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Threats of flooding of selected mining areas – repair measures

Zagrożenia powodziowe wybranych obszarów górniczych – działania naprawcze

Abstract

Terrain surface subsidence observed in mining areas results in the flattening of riverbeds and their embankments. This leads to increasingly deep erosion and siltation of riverbeds and surface currents, which causes the emergence of permanent overflow lands. This paper presents hydro – engineering solutions applied in the areas of the mining activity of JSW S.A., which serve the purpose of repairing and eliminating mining damage in the existing infrastructure. The presented repair measures make it possible to eliminate the threat of flooding in mining areas.

Keywords: mining damage, longitudinal river profile, repair measures

Streszczenie

Występujące w obszarach górniczych osiadania terenu powodują obniżenia koryt rzek i ich obwałowań. W następstwie dochodzi do zwiększonej erozji dennej lub do zamuleń koryt rzecznych i cieków powierzchniowych, co powoduje powstawanie trwałych zalewisk. W artykule przedstawiono rozwiązania hydrotechniczne stosowane w rejonach działalności górniczej JSW S.A., które służą do naprawy oraz likwidacji szkód górniczych w istniejącej infrastrukturze. Przedmiotowe działania naprawcze pozwalają na wyeliminowanie zagrożenia podtopieniem terenu górniczego.

Słowa kluczowe: szkody górnicze, profil podłużny rzeki, działania naprawcze

1. Introduction

Underground mining operations disturb the geostatic balance of rock mass and adversely affect the surface, changing its topography. This results in hydrological and natural transformations. Underground mining operations cause disruptions to river, stream and water currents, and change water and soil conditions. This can result in a drop in groundwater levels if the aquifers are not insulated well enough. When the aquifers are separated with a watertight series, excessive water accumulation in the soil can take place, as can flooding and the emergence of overflow lands [1].

Flooding means a process which leads to excessive water accumulation in the soil caused by subsidence, as well as a state resulting from this process. Flooding does not have to appear on the surface as overflow land [2]. Overflow land is an accumulation of water in an area affected by subsidence due to underground mining. The emergence of overflow land and flooding is conditional upon the extent and distribution of post – mining subsidence areas as well as upon factors related to subgrade permeability and topography [3].

The negative effects of mining in the areas of rivers or surface watercourses are expressed mainly in the form of damage to riverbed embankments and disturbances to the water flow in subsidence troughs [4]. Additionally, the riverbed is subject to increased deep erosion or siltation, which causes water to spill into the adjacent areas and form permanent overflow land. The most disadvantageous situation can be observed in forested areas affected by unrestricted exploitation where its influence on the area is controlled to the least extent, which often leads to surface degradation [3].

The occurrence of mining – induced damage to such objects as rivers and surface watercourses requires appropriate repair measures. These should be aimed at preserving the original surface features or modifying them in such a way as to maintain the conditions for the free flow of surface water [2, 5, 6].

This article presents the results of subsidence caused by long – term mining which has caused changes in water conditions in the riverbed of the Boryński stream. The problem in question also applies to the Pszczynka river, into which the Boryński stream flows, and where the mining operations resulted in embankment damage. The purpose of the repair measures presented in this paper, mainly of a construction nature, is to eliminate flooding and simultaneously restore the river condition to the previous controlled condition and the stream to a state close to natural.

2. The geological conditions in the analysed region

The analysed area surrounding the Boryński stream has a gently undulating surface and its heights ranges from around 256.0 to 280.0 m above sea level. The adjacent area features residential and commercial buildings and croplands.

The Boryński stream flows from the north – west to the south – east and is the largest tributary of the river Pszczynka. It belongs to the hydrometric network of the Vistula river catchment area.

Fig. 1. The layout plan of the analysed area showing the Boryński stream

The geological structure of the area in question has the following layers: Quaternary (Holocene, Pleistocene), Tertiary (Miocene) and Carboniferous (Orzeskie, Rudzkie and Siodłowe).

