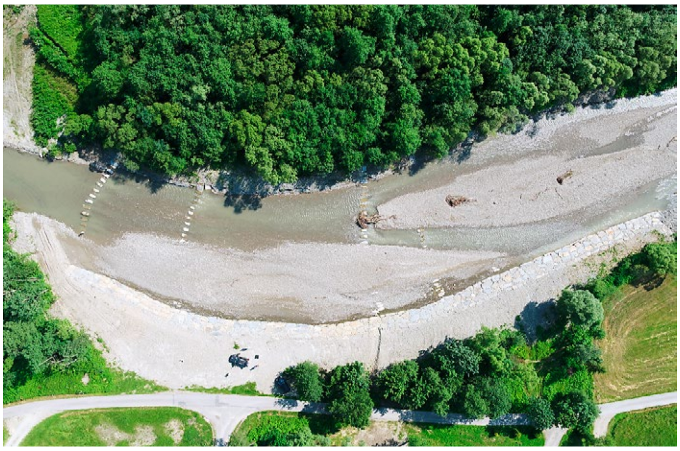
REPORT

on the implementation of the project

RESTORATION OF ECOLOGICAL CONTINUITY AND ACTIVITIES IMPROVING FUNCTIONING OF THE FREE MIGRATION CORRIDOR OF THE BIAŁA TARNOWSKA RIVER



National Water Holding Polish Waters
Regional Water Management Board in Kraków

2022

European Funds
Infrastructure and Environment

Państwowe
Gospodarstwo Wodne
Wody Polskie

European Union
Cohesion Fund

PROJECT
'Restoration of ecological continuity and activities improving functioning of the free migration corridor of the Biała Tarnowska River'
Project implemented under the Infrastructure and Environment Operational Program 2014–2020

PROJECT DURATION
2017-2022

TOTAL COST OF THE PROJECT
PLN 39,3 million

EU FINANCING FROM THE COHESION FUND
PLN 33,4 million

PROJECT BENEFICIARY
National Water Holding Polish Waters
Regional Water Management Board in Kraków
ul. Marszałka J. Piłsudskiego 22, 31-109 Kraków

PREPARATION OF DESIGNS AND AUTHOR'S SUPERVISION
Ośrodek Usług Inżynierskich STAAND Sp. z o.o

PROJECT MANAGEMENT NATURAL SUPERVISION, PROMOTION
Roman Żurek Zakład Badań Ekologicznych

INVESTOR'S SUPERVISION
Biuro Obsługi Budownictwa „Bień" Jan Bień

EXECUTION OF WORKS
Przedsiębiorstwo Produkcyjno-Usługowo-Handlowe WOLIMEX

DELIVERY AND INSTALLATION OF MONITORING DEVICES
Zakład Produkcyjno-Handlowy PIWI

DESIGN OF MIGRATION CORRIDORS
P.P.H.U AdEko s.c.

SUPERVISION OF THE CONSTRUCTION OF THE MIGRATION CORRIDOR
F.U.H.P „AQUA EKO" Stanisław Brzęk

AUTHORS OF THE TEXT
Roman Żurek, Karol Ciężak, Roman Konieczny, Małgorzata Siudak

PHOTO AUTHORS
Drone images Roman Żurek Zakład Badań Ekologicznych, other photos: arch. PGW WP RZGW, K. Ciężak, M. Jelonek, R. Konieczny, M. Siudak, R. Żurek

TYPESETTING
Wydawnictwo Attyka

PRINTING
Drukarnia Delta

Print run of 500

Unblocking the Biała Tarnowska for fish and giving space to the river

Introduction

The project entitled 'Restoration of ecological continuity and activities improving the functioning of the free migration corridor of the Biała Tarnowska River' was implemented in 2017–2022 by the State Water Holding Polish Waters, Regional Water Management Authority in Kraków, as one of the twin projects on river unblocking. For the Biała River, the first stage of unblocking hydrotechnical structures for fish in this river was implemented in 2012–2016. In the first stage, four migration barriers were unblocked; in the second stage, the remaining 15 weirs were unblocked.

Why is it important to open a river for fish migration? The answer is simple: because our goal is to preserve the proper biodiversity of ichthyofauna. Simply unblocking the river does not solve all the problems of the river, but providing fish with places for breeding, located in the upper parts of the rivers, is crucial for their existence.

Many rivers in Poland, including the Biała river, lost their natural character as a result of the construction of dams, barrages,

Fig. 1. Reocren type source of Biała.

Fig. 2. One of the sources of the Biała stream of the helocrene type.

European code of surface water bodies	Name	Abiotic type	State of the water body
PLRW2000122148199	Biała to Mostysza, without Mostysza	flysch creek	natural water body
PLRW200012214832	Biała from Mostysza to Binczarówka with Mostysza and Binczarówka	flysch creek	heavily modified water body
PLRW2000142148579	Biała from Binczarówka to Rostówka	little fliche river	heavily modified water body
PLRW200014214899	Biała from Rostówka to the mouth of the Dunajec river	little fliche river	natural water body

Table 1. Water bodies delineated on the Biała Tarnowska.

embankments, regulation of riverbeds and strengthening of banks to protect against flooding. These constructions have not always been effective. In addition, they have contributed to the reduction of fish populations or extinction of many fish species. Today, we know much more about the functioning of the river systems than before. We are able to modernise the existing constructions in such a way that they not only reduce the risk of flooding, but are also friendly to fish and other aquatic organisms. They do not interfere with the natural character of the river and help to restore its wild nature. As a result, conditions for the development of fish habitats and for spontaneous recovery of vegetation that is a habitat for other animals will be created. The landscape values that contribute to the development of tourism in the region will be enhanced.

Characteristics of the Biała Tarnowska River

Biała Tarnowska, the largest tributary of the Dunajec river, is 101.8 km long. It collects waters from a catchment area of 983.3 km2. The river has five springs on the northern slope of Lackowa (Figs. 1 and 2), and the river itself is fed by 32 streams. In its upper reaches, from the springs to Binczarówka stream, the Biała is a lowland stream; then, to the mouth of the Dunajec River, it is a small, lowland river. In the area of the village of Izby, the river has formed a braided riverbed (Figs. 3 and 4). Four surface water bodies have been identified on the river (Tab. 1). The middle part of the river is characterised as heavily modified.

The Biała was a spawning ground for the diadromous fishes, which we ultimately want to restore. The river is also important for local communities because of its great natural landscape and cultural values connected with the settlement (Fig. 5).

Fig. 3. Braided channel of the Biała River in the upper reaches.

Fig. 4. Braided channel of the Biała River in the upper reaches.

Fig. 5. Orthodox church of St. Michael the Archangel.

Natura 2000 sites on the Biała River

On part of the river, a Special Habitat Protection Area Natura 2000 was designated and established[1], recorded in the Central Register of Nature Conservation Forms under the code PLH120090. The 957.46 ha area includes the narrow valley of the Biała River from the bridge in the village of Izby to the bridge along road 94 near Tarnów.

The Biała Natura 2000 area includes a significant proportion of the resources of four habitat types in the Alpine region included in Annex I to Council Directive 92/43/EEC: pioneer vegetation on gravel of mountain streams; willow thickets on gravel deposits and gravel pitches of alpine streams and their ligneous vegetation with predominance of the German tamarisk *Myricaria germanica* (*Salici-Myricarietum*) and willow thickets on stony and gravel banks of mountain streams *Salici-Myricarietum* (Fig. 6) with dominant willow and willow, poplar, alder and ash riparian forests - *Salicetum albae*, *Populetum albae*, *Alnenion glutinoso-incanae*, spring alder forests. On the banks of the Biała River, three patches of septate and heather thickets were distinguished with a total area of 0.47 ha, which is less than 0.05% of the entire Natura 2000 area. This is a much smaller area than previously reported. Two of these patches (in Brunary and in Śnietnica) were destroyed during regulatory works in 2019.

[1] COMMISSION DECISION of 10 January 2011 adopting, pursuant to Council Directive 92/43/EEC, a fourth updated list of sites of community importance for the Continental biogeographical region (2011/64/EU), Official Journal of the European Union, L 33 p. 146.

Fig. 6. German tamarisk Myricaria germanica.

Fig. 7. The yellow-bellied toad Bombina variegata.

Fig. 8. The yellow-bellied toad Bombina variegata.

Fig. 9. Thick shelled river mussel Unio crassus.

Fig. 10. Carpathian barbel Barbus carpathicus.

In the Biała Natura 2000 site, the Standard Data Form (SDF) listed in 2014 six animal species listed in Article 4 of Directive 2009I147I EC in Annex II of Directive 92I43IEWG. After the November 2019 update, five species remained: *Aspius aspius*, *Barbus carpathicus*, *Salmo salar*, *Bombina variegata* and *Unio crassus*, i.e. asp, Carpathian barbel, salmon, the yellow-bellied toad and thick shelled river mussel, respectively (Figs. 7, 8, 9, 10). Fathead minnow has been added to the list, but *Cottus gobio* and *Lampe- tra planeri* (European bullhead and brook lamprey) have been removed.

Project objectives

The project had two objectives. The first was to restore the continuity of the river for fish and other aquatic organisms by rebuilding the existing weirs on the river, thereby improving its ecological status.

In the 20th century, 19 transverse barriers, which were impossible for fish to cross while searching for convenient spawning places, were built on the river. The barriers were usually weirs with stilling basins, intended to guarantee the stability of the bridges. In two villages, these were also periodically raised dams, whose purpose was to dam up the river in the summer in such a way as to create a bathing area for villagers.

The accessibility of the Biała for fish migration was increased in two stages. In the first stage (2010–2014) four migration

Fig. 11. Weir in Ciężkowice before modernisation. Reconstructed in the 1st stage of the project.

Fig. 12. Cascade of weirs in Grybów after modernization in the 1st stage of the project.

