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## MINING INFLUENCE IN THE AREA OF THE PSZCZYNKA RIVER AND THE METHOD OF RIVERBED RESTORATION

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### ODDZIAŁYWANIE EKSPLOATACJI GÓRNICZEJ W REJONIE RZEKI PSZCZYNKI A METODA RENATURYZACJI JEJ KORYTA

#### Abstract

This paper investigates the influence of extraction on the surface in the area of the Pszczyńska river. The mining-enhanced terrain subsidence hitherto observed has also resulted in the subsidence of the riverbed and its embankment. Some geotechnical solutions are proposed, including the reconstruction and repair of damage to the existing infrastructure. Such measures should facilitate a proper flow of water in the riverbed which is similar to a natural flow.

**Keywords:** extraction influence, subsidence trough, longitudinal river profile, restoration, mining damage

#### Streszczenie

W artykule przedstawiono wpływ dotychczasowej eksploatacji górniczej na powierzchnię terenu w rejonie rzeki Pszczyńki. Występujące osiadania terenu spowodowały obniżenia koryta rzeki i jej obwałowań. Zaproponowano rozwiązania geotechniczne polegające na wykonaniu przebudowy i naprawy szkód w istniejącej infrastrukturze. Podjęte działania pozwalają na prawidłowy przepływ wody w korycie rzeki zbliżony do naturalnego.

**Słowa kluczowe:** wpływy eksploatacji górniczej, niecka osiadań, profil podłużny rzeki, renaturyzacja, szkody górnicze

## 1. Introduction

Underground mining excavation not only results in the occurrence of both continuous and discontinuous deformations in the surface but also in the disturbance of hitherto-existing water conditions, both within the subsidence trough and beyond its edge. As a consequence, the profiles of riverbeds and other surface watercourses become seriously disturbed. Such a type of mining damage is frequently observed in the case of relatively small downslopes in surface watercourses and large mining-induced surface subsidence. As a result of such conditions, riverbed embankments are also damaged. In addition, excessive bottom erosion or silting occurs in the riverbed, which causes the water to flow to the nearby areas and create permanent bayous [1–3].

The specificity of mining damage in water objects requires the application of special protective measures. Such methods should aim to preserve the original landform in the surface or change it without constraining the free flow of surface waters (i.e. river restoration) [4].

The paper presents and discusses the results of surface subsidence caused by long-term and multi-layer mining excavation which has seriously modified water conditions in the bed of the Pszczyńska river. Wide-ranging repair measures, mostly related to construction works, were undertaken; this helped to eliminate occurrences of flooding and the inundation of the nearby areas whilst simultaneously restoring the previously-regulated river to its almost natural profile.

## 2. Geological conditions in the analyzed area

The terrain surface in the village of Krzyżowice (Silesian Voivodeship) is moderately ridged and its altitude ranges between 252.0 and 262.0 metres above sea level. The minimal altitudes occur in the Pszczyńska river valley. In the nearby area, there are residential and investment buildings, as well as roads running along and across the course of the river.

The river Pszczyńska flows eastbound from the west and belongs to the hydrographic network of the Vistula river basin.

In the area that is the subject of this research, there is a hard coal seam of industrial value down to a depth of approx. 1,000 m. The geological structure of the analyzed area consists of Quaternary layers (Holocene, Pleistocene), Tertiary layers (Miocene) and Carboniferous layers (Orzeskie and Rudzkie).

The Quaternary layers are represented by alluvial Holocene deposits and Pleistocene formations of water and glacier origin. The Holocene alluvia consist of fine and medium-grained sands and muds occurring in the river valleys. The thicknesses of the Quaternary formations in the area of the river Pszczyńska range between approx. 24 and 51.5 m.

The Tertiary formations are deposited directly on the Carboniferous series. Their thicknesses vary, which is related to the morphological variation of Carboniferous roof, and range between approx. 200 and 440 m in the northern part of the area. It is a monotonous series of grey and grey-green marl, often with fauna inclusions and interlayers of dusty sands and thin

straps of tuffites. Locally in the walls of Miocene there are deposits of sands and sandstones. The Tertiary formations constitute a sufficiently impermeable isolation of the deposit series against the infiltration of rainwater and the waters of the Quaternary water-bearing floor.

