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Revitalization of Small Watercourse †

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Abstract: The paper deals with a proposal for a small-watercourse revitalization measure, which is currently regulated by a post-local treatment. The sections of the watercourse are relatively straight and direct. The current shape of the stream does not retain water in the landscape. Any surface water in the watercourse is quickly transferred to the receiving watercourse, which is the important Hvozdnice watercourse. The practical part includes the design of revitalization measures, a new longitudinal profile, and sections. The watercourse is loosened by curves and the total length of the watercourse has been extended by 161.56 m. The route includes a wetland, four pools, and two pond wedges. An economic estimate of the proposed measure was made.

Keywords: revitalization; small watercourse; longitudinal profile; watercourses channel route

1. Introduction

Revitalization in Europe, as well as in other parts of the world, is increasingly including considering physical processes, such as bank erosion, sediment transport, channel incision, and water flow patterns, as necessary conditions for improving river conditions and promoting channel recovery. Today, it is primarily a process-based approach, aimed at restoring natural geomorphic processes and promoting spontaneous physical diversity rather than solving problems using local interventions. Revitalization is mainly concerned with retaining water in catchments, the slowing down of water flows during minimal floods and flooding, and increasing groundwater near water streams [1,2]. This involves the re-meandering of the straight channel of streams [3].

Watercourse revitalization has many benefits. It can improve water quality by eliminating excess nutrients, heavy metals, and organic compounds from river water [4,5]. Revitalization is also one of the strategies for drought adaptation, which is one of the most important challenges for society nowadays. In the Czech Republic, it is mainly hydrological drought which has caused precipitation decline as well as reduced flow rates in watercourses and groundwater levels. When there is no water supply in the soil and other subsurface layers, evapotranspiration and the related cooling effect will be reduced. Changes in the hydrological cycle and water quality, particularly in agricultural irrigation may disrupt the functioning of water infrastructure and increase demand for water abstraction [6,7].

The Czech Republic has adopted a climate-change adaptation strategy in line with the EU adaptation strategy [6,7]. The implementation document is the National Climate Change Adaptation Plan (Action Plan) which defines the adaptation measures in many areas such as forestry, agriculture, urbanization, and landscape water management. In the field of water management, this includes, among other things, the planned support for watercourses and flood plains, such as revitalization of watercourses and floodplains, restoration of natural spillways, and slowing down water flow [8].

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It is well known that the water balance of large rivers is based on the flow of small rivers. The hydrology of small rivers, hydrochemistry, and water quality are closely related to the geological–geomorphological, soil-plant conditions and thropogenic processes that occur in the catchment area. The formation of small rivers and their basins is determined by surface flow from regions and landscape complexes, so the impact of natural and human factors on these areas manifests itself more rapidly and clearly [9].

The article deals with the proposal of revitalization measures for an unnamed stream located in the cadastral area of Slavkov near Opava, which is currently modified into straight and linear sections. The character of this stream does not retain water in the landscape; all surface waters are rapidly drained away.

2. Materials and Methods

2.1. Location Description

The watercourse 10214099 (Figures 1 and 2) is an unnamed stream that can also be defined as a left-bank tributary of the Hvozdnice watercourse, 4.185 km. This small watercourse, ID 10214099, has a total length of 2.057 km and flows through the municipality of Slavkov near Opava in the Moravian–Silisian region. The watercourse is located in HOD_0390-Hvozdnice unit from the source to the mouth of the Moravice River. The watercourse is managed by the Odra River Basin, a state-owned enterprise. The watercourse is located in HP 2-02-02-0940-0-00 with a catchment area of 1.58 km^2.