Fig. 13. The weir in Florynka before modernization. Reconstructed in the 2nd stage of the project.

barriers were removed – in Kąclowa, Grybów, Pleśna and Ciężkowice. In the second stage 15 barriers – in Banica, Śnietnica (2 barriers), Florynka (3 barriers), Kąclowa, Grybów (3 barriers), Biała Niżna (2 barriers), Stróże, Jankowa and Bobowa (Figs. 11, 12, 13, 14). In practice, the reconstruction consisted in building fish ladders in places of weirs (Fig. 15). In total, 80 km of river were unblocked.

A second objective was to improve flood safety by widening the riverbed and floodplains in several sections. By widening the river, it is possible to initiate the process of the river shaping its own bed—within a certain acceptable range, of course. This will improve the ecological condition of the river and improve flood safety for local residents. Construction work on the free migration corridor of the Biała river started in the area of Kąclowa, where the river was 'de-corridorised' along a stretch of over 1 km by the building of five deflectors. Depending on the specific situation, different solutions, i.e. different types of fish ladders, have been used. Most of the solutions are close to nature in the form of a stone riffle (e.g. honeycomb or fan). In one case, the fish ladder has been placed in the stilling basin of a weir.

Within the project, the operation of all reconstructed barriers was verified by hydraulic tests (flow velocity measurements) and fish migration monitoring.

Fig. 14. The fish ladder in Kąclowa after modernization in the 1st stage of the project.

Modernization of Weirs

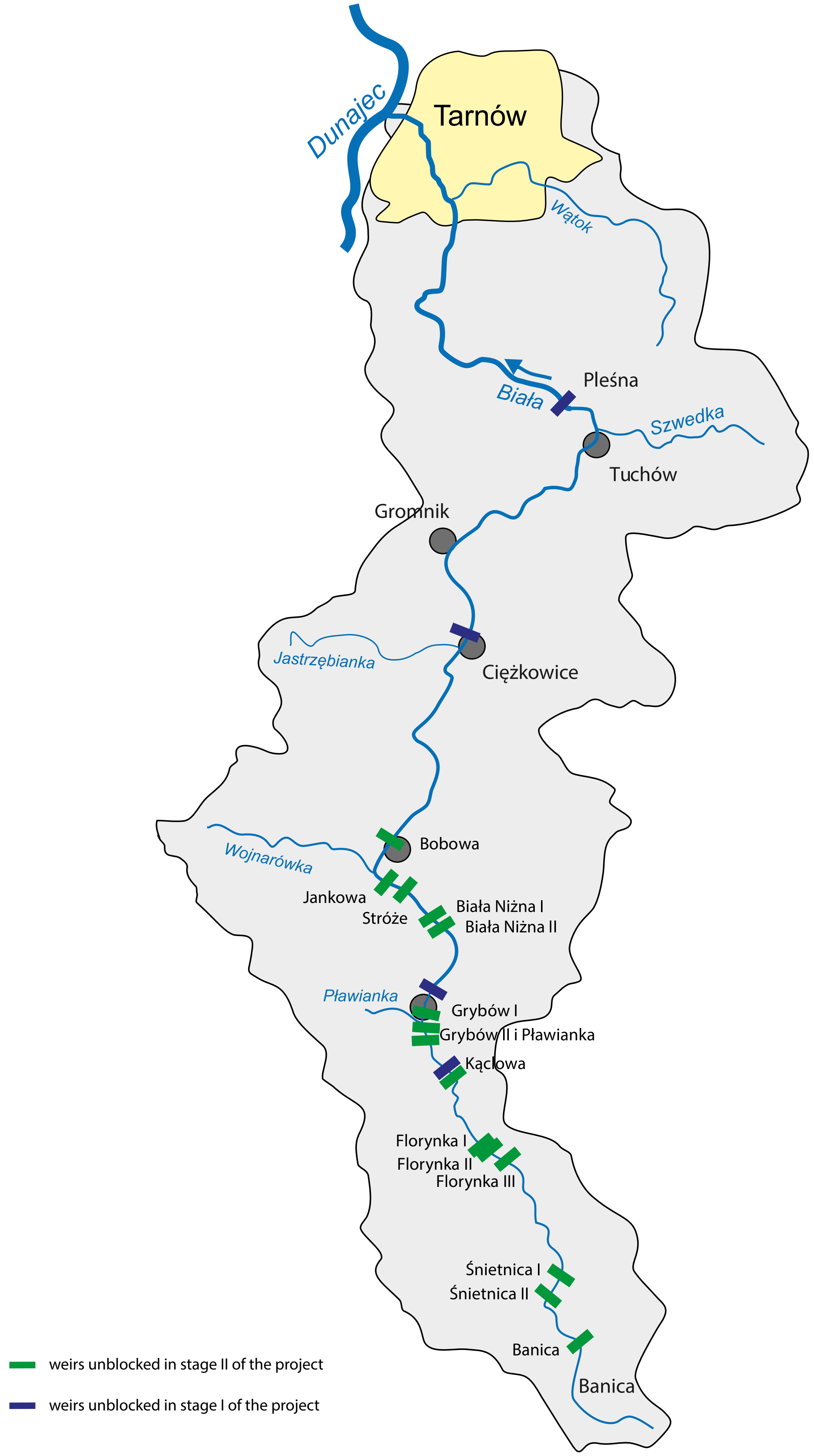


Fig. 15. Location of fish ladders built during the 1st and 2nd stage of the Biała river restoration.

1

BOBOWA
(58.700 km)

Fig. 16. The weir and the bridge before modernisation.

The barrage was built in the 1950s (Fig. 16). The purpose of the barrage was to protect a three-span bridge and to create an accumulation of water for drinking purposes in Bobowa village. Before modernisation, the height of the dam from the river surface to its crest was about 0.9–1.0 m. Below it, there was a stilling basin to dissipate the energy of the flowing water. Before the reconstruction, the light of the bridge under the two spans was blocked by a thick layer of sediment deposited over decades. As part of the modernisation of the dam, these sediments were removed, thus increasing the free passage of floodwater. The damming weir itself was rebuilt. The damming height was lowered, and triangular cut-outs for low water were added. The pool between the sills was fitted with boulders and wooden beams to provide temporary shelter for the fish (Figs. 17 and 20). Above the weir and bridge, a new fish ramp in the form of a honeycomb was built (Figs. 18, 19, 21, 22). More than 600 stones with a total weight of about 3,300 tonnes were used in the construction, with individual weights of up to 12 tonnes.

Fig. 17. Boulders and logs as microhabitats for fish.

Fig. 18. Riffle in the shape of a honeycomb.

Fig. 19. The weir after reconstruction and new fish ladder.

Fig. 20. The weir after reconstruction.

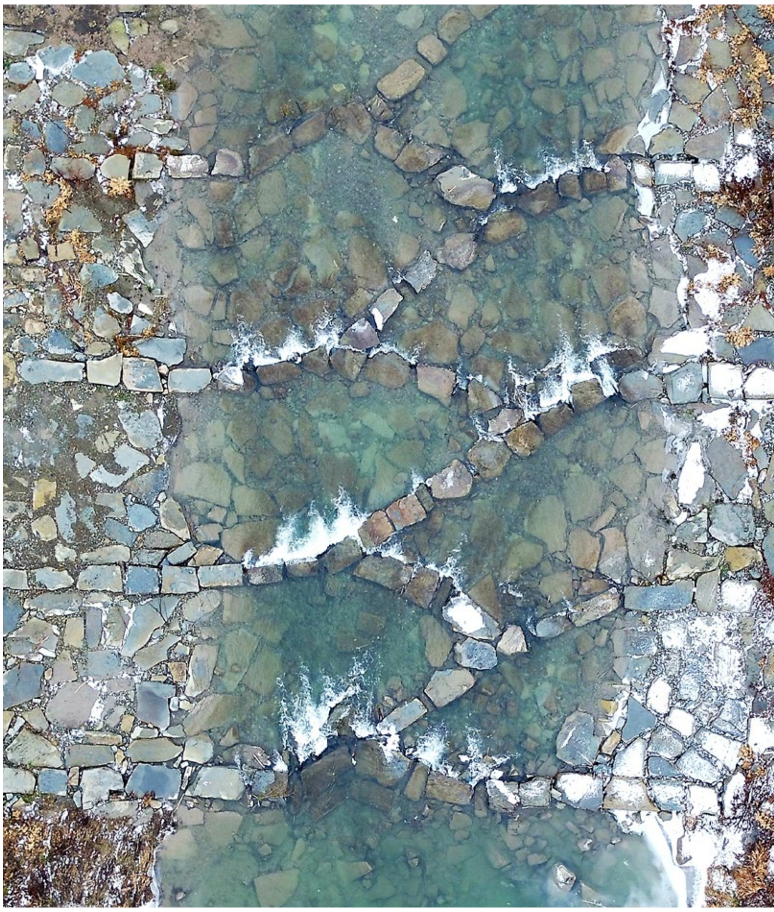


Fig. 21. Riffle in the shape of a honeycomb.

Fig. 22. The weir after reconstruction and new fish ladder close to nature.

2

JANKOWA
(61.160 km)

The weir was built to protect the multi-span bridge (Fig. 23). Above the bridge, a groyne was also built to divert the river under the bridge. However, the river went around this sill from the right side, and the sill was rendered useless. The bridge itself posed a flood risk because the side spans were blocked by deposited material, vegetation and overhanging vegetation. In 2019, it was demolished and replaced with a new single-span bridge. As part of the upgrade of the weir below the bridge, a honeycomb fish ladder was built. At the same time, the deposited sediments that narrowed the riverbed and impeded the flow of high water were removed (Figs. 24 and 25).

Fig. 23. View of the weir before modernization

Fig. 24: View of new bridge, fishway and area with sediment removed on the right bank.

