECKER ET AL., 1886). The plans, valley sketches and cross-sections drawn up in the late 18th century and in the first half of the 19th century had scales ranging from approximately

1:2000 to 1:5000. They mainly included those reaches of the River Vistula that were prone to shifting their course. These included the areas of Jedliny and Czarnuchowice and also those close to the location where the River Przemsza entered the River Vistula (Fig. 2).

Fig. 2. Hydraulic structures in the River Vistula channel around the mouth of the River Przemsza – the arrangement and locations of groynes by J.A. Eytelwein (after Copie eines..., 1834)

In the mid-19th century, both the Prussian and Austrian authorities commissioned detailed topographic maps to be produced. These maps exhibit planimetric parameters similar to those of modern maps. These were plane-table maps of the Duchy of Pless (Pszczyna) drawn up by Augustini (1863–1867) and Austrian topographic maps of Western Galicia from 1861–1862. In the second half of the 19th century, a number of detailed plans of the River Vistula valley were also drawn up in order to prepare the areas in question for hydro-engineering procedures (river channel regulation, land improvement, levee construction, etc.).

In the years 1885–1896, a detailed plan of the borders of the Kingdom of Prussia was drawn up with a 1:1500 scale, which included a plan of the River Vistula channel within the reach examined; a more general plan with a 1:5000 scale was produced as well. The plan includes a strip (half a kilometre wide) on both banks of the River Vistula and shows the locations of oxbow lakes, which permitted the analysis of the natural development of the River Vistula meanders in the second half of the 19th century.

An accurate assessment of human-made alterations to the River Vistula channel by the end of the 19th century was made possible thanks to extant plans concerning the regulation of individual river reaches and to 1896 plans that depict changes to the river course. The transformations included mainly the narrowing of the river as a result of levee construction, a few meanders being cut off and the reach of the River Vistula in the vicinity of the mouth of the River Przemsza being regulated (Fig. 3). The plan concerning the maximum flooding zones within the River Little Vistula valley was also drawn up at that time.

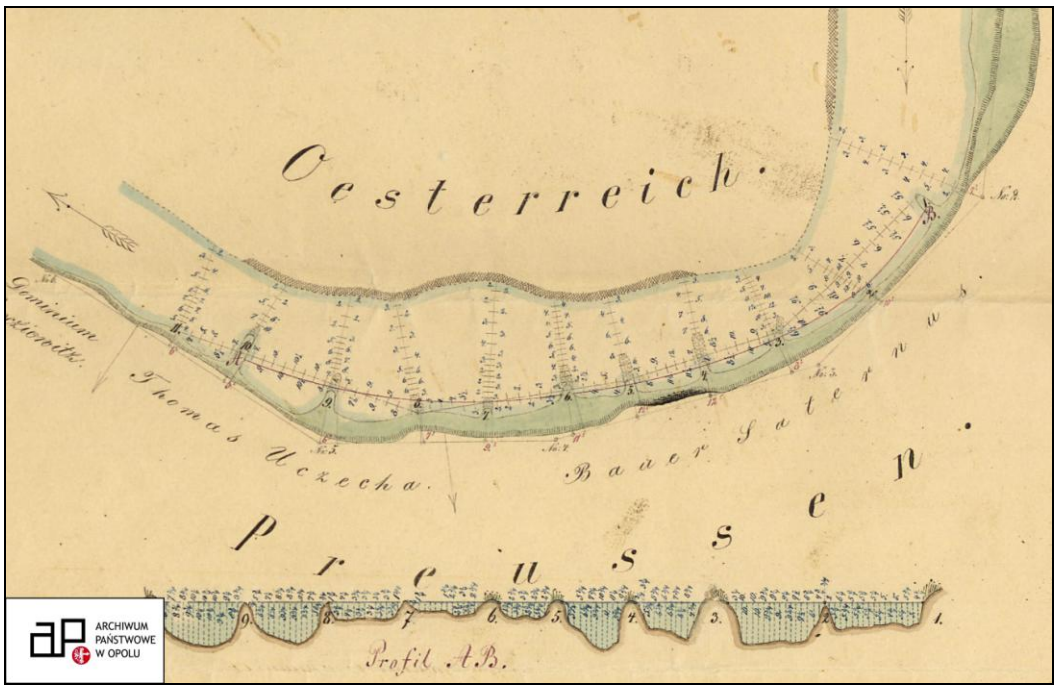

Fig. 3. Hydraulic structures in the River Vistula channel around Czarnuchowice – arrangement and location according to C. Becker (after Situations..., approx. 1840, original scale: ca. 1:2,000)

The last historical topographic map used for analysis purposes was the 1925 map of rivers in the Silesian Province with a scale of 1:100 000. This map shows, among others, the River Vistula reaches that were regulated before 1924, and further regulation plans with respect to the river. Maps concerning the regulation of, and hydraulic structures in, the valley of the River Little Vistula from the first half of the 20th century, mainly from the years 1905–1920, have also been preserved. These primarily concern the reach of the River Vistula between the mouth of the River Biała and the mouth of the River Przemsza (SITUATIONS-PLAN..., 1908). An archive query was made by Aleksandra Starczewska-Wojnar, Branch manager and archival materials AP Opole.

3. Impact of natural factors on changes in the River Vistula channel

The reach of the river under examination does not include any major tributaries and thus can be considered homogeneous in hydrological terms. The hydrological regime of this section of the River Vistula is shaped by almost equally large spring and summer floodings and is characterised by rapid water runoff, which leads to considerable fluctuations in daily flows (DYNOWSKA, 1971). However, major high water stages occur in the summer months and are caused by simultaneous precipitation throughout the source area of the River Vistula and of its tributaries, the Rivers Iłownica and Biała situated in mountain foothills.

In historical materials that mention, or describe, major floods in the upper reach of the River Vistula in the 18th century, the most common references are the catastrophic flood of June and July 1736 and also a series of floods in 1772–1775 and 1785–1788 (MEMEL, PREGEL UND..., 1899; SZEWCZUK, 1939). An analysis of Wieland's map (1736) and of the plan of the River Vistula valley (1754) shows that the 1736 flood caused a shift in the course of the river. These changes are also indicated on Austrian maps from 1780 and Prussian ones from 1823 – the two parallel channels are labelled the "old" and "new" River Vistula (Alte Weichsel and Neue Weichsel) (Figs. 4, 5). Probably during the flood in 1736, the swollen waters of the River Vistula entered a mill race within the village of Zarzecze, which subsequently became the new main course of the river. The maximum distance between the channels was ca. 1,000 m, and the river channel was shortened from 7.2 km to 5.5 km. Through almost the entire 19th century, the Vistula river channel underwent no major changes. The small transformations that happened were linked to local river regulation and the construction of levees. In the 19th century, river bends were only cut off twice by natural causes. In all other cases, the cuttings were related to the regulation of the river. No major river engineering work was carried out at that time. In the 19th century, river regulation shortened the channel by about 1.8 km, and natural processes reduced its length by approximately 1.6 km.