Carbon formations consist mostly of shale, silty shale and sandstone, whereas the coal deposits belong to the Orzeskie and Rudzkie layers.

The following soil strata can be distinguished in the flood protection dykes of the Pszczynka river [5]:

- I – embankment constructions of flood protection dykes, made of colliery shale, burnt colliery shale, as well as clay and clayey sand dry,
- Ia – embankment constructions of flood protection dykes, made of colliery shale, burnt colliery shale, as well as clay and clayey sand, moist,
- II – hard-plastic brown clay occurring below the shale embankments,
- IIa – plastic brown clay occurring below the layer II,
- III – dark grey and black clayey mud, soft-plastic and plastic, occurring above the peats,
- IV – brown peats, occurring above the muds, are strongly saturated with water,
- V – brown plastic clays occurring below the peats.

The water-bearing layer in the Quaternary formations consists of peats and silty muds. The thickness of the water-bearing layer varies depending on the local development of Quaternary formations and ranges from several dozen centimetres to several metres. The water table has a slightly tense character and stabilises at a depth of 1.0 to 6.6 m below the surface level.

### 3. Hitherto-executed mining and its impact on rock mass and surface

In the analysed area, hard coal exploitation has been performed with the use of the longwall system with roof caving since the early 1980s. In the area of the Pszczynka river, the mining was executed in the parts “K-3”, “K-3,C” and “C” for a total of sixty walls in eleven seams: seam 346/1 of walls C-1÷C-3 and K-1÷K-5; seam 347/1 of walls K-1÷K-4; seam 352/1 of walls C-4÷C-7; seam 356/1 of walls C-4÷C-7 and K-5A, K-1, K-12÷K-14; seam 357/1 of walls C-4÷C-8 and K-4÷K-11; seam 360/1 of walls C-4÷C-7 and K-7÷K-11; seam 361 of walls C-4÷C-6 and K-4÷K-5; seam 362/1 of walls K-1÷K-2; seam 363 of walls C-4 and K-1; seam 401/1 of walls C-4÷C-5; seam 404/1 of walls C-4÷C-5.

The thicknesses of the excavated walls ranged between 1.1 m and 4.3 m, usually approx. 2 m. The largest intensity of mining occurred during the 1980s and 1990s. In this period, as many as thirty five walls were excavated within the analysed area, and ten further walls were mined out over the following five years.

Fig. 1 presents the distribution and shape of particular walls and the positioning of the measurement line where the measurements were performed from 2005.

The process of subsidence trough formation, enhanced by mining exploitation in the discussed area, is documented by the results of geodesic measurements from the period June 2005 to June 2018, taken on the observation line running along the riverbed. The 2,000-metre long line consists of 20 geodesic points fixed at every 100 meters on both sides of the river,