Fig. 25. Weir after reconstruction.

The old weir in the form of a cascade of four dams dammed up the water for the town's water supply. Later, the construction of a small hydroelectric power plant was started but never completed. During the flood in 2010, the weir was heavily damaged (Fig. 26). As part of the modernisation of the weir, the power plant was demolished and the sill dismantled. The damming height was lowered by about 1 m. A new water intake was constructed in the form of a drainage intake from under the riverbed. The sill was replaced by a honeycomb fishway (Figs. 27 and 30). In addition, an observation room, equipped with a glass window, a fish counter and a visible light and infrared camera to record a short video of each fish passage, was built at the bank to monitor fish migration (Figs. 28 and 29). In order to force the migrating fish to enter the counter chamber, a raised grating was installed across the river (in the bottom).

STRÓŻE
(69.105 km)

Fig. 26. The weir before reconstruction.

Fig. 27. View of the fish ladder.

Fig. 28. Installing a scanner in the monitoring building.

Fig. 29. The screen of migratory fish recorder.

Fig. 30. The fish ladder after reconstruction of the weir.

BIAŁA NIŻNA I
(70.200 km)

In Biała Niżna, there was a concrete dam with a stilling basin, whose drop of 1.3 m constituted a migration barrier (Fig. 31). Due to its poor technical condition, the structure was not functional. As part of the modernisation, a solution was adopted consisting in the partial elimination of the weir. The upper part was removed, and the basin was filled with gravel. Three stone bottom gourds in the form of arches were added to protect the channel against excessive erosion, as well as stone ripraps on the banks (Fig. 32).

Fig. 31. The weir before decommissioning.

Fig. 32. Weir after decommissioning and rebuilding.

5

BIAŁA NIŻNA II
(70.887 km)

A concrete damming weir with a stilling basin was constructed in Biała Niżna to prevent channel incision (downcutting) (Fig. 33). The damming-up height was 1.2 m. The stilling basin was replaced by a fish ladder as part of the upgrade. Three concrete baffles with alternating triangular cuts were built across the basin. The whole stage was supported by a stone girder (Figs. 34 and 35).

Fig. 33. Weir before modernization.

Fig. 34. Fish pass in stilling basin.

Fig. 35. Weir after modernization.

At the beginning of the 20th century, the railway and road bridges located in the centre of Grybów were secured (Fig. 36). These were concrete weirs to slow down the water flow and concrete boulevards supporting the banks for a length of 300 m. Part of these concrete weirs below the road bridge were converted into a fish ladder during the first stage of the project in 2013. The remaining part of the protection, a cascade of six weirs stabilising the channel under the railway bridge (72.050 km), was rebuilt during

GRYBÓW I
(72.050 km)

the second stage of the project. The old concrete bank reinforcement was left in place, the weirs were removed and a close-to-nature fishway in the form of a honeycomb was constructed in their place (Figs. 37, 38, 39, 40).

Fig. 36. The weir cascade before reconstruction. View upstream.

Fig. 37. Reinforcement of the left bank and mouth section of the tributary before the bridge.

Fig. 38. Close-to-nature fishway in the form of a honeycomb.

Fig. 39. Lower part of the fish ladder.

Fig. 40. General view of the fishway.

Many years ago, a cascade of weirs was built here to secure the road bridge (Fig. 41). Above, the left-bank tributary of the Pławianka stream flows into the Biała. This stream, in its lower course, was regulated in the form of a concrete culvert. As part of the modernisation, the cascade of weirs on the Biała and the mouth section of the Pławianka were rebuilt. Some of the concrete weirs were removed, cut-outs for low water were made and a close-to-nature honeycomb fish ladder was added below (Figs. 42 and 44). The

GRYBÓW II AND MOUTH OF THE PŁAWIANKA RIVER
(72.750 km and 72.890 km)

concrete-liner at the mouth of the Pławianka River was dismantled, and boulders were installed between concrete bank reinforcements, creating a meandering channel with a natural gravel bottom (Fig. 43).

Fig. 41. Weir before reconstruction (visible mouth of the Pławianka River).

Fig. 42. Close-to-nature fishway after weir reconstruction.

Fig. 43. The mouth of the Pławianka stream after reconstruction.

Fig. 44. View of the fish ladder and mouth of the Pławianka River after reconstruction.

KĄCLOWA
(79.013 km)

8

At this location, there was an old, dilapidated weir that no longer served any function (Fig. 45). As part of the redevelopment in Phase I of the project, the weir was demolished. Within a few years, the river returned to its natural gradient at this location with a small rapid and a riffle below (Fig. 46). As part of Phase II, a stone rapid was added here, and the left bank with a landslide was reinforced by a stone embankment (Fig. 47).

Fig. 45. Weir before decommissioning.

Fig. 46. View of the renaturalised river after the removal of the weir.

Fig. 47. View of the added stone girder.

9

FLORYNKA I and II

(82.200 km and 82.422 km)

Both structures are located close to each other at a distance of 224 m. The upper weir (Florynka II), with a height of 1.75 m, was built in the middle of the 20th century by a private investor in order to dam up water for a planned hydroelectric power plant or a sawmill. It was a classic anti-rubble dam. This purpose was never realised (Fig. 48). The task of the lower stage (Florynka I), with a height from the bottom of 1.25 m, was to support the anti-rubble dam (Fig. 49). The technical condition of both weirs was very poor, and these low-head dams constituted an impassable barrier for fish. As part of the modernisation, the rebuilding of both weirs was planned so that fish migration would be possible while maintaining the damming ordinate. At the Florynka I, the whole weir was left together with the stilling basin. The upper weir crest was lowered, and a close-to-nature honeycomb fish ladder was built on the downstream side (Figs. 50 and 52). In the upper weir (Florynka II), the stilling basin was eliminated, and on the downstream side, a close-to- nature honeycomb fishway was added (Figs. 51 and 52). Above the weir crest three gourds were constructed to protect the ford.

Fig. 48. The Florynka II weir before reconstruction.

Fig. 49. The Florynka I weir before reconstruction.

Fig. 50. The Florynka I weir after reconstruction.

Fig. 51. The Florynka II weir after reconstruction.

Fig. 52. View of both fish ladders after rebuilding of the weirs.

10

FLORYNKA III
(84.004 km)

In 2000, the construction of a small hydroelectric power station was started in this section. Construction was completed in 2009. The power station operated until 2010, when a flood flooded the turbine and generator room, and was not rebuilt. The river bypassed the damming weir and over time practically cover with gravel the spillway of the weir (Figs. 53 and 54). The right bank at the step was washed away by flood waters. As part of the reconstruction, the weir was removed, and six rows of boulders were inserted into the bottom of the riverbed. The right bank was reinforced with a stone embankment (Figs. 55 and 56).

Fig. 53. Damming weir for a small hydropower plant before flooding in 2010.

Fig. 54. The concrete left behind acted as a deflector and the river washed out the right bank.

Fig. 55. A view of the stone shafts and bank reinforcement after a flood. The constructed stone shafts were backfilled with gravel.

Fig. 56. Biała River after the weir's decommissioning.

ŚNIETNICA I
(92.680 km)

The retrofitted reinforcement of the bed of the channel under the bridge was made to protect this new single-span bridge. The concrete-and-stone reinforcement resulted in a small waterfall that no fish could traverse (Fig. 57). The decision was made to leave this reinforcement in place and use the difference in height to build a fish ladder. A 2-m-wide and 0.8-m-deep trench was cut in the old bottom reinforcement under the bridge, and several stone deflectors were installed. This resulted in a micro-mandrel effect (Fig. 58). After one year of operation, the river backfilled these micromanders with gravel. A fan-shaped fish ladder was constructed below. Each of these fans has a cut-out for small water (Figs. 59 and 60).

Fig. 57. View of the waterfall from the bottom reinforcement under the bridge.

Fig. 58. Micromeander in cutting out reinforcement partially backfilled with gravel.

Fig. 59. View of the fish ladder.

Fig. 60. General view of the fish ladder after construction.

Similar to the bridge at Śnietnica I, the upgraded concrete riverbed reinforcement was made to protect the road bridge (Fig. 61). A cut was made in the bottom reinforcement under the bridge, into which stones were inserted to form several small meanders (Fig. 62). A fish ladder with several pools was added below (Figs. 63 and 64). After a year of operation, the cut in the reinforcement under the bridge was slightly backfilled with gravel. The lack of gravel in this section of river causes severe erosion. For this reason, the last elements of the fish ladder were washed out after the floods. The problem was solved by adding additional concrete and stone shafts to stabilise the riverbed at the necessary height.

ŚNIETNICA II
(94.190 km)

12

Fig. 61. A waterfall under the bottom reinforcement under the road bridge.

Fig. 62. Micromeanders cut in the bottom reinforcement under the bridge.

Fig. 63. View of the Śnietnica II fish pass after the completion of construction.

Fig. 64. General view of the fishway after construction.

The modernized facility was built to protect the bridge. The bridge designer reinforced the riverbed with concrete. As a result, after many years, the end of this bottom reinforcement acted as a weir under which the river eroded its own stilling basin (Fig. 65). The same solution was applied as in the case of the bridges in Śnietnica (Fig. 67). Contrary to the fish passes in Śnietnica, the shape of the fish pass basins was changed to a fan arrangement (Figs. 66 and 68). Each fan has a recess that allows the fish to pass through at low flows.

BANICA
(95.850 km)

13

Fig. 65. View of the Banica reinforced river bottom before reconstruction. Visible concrete strengthening of the bottom under the bridge.

Fig. 66. The fishway after construction.

Fig. 67. Micromeanders cut in the bottom reinforcement under the bridge.

Fig. 68. General view of the fish ladder after construction.