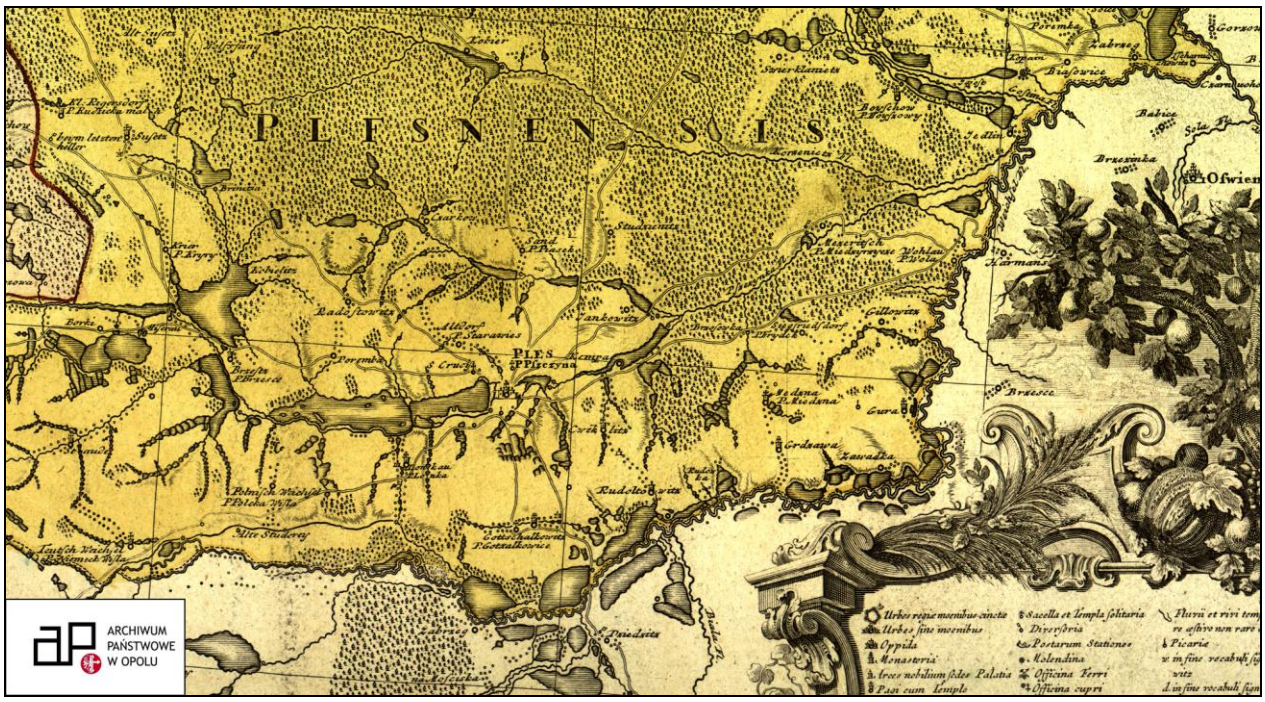

Fig. 4. Pond complexes and the layout of the surface hydrographic network in the River Little Vistula valley in the first half of the 18th century (Wieland, 1736, original scale: ca. 1:106,000, State Archives in Katowice)

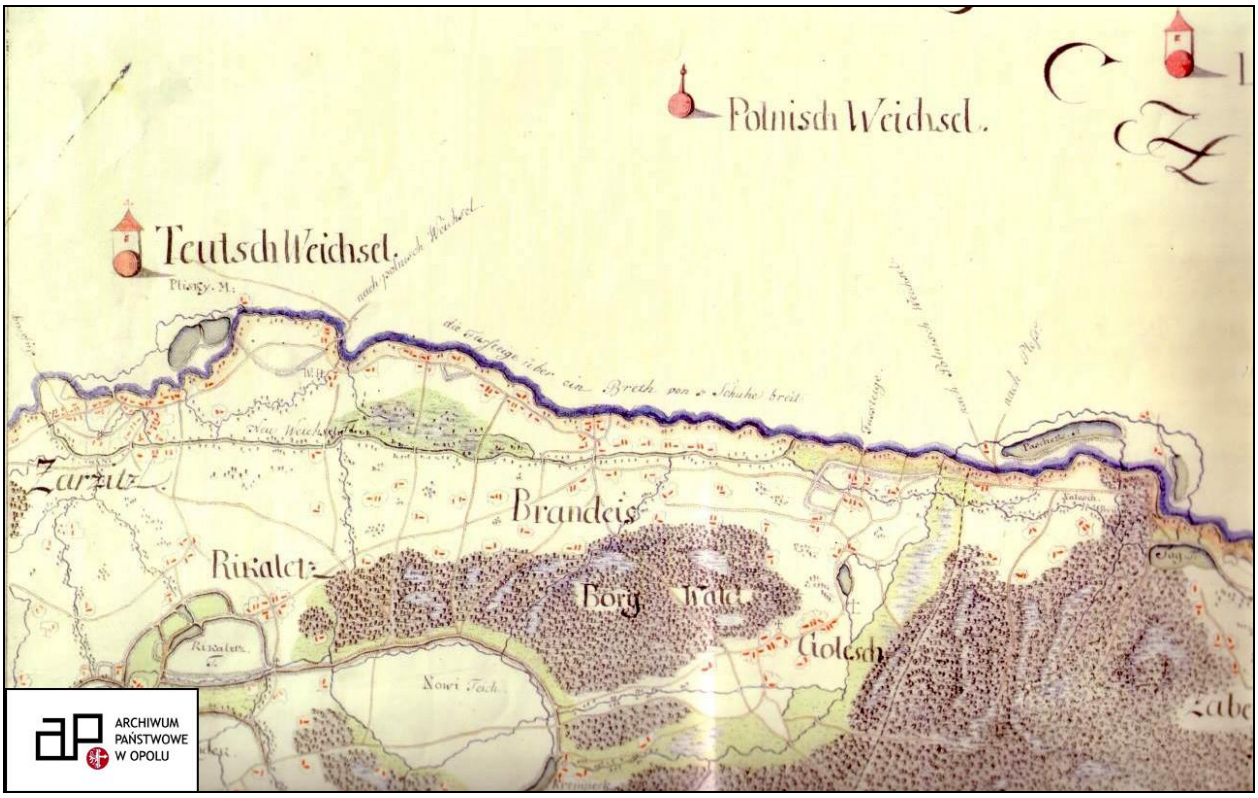

Fig. 5. Changes to the Little Vistula channel after the July flood of 1736 (after General-Mappa..., 1763–1764, 1780 Kriegsarchiv, Vienna)