Quaternary formations belong to Holocene alluvial and Pleistocene glacial deposits. Holocene sediments are represented by fine – grained and medium – grained sands and alluvial soils. Pleistocene sediments were formed in the form of grey clays, brown and light grey dusts and clays, light yellow and grey gravels and light grey sands. The sands are either diverse in terms of grain size or are fine – grained. The gravels include sandstone, igneous rock and quartz pebbles.

Miocene formations are present in the form of clays and clay stones of a greenish hue, sanded up to a varied degree, stocked with insertions or thick layers of friable and firm dusty sands or fine – grained sandstones. The Orzeskie layers are represented by clayey and sandy sediments. The Rudzkie layers are surrounded by sandstones with claystone and mudstone insertions. The sandstones in these layers are characterised by variable grain size from fine – grain to conglomerates and clay – siliceous or clay cement. The Siodłowe layers are formed as a series of thick – bedded, large – grained and conglomerate sandstones with clay – siliceous or siliceous – clay cement.

Based on the geotechnical surveys performed in the area of the Boryński stream, the following soil layers were distinguished: yellow light – grey dust, sandy dust, light – grey loam, grey sandy clay with admixture of gravel, compact dark – yellow clay, medium light and grey sand, medium sand with admixture of gravel, thick yellow sand, light grey – yellow sand, and clayey sandy gravel (Fig. 2).

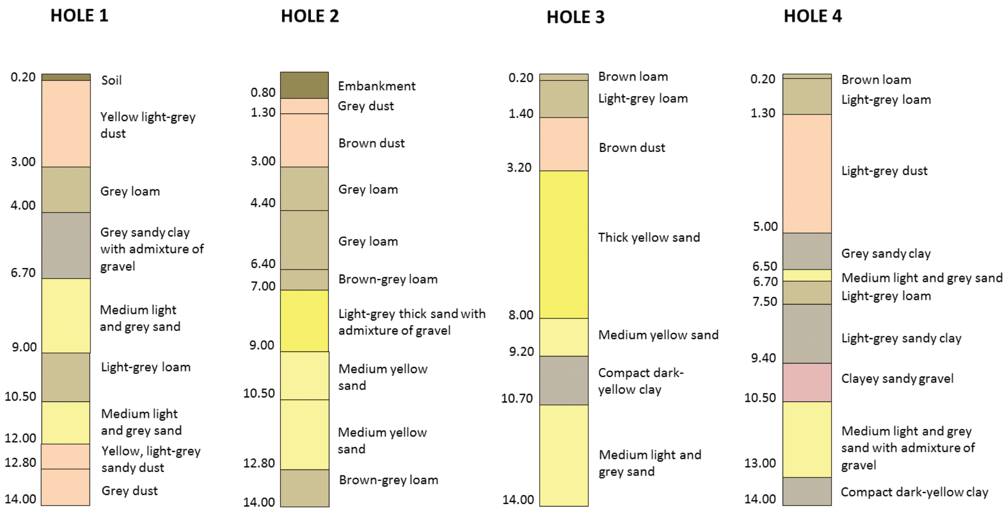


Fig. 2. The geotechnical layers in the Boryński stream area

3. The impact of mining on the rock mass and land surface

The region in which the section of the Boryński stream in question is located is in the range of the impact of previous mining and will be under the subsequent influence of the planned mining.

In the area of the Boryński stream, mining has been conducted in seventy longwalls in fourteen seams since 1972. These are: seam 357/1 of walls D1÷D2, D11÷D13, C2a, C2÷C4, C7, C9; seam 358/2 of wall E4; seam 358/2 – 3 of walls C2÷C5, C7, C9, D1a÷D2a, D2, D11a, D12÷D14, Z10b; seam 359/1 of walls E1÷E2; seam 359/3 of walls 1, C1÷C2, D1÷D3, D11a, D11÷D13; seam 360/1 of walls D1÷D6, D11a, D12÷D13; seam 361/1 of walls 1, D11a, D11÷D12; seam 362/1 – 2 of walls D1; seam 362/1 – 3 of walls D1, D3a, D3÷D4; seam 362/2 – 3 of walls D21÷D22, D24; seam 363/1 of walls D1÷D2; seam 404/1 of walls D21÷D22; seam 405/1 of walls D1÷D3, D11÷D34; seam 406/3 of wall A31. Figure 3 presents the locations and shapes of the individual mining parcels.