Fish migration monitoring

In order to assess whether the installed fish ladders are effective, i.e. if fish can pass over them, migration monitoring was carried out. Apart from biological monitoring, hydraulic monitoring was also carried out to determine whether the technical parameters of the fish ladders—water flow speeds in the gaps—were adequate.

Biological monitoring methods

Different methods have been used to study fish migration through fish ramps, and these have been selected according to site conditions. Not every method can be used at every site; most often, the size of the river determines the method of surveillance.

Radio telemetry transmitters

Fish were implanted with radio transmitters transmitting a unique signal, and then the tagged fish were located using directional antennas (Fig. 69). Sixty fish were tagged in this way.

RFID telemetry tags

The method involved tagging fish with telemetric RFID passive tags (Fig. 70) , allowing identification of the fish (tag) passing through a recording gate.

Riverwatcher scanner

The VAKI Riverwatcher scanner was installed in a purpose-built building at the fish ladder in Stróże. The building has a window with glass to allow visual inspection of the fish (Fig. 72). Fish are guided to the scanner by grids mounted across the river and lifted from the riverbed during the survey period. After the observation period, the grids are laid on the bottom. Software allows remote access to the scanner. A description of the scanner operation is given below.

Fish traps

Fish traps with a 10-mm net mesh and dimensions of 80 x 40 cm were placed in the river (Fig. 73). The size of the traps made it possible to catch even small fish such as minnows. The traps were checked once a day.

Biological monitoring results

Below is a description of the fish migration survey and results for each of the completed fish ramps. The photos (Figs. 78, 79, 80, 81, 82, 83) show the occurring species of fish.

Bobowa

For this fish ladder, the radio telemetry method was applied. Ten out of 31 tagged fish migrated upstream through the constructed fish ladder.

Jankowa

In Jankowa, two methods of migration survey were applied: radio telemetry and fish traps. Ten out of 29 tagged and released nases (*Chondrostoma nasus*) and chubs (*Squalius*

Fig. 69. Directional antenna for locating fish.

The method of tagging fish with implants is invasive. For this reason, great importance was attached to safety during performance—sterility of tools and painlessness of the "procedure". Each wound was sutured, protected with special tissue glue, and disinfected. Fish were temporarily put to sleep for the duration of the procedure (Fig. 71).

Fig. 70. Telemetry transmitters.

Fig. 71. Transmitter implantation.

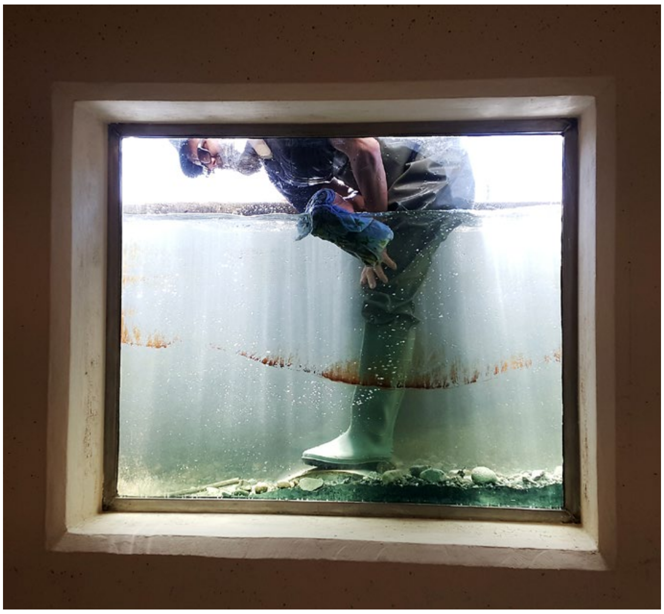


Fig. 72. Cleaning the glass in the monitoring building in Stróże .

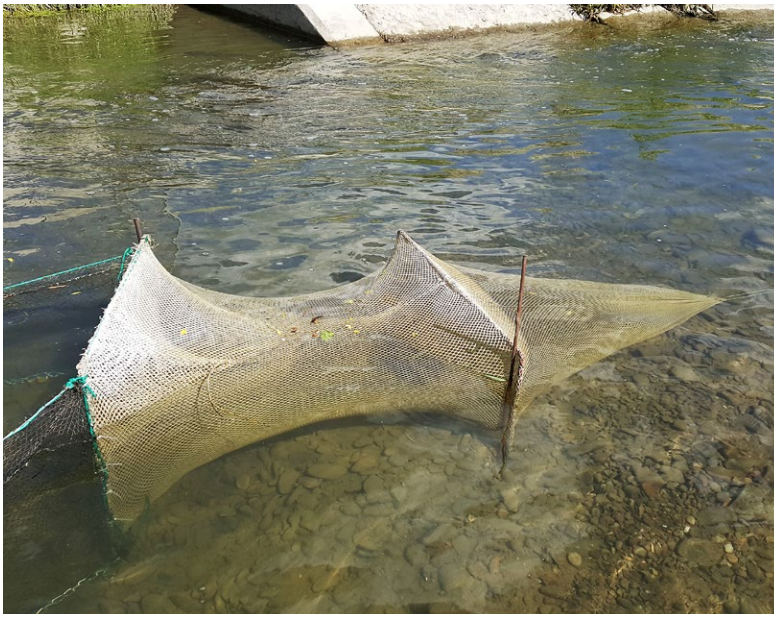


Fig. 73. Fish trap.

cephalus) below the fishway swam through the riffle. In addition, three fish released below the Bobowa fishway also passed the Jankowa fishway. In the net trap installed upstream of the fish ladder, 14 fish crossed the fishway during one day of observation. These were barbel, chub, gudgeon and spirlin, ranging in size from 6 cm to 22 cm.

Stróże

The scanner installed in the building by the fish ladder in Stróże worked for 29 days. During this time it recorded 313 fish passes upstream and 472 fish passes downstream of the fish ladder (Fig. 74). The results from the scanner require individual tracing of each record and correction of erroneous results.
It appeared that the VAKI system was being misled by fish that were hunting in the scanner. Several attacks by the same brown trout on small minnows were observed. Each time the brown trout backed away, but the scanner recorded this as passing through the fishway. Also, a brown trout swimming downstream but facing head-on upstream was counted as a fish that had passed upstream. Drifting debris was also counted as a passage. Disturbed signals and correct fish silhouettes are shown in the photographs below (Figs. 75, 76, 77).

Fig. 75. View of correct fish registration.

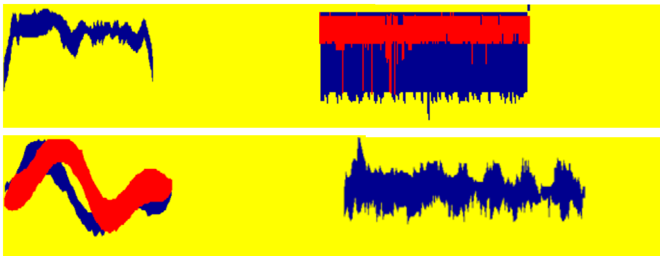


Fig. 76. View of registration of several disturbances.

Fig. 77. Example of a fish migrating through a scanner.

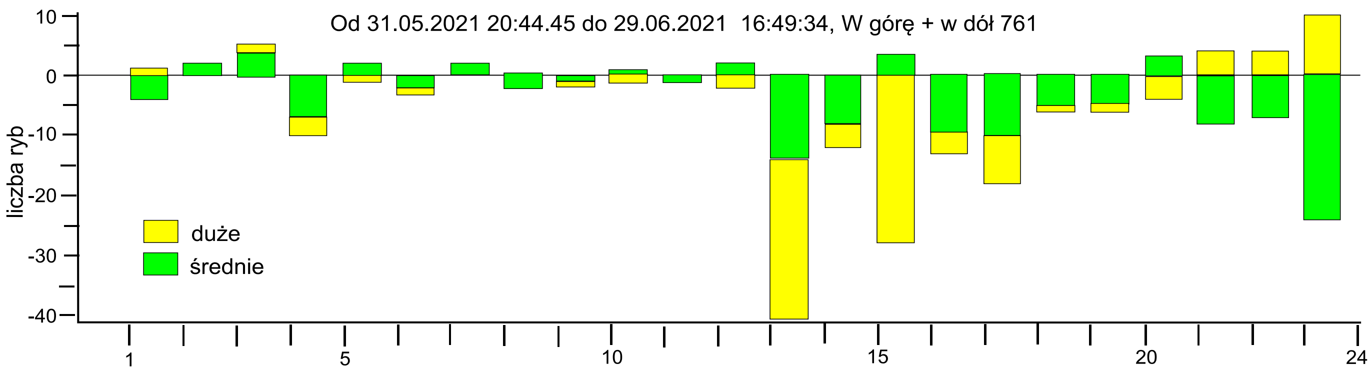


Fig. 74. Example of ‹raw› daily migration recording by medium and big fish (scanner in Stróże).

Fig. 78. Stone loach (Barbatula barbatula).

Fig. 79. Gudgeon (Gobio gobio).

Fig. 80. Spirlin (Alburnoides bipunctatus).

Fig. 81. Carpathian barbel (Barbus carpathicus).

Fig. 82. Chub (Squalius cephalus).

Fig. 83. Brown trout (Salmo trutta m. fario).

Fig 84. Alpine bullhead (Cottus poecilopus).

It is interesting to note that during the field research, the occurrence of alpine bullhead was recorded in Biała (Fig. 84). A few fish of this species were caught above the Izby village, i.e., at quite high altitude (ca. 585-665 m above sea level).

Biała Niżna I

Monitoring of fish migration through the fishway was carried out using two methods: passive tags and trap nets. Both methods showed that fish migration upstream through the fishway is possible. Greater success was definitely observed in the fish trap monitoring results. A total of 198 fish of the following species: gudgeon, barbel, spirlin and chub, ranging in size from 4 to 12 cm, were caught in this way over 3 days. Passive tags were used to mark 30 fish. Reading with recording antennas showed that on 4 incomplete days four barbel crossed the fishway. Two passed the fishway within the first 24 hours and another within 2 days of release.