4. Changes to the arrangement and nature of channels caused by river engineering

The development of the River Little Vistula valley, primarily involving the construction of huge fish ponds and a dense network of mill races, resulted in significant changes to river runoff formation. As a consequence, the need arose to protect structures such as manor houses, mills, iron smithies, sawmills and fulling mills, and also dykes and ponds from the effects of floods. The development process of the River Little Vistula valley can be divided into three stages.

4.1. The first stage

The first stage covered the period from the 17th until the mid-19th century. At that time, the development of the valley primarily consisted of the construction of huge fish ponds and a network of mill races. Extant maps and plans of the River Little Vistula valley demonstrate that in the mid-18th century, there were 48 ponds with a total area of 12 km^2. The mill race network in the western part of the valley of the River Little Vistula (from Strumień village to the mouth of the River Biała) had a total length of 62 km. In this part of the valley, as many as 18 water wheels operated. It was at that time that the structures were protected by small levees that also served as access roads, or by pond dykes. Following the construction of mill races, it was necessary to protect their banks against washing out during floods and also to maintain a constant flow of water which was required to drive water wheels in their channels. Mill race banks were secured with wicker affixed with oak piles, which were driven into the bottom of the bank at intervals of two ells (around 1 metre). These structures were reinforced with oak logs and fascine bundles. Finally, the entire structure was covered with fertile soil up to the top of the canal bank. If a structure was damaged during a flood, it was immediately repaired (NEÜWERTZ, 1783). The description suggests that these structures were very expensive, and thus not everyone who owned land close to waterway banks could afford such a project. In the period described, the first groynes started to be constructed within the River Vistula channel as well. These were usually located in places where the current was undermining river banks. In order to direct the current further away from the banks, oak piles were driven into the riverbed and were subsequently covered with wicker (Fig. 3).

The River Little Vistula was not used for freight transport due to its low flow rates and the limited depth of its main channel. There were also no major settlements in the valley and thus no incentive for river engineering works that would make the river suitable for such transport. However, in the mid-19th century several meanders were artificially cut off and broad sections of the river channel were narrowed by erecting wicker structures and groynes in the river banks. The framework for older groynes used to be provided by very costly wooden piles reinforced with iron pegs, and the loose bundles of wicker that filled the spaces between them were not stable or fixed to the riverbed. EYTELWEIN (1800) proposed a new method for constructing such structures. This consisted of making so-called "packages" of alternate layers of compacted fascine and sand or earth. Such a structure with a broad base lent internal cohesion to the groyne, making it much more able to withstand the force of the river current.

4.2. The second stage

In the second stage of the development of the River Little Vistula valley, which covered the period from the 1850s until 1914, river engineering work had similar objectives to those of the previous period. However, these were pursued using somewhat altered, and more modern techniques, and the most important tasks were:

- securing structures and agricultural areas with levee systems and making new land within the valley suitable for agriculture;
- large-scale land improvement works, which involved primarily the left (Prussian) side of the River Little Vistula valley;
- limiting the cutting off meanders in order to "straighten" the River Vistula channel and changing groyne designs.

In the second half of the 19th century, no further *ad hoc* river engineering work was conducted in selected reaches of the river channel. According to the guidelines issued by the Prussian engineer Becker, engineering work was to be carried out in longer, several kilometre-long reaches of the River Vistula valley, moving in accordance with the direction of the river current. At the same time, a new way of constructing groynes was introduced. The new structures were erected in consecutive submerged layers; a new layer was only placed on top if the river channel in their vicinity became silted up or was raised. Another innovation introduced by Becker was making the slope of the structure facing the current gentler, which limited powerful whirlpools that caused "bumps" in the riverbed and deformed the channel as a result (BECKER, 1868). As already mentioned, the first comprehensive designs for regulating the River Little Vistula come from the late 18th and early 19th centuries, but more extensive work was only conducted in the late 19th and early 20th centuries. At that time, work was performed to protect banks in long reaches of the river channel, primarily through installing a system of groynes.

During the period in question (the second half of the 19th century), meanders were cut off between the mouth of the River Gostynia and the mouth of the River Przemsza near the villages of Rudołtowice, Grzawa and Dębina. These cuttings can be seen in the 1885–1896 map showing the

border between Austria and Prussia and in the 1908–1910 plans concerning the regulation of the River Vistula (Fig. 6).

The river engineering work conducted before World War I was complicated by the fact that the border between Austria and Prussia ran along the river. Thus, apart from technical river engineering issues, meanders had to be cut off in such a manner so as not to change the territories of the two neighbouring countries. Such regulations, which were carried out along some river reaches, were irrational since they did not take into account the river's natural tendency to meander (MATAKIEWICZ, 1920). The assessment of the river engineering efforts implemented until 1914 leads to the conclusion that the work was driven by political considerations (Figs. 7, 8).

