# Supporting the advancement of nature-based solutions in the water management of hillside settlements

**Project co-funded by European Union funds (ERDF) wiht the financial contribution of partner states and institutions. This study was prepared by the EUSDR PA5 from the project DTP PAC2-PA05 (Acronym: PA05 Environmental Risk)**

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Prepared by
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## EXECUTIVE SUMMARY

In Hungary, many hillside settlements are affected by the increasingly frequent extreme climate phenomena. Among these, flash floods are one of the most significant problems. In current practice, it is common for the amount of water that falls during heavy rainfall events to flow out of the area in drainage ditches and enter the receiving watercourse within a short period and in a short distance - without being utilized. This method is not forward-looking and can even be harmful if the hydraulic facilities and the receiving watercourse do not have adequate capacity or are not regularly maintained. The other side of the problem is that the rapid emptying of water from a given area in this way contributes to the increase of water shortages in the later - increasingly prolonged - drought periods. The primary task is the water management of the slopes: the retention and local reservation of the fallen precipitation.

Slowing down runoff is an extremely complex task, so we must not forget that hydrological problems not only stem from water management, but from agricultural reasons as well. These largely - but not exclusively - derive from soil degradation problems. Therefore, hydrological problems and their treatment can by no means be narrowed down to the tasks of water management and the water sector, because agriculture and farmers also have a prominent role in it. However, unfortunately it is less well known among today's farmers and lawmakers that one of the most effective ways to reduce the erosion of agricultural land and surface runoff would be the proper application of agricultural production and management methods. Nevertheless, underestimating or ignoring the importance of agrotechnics is one of the roots of the destruction caused by erosion and flash floods (Kohut, 2020). Without the application of agricultural methods aimed at preventing water erosion, most of the hydrotechnical solutions for reducing runoff discussed in this study only provide "symptomatic treatment"- albeit a significant portion of these issues could be treated at the source by choosing the correct agricultural practice, thus reducing the need for hydrotechnical interventions on a catchment or watercourse level.

Regarding water construction methods, in the future we will need simple, easy to implement, environmentally friendly water retention solutions, which are also very effective responses to water shortages. By getting to know the hydrological properties of small watercourses, the phenomena that can be easily remedied with nature-based solutions become more understandable. Such solutions can be, for example, wave ditches, grass infiltration ponds or drainage ditches; small lakes, reservoirs, pools; brushwood and log dams; gully control; flood plain restoration; meandering restoration.

There are many positive foreign examples available from the recent past, which can also serve as a model for domestic hillside settlements to minimize the risk of flash floods. We primarily present nature-based solutions from Europe, but successful small- and large-scale projects have also been implemented in the USA, Australia and South America.

In the case of watercourses close to the border - considering Hungary's basin-like topography - we cannot take into account small watercourses exiting the country's borders, and so have to ignore cross-border downstream effects. Interventions carried out on the other side of the

borders, which affect the quantitative and quality parameters of the waters entering the country, can affect us more.

One of the most effective nature-based methods of slowing the flow of small watercourses in the hills is the construction of log and brushwood dams. These are near-natural solutions which are excellent for mitigating the fall of watercourses, quieting and moderating the flow of water, as well as partially or periodically retaining water. Depending on their design, they can also be used to trap transported sediment. Brushwood dams are smaller and look more like natural formations, while log dams are larger and can be considered rather as built structures, that can withstand and dampen large amounts of water energy.

By using stone, wire, stakes, or other reinforcement, the dimensional stability of these structures improves, and the elements of the structure work better together. In general, the brushwood dam does not require a special foundation, the brushwood structure flexibly takes the shape of the natural bed formation. The log dam, on the other hand, is stiffer and more durable than the brushwood dam, which is why it requires engineering design, especially if it is made in combination with stone. When designing, it is always important to determine to what extent we want to retain water with the given structure and reduce the energy and velocity of the propagating flood wave.

The construction of simpler brushwood dams does not require special expertise or specialized work, but their impact on the catchment and watercourse must be considered, which are tied to professional knowledge. Whereas the assembly of vertically placed and layered log dams and the cutting of wood to size, the movement of heavier materials definitely requires a more detailed design of the structure and the use of experienced labor.

Since dams can only be partially hydraulically sized during designing, it is necessary to check not only their stability, but also their role in water management after construction, and to regularly carry out the necessary maintenance work.