Biała Niżna II

Fish traps were used to monitor this fishway and all others described below. The traps were set twice for 3 days. The first time, 17 fish of the following species were caught: Carpathian barbel (12 cm) and spirlin (7–8 cm), while in the second instance 7 carpatian barbels of 6–8 cm and one of 18 cm and 1 chub of 7 cm total length were caught.

Grybów I

During the first exposure of the fish traps, no single migrating fish was caught for 6 days. Only the next attempt brought results: for two days 18 fish (8–9 cm) of the following species were caught: Carpathian barbel, spirlin and chub and two barbs of total length 18 cm.

Grybów II

The first exposure of the fish trap did not bring any results. During the next 2 days, the pass was defeated by four fish 8–9 cm in size (chubs and barbs) and one Carpathian barbel with a total length of 14 cm.

Kąclowa

During the two-day exposure of net fish traps, the fish pass was defeated by 18 small (6–12 cm) fish: Carpathian barbels, chubs and brown trout.

Florynka I

The fish trap was installed for a period of 4 days and a total of four spirlins (5–9 cm), four barbs (8–10 cm) and one larger (18 cm) fish were caught.

Florynka II

During the exposure of the trap, which lasted 5 days, the fish pass was defeated by 10 fish: spirlins 7–10 cm long, barbs (10–16 cm) and chub (13 cm).

Florynka III

At this site, during 5 days of trap exposure, the following were caught: four barbs (8–12 cm), one chub (6 cm) and one brown trout (13 cm).

Śnietnica I

The trap was installed for more than 3 days, and during this time, fish of the following species were recorded migrating up the river: barb (9–14 cm), trout (8–12 cm) and minnow (5–8 cm).

Śnietnica II

During trap exposure, which lasted more than 3 days, a total of seven fish migrating upstream of the following species were noted: barb (10–14 cm), trout (12–14 cm) and stone loach (11 cm).

Banica

During trap exposure lasting more than 3 days, a total of four brown trout (12–17 cm) migrating upstream were recorded.

Summing up, migration studies confirmed that all fish ladders allow the migration of fish found in Biała River.

Hydraulic monitoring

Hydraulic monitoring consisted of measuring the velocity of water flow in each gap of each fish ladder. Water velocity is a key technical parameter on which depends the possibility of fish passage upstream. The energy dissipation of the water in the fish ladder basins and the turbulent kinetic energy was also measured. The result of such measurement informs the biologist of whether the design criteria have been met. It is assumed that all fish species living in the river should pass the fishway. The swimming abilities of fish vary. Therefore, the maximum water velocity in the fish ladder should not exceed 2 m/s for salmonids (salmon, brown trout, huchen (Hucho hucho), grayling), 1.5 m s^{-1} for cyprinids (asp, vimba, barbel, ide, chub, nase) and 1 m s^{-1} for all other species (including small and juvenile fish). Therefore if the fishway is to be non-selective, the water velocity at the bottom should be approximately 1 m s^{-1}. An intermediate value of 1.4 m s^{-1} was used as a criterion for the correctness of the slots.

Flow velocities were measured at all of the gaps of each fishway (Figs. 85 and 86). Two criteria were adopted: mean and maximum velocity. Mean velocity was calculated as the so-called "weighted mean", i.e. geometric mean. Measurements were made for the flows in the range NTQ – SSQ (the longest lasting flow and the average flow from many years) in 2 measurement series. Measurements of hydrometric vertical profiles in the slots were made at the following relative depths: bottom velocity, 20%, 40%, 60%, 80% distance from the bottom. For small fills, below 10 cm, measurements were made at a distance of 40% from the bottom. With larger fills, the number of measurements was increased according to the scheme above. In the case of pools with a filling level of 0-20 cm, measurements were taken at a distance of 40% from the bottom; in the case of depths of 20-50 cm, three measurements were taken at a distance of 20%, 40% and 80% of the filling level; in the case of deeper pools, measurements were taken additionally at a distance of 0-10 cm.

An example hydrometric profile is shown in Fig. 87. The calculated mean value of the velocity in one of the measurements at the Bobowa site is vmean = 0.19 m s^{-1}, and the filling is h = 0.54 m and flow Q=1.547 m^3s^{-1}.

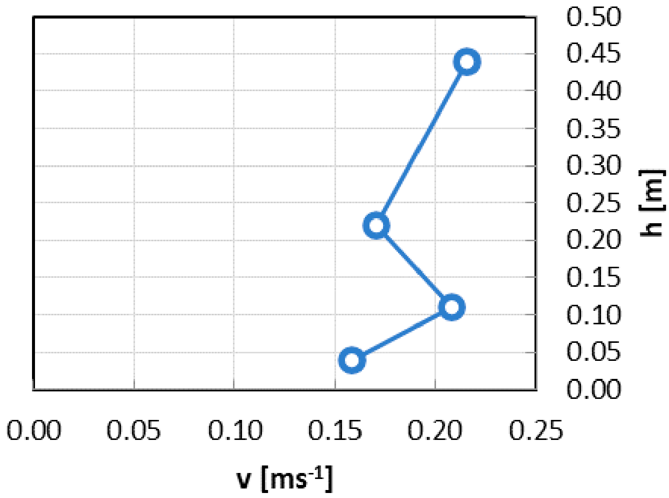


Fig. 87. Example of velocity profile in one of the slots in the Bobowa fish ladder.

Turbulent kinetic energy (TKE) was also measured in the pools. TKE is the average kinetic energy per unit mass of fluid with respect to turbulent flow structures. Physically, turbulent kinetic energy is characterized by the standard deviation of the velocity fluctuations and it is determined according to the formula:

$$TKE = 0{,}5\,(\overline{v_X'^2} + \overline{v_Y'^2} + \overline{v_Z'^2})$$

Where:

TKE – turbulence kinetic energy [$m^2 \cdot s^{-2}$]

v – denotes the instantaneous velocity components [m s^{-1}]: v'_x – in the current direction, v'_y – transverse to the current and v'_z – in the vertical direction.

Instantaneous velocities were measured using the Flow Tracker 2 probe (acoustic single-point Doppler velocity meter), which allows measurement of three velocity components at high frequency. TKE was calculated for 197 pools in the first measurement series and 223 pools in the second series. The volumetric dissipation of water energy in the pools was also calculated.

Fig. 85. Hydrometric measurements with the Flow Tracker 2 probe.

Fig. 86. Hydrometric measurements.

Results of hydraulic monitoring

The fishway was considered unobstructed if the migration route was determined in both measurement series. The Biała Niżna I fishway meets the criteria of maximum velocity in each of its slots vmax < 1.4 m s^{-1}. In the case of the following fishways: Florynka III, Grybów I, Biała Niżna I, Bobowa (the baffle part) and Śnietnica I, Kąclowa, Pławianka – the maximum velocity criteria was not met in all of the slots. The Banica, Śnietnica II, Florynka II, Florynka I, Grybów II, Stróże and Jankowa gates at gauged flows do not meet the maximum velocity criteria in most of the gaps.

In the case of the fish ladders at Jankowa, Grybow II, Florynka I and Śnietnica I, there is a limitation in the operation of the fish ladders due to them having exceeded the critical value of the turbulent kinetic energy of water flow (TKE).

In the first series of TKE measurements, in 154 cases, the value of TKE is within the range of 0-500 cm^{2}s^{-2}, and in 43 cases, it exceeds this value, which constitutes 21.8% of all measured basins. In the second series of measurements, the TKE value in 185 cases falls within the value range of 0-500 cm^{2}s^{-2} and in 38 cases exceeds 500 cm^{2}s^{-2}, representing 17.0% of all measured pools. Comparatively, at the Skawa River rapids, the TKE value is about 600 cm^{2}s^{-2} and in the current it is below 200 0 cm^{2}s^{-2}. Similar studies yielded results for the pool, current and rapids with mean values of 40.3, 104.8 and 421.4 cm^{2}s^{-2}, respectively.

Having obtained data on fish passage velocities, we proceeded to determine possible fish migration routes for the criteria of average and maximum velocity.

Figures 88 and 89 show the migration routes according to the criteria of mean velocity in the 1st and 2nd measurement series at the Bobowa fish ladder (the upper part of the fish ladder above the bridge). The green colour indicates the location of hydrometric profiles where mean velocity was lower than the critical value vmax <1.4 m s^{-1}, and the red colour indicates vmax >1.4 m s^{-1}. The situation for the maximum velocity criteria in the 1st and 2nd second measurement series is presented in Figures 90 and 91.

Measurements of flow velocity and transit depth at low flows indicate that small fish may periodically have difficulty in passing the fish ladders. However, at other times, this is not the case and they are able to pass them, as demonstrated by fish migration monitoring.

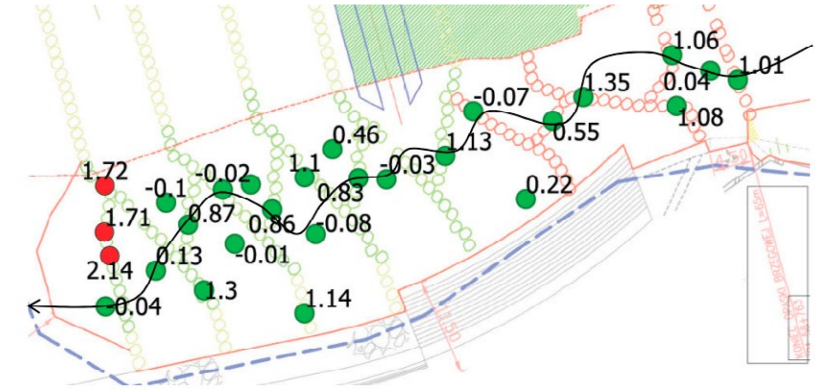


Fig. 88. Migration route for measurement series 1 at Bobowa fish ladder according to average velocity criterion v_{mean}.