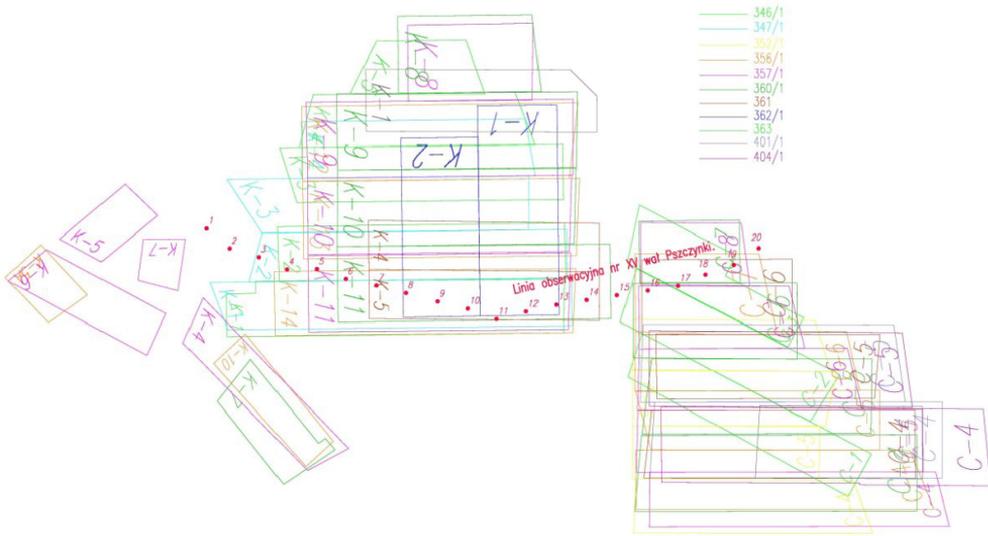


Fig. 1. Excavation in the area of the Pszczynka river and the positioning of the observation line



Fig. 2. Map of the analysed area and positioning of the measurement line

relatively close to the riverbed. A map showing the distribution of the measurement points in the area of the bed of the Pszczynka river is presented in Fig. 2.

Altitude monitoring made it possible to interpret the process of deformation. During the period of thirteen years of measurements, the maximal surface subsidence created two subsidence troughs with maximum values of 1.79 m at point No. 8 of the measurement line and 1.79 m at point No. 18 of the line. Undoubtedly, the walls excavated directly below the measurement line exerted a crucial impact on the volume and rate of subsidence. The values of subsidence at the end points of the observation line in the western direction indicate a clearly decreased character (subsidence of only 0.23 m in point No. 1). The subsidence also decreases eastbound (0.73 m at point No. 20). In the middle of the measurement line (point No. 11), the subsidence reached the value of 0.28 m. The increase of subsidence is presented in Fig. 3.

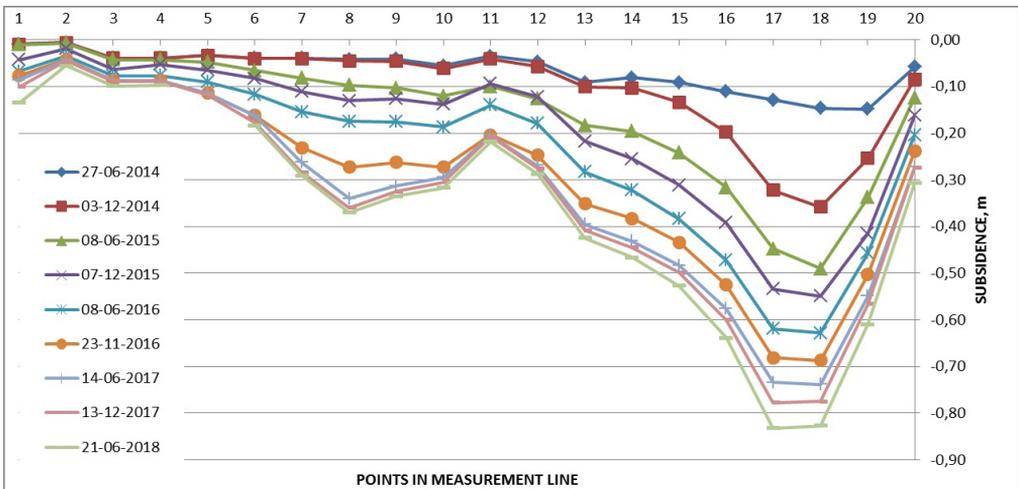


Fig. 3. Subsidence of points on the measurement line in the area of the Pszczyńska river in the period June 2005–June 2018

In the next stage of the study, a period of low exploitation intensity (November 2013–June 2018) was examined, when five longwalls in three seams (362/2, 401/1 and 404/1) were extracted. Surface subsidence reached values approaching 0.83 m at points Nos. 17 and 18, which is presented in Fig. 4. From the west, mining exploitation was also executed in walls C-4 and C-5 in seam 401/1, and in walls C-4 and C-5 in seam 404/1, which is illustrated by the subsidence at points Nos. 15–20 on the measurement line. The line remained within the exploitation area, thus it is impossible to record the entire subsidence trough. The measurement line indicates the reduction of subsidence mainly from the west side (exploitation of one wall K-1 in seam 362/1).