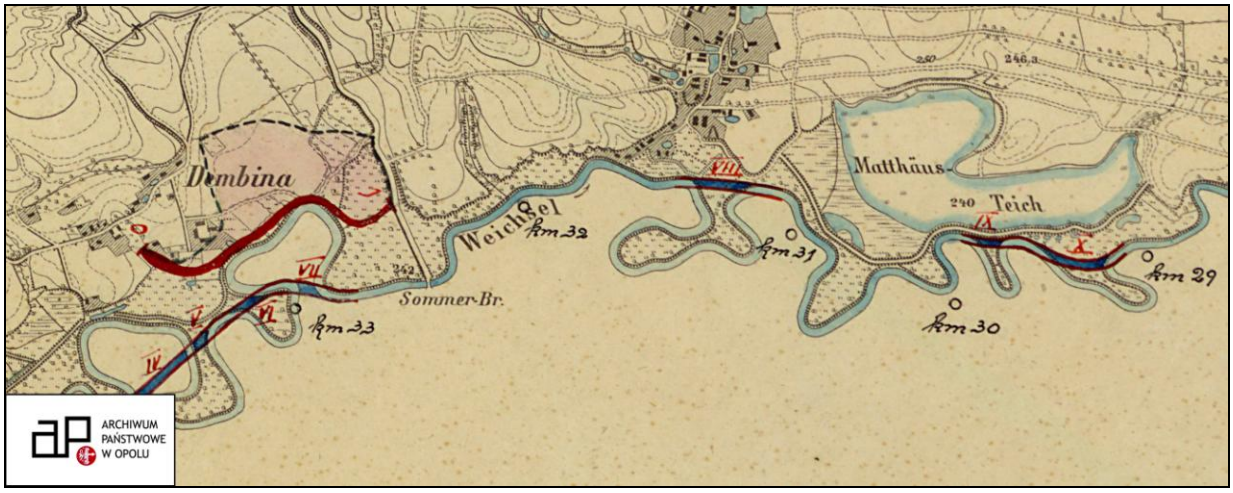

Fig. 6. Hydraulic structures within the River Vistula valley in the vicinity of Grzawa and Dębina (after Regulierung der..., 1907–1908, original scale: 1:25 000, State Archives in Opole)

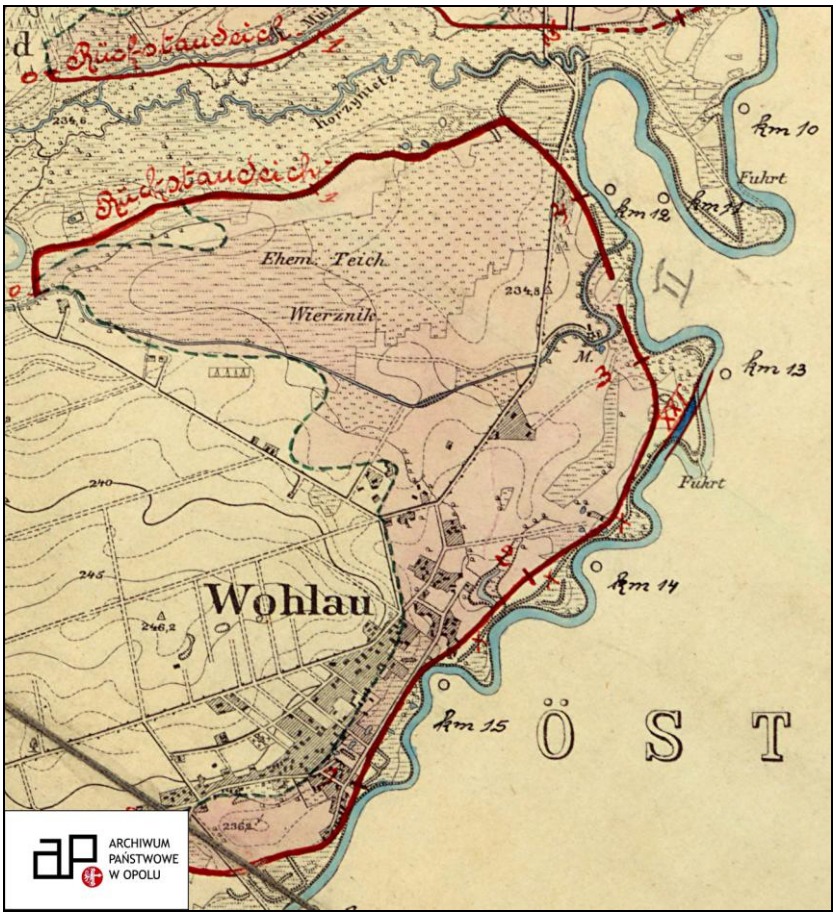

Fig. 7. Hydraulic structures within the River Vistula valley and in the final reach of the River Korzenica in the vicinity of Wola (after Regulierung der..., 1907–1908, original scale: 1:25 000, State Archives in Opole)