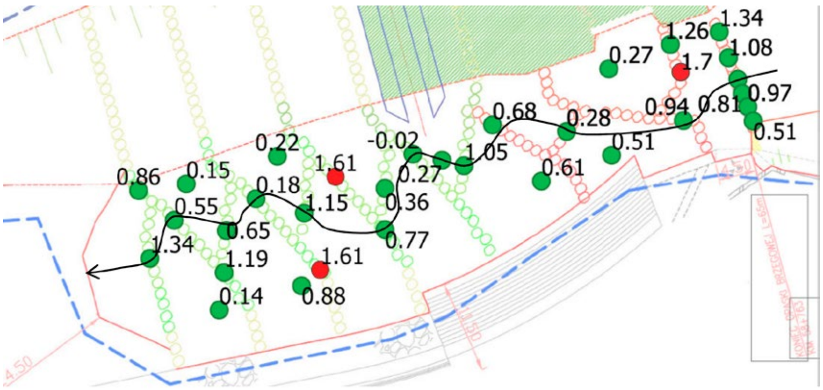


Fig.89. Migration route for measurement series 2 at Bobowa fish ladder according to average velocity criterion v_{mean}.

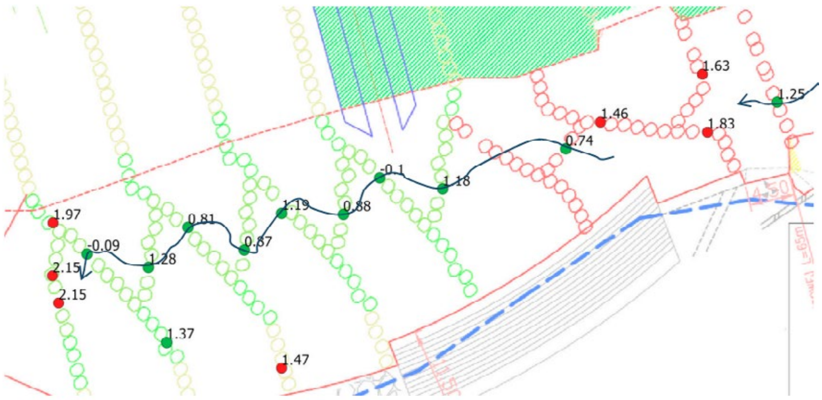


Fig. 90. Migration route for measurement series 1 at Bobowa fish ladder according to maximum velocity criterion v_{max}.

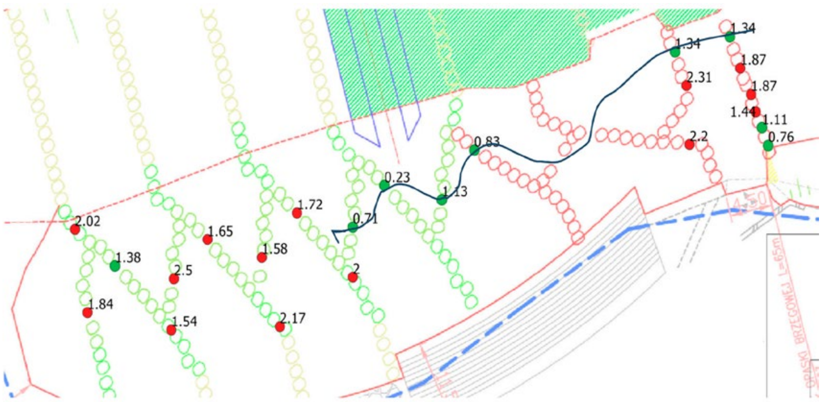


Fig. 91. Migration route for measurement series 2 at Bobowa fish ladder according to maximum velocity criterion v_{max}.

Site organisation

Any activity in the riverbed and riparian zone is detrimental to the river because it changes the conditions that the river has optimised over hundreds of years. The construction process itself is, to say the least, disruptive to the water and riparian habitat inhabitants. For this reason, as part of the construction supervision, care was taken to ensure that the construction work was carried out properly and that the conditions laid down in the environmental decision were adhered to.

Construction site

For setting up equipment and the construction office, contractors always chose environmentally neutral sites, which are already heavily degraded (Fig. 92). Upon completion of the work, these sites were cleaned up. The timing of hydrotechnical work had to be adapted to the requirements of the river inhabitants. During periods of fish spawning, work in the riverbed was banned, and outside these periods, prolonged muddying of the water was prohibited. At other times, various safeguards were used to prevent water turbidity, but this could not always be avoided. The basic way to avoid water turbidity was to surround the work site with a gravel and sand fence (Fig. 93). Another was to use straw bales to filter the turbid water (Fig. 94). According to the situation, contractors were provided with plans of action (Fig. 95).

Technical details

Rocks weighing up to 12 tonnes and averaging between 4 and 8 tonnes were used to construct the fish ladders. The accuracy of their placement was 5 cm. This required a high level of skill and cooperation between people and equipment (Fig. 96).

Fig. 92. Example of construction site organisation (Jankowa).

Fig. 93. Fencing the worksite with a gravel and sand fence (Jankowa). Work is carried out 'dry'.

Fig. 94. Rolled straw (rolon) filtering turbid water.

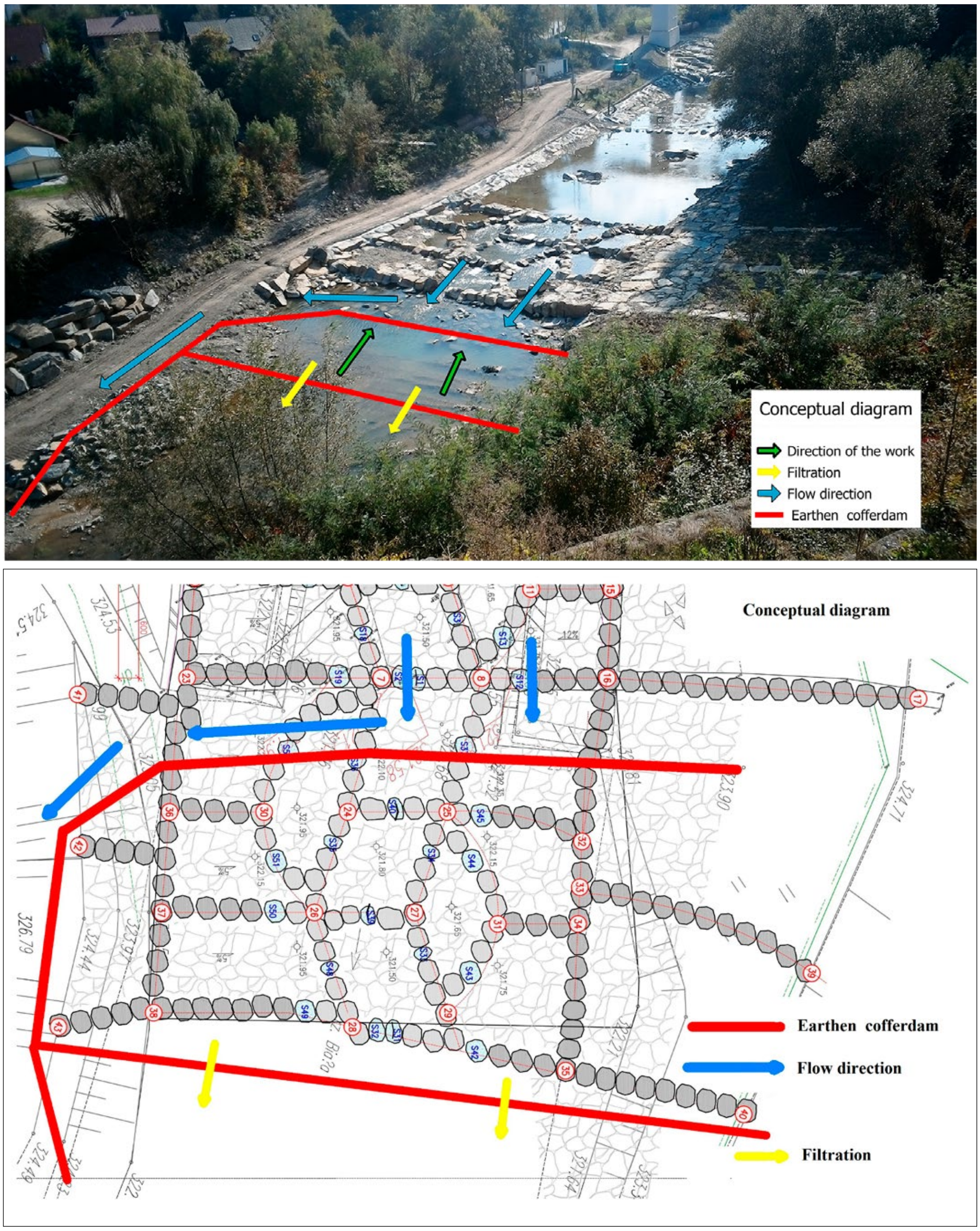


Fig. 95. Scheme of cofferdam construction in a specific situation (Grybów).

Fig. 96. Placement of rocks at the fish ladder in Grybow.

Other threats to fish and aquatic organisms

Natural migration barriers on the Biała River

There are other migration barriers in the upper reaches of the river, above the Izby village. These include two fords supported by cascades and one waterfall formed by contemporary plunging erosion. This process is rapidly accelerated by human activity in the middle reaches of the river. Gravel is a valuable building material. Therefore, the local population often uses these resources, sometimes exploiting them. Often for this reason, rock outcrops of the subsoil are exposed in the channels. Strong erosion led to the formation of waterfalls, which blocked the possibility of fish migration along the riverbed.