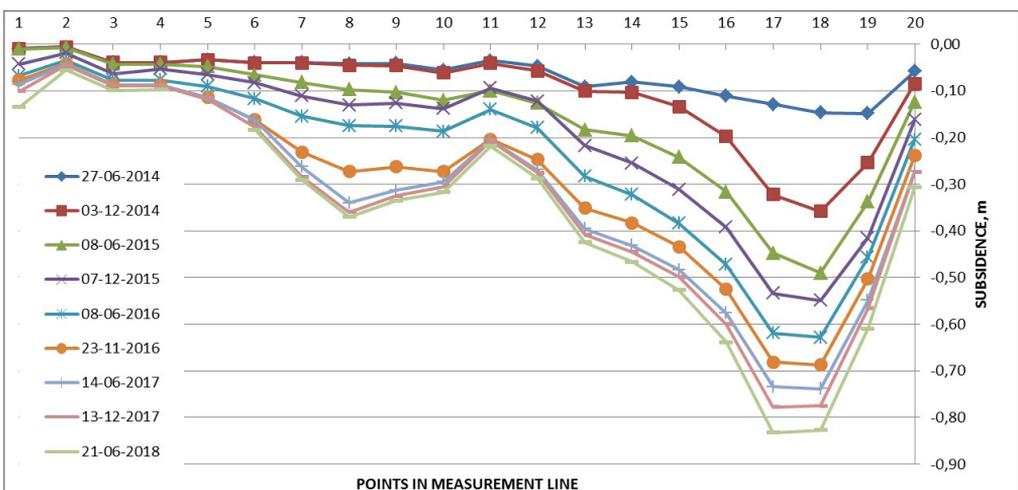


Fig. 4. Subsidence of points on the measurement line in the area of the Pszczyńska river in the period November 2013–June 2018

The mining influences on the terrain surface are characterised by the deformation indices in the measurement points in the area of Korfantego Street Bridge, Zwycięstwa Street Bridge and P-2 pump station, as presented in Table 1.

Table 1. Deformation indices in the area of the measurement line

Area	Subsidence w [m]	Slope T [mm/m]	Deformation $\varepsilon$ [mm/m]
Korfantego Str. near point No. 6	5.401	15.4	11.3
Zwycięstwa Str. near point No. 9	6.956	24.2	10.9
pump station P-2	4.96	12.6	9.4

#### 4. Restoration of the Pszczyńska river

The concept of river restoration is embedded in restoring the earlier-regulated rivers to their pre-impacted natural state, i.e. the state existing before regulation of the river or that which typically occurs in the natural environment. In actuality, a complete river restoration to its natural state is hardly ever possible, hence the restoration process is usually based on a limited range of measures taken or on some kind of a compromise [4].

As a matter of fact, in most cases it is difficult to precisely define the scope and range of measures to be taken or the ideal target state that could be assumed as being natural. This is because the rivers are subject to regular changes enhanced by various factors, including natural factors.

Restoration activities may be conducted in various zones; however, they are most frequently undertaken in the riverbed or riverbanks. Repair works in the riverbed lead to streamlining the river flow and changing the cross sections in order to obtain the optimal depth along the course of the river. Restoration of the riverbanks mostly involves the reconstruction of riverbank reinforcement and protection.

The effectiveness of restoration processes largely depends on the adequacy of the preselected and proposed concepts of supporting activities based on proper surveying of the state of the natural environment already in the conceptualisation phase. As a rule, such a survey should embrace wide-ranging aspects: hydrological, hydraulic and natural. Obviously, the range of survey undertaken for the sake of a restoration process varies depending on the particular concept and specificity of a given object [4].