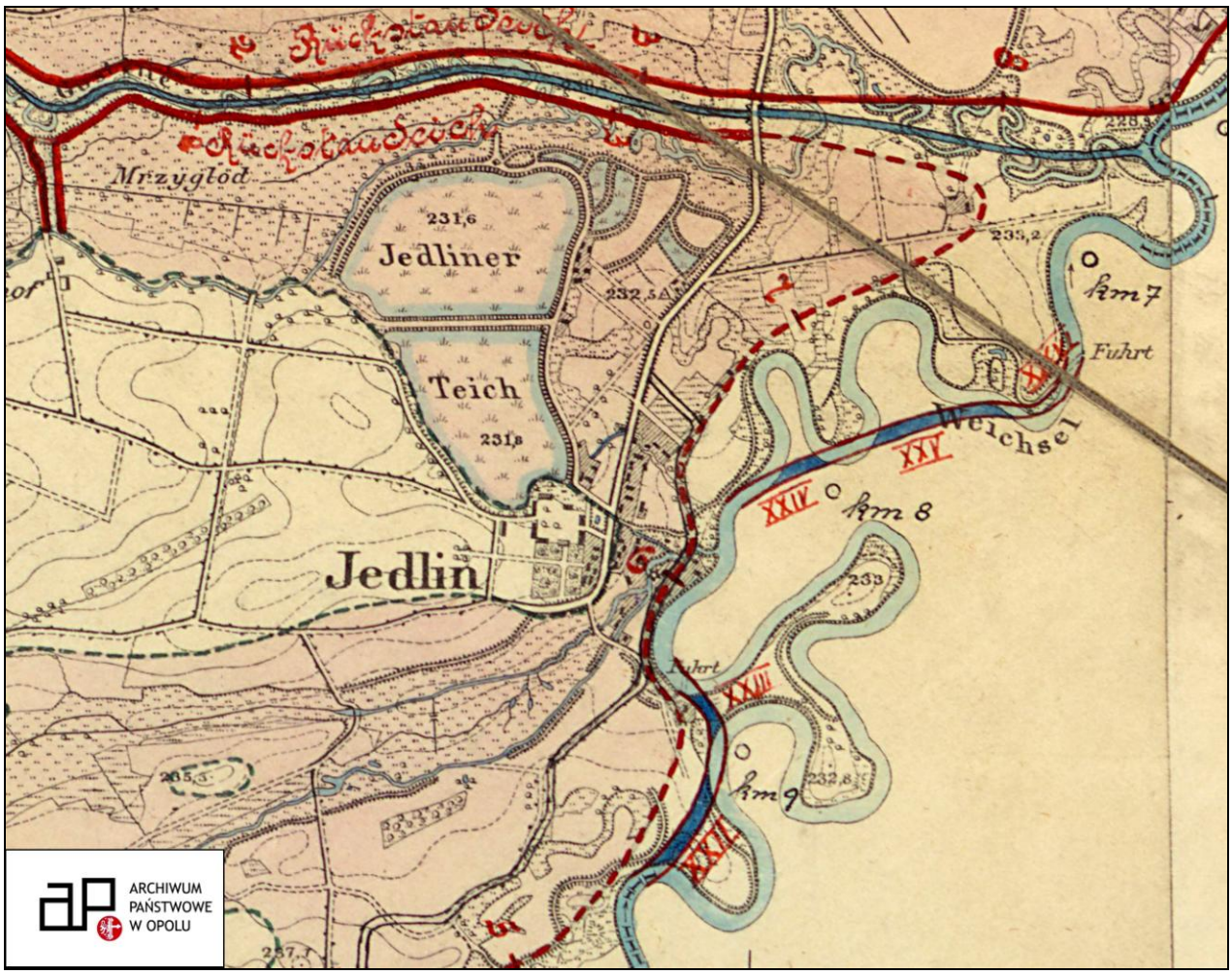

Fig. 8. Hydraulic structures within the River Vistula valley and in the final reach of the River Pszczyna in the vicinity of Jedlina (after Regulierung der..., 1907–1908, original scale: 1:25 000, State Archives in Opole)

In the third stage of the river engineering work conducted within the valley, comprehensive flood protection measures were introduced. A system of levees was constructed along the River Vistula channel and along the estuary reaches of its major tributaries. The third stage can be divided into two periods. The first one covered the inter-war years from 1920 until 1939. At that time, a detailed assessment was conducted of the condition of the flood protection structures and levees that had fallen into disrepair or had been destroyed during World War I. Designs for repairing them were prepared as well (MAPA RZEK..., 1925; MATAKIEWICZ & RYBCZYŃSKI, 1926). Comprehensive river engineering work was carried out in the years 1926–1929. A system of levees, retaining walls and check dams, which was based on Prussian and Austrian plans to regulate the River Little Vistula dating from the years 1906–1908, was constructed (Figs. 9, 10, 11). The course of the main channel of the River Vistula was also adjusted while maintaining the general direction of the current. As a result of the river engineering work conducted, the River Little Vistula channel was shortened by nearly 21 km, i.e. 25% of its original length. Solely on the basis of map analysis, it may be concluded that the regulation, which consisted of reducing the length of the channel, must have resulted in a local increase in the river gradient, causing the Vistula riverbed to be lowered. Lateral channel erosion must have been significantly affected (inhibited), and it only occurred thereafter during major floods. This conclusion was confirmed by research conducted by CZAJKA (2007) who concluded that from the 1930s, the river channel in the vicinity of Goczałkowice was already becoming steadily deeper and the maximum depth of the incision was approximately 2 m. The alluvia excavated during river channel deepening work were deposited at a distance of about 2–3 km from the area from which they were dredged, in the vicinity of the villages of Zawadka, Jawiszowice and Góra.

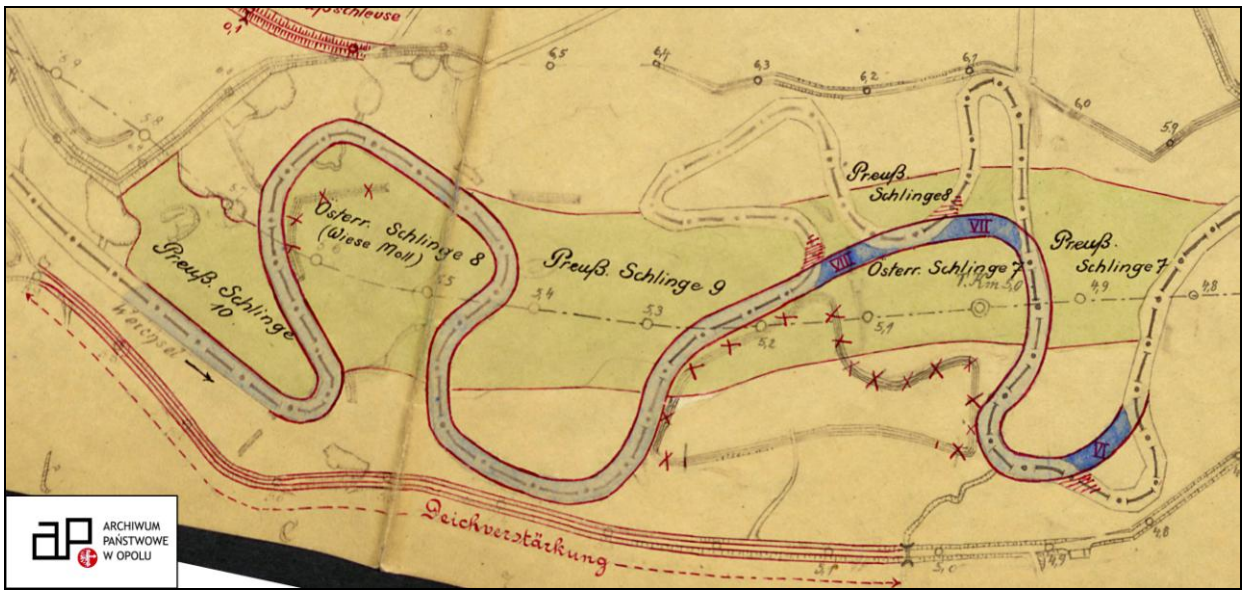

Fig. 9. River engineering work design – River Vistula valley (after Regulierung der Österreichische Weichselstrecke, 1892–1901, original scale: 1:5000, State Archives in Opole)