Dams built by beavers are also natural migration barriers. However, these are periodic: beavers abandon them after a few years of use, and larger river surges eventually destroy them, restoring river continuity (Figs. 97 and 98).

Fig. 97. Beaver dam on the Biała river at Śnietnica.

Fig. 98. The same dam after a flood event.

Alien species

The valley of the Biała is in places overrun by strong populations of invasive plants. More or less from the Śnietnica river downstream the Sosnowski hogweed (*Heracleum sosnowskyi*) is abundant (Fig. 99). Locally, on ruderal sites, large patches of *Reynoutria japonica* (Fig. 100), *Impatiens glandulifera*, *Echinocystis lobata* and goldenrod (*Solidago sp.*) can be found. The goldenrods are particularly expansive. They grow to over 2 m in height, strongly shade the ground and prevent the growth of other native species. There are two species—giant goldenrod (*Solidago gigantea*) and Canada goldenrod (*Solidago canadensis*).

Fig. 99. Sosnowski hogweed site at Śnietnica.

Fig. 100. Knotweed in Bobowa.

Recreational use of fish ladders

Rural and urban dwellers are very keen to use the fish ladders for recreational purposes. The stones of the fish ladder are a comfortable place for sunbathing or camping (Figs. 101, 102, 103), and the resting pools for fish are a great place for bathing. However, sometimes this use raises problems. If the water is too shallow, residents block the gaps or add their own dam (Figs. 104 and 105).

Fig. 101. The fish ladder in Grybów (Grybów II).

Fig. 102. The fish pas at Banica.

Fig. 103. The fish ladder in Stróże.

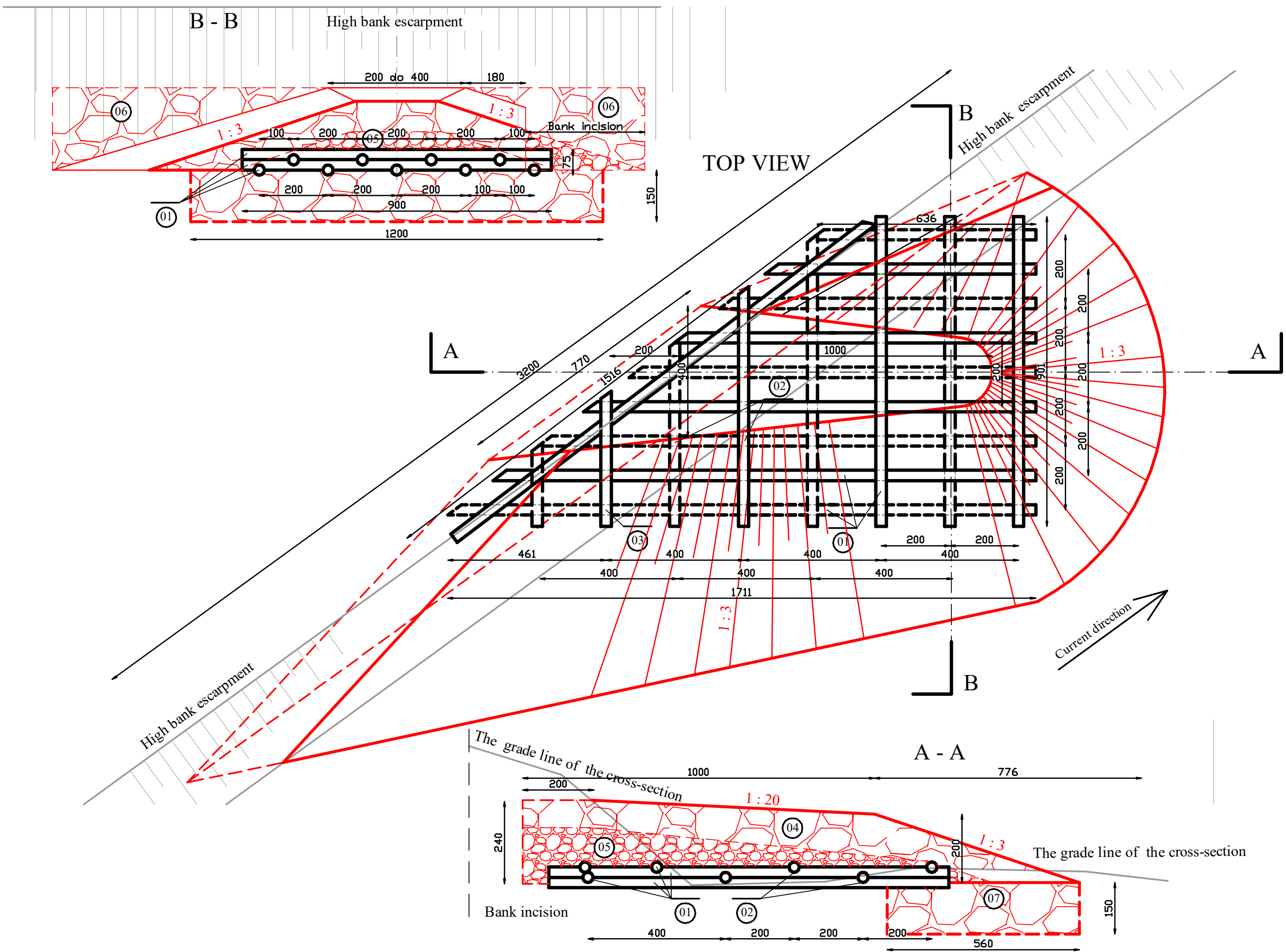
Fig. 104. Blocked slot at Banica fish pass.

Fig. 105. Raising of the damming level at the Biała Niżna II fish ladder.

Stream Channel Migration Zones

The area within which a river channel is likely to move over a period of time is often referred to as the channel migration zone.

The Biała River in its middle reaches has cut into the floodplain to a depth of about 5 m. There are two main reasons for this. The first is the exploitation of gravel in the upper course. This gravel was missing in the middle course, and the river regained it by eroding the bottom. The second reason was, and still is, the significant blockage of bottom sediment transport. Therefore, one way to supply the river with material is to allow the banks to erode. A straightened river will not do this on its own, so we need to initiate lateral erosion. The easiest way to do this is to install a so-called deflector at the bank, from which the river current will rebound and begin to erode the opposite bank. As there are important objects in various parts of the river valley—roads, tracks and houses—it is important not to let the river wash them away. As a preventive measure, special barriers, so-called 'dormant' protections, must therefore be installed in suitable locations. When the



Legend:

red colour refers to the stone structure, and black colour refers to timber crib construction.

01 – timber crib made of logs with a minimum diameter of 30 cm.

Total length of the beams approximately 175 m.

02 – centre lock for mutual joint reinforced with carpentry clamps.

03 – knotted lock with logs reinforced with carpentry clamps.

04 – outer layer of stone filler laid and wedged from billets of rock minimum weight 1800 kg. Cubic capacity of stone approx. 164.0m^3.

05 – internal layer with filling of the grate, min. stone bed of 30 cm.

Cubic capacity of stone approx. 134.0 m^3.

06 – stone surcharge laid and wedged on the bank slope from rock chunks weighing min. 1800 kg.

Cubic capacity of stone approx. 24.0 m^3.

07 – deflector head foundation of stacked and wedged stone from rock billets weighing a minimum of 1800 kg.

Cubic capacity of stone approx. 101.0 m^3.

Fig. 106. Project of timber crib deflector.

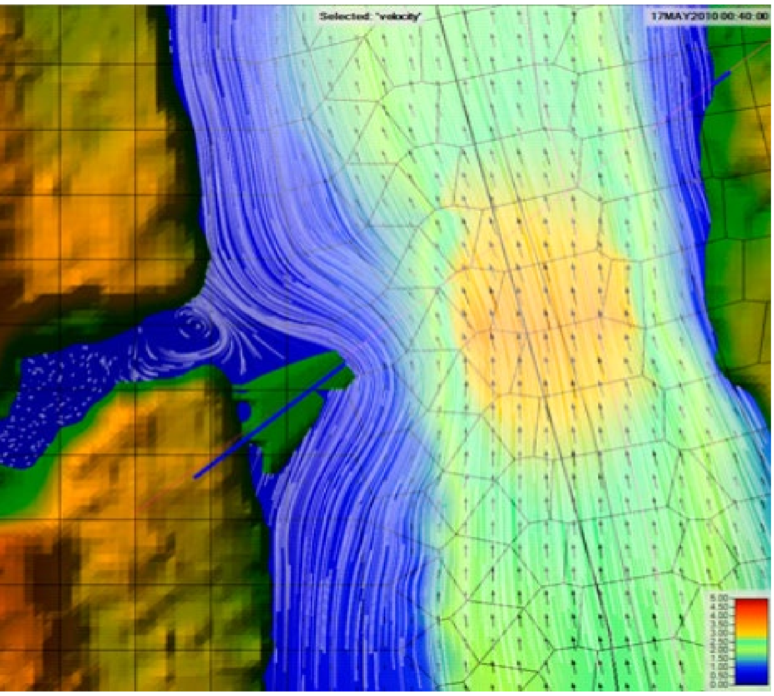


Fig. 107. Example of flow conditions with build-up for deflector No. 6.

riverbed reaches such protection, it will bounce back in the opposite direction. Unfortunately, we are not able to model this process accurately. We do not know the structure of eroded sediments, their properties and many other parameters. Therefore, the sites of the dormant reinforcements were selected using an expert method. The authors expect another positive effect: the riverbed will rise at the cost of material taken from the banks. The channel capacity will increase; the valley will absorb high waters faster and will act as a polder. The roughness of the flooded terrace will slow down the flow and give the water time to drain away safely. This will reduce the risk of flooding and increase safety downstream.