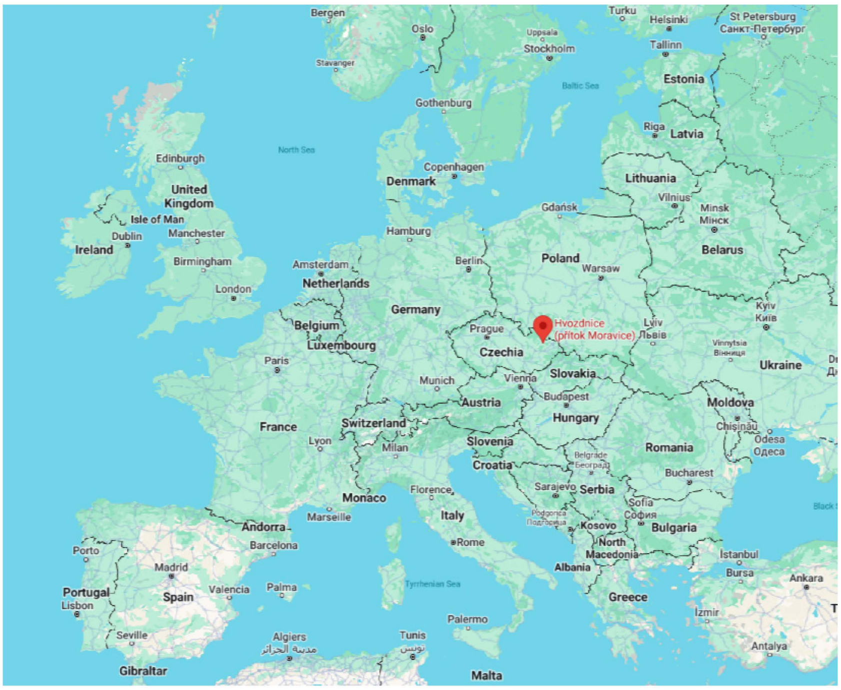

Figure 1. The simplified sketch map—localization in Czech Republic (modified by [10]).

The watercourse flows through two small water reservoirs (ponds), which serve for the rest of the local inhabitants and cross two field culverts and the Olomoucka Road II/46. From the lower pond, Pod Kovalem, the stream was dammed, and after 115 m beyond the railway crossing, it flows into the important Hvozdnice River at 4.185 km.

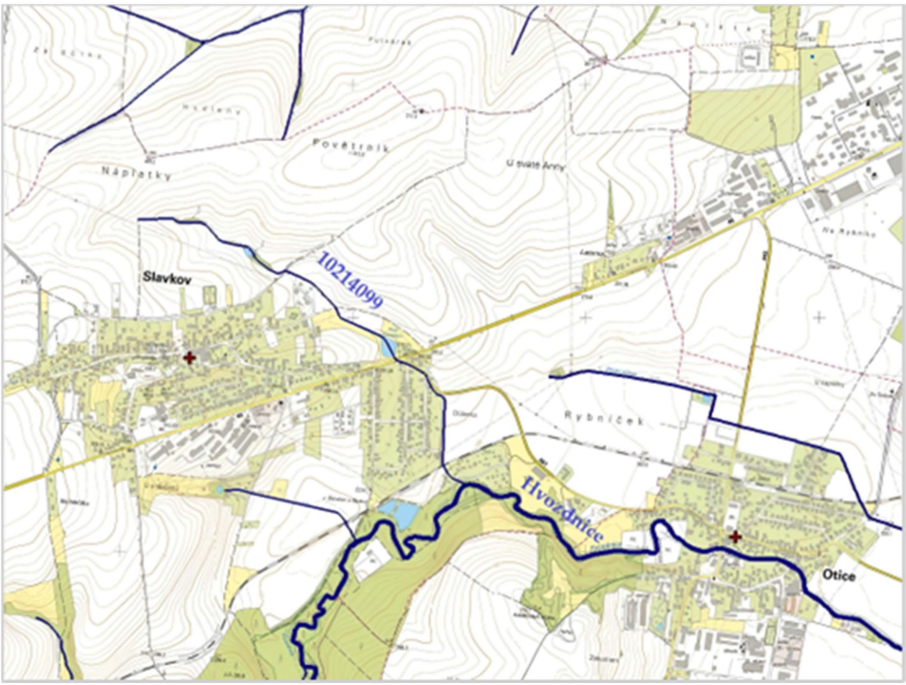

Figure 2. Watercourses ID 10214099, left—bank tributary of the Hvozdnice watercourse (modified by [11]).