We have examined the legal environment of these water retention methods from the point of view of technical design, permits, establishment and operation. During the examination of water rights issues, it must be decided for each facility whether we build a water management facility and consider the legal categorization of the structure – operational issues must not be overlooked either. In accordance with the current regulation, during the environmental permit process, either an Environmental Impact Assessment process or Environmental Screening has to be done. In case not even a preliminary assessment has to be carried out, the environmental protection regulations are usually incorporated in the water permit design, construction design.

Given the evolving approaches and circumstances, the management of flash floods requires solutions which differ from the current practices – both from a technical and legal point of view. Solutions presented in this study, are to substantially facilitate these.

# I. THE BASICS OF HILLSIDE WATER MANAGEMENT

## I.1 Basic hydrotechnical concepts of water retention

Today, climate change is not only present in our lives as a global scientific conclusion but has also become a phenomenon that affects local communities prominently. The effects of climate change - whether we look at the increase in average temperature or the increase in the frequency of extreme weather events - are becoming more and more of a problem both at the organizational level and for the population. As part of this process, periods of water shortage and drought are noticeably increasing in Hungary, while the precipitation is becoming more and more unpredictable and intense, worsening floods and inland water inundation problems.

As one of the main manifestations of extreme water regime phenomena, many low mountain and hillside settlements are affected by flash floods with increasing intensity and frequency, with human and financial losses. These have a more rapid course than floods that form on rivers, and due to their intensity and extreme volume, pose a serious threat to the natural and built environment.

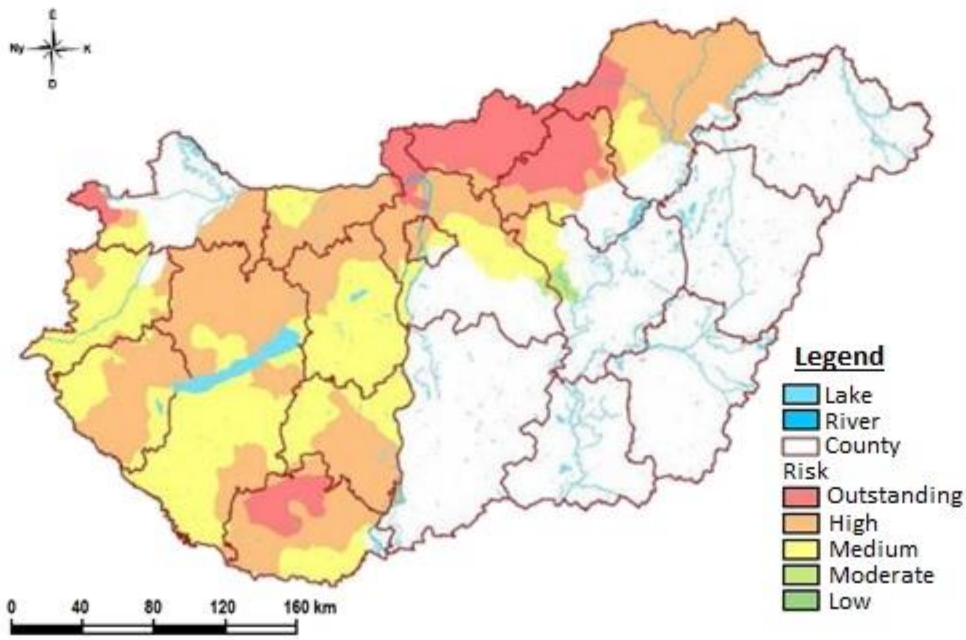


**Figure 1 Flash flood risk map of Hungary (Kelemen et al. 2017)**

Our hilly areas, which make up about 55% of the territory of our country, are characterized by the fact that the steep hillsides are largely covered with forest, and the gentler hillsides are partly used for variable cultivation (arable, orchards). 60% of the valley floor areas are cultivated or built on.

Hilly watercourses have a low water flow for most of the year. Floods are formed by sudden snowmelt or summer thunderstorms, and they propagate very quickly (1-3 days). A large amount of precipitation that falls suddenly always finds its way along the slopes and flows down to deeper areas - this process is called free concentration. Moving away from the watersheds towards the valley floor, the water flowing from the growing catchment area adds up, i.e. the amount of runoff increases as we go down the slope. A large amount of runoff water that suddenly occurs on the surface results in very short, intense, soil destroying flow within one or two hours, which can cause considerable damage to settlements and technical facilities (roads, railways).