The area within which a river channel is likely to move over a period of time is often referred to as the channel migration zone. Channel migration zones are areas on floodplains where the channel of a stream or river will naturally move over time in response to gravity and topography.

The authors of the project found five such places in the upper and middle reaches of the river. These are sites in Kąclowa, Pławna and one each in Ciężkowice, Tursko and Bogoniowice. The principle was to minimise the number of deflectors and place them in precisely planned places and at right angles. Deflectors have the task of not only deregulating the river but also protecting critical places such as roads or farms. The dormant revetments are planned at distances of between 50 and more than 100 metres from the current bank. In addition, the construction of the revetments will not destroy patches of woodland. The structures themselves are made of natural material. They will be timber and stone cribs (Fig. 106). The areas for these investments have been purchased prior to its implementation.

Below is a description of the elements of the channel migration corridor in Kąclowa. The data are from the construction project by Piotr Radzicki (2020).

Fig. 108. Base for construction of deflector, stone rip-rap in the background.

Each deflector at the construction stage is individually adjusted to the bank slope and the riverbed. This is a necessary action, as the morphology of the riverbed system, both in cross-section and along the shoreline, changes after the passage of each flood wave.Deflectors of timber cribs construction are set at an angle of approximately 35 degrees to the shoreline.

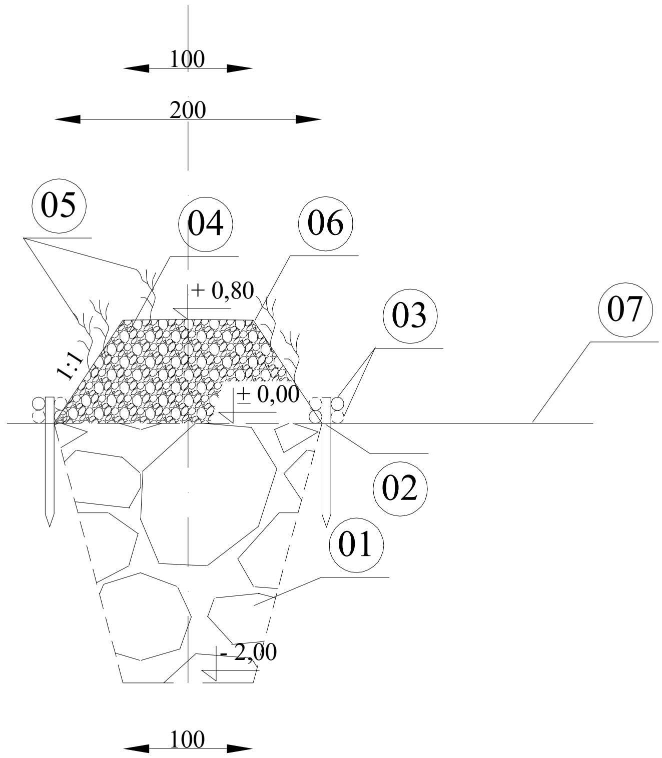
The deflector consists of:

- a three-layer cassette of wooden beams with a diameter of min. 30 cm (total height: 90 cm),
- beams on central locks connected to each other with a notch reinforced with a carpentry clamp,
- knotted locks connected to each other with log ends and also reinforced with a carpentry brace
- the filling is made of rip rap.

The stone filling that forms the deflector consists of two layers:

- a layer of filling inside of the deflector, made of stone filler with a minimum grain diameter of 30 cm,
- an external layer made as a stone filler of min. 80 cm of rock weighing min. 1800 kg laid and wedged with smaller boulders.

The timber for the construction of the crib must be impregnated by means of a long-lasting cold bath, with agents certified for use in an aquatic environment. Due to the morphology of the trough, two types of deflectors differing in crown length were designed with the following parameters:



Legend:

01 – Stone rip-rap of minimum size 1.0 × 0.9 × 0.8 laid and wedged with smaller stones F1 = 14.50 m^2.

02 – Wooden piles 80 cm long, diameter 5-6 cm under the fascine bush weaving, spaced at 60- cm intervals.

03 – Plotting a band of double fascine bush with a diameter of 10 cm.

04 – Filling in the trough with material obtained from the excavation F5 = 60 m^2.

05 – Seedlings at a spacing of 2 pcs/m^2.

06 – Humusage, 15 cm thick, sown with mixed grass F7 = 1.50 m^2.

07 – Existing ground.

Fig. 111. Cross-section of the dormant fortification on the floodplain .

- crown length 7 m (for type I) and 10 m (for type II),
- slope of the crown 1:20,
- variable width of the crown from 4 to 2 m,
- slope of deflector slopes 1:3.

Before the final placement of the deflector, the site and design were reviewed by the nature supervisor and verified by hydraulic modelling (Fig. 107).

Construction of the channel migration corridor started in Kąclowa from deflector no. 4 counting from upstream. The pictures show the stages of construction and the finished deflector (Fig. 108, 109, 110). The construction is cut into the bank and the riverbed.

Dormant revetments are planned for the floodplain at a distance of 50–150 m from the riverbed. Their function is to deflect the river current in the opposite direction in future. Some of these dikes will protect a railway line or a road. As these revetments are hidden deep in the alluvium of the valley and covered with soil, they are unnoticeable to the uninitiated person (Fig. 111).

Fig. 109. Construction of the deflector. Visible timber crib filled with stones.

Fig. 110. Finished deflector.

Information and Promotional Activities

An important element of the project was activities related to its promotion and informing local communities about investments carried out in their areas. This is particularly important as it is the first time such large-scale projects have been undertaken in Poland. The experience gained from their construction cannot be overestimated and should be used in other projects and other places in Poland.

As part of these activities, a project website was prepared, containing not only its description—objectives, tasks and investments—but also a lot of additional information and interesting facts, as well as educational materials. Efforts were made to prepare interesting texts on the subject of the project and short interviews with people involved in its implementation. More than 20 such texts were prepared (Fig. 112). A fan page was also maintained, on which a total of 172 posts were posted, including 14 videos. Several posts had the highest number of views – approximately 2,400. The number of people watching the page is 502, and those who liked it, 473.

As part of the promotion, a project information brochure was developed, a media release was sent out, followed by at least six publications in local media (including Facebook). The 2018 World Fish Walking Day celebrated in April was used to promote the project and its website in the media.

An attractive form of project promotion is the film 'History of one river – Biała Tarnowska' by Dr Piotr Topiński. The film, among other things, tells the history of the Biała Tarnowska valley, presents correct methods for managing water resources in the mountainous area and shows the basic assumptions and genesis of the project.

The project was promoted at international conferences. At the International Conference of the Brandenburg Academy in 'Schloss Criewen' entitled 'Flowing waters and their maintenance – between ecology and economics' in November 2018, a paper was presented entitled 'Environmental and economic benefits of comprehensive restoration of the Biała Tarnowska River'. In Turkey, it was presented at the 3rd cyclical conference related to the Black Sea region entitled 'Balancing Agriculture and Environment' organized by Gaziosmanpasa University in Tokat and at the session of the Polish-Slovak Water University titled 'People, water, climate, landscape, future' organized by European Territorial Cooperation Group TRITIA together with Oz Chováme doma Civic Association (online lectures).

Fig. 112. Project website.

The project was promoted at national meetings, including the XXVIII Economic Forum in Krynica Zdrój in September 2018, at the POL-ECO-SYSTEM International Trade Fair for Environmental Protection in Poznań in October 2018, during the debate 'Polish waters in the context of the Water Framework Directive' organized by the Polish Ecological Club, the Polish Committee of the Global Water Partnership and the Save the Rivers Coalition in May 2019 (a paper entitled 'Regulation or revitalisation of rivers?' was delivered). The work was also presented at several local meetings organised as part of the project. At the ceremonial commissioning of the Bobowa fish ladder (Fig. 113), at the training for tourist guides (Fig. 114), at the on-line meeting with anglers or at the meeting with councillors of the Grybów Municipality (Fig. 115). Special materials concerning fish ladders were prepared for the training for tour guides organised in cooperation with the Directorate of the Natural Museum in Ciężkowice. During the on-line meeting with the representatives of the Polish Anglers' Union districts, problems associated with the operation of

Fig 113. Handover ceremony of the Bobowa fish ladder on 3 July 2018.

Fig. 114. Training for tourist guides in Ciężkowice.

Fig. 115. Meeting at the Municipal Office in Grybów.

Fig. 116. Studio of the webinar on the occasion of the World Fish Migration Day.

the fish ladders, mainly their cleaning and, in particular, possibilities of cooperation in the ongoing monitoring of their condition were discussed. One of the major events in the project was a webinar conducted on the occasion of the World Fish Passage Day in 2020, which was reported as one of the Polish contributions to this international celebration (Fig. 116).

Where possible, other meetings organized locally to promote the project were also attended. Among other things, at a meeting organized at the Municipal Office in Tuchów in January 2020 by the Foundation for Supporting Ecological Initiatives as part of the project 'Carpathian Rivers – Pure Natura 2000' and then in a similar meeting organized as part of the same project in Jasło at the seat of the Wisłoka River Basin Communes Association.

Each place where modernization work was carried out was marked with special boards; promotional materials in the form of posters and roll-ups were prepared.

Project website address: www.biala-tarnowska.org, Facebook – Facebook – Przywracamy-Białą-Tarnowską-przyrodzie-i-ludziom, (We are restoring-Biała-Tarnowska-nature-and-people).

Notes:

The project was carried out by the
National Water Holding Polish Waters
Regional Water Management Board in Kraków
as part of the Operational Programme
Infrastructure and Environment 2014-2020

Total cost: PLN 39,3 million
EU financing: PLN 33,4 million
Project duration: 2017-2022

www.biala-tarnowska.org

2022