Based on the evaluation of data from the drainage constriction and irrigation information system (ISMS), the watercourse can be concluded to serve as major drainage recipient [12]. According to the assessment of the drainage structures, it is a modified watercourse with open and closed sections [11].

2.2. Watercourses Section

The whole watercourse is divided into five sections (Figure 3). The sections are divided by specific objects—dams, reservoirs, culverts, reservoir, and spring. Points and river miles are marked from the mouth to the source, according to CSN 75 2120 [12].

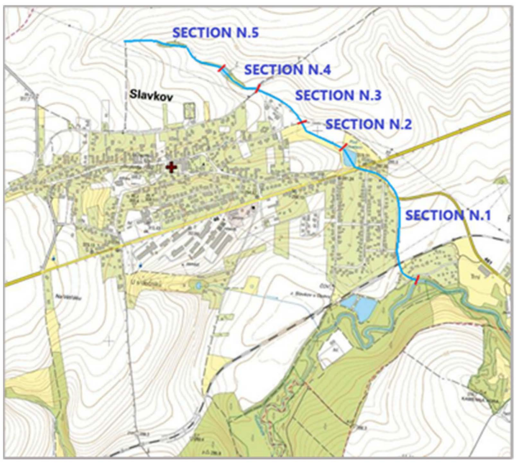

Figure 3. Watercourse sections (modified by [11]).

Section 1: About 810 m long from the mouth of the Hvozdnice River to the Pod Kovalem pond (Figure 4). The watercourse crosses the railway line for about 115 m from the mouth, then runs in a straight open channel to the local road III/461 called Otická. After that, the course of the route is in parallel with this road in the arched part. Then, it follows the dammed stream under the junction of roads II/46 and III/461 (Olomoucká x Otická). In the arched part, the flow is led through the outlet of the pond through an open two-lane fireplace. In the above-described section of the watercourse, no revitalization is planned.

Figure 4. Section 1—Pod Kovalem pond (photo by Rogozná).

Section 2: The revitalized part of the watercourse begins with section 2. It is located between the outlet of the Pod Kovalem pond (km 0.810) and the Na Lůčky culvert (km 1.060). The stream runs above the pond between the fields. In this case, the pollution and degradation of the stream is most evident in agricultural activity, where the stream is cultivated to the banks of both sides (Figure 5). Not far from the Na Lůčky is a junction with a road ditch which drains surface water. The Na Lůčky culvert (Figure 5) consists of a DN800, concrete pipe fitted with a concrete face on both sides. The flow is almost straight in section 2. The channel bed width is 0.3 to 0.5 m. The channel is overgrown with herbaceous vegetation, and, in places, the channel consists only of stones and soil.

Figure 5. Section 2 (photo by Rogozná).

Section 3: Between the Na Lůčky culvert (1.060 km) and Bocianova Street culvert (km 1.335). The Bociana Srteet culvert is a concrete pipe DN800, equipped with a concrete head. The stream flows through forest on the Na Lůčky culvert. On the banks and directly in the stream bed there are mature trees. The left bank of this section of watercourse is cultivated from the adjacent meadow to the shore (Figure 6).

Figure 6. Section 3 (photo by Rogozná).