The height of the mined longwalls ranged from 1.15 to 3.2 m, and usually exceeded 2 m. The highest mining intensity was in the 1980s, and in this period, forty – one longwalls were mined in the area in question. Between 1990 and 2018, 22 more longwalls were mined.

The values of subsidence caused by mining in the area in question are documented by the geodetic surveys performed from October 1974 to June 2017. The article presents subsidence occurring at two characteristic measuring points 2806 and 2933 – wall benchmarks. At measuring points 2806 and 2933, the subsidence levels observed over 43 years are 3.97 and 6.98 m, respectively. These values illustrate the effect of coal mining in the referenced region. The course of subsidence over time at the selected benchmarks are presented in Fig. 4.

The mining operations of 1978 to 2019 resulted in category IV to V surface deformations. The smallest subsidence was observed in the locations of gravity flow, while the greatest occurred near a pumping station, where the hydraulic continuity of the stream was interrupted.

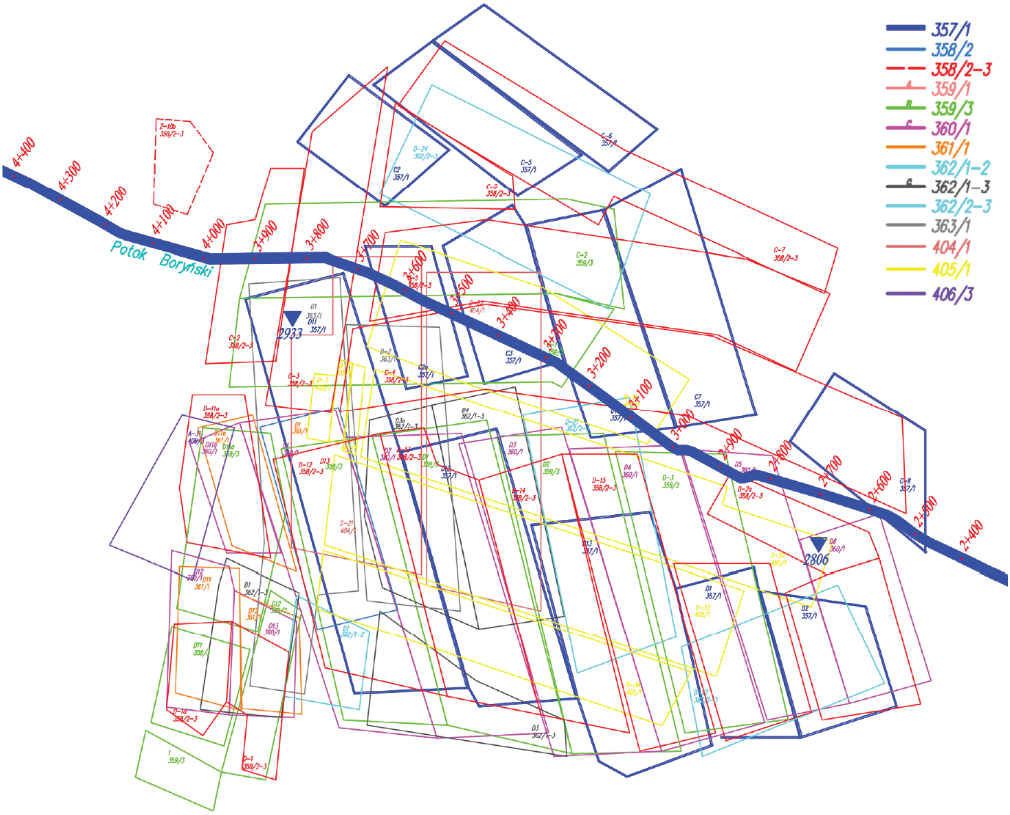


Fig. 3. Mining in the Boryński stream area in the period 1972–2018 and the location of benchmarks