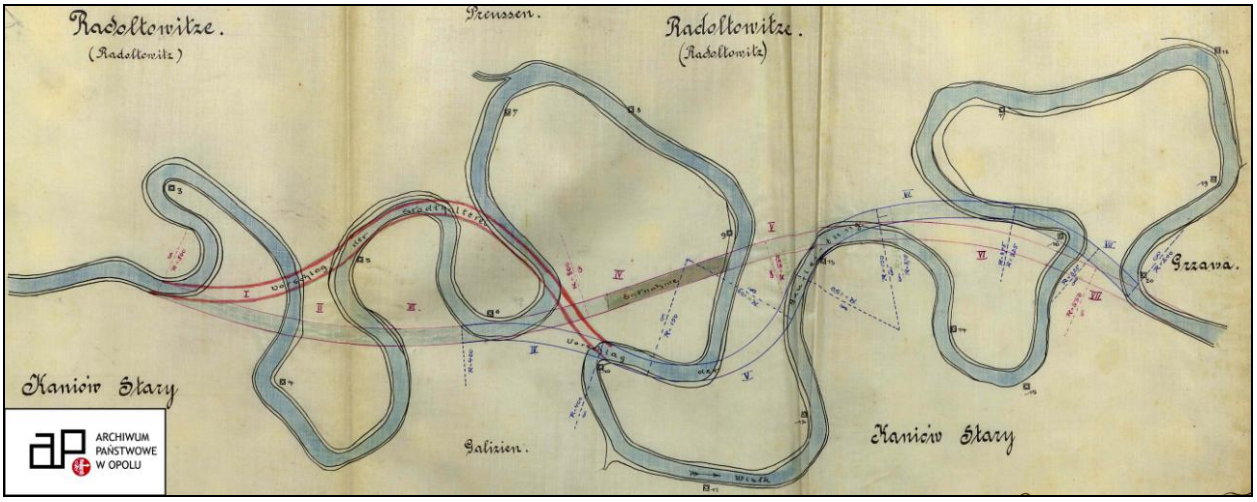

Fig. 10. River engineering work design – River Vistula valley in the vicinity of Kaniów (after Betrieb Weichsel Regulierung, 1904–1906, original scale: 1:5000, State Archives in Opole)

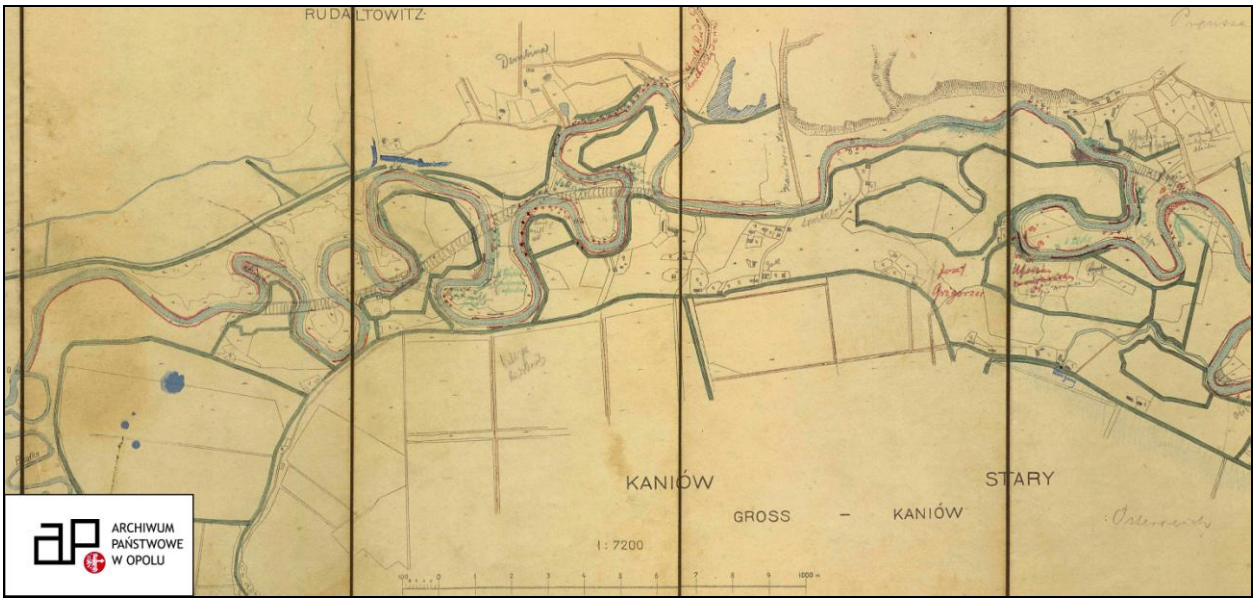

Fig. 11. River engineering work design – River Vistula valley in the vicinity of Kaniów (after Regulierung der…, 1907–1908, original scale: 1:7200, State Archives in Opole)

This conclusion is borne out by the fact that in the vicinity of these villages, the River Vistula channel became shallower by up to 1 m. Considerable erosion of the River Vistula channel was also observed after 1948 at the mouth of the River Przemsza, where it had become deeper by ca. 2 m. The deep erosion process in this reach was halted in the early 1980s (CZAJKA, 2007).

The end of World War II marked the beginning of the second period in the development of the River Vistula valley, which has continued until the present. Economic difficulties immediately after the war prevented any major river engineering work from being carried out. Such work was conducted only occasionally and in short reaches of the valley and thus many structures fell into disrepair due to lack of maintenance work. The poor condition of hydraulic infrastructure resulted in serious damage to structures in the River Little Vistula valley during snowmelt floods in February and March 1947 and also during the flood caused by rains in June 1958. That damage provided an incentive to start intensive river engineering work. However, the largest hydro-engineering project in the valley after World War II was the construction of the huge reservoir in Goczałkowice. Constructed from 1953 to 1955, the Goczałkowice Reservoir is one of the largest impoundments in Poland both with respect to surface area (32.5 km^2) and capacity (165.6 m^3). It ranks as the fifth among reservoirs impounded by dams in Poland. It is a multi-purpose reservoir whose functions include providing water supply, protecting land in the River Vistula valley below the dam from flooding, providing additional flow during low-water periods and facilitating fisheries management and nature conservation. The main purpose of the reservoir is to supply water to the Upper Silesian Industrial District and to the Rybnik Coal District. Thus the overarching goal of land management around the reservoir, and in its direct vicinity, is maintaining requisite water purity standards. Another extremely important function is providing flood protection to the municipalities situated in the River Little Vistula valley. Owing to the fact that the risk of flooding has increased in the last several years, the Goczałkowice Reservoir flood reserve capacity has been almost doubled. This has been achieved by temporarily lowering the normal impoundment level from 255.5 m a.s.l. to 254.5 m a.s.l., which increased the flood reserve capacity from 45.0 million m^3 to 72.4 million m^3 (KONIECZNY, 2010).