Section 4: Begins with a field culvert near Bocianovy Street (1.335 km) and ends with a small water reservoir/pond (1.540 km). In the field culvert, the watercourse flows in a concentrated channel into the watercourse, and then flows upstream through dense forest cover. At the top of the forest there is a confluence of surface waters from the adjacent alluvial fields (Figure 7). Above this confluence is the outlet of the pond. The water is discharged from the pond through the DN 600 downstream, which flows into the stream at km 1.660. The water is discharged to this outlet using an open single-slot spillway. In the southern corner of the pond is a safety spillway paved with quarry stone. The small water reservoir (Figure 7) was revitalized between 2017 and 2018. It is a flow-through reservoir with a volume of 1690 m^3 and a length of 70 m (Revitalization of pond parcel No. 1426—Slavkov: Approval for the use of the construction, 2019, Opava). Today, the reservoir is used for capturing surface water, for recreational and landscape purposes.

Figure 7. Section 4 (photo by Rogozná).

Section 5. The last section begins from the outlet to the above-mentioned small water reservoir (1.540 km) and ends with the spring area (2.057 km). The entrance to the pond is 1.737 km. In this part of the stream, the area's agricultural activity is, again, very evident. Between 1.831 and 1.900 km, the stream flows through a field and takes a very sharp trapezoidal channel. The countercurrent from this part of the stream is the last area of vegetation with a very wide channel. In the last 120 m up to the source, the stream channel has a slope of approximately 1:1. (Figure 8).

Figure 8. Section 5 (photo by Rogozná).

2.3. Revitalization Measures

Revitalization methods may include some natural techniques generally used in flood-control demand [2]. As part of the technical revitalization solution, the flow course must be modified by the rotation of the route, creating of the longitudinal profile of the existing channel, and the design of a new longitudinal profile [13]. Small-scale river ecosystems are more vulnerable both to the direct impact of pollutants on them and to the indirect impact. The revitalization of small channel streams can involve re-meandering, during which a sinuous channel is artificially created, and then, to some extent, adjusted, or through a cessation of activities such as dredging and bank stabilization, which simplify or limit the channels [14,15]. In addition to the proposal to change the channel, the design of wetlands, pond systems, and pond wedges is also related, which contributes to biodiversity development and provides more space for shelter for small animals living in the area.

3. Results

3.1. Design of a New Watercourse Channel Route

The design of the new watercourses channel routs (Figure S1) was carried out in accordance with the requirements for revitalization of watercourse channels. The existing route is mainly straight, and the channel passes through inappropriate terrain conditions. The channel is being degraded by landowners adjacent to the watercourse channel and farmers from adjacent parcels. The watercourse was thus regulated, loosened according to the possible spatial arrangement, and thus extended by 161.56 m. The positive impact of expanding the channel's route is to reduce the flow of water flows from the watercourse and to hold more water.

According to the new design, the area above the pond, Pod Kovalem, can be effectively used on the left bank, where the flow is more relaxed and a pool can be placed. On the right bank, the rest of the material from the excavation of the new channel will be flooded. This leads to the formation of occasional pools in the old channel; these pools are filled during the rainy season and dry during the dry season. Na Lůčky Street culvert was moved. In the meadow above this relocated culvert, the most extensive loosening and shifting of the channel away from the houses occurs. The flow through the upper culvert has been maintained in the reservoir and the field culvert near Stork Street. From the outlet to the pool, above the small reservoir, and near the spring, the new channel is mostly guided in the existing valley. This proposal will reduce the amount of landwork in the most important part of the stream and thus reduce the cost of revitalisation.

The design of the new route is directionally similar to the existing stream-channel route, with the addition of pools and wedges added. The design of the new channel consists of alternating counter curves.

3.2. New Longitudinal Profile Design

The new longitudinal profile (Figure S2) is based on the current situation of maintaining three existing structures on the stream. These objects are the end of the Pod Kovalem pond, the preservation of the Bocianovy Street culvert, and a small water reservoir near the Bocianovy Street culvert. The new longitudinal profile incorporates a flowing pool to mitigate the longitudinal slope of the stream bed.