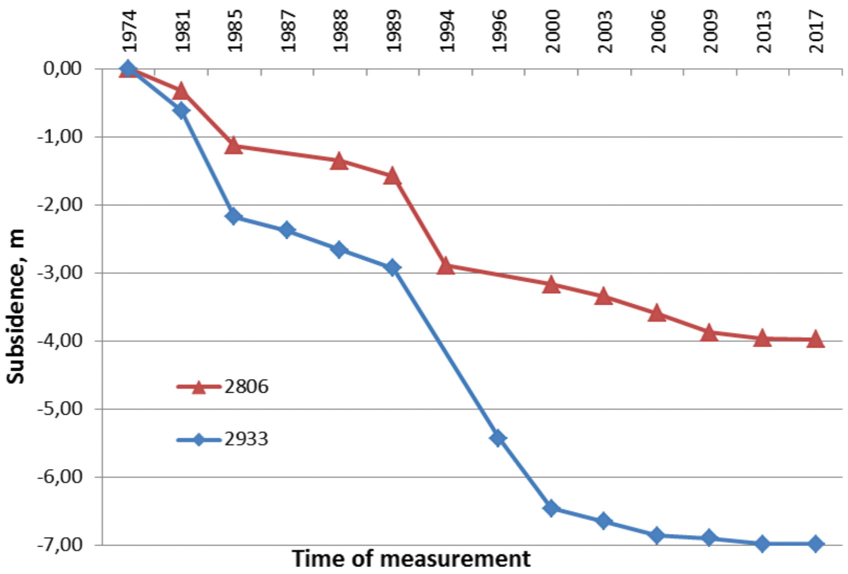


Fig. 4. The subsidence of points located in the analysed region in the period 1974–2017

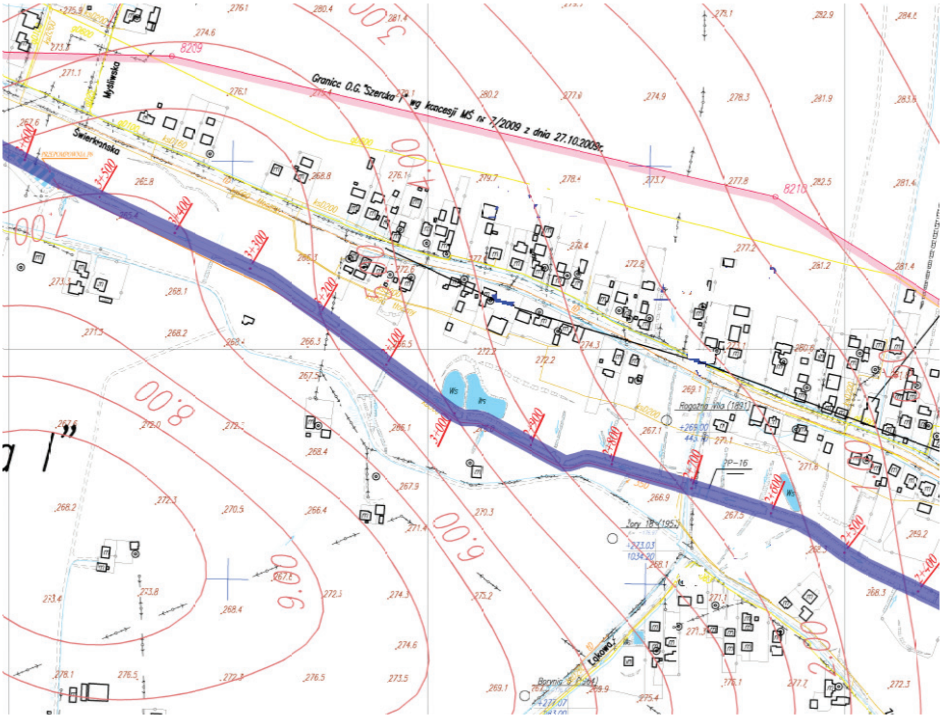
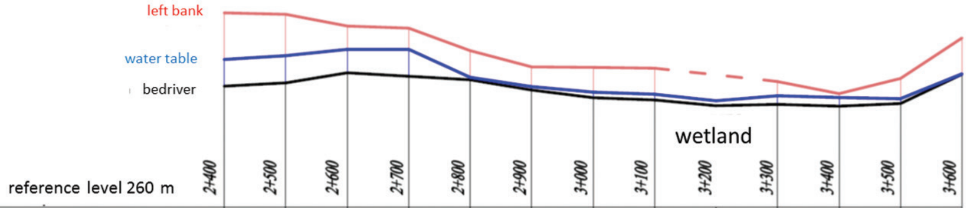