The construction of the Goczałkowice Reservoir caused a large part of the river sediments to be retained within the Reservoir and the gradient of the river to increase. This clearly intensified deep erosion below the dam. The river engineering work carried out after World War II, which consisted of river channel regulation, resulted in its further shortening. As a consequence, since the mid-18th century the River Vistula channel has been shortened by about 35.3 km or ca. 40% of its original length.

5. Changes in runoff formation in the valley of the River Little Vistula

Historical sources demonstrate that already by the middle of the 18th century, the valley of the River Little Vistula had been largely transformed as a result of human activity. The dominant features of the landscape at that time were the huge fish pond complexes that occupied more than 14% of valley area. These started to be constructed as early as the first half of the 17th century. Moreover, in the western section of the valley (from Strumień village to Czechowice-Dziedzice), a dense network of mill races was constructed at that time, which drove a total of 18 water wheels . After the great flood of 1736, which resulted in the formation of the new River Vistula channel between the villages of Zarzecze and Mała Wisła, river engineering work began in order to protect people and property from further high water episodes. The primary method used in river engineering at the time was digging cut-offs to eliminate the numerous meanders of the River Vistula. The immediate effect of that work was to increase the gradient within the canals dug in the process, which significantly increased the river's erosive power, as a result of which, the channel incised deeply into the soft alluvial sediments. The consequence of this process was the lowering of the base of the flood plain, which activated lateral erosion, resulting in the banks sliding and caving in. This phenomenon was observed within most cut-off meanders, and the depth of the incision of the new river channel bed reached up to 2 m. As a result of deep and lateral erosion and of the river transporting more material, alluvial sediments were deposited within those channel reaches where the river gradient was clearly smaller. The result of that process was the silting up and rising (shallowing) of the Vistula riverbed, which was particularly noticeable below the cut-off zones. An unintended effect of deep and lateral erosion processes was the Vistula branching and running wild again. That phenomenon was detrimental to runoff during high water stages. In the reaches where the gradient was considerably reduced and the river

was braided, the speed of the flood wave declined, which caused water levels to rise.

Regulation work consisting of the construction of groynes within the banks of the River Little Vistula was not as extensive as in the case of the upper River Oder. The principal reason was the fact that the River Vistula was not navigable in this reach; thus the groynes were only constructed in order to protect the banks against washing in places where rural structures were at risk rather than to improve conditions for communication and river transport.

Summing up, the effects of river engineering work on the surface hydrographic network and on conditions for river runoff formation, it should be stated that the effects observed are most likely the sum total of human economic activity that spanned many centuries and had numerous directions. River network changes are the most pronounced modifications in this respect. River channels were modified through the cutting off of meanders, the installation of groynes and the construction of mill races and levees. These works altered the natural hydrographic network, and their nature and scope have brought about its current shape. The river engineering work conducted gave rise to a considerable number of artificial oxbow lakes, and the analysis of historical and contemporary topographic maps demonstrates the extent of anthropogenic change to the River Little Vistula channel. In some cases, the natural and artificial cutting off of meanders changed the course of the River Vistula tributaries. Such a situation occurred around the mouth of the River Przemsza where several meanders were eliminated during regulation work (Fig. 12). As a result of centuries of development in the River Vistula valley and the structures constructed within its channel, traces of the original river network layout have been almost completely erased in some valley reaches. The economic activity described here led to major changes in the land relief of the River Little Vistula valley as well. The floodplain was transformed to the greatest extent, mainly as a result of the construction of levees. The river engineering work conducted has also resulted in an almost complete transformation of vegetation. Currently, this mainly consists of secondary communities – grasslands, agricultural land and artificial plantations, and also initial aquatic vegetation within ponds and other water bodies. Meadows and fields in the area between the levees are periodically subject to agrotechnical procedures. Only small patches of the original riparian forests remain; these presently account for just 5% of the valley area.

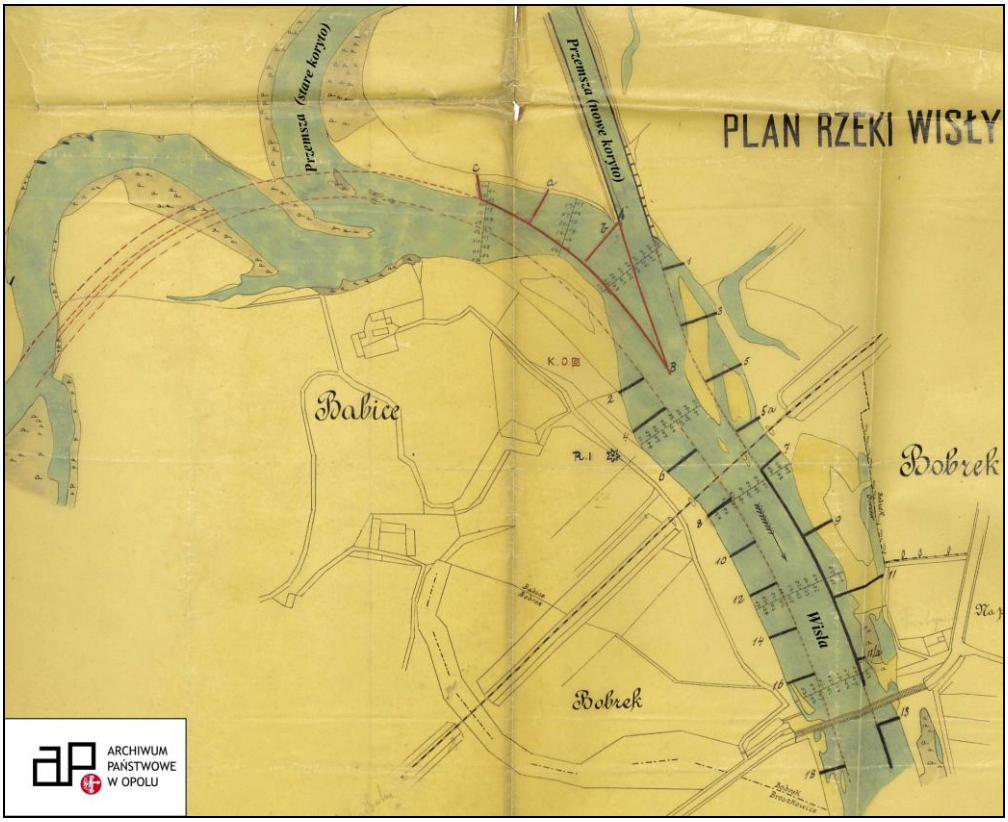

Fig. 12. River engineering work at the location where the River Przemsza enters the River Vistula in 1906 (after: Regulierung der Przemsza, original scale: 1:5,000, State Archives in Opole)