The original average longitudinal profile slope was 19.36‰. The flow axe in the spring area was 301.17 m above sea level, and the outlet of the Pod Kovalem pond was 277.74 m above sea level. The average slope is calculated as simply (301.17–277.74)/1210 (the length of the original channel), and then multiplied by 1000 to obtain the result. In a similar calculation, the length of the stream was changed to 1371.56 m, and the average slope of the new longitudinal profile was 17.08‰.

3.3. Cross-Section Design

The original stream channel has a slope gradient of approximately 1:1, except for 1:2, and the stream channel is straight in many sections and strongly regulated. There are sinkholes or plant deposits in places that form a barrier to flow.

The revitalization design includes 32 cross sections of 50 m each (Figure S3A,B). Two examples of cross-sectional profiles are shown in Figure 9. The proposal has a trapezoidal shape and a slope gradient of 1:3. Due to the reduction in permanent land occupied by private entities and the simplified settlement of property ownership, these slopes are easily linked to the existing terrain. The width of the channel at the bottom is 0.8 and 0.5 m. The bottom of the channel with a width of 0.5 m can be found in the area of the source to the field culvert on the Bocianovy street, and then the bottom of the channel with a width of 0.8 can be found from the outlet to the Pod Kovalem pond.

The flow capacity is designed to be Q10 or more depending on the terrain morphology. The water level of the stream is 0.5 m at Q10 flow.

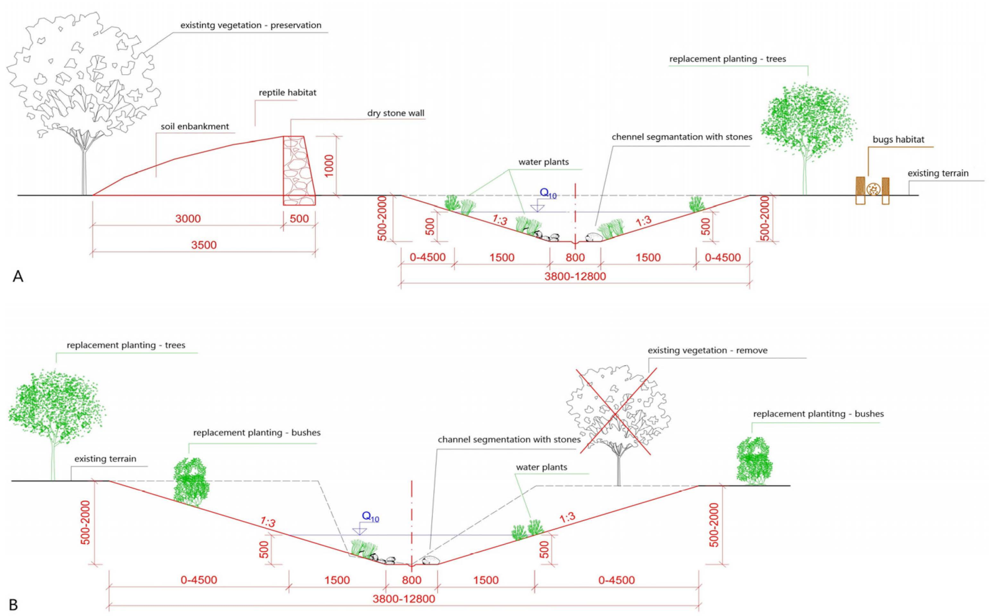

Figure 9. Sample cross profiles (**A**) and Sample cross profile (**B**).

3.4. Pools, Wetland, and Vegeation

The proposed stream length of 1.372 km, including a design for four pools, located at 0.140–0.500 km, 0.350–0.400 km, 0.450–0.500 km, and 0.871–0.900 km. The pool is deep, up to a maximum depth of 0.5 m from the flow level. During normal flows, the normal water level is 0.5 m or higher. Such a permanently high water level in the pool can be achieved both by landscaping the water hole and by subsidizing the water from a small reservoir. At the Q10 flow in the stream, the water in the water pools has a water level of 1 m. The pool is designed with a slope gradient of 1:2–1:8. The cross sections of the pools are shown in the Figures S4–S7. The pools are heavily planted with vegetation ranging from aquatic plants to coastal plants on the pool banks, and the root system stabilizes the pool banks. The choice of another fortification may not be visually and functionally suitable for the landscape. Pools are an appropriate location to catch sediments and protect small reservoirs from excessive sedimentation. Over time, sediments in pools will have to be removed due to siltation.