Fig. 5. Land surface subsidence trough – mining conducted in the period 1974–2017

The longitudinal section of the analysed section of the Boryński stream illustrates that the riverbed of the stream is slanted in the opposite direction to the outflow of water from the catchment area (Fig. 6). This results in no outflow from the catchment area and the emergence of overflow land. The existing pumping station is unable to effectively pump out the water flowing within the Boryński stream riverbed. The outlet of the pressure piping of this pumping station is permanently flooded due to the lack of runoff.

Further mining in this area is expected from 2019 to 2025 in seams 404/1, 405/1 and 404/1łg, which will result in the area in question depressing by 0.148 to 1.049 m.



	2+400	2+500	2+600	2+700	2+800	2+900	3+000	3+100	3+200	3+300	3+400	3+500	3+600
height of water table	265.946	266.123	266.433	266.380	265.250	264.873	264.648	264.536		264.502	264.430	264.387	265.395
height of the left bank	267.860	267.796	267.328	267.239	266.327	265.674	265.650	265.620		265.081	264.591	265.203	266.847
height of the bed	264.896	265.023	265.433	265.321	265.150	264.733	264.428	264.336		264.152	264.080	264.187	265.375

Fig. 6. The longitudinal section of the Boryński stream

4. Repair measures

The mining – induced damage which occurs in the analysed region causes interruptions in the outflow of surface water. An interior basin formed at the 2+400 to 3+600 km section of the Boryński stream riverbed. It is drained using the pumping station on Zamkowa Street. The outlet of the pressure piping of this pumping station is at 2+710 km (above Łąkowa Street level). The pumping station is unable to effectively pump out the water from the basin, especially in the case of heavy rainfall.

The analysis has demonstrated that with the expected depressions of 1.0 m, this will result in the existing basin becoming deeper and the area of the flood land expanding to 8.5 ha. This situation necessitates the reconstruction of the existing drainage system.

The condition of the existing riverbed of the Boryński stream also contributes to this hazard. The riverbed, most of which is deformed, has fragmentary vegetation – based flood management measures.

The entire section of the stream riverbed covered by the analysis is unsuitable for the drainage of storm water. It is therefore necessary to deepen the riverbed and make it slant towards the designed retarding reservoir and pumping station.

Interruptions to the outflow of water along the Boryński stream riverbed have been observed for many years. Unfortunately, the technical facilities made in 2006–2007 are becoming ineffective in the case of heavier precipitation. The interior basin which forms between the Zamkowa and Świerklańska Streets fills up with water during heavy rainfall and results in the flooding of areas and buildings adjacent to the riverbed. In order to solve this problem, it is necessary to change the subsidence trough drainage system.

In order to ensure the correct waterflow in the riverbed and to maintain appropriate technical and hydraulic parameters, appropriate construction works were planned [7] (Fig. 7), including:

- the construction of a pumping station equipped with two pumps with a capacity of $Q = 55$ dm^3/s and one pump with a capacity of $Q = 300$ dm^3/s;
- the creation of a retarding reservoir in the Boryński stream riverbed with dimensions of 71 x 160 m and a volume of 27 650 m^3;
- the installation of pressure piping with diameters of 355 mm and lengths of 1210 and 1166 m along the stream riverbed, up to the location of gravity flow;
- the installation of a decompression chamber at the pressure piping outlets;
- Boryński stream riverbed improvement along a section of 1220 m;
- elevation and development of degraded area for agricultural purposes.

The designed retarding reservoir is to be located in the deepest depression of the Boryński stream riverbed from 3+318 to 3+456 km. This reservoir collects water from subcatchments located downstream of 2+400 km. Water from the reservoir will be gravitationally discharged to two wells with pumps. Up to a height of 265.00 m, the reservoir will have vertical walls of steel sheet piles topped with caps. The bottom of the reservoir will be profiled accordingly and provided with a 6‰ slope towards the axis of the Boryński stream.