As a result of mining exploitation, the bed of the Pszczyńska river suffered from serious deformations. Surface subsidence caused the subsidence of the riverbed and the embankment of the river. Thus, hydraulic parameters in the riverbed changed, causing the decrease of the velocity of water streaming. The bed of the Pszczyńska river began to function as a kind of sedimentation tank. In addition, the geotechnical parameters of the embankment seriously worsened, which negatively affects flood safety in the nearby areas with residential and

investment buildings. Therefore, particular construction works were undertaken in relation to the requirements of flood safety, proper water streaming in the riverbed and the preservation of satisfactory technical and hydraulic parameters (Fig. 5). These works involved [5]:

- ▶ repairing the existing flood protection dykes by raising the levee crowns and levee corpus development;
- ▶ raising and broadening the left and right levee corpus in the section with the largest surface subsidence;
- ▶ rebuilding perimeter drainage ditches colliding with the renovated flood protection dykes;
- ▶ rebuilding outlets of the drainage pump stations;
- ▶ rebuilding and protecting the hitherto-existing technical infrastructure intersecting with the flood protection dykes and the Pszczynka river in the discussed section.

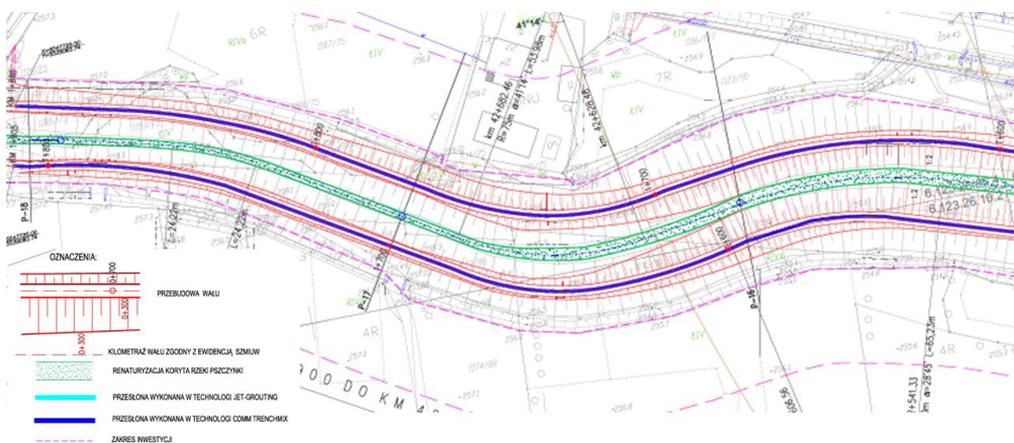


Fig. 5. Fragment of topographical map: river section with inserted design solutions

Irregular subsidence of the riverbed of the Pszczynka causing a lack of adequate gravitation slope and serious decrease of the water flow velocity resulted in the creation of the water ponding zone. Therefore, the riverbed had to be stabilised in the section of 1 km. As part of the re-profiling process, the river bottom was reinforced with stone riprap, assuming a waterbed with a maximum bottom width of 4.0 m (Fig. 6) [5].

The restoration of the river Pszczynka will help to re-establish the original width of the riverbed from before the process of subsidence. In order to make the works in the river current possible, a special steel wall will be installed at depth of 6.0 m along the riverbed and the works will be executed on both sides of the wall interchangeably (Fig. 8).

As soon as the river bottom is stabilised, the Ø 25 cm fascine bands will be laid between the rows of poles in the footing of the slopes, followed by the formation of the slopes of the embankment. Most importantly, the fascine will be made after the river bottom stabilisation and before forming the embankment slopes. The total length of the fascine bands is 4 km (Fig. 9).