In the source area, a wetland of 2574 m^2 was proposed, and the terrain conditions were not very favorable. The area will be planted with wetland trees and plants, for example, Sedge, Iris, Chrastice, etc., are suitable plants. Wetland plants grow along the stream banks, shallow pools, and in water-draining areas. Wetland will remain for natural development.

Replacement planting should be established not only near pools, but also along the watercourse according to the geobiogens that are well developed for the Czech Republic. According to maps, the interest area belongs to the Polonska sub-province and, according to geobiocenes, is classified as the Oak vegetation phase where this phase dominates completely [16]. The map documentation indicates that the area of interest can currently be considered to be Linden Oak Forest as it has potential natural vegetation. In the field of interest, we can see more specifically L2.2 and K2.1 habitat types. The biotope L2.2 indicates that there were originally valley ash and alder bushes. The biotope K2.1 indicates that the area's native grass is of clay and sandy willow grass. This is mainly a grass of various species of willow.

3.5. Economic Cost

Actual prices may vary depending on time and location. Other aspects that determine the final cost of changes are, for example, the implementation company, the work time required, material costs, and the removal and processing of materials depending on their composition. We can include the Documentation for the Zoning Decision (DZD), Building Permit documentation (DBP), or joint proceedings.

Other costs may include extensive mapping of the revitalized watercourse in the area, research on pedological and hydrological conditions, new surveys, and geodesic plans for land acquisition. Furthermore, construction works carried out by a specific company specializing in watercourse revitalization and channel improvement. These works include all landworks, as well as the removal and processing of materials (based on laboratory assessment), the relocation of the culvert, the replacement of the plant, and the excavation and the seeding of a new stream path adjacent to the plant.

Other items are the preparation and securing of the development, the organization's facility which plans construction, and engineering activities. All the above indicative costs are presented in Table 1. The cost table does not include the cost of land acquisition, as this is determined on the basis of an expert's report, which varies for each individual plot.

Table 1. Cost estimation.

Cost Estimation	Price without VET (Thousands of EUR)
Exploration and project surveys	
Exploration works	7.50
Project documentation	13.10
Geodetic measurement	4.20
DZD+DBP	17.40
Engineering activity	22.80
DPB	5.0
Exploration and project surveys total	70.00
Construction work	
Site preparation, site equipment, site layout	3.30
Landworks	663.00
Disposal of excavated material	82.90
Replacement planting	10.40
Incidental organisational costs ~10%	76.00
Construction work total	835.60
Finishing activities	
Geodetic survey of the actual construction	8.30
DBP	4.10
Finishing activities total	12.40
Total coast	918.00

4. Conclusions

The length of the stream was increased from 1210 m to 1371.56 m. The transverse profile was changed to achieve a gentler bank slope of 1:3. Along the route are four pools, as well as large wetland. In this work, the treatment of vegetation and replacement planting are proposed in accordance with the applicable geobiocene. However, this work also included an economic estimate, but did not include the purchase price of the land. Revitalization is designed so that after implementation it does not further burden the administrative stream, the revitalization investor, or the water-company owner. Revitalization will initiate the process of naturalization, leaving channel and vegetation to develop in a natural processes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/engproc2023057019/s1, Figure S1: Design of a new watercourse channel route; Figure S2: Design of new longitudinal profile of the watercourses 10214099; Figure S3: Cross profiles; Figure S4: Pool N.1; Figure S5: Pool N.2; Figure S6: Pool N.3; Figure S7: Pool N.4.

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