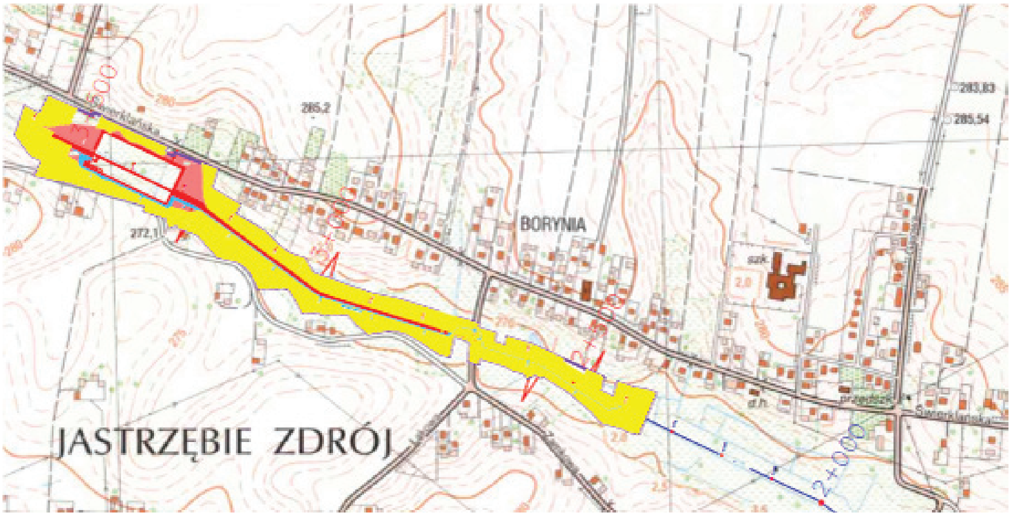


Fig. 7. A layout plan showing location of repair measures in the Boryński stream area

As part of the stream riverbed improvement, a bipartite riverbed has been designed with permanent bed and scarp reinforcements. The main riverbed will be made of double – driven sheet piling made of GW 300 vinyl sheet piles with a length of L = 4.0 m. Bieruń – type reinforced concrete prefabricated elements with a width of 1.24 m will be laid in the riverbed on geotextile and a 15 cm thick bed made of gravel or a sand – gravel mixture. The sheet piling will be topped with a vinyl cap. In the piling, at a height of 70 cm above the riverbed, filter holes with a diameter of 5 cm will be cut every 2 m, while on the ground side, the holes will be secured with geotextile (Fig. 9).

Benches and scarps above will be reinforced with 90 x 60 x 10 cm openwork concrete slabs, laid on the geotextile and a 15 cm thick bed made of gravel or a sand – gravel mixture [8]. Openings in the openwork slabs will be filled with humus with grass seeds. The scarps will be covered with humus and sown.

As part of Boryński stream riverbed improvement, five spillways are to be constructed, which will constitute passages to fields situated along the stream.

In the adjacent area not included in the analysis, below the outlet from the pressure piping, the stream riverbed has a marked slant and significant significant dimensions. The flow of water is clear. No impact of mining is expected on the surface of this area; therefore, no deterioration of water flow conditions in the stream riverbed due to mining is to be observed there.

During the works related to the riverbed improvement of the Boryński stream, construction of the retarding reservoir and pressure piping, production on grasslands and arable land within the boundary lines will be discontinued. Some of the grasslands are degraded due to constant flooding. The basin area is excessively damp, which results in the severe invasion of wetland and aquatic vegetation. The area within the basin will be elevated with mineral soil.

The repair measures taken in the Boryński stream area are not the only project performed in the mining areas of JSW S.A. in order to eliminate the threat of flooding [6].