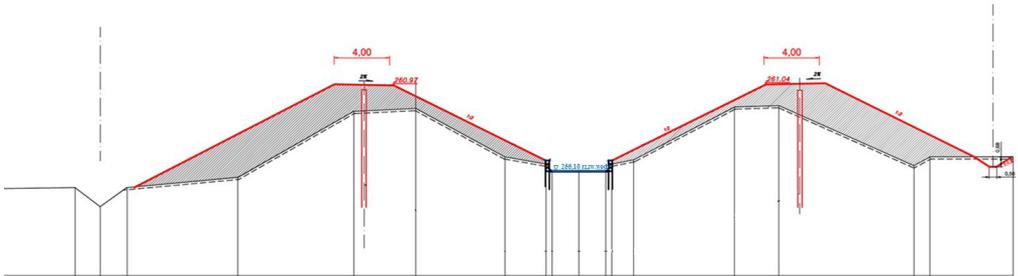
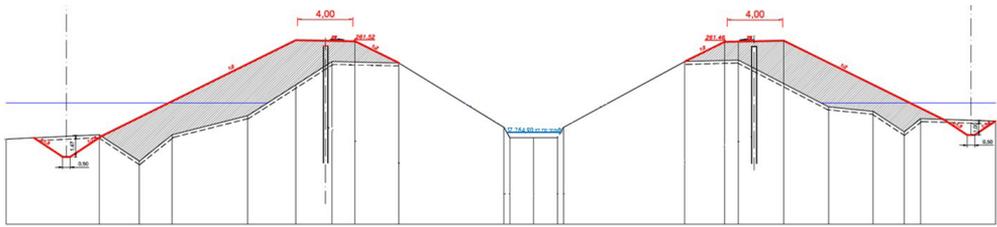


Fig. 6. Characteristic cross section of left and right embankment of the river Pszczyńska



Fig. 7. Preparing riverbed for restoration



Fig. 8. Topsoiling of slopes



Fig. 9. Fascine construction works



The method of restoration presented above proved most effective in the given local conditions (Fig. 10).



Fig. 10. Completed works after the most recent restoration

In future repair works of the embankment of the Pszczyńska river, the application of a jet grouting method is planned [6, 7]. In this method, a dynamic stream of water or cement cuts out and crumbles the soil to mix it with cement grout and create the so-called soil cement after cement curing inside the soil mass. At the same time, the remaining ground particles mixed with cement grout fill in the empty spaces in the ground as a result of turbulence. The impact radius of jet grouting depends on the selected variant of the technology and varies from 0.6 to 5 metres. The method has been commonly applied in embankment repairs, slurry wall construction, horizontal water-bearing screen construction and flood-protection dyke sealing [8].

## 5. Conclusions

The concept of river restoration is embedded in a complex of efforts aimed at bringing back the degraded river sections to their pre-impacted natural state. Initially, such efforts focus on strictly technical activities, eliminating any obstacles hindering the natural river processes. In the next phase, the process of restoration is instigated and controlled by the forces of nature.

Mining exploitation causes surface subsidence and thus it also changes water conditions. This problem, to a varied degree, exists in the entire Upper Silesian Coal Basin. As a result of hard coal extraction since the 1980s, such a situation also occurs in the village of Krzyżowice, where the bed of the Pszczyńska river suffered from serious deformation. The surface subsidence also affected the bottom and the embankment of the river.

The analysed area of the river Pszczyńska is influenced by the hitherto executed and planned longwall mining with roof caving in the seams of the Orzeskie and Rudzkie layers. The predicted values of riverbed and embankment subsidence may maximally reach approx. 2.5 m by the year 2030.

The proposed technical solutions related to repairing the flood protection dykes of the Pszczyńska river in its section affected by earlier mining allow for further exploitation as planned until 2030.

The hitherto gathered expertise, however, fails to exclude the risk of flooding in the area directly outside the embankment of the river. The coal mines try to deal with this problem by means of building local pump stations, transferring rainwater into the riverbed. As time passes and during further intensive mining, the flooded areas outside the embankments transform into excessive bayous outside the riverbed. However, the question arises here of whether keeping a gravitation streaming of water in a restored riverbed should be maintained at any cost. Keeping in mind the necessity to increase the water retentiveness of local areas and facilitate biodiversity in nature, it seems fair enough to promote and justify a totally different attitude to the issue. Areas rich in water are nature friendly and they should not always be liquidated by means of building expensive hydrotechnical systems. Maybe it would prove far more advantageous for nature if the areas endangered by the occurrence of bayous were specially prepared for filling with water.

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