6. Summary and conclusions

The study of the changes in the River Little Vistula land development patterns from the mid-18th century until the present day has demonstrated the usefulness of historical maps for reconstructing such changes in detail. It also provided the basis for the absolute dating of the river engineering works conducted within the valley. However, the use of old maps and plans was necessarily preceded by analyses of their (planimetric) accuracy, which enabled the elimination of errors and transferring their contents to today's base maps. It was found that:

1. During the last 260 years, the main channel of the River Little Vistula moved within the meandering zone whose width was almost constant. Within the valley reach between the Zarzecze and Mała Wisła villages, a "new" River Vistula channel was formed, which was shifted by around 0.5–1.0 km to the south compared to the "old" one. This was the effect of the great flood in July 1736.
2. The construction of levees and other hydraulic structures caused huge amounts of water to be excessively "compressed" between the levees, which resulted in their frequent failures – caving in and breaching. The encroachment of flood waters on the valley zone between its edge and the levees led to flooding and considerable morphological transformations of the valley floor.
3. The regulation of the River Little Vistula affected the formation of runoff within its valley. It has been found that both anastomosis processes and river meandering were inhibited. In some channel reaches, the temporal activation of deep erosion processes as well as channel shallowing were observed. These processes occurred during river engineering work. At the same time, it has been found that the riverbed took around a dozen years to stabilise following the completion of the work.

References

Augustini J. 1863–1867. *General Karte des Furstenthums Pless,* 1:25 000. Zbiory Kartograficzne Archiwum Państwowego Katowice [manuscript].

Becker C. 1868. *Zur Kenntnis der Oder und ihres Flächengebietes*. Berlin.

Betrieb Weichsel regulierung. 1904–1906. 1:5000. Archwium Państwowe w Opolu.

Bodecker H., Kourbiere J., Prihoda K. 1885–1896. *Plany granicy prusko-austriackiej 1:1500 i 1:5000*. Opawa. Zbiory Kartograficzne Archiwum Państwowego Katowice.

Copie eines Theiles der Karte von Weichsel Strom. 1834. About 1:5000 Archiwum Państwowe w Opolu.

Czaja J. Rahmonov O. 2016 Land use changes in the Mała Wisła valley in the western part of the Oświęcim Basin, from the 18 th to modern time [in print].

Czajka A. 2007. *Środowisko sedymentacji osadów przykorytowych rzek uregulowanych na przykładzie górnej Odry i górnej Wisły*. Wyd. Uniwersytetu Śląskiego, Katowice.

Dynowska I. 1971. *Typy reżimów rzecznych w Polsce.* Zesz. Nauk. UJ. 268, Prace Geogr. 28.

Eytelwein J. A. 1800. *Praktische Anweisung über den Faschinenbaum*. Berlin.

General-Mappa des Merzogthums Ober-Schleisien (Pierwsze Wojskowe zdjęcie Śląska). 1763–1764, 1780. Kriegsarchiv. Wiedeń.

Konias A. 2000. *Kartografia topograficzna Śląska Cieszyńskiego i zaboru austriackiego od II połowy XVIII wieku do początku XX wieku*. Wyd. Uniwersytetu Śląskiego. Katowice

Konieczny K. 2010. *Zabudowa hydrotechniczna i prace regulacyjne w dorzeczu górnej Wisły w XX wieku.* Archiwum Katedry Geografii Fizycznej. WNoZ UŚ [manuscript].

Lageplan der Klainen Weichsel Kreis Pless, about 1895. 1:75 000. Zbiory Kartograficzne Archiwum Państwowego w Opolu.

Mapa rzek województwa śląskiego. 1:100 000. 1925. Zbiory kartograficzne Archiwum Państwowego Katowice [rękopis].

Matakiewicz M. 1920. *Regulacja Wisły. Monografia Wisły*. Z. 10. Warszawa.

Matakiewicz M. Rybczyński J. 1926. *Ekspertyza projektu generalnego regulacji Wisły inż. Ingardena*. Archiwum OZDW Kraków [manuscript].

Memel, Pregel und Weichselstrom, ichre Stromgebiete und ihrewichtigsten Nebenflüsse, 1899, Band I – IV, Verlag von Dietrich Reimer, Berlin.

Neüwertz J. H., 1783. *Beschreibung der Oder usw. neue Ökonomische Nachrichten der patritischen Gesellschaft in Schlesien*. Breslau.

Plan regulacji Wisły w latach 1794–1796 oraz 1820–1840. 1:2000 i 1:5000. Zbiory Kartograficzne Archiwum Państwowego w Pszczynie.

Plan regulacji Wisły w rejonie Kaniowa. 1906. Original scale 1:2880.

Plan von situations des Wiechsel und dessen Lauff von der Schwartzwasserischen Graentze bis anden Flussbiala und das Konigreich Pohlen...1754, Scale about 1:4200. Zbiory Kartograficzne Archiwum Państwowego w Opolu.

Regulierung der galizischen Weichselstrecke von Biala Przemsamündung. 1907. 1:25 000. Archiwum Państwowe w Opolu.

Regulierung der Österreichische Weichselstrecke. 1892-1901. 1:5000.Archiwum Państwowe w Opolu

Regulierung der Przemsza. 1906. 1:5000. Archiwum Państwowe w Opolu.

Situations-plan des Weichsel-Flusses von der Mundung der Białka (km 0 bis zur Mundung der Przemsza km 51. 1908. Original scale 1:25000. Archiwum Państwowe w Opolu.

Situationsplan des Wiechselfluses bei Pustynia. 1891. Original scale 1:2880. Archiwum Państwowe w Opolu.

Situations-u. Peilungs-Plan der Weichsel bei Czarnuchowitz, about 1840. Original scale about 1:800. Archiwum Państwowe w Opolu.

Szewczuk J. 1939: *Kronika klęsk elementarnych w Galicji w latach 1772–1841*. Lwów.

Ubersicht der Militar Aufnahme von Mahren und Schlesien. 1861–1863. 1:28 800. Archiwum kartograficzne. Wiedeń.

Urmestischkartte, 1827–1835, 1:25 000, Berlin.

Wieland I. W. 1736. *Principatus Silesiae Rattiboriensis*. About 1:106 000. Wojewódzkie Archiwum Państwowe, Katowice.