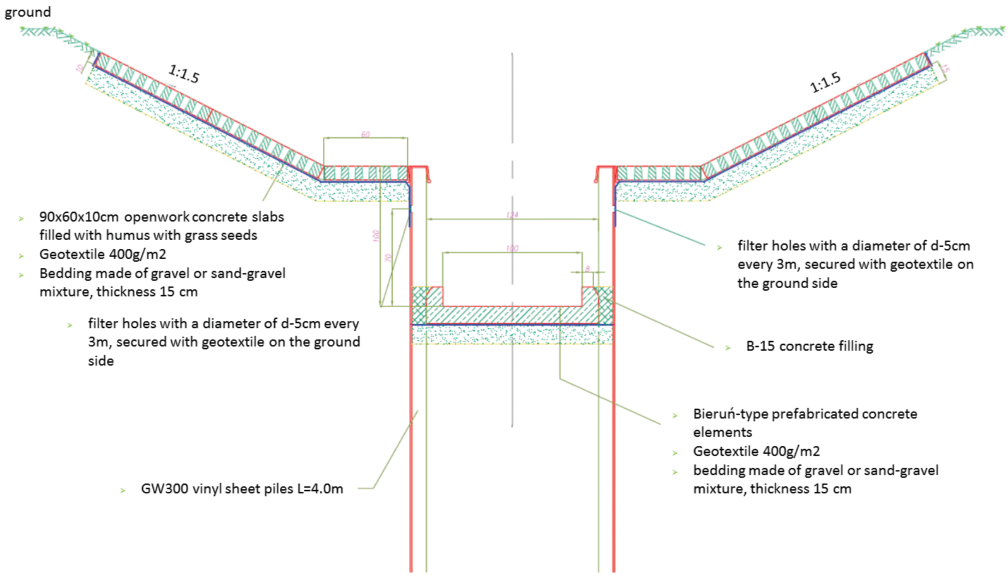


Fig. 9. Boryński stream riverbed reinforcement

Due to the formation of a stagnation area caused by the uneven subsidence of the Pszczynka riverbed, into which the Boryński stream flows, the riverbed was reinforced over a distance of 1 km [6, 9]. As part of reprofiling, the riverbed was reinforced with riprap, assuming a riverbed with a maximum bottom width of 4.0 m (Fig. 10).

The works performed in the Pszczynka riverbed focused on natural restoration and made it possible to restore the width of the riverbed to its original condition, prior to its subsidence.

Fig. 10. Works related to the incorporation of fascines and humus – covering the scarps along the Pszczynka river

5. Conclusion

Surface subsidence caused by mining operations results in, among other things, changes in water conditions. The analysed area of the Boryński stream and the Pszczynka river is influenced by multi – bed mining with caving. The transformations occurring in the bed of the river and stream require repair measures.

The riverbed improvement in the Boryński stream will result in the riverbed, along the section from 2+400 to 3+476 km, sloping towards the retarding reservoir and pumping station. An increase in sloping will increase the speed of water flow, thus improving the hydraulic flow conditions in the stream riverbed. The applied reinforcement utilising sheet piling and reinforced concrete elements guarantee the durability of the stream riverbed, even if the water flow speeds increase. The adopted maximum level of water accumulation in the retarding reservoir of 265 m above sea level will not cause overbank flooding even if the target mining prediction is met. The implementation of the adopted design solutions will enhance flood safety by preventing the occurrence of flood lands and flooding of the adjacent buildings and streets.

The threat of surface flooding in the area of mining influence can be eliminated by means of building local pumping stations to discharge rainwater to the riverbed, or potentially to the redeveloped riverbank reinforcement. However, in the case of intensive mining, flood lands can emerge. Taking into account the need to increase the water retention capacity of local areas as well as the need to improve biodiversity, it appears that expensive hydrotechnical systems should not be used in all cases.

The occurrence of flood lands can also be positive. There are many examples of flood lands becoming permanent elements of the landscape, and attempts to eliminate them are met with protests from residents and ecologists, who see natural values in the forming ecological niche. It is often proposed to protect the existing flood lands as ecological sites or natural and landscape complexes. Flood lands can also constitute alternative sources of water supply for industrial and firefighting purposes. Therefore, sometimes it would be more beneficial for the environment affected by mining operations to adapt the area for the emergence of a flood land. Such solutions are also more attractive due to the lower costs of the repair measures to be implemented.

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