The damages are partly due to the fact that the energy of the water flowing down the slopes can erode the surface of the soil. Since the upper layer of the soil cannot absorb high intensity precipitation or water from sudden melting with sufficient speed, plane flow breaks up and carries away the soil particles. The resulting soil erosion is a significant surface shaping process, during which a valuable, conditionally renewable natural resources are destroyed, and as a result of human activities – such as field cultivation carried out with incorrect methods or deforestation – this natural process is accelerated many times over. Erosion actually begins as soon as the falling precipitation reaches the soil surface with droplet erosion, and even with chemical erosion (dissolution), and then we have to take into account plane flow, furrow, and rill erosion as well. The topography and climate of the country favor erosion: 40–55% of its area is threatened by soil erosion (Bihari et al. 2004; Bádonyi 2006). The average annual loss rate is 1 t/ha/year, which is approximately equal to the average European soil loss rate (Credan et al. 2010).

As a result of the accelerated soil destruction, the soil layer on the slopes becomes thinner and gullies appear (Stefanovits 1992). The risk of the formation of gullies depends on many other factors besides the soil structure of the given area, including the steepness, exposure and surface coverage of the slope. In Hungary, surfaces with a slope angle exceeding 25% are often forested areas, which do not favor the formation of gullies. At the same time, the formation of gullies can take place in a very short time, especially in view of how long certain interventions affect the surface development of the area (Kertész, Jakab 2011). For example, with a steeper slope, gullies can also form as a result of a single clearing. The effects of more intensive human activities are well illustrated by the fact that the edges of mountains and the foothills – despite being made up of areas with a lower slope – are richer in gullies. This is due to (improper) agricultural cultivation.

On the other hand, damages caused by sudden, large amounts of precipitation – besides erosion – result from the fact that hilly watercourses cannot drain the suddenly increased amount of water, so they overflow their beds and flood the surrounding areas, depositing sediment from eroded surfaces.

The primary task is therefore the protection of the slopes against erosion, i.e. the drainage of the slopes: the retention of the fallen precipitation. The impact of erosion can be significantly reduced with the use of land adapted to the natural features (e.g.: afforestation, ensuring plant cover, contour cultivation, terrace cultivation) with the help of appropriate water management facilities (e.g.: drainage ditches, grade reducing structures, sediment traps). In addition to protecting the topsoil, this relieves the receivers of the waters from heavy sediment loads, so they can fulfill their drainage function.

Modern water management requires both storage, water utilization and groundwater level control. In addition to the highest possible rate of local utilization of surface water, another important task of water management in mountainous and hilly areas is to prevent damages from runoff. In the current practice, it is common that the amount of water that falls during heavy rainfall events flows out of the area without any use – in a short time and on short path – in drainage facilities and enters the receiving area. This method is not forward looking and can be harmful if the hydraulic facilities and receivers do not have adequate capacity or are not regularly maintained. The harmful consequence of this water management practice is that the diverted water will be missed when desperately needed during the increasingly long periods of drought.

The long-term successful implementation of water management tasks requires complex management of catchment areas, which presumes the preplanned and coordinated activities of owners, land users, and managers.

A real solution would primarily be a change of attitude, so that water would not be seen as a source of danger, but rather as a value and a resource. In practice, this means that the basis of water utilization must be water storage, either in natural or artificial reservoirs or fields (Szlávik 2013), which provides the opportunity for delayed infiltration of excess water. The key is to extend the water concentration, to prolong concentration time. By making the most of the possibilities of soil cultivation and water management, as much precipitation as possible should be retained at the point of fall, or collected and stored, and only unusable water should be drained away.

As far as the water management approach mentioned, although, technical and engineering methods and measures are still relevant, nature-based solutions (NBS) have to be a significant way of water retention in the future. Nature-based solutions are “actions which are: inspired by, supported by or copied from nature” (European Commission 2015, p. 5)

## I.2 The significance of agrotechnical methods in water management

Slowing down runoff is an extremely complex task, therefore we must not forget that the development of hydrological problems does not only stem from water management issues, but from soil conditions as well; which largely - but not exclusively - come from soil degradation problems. Therefore, hydrological problems and their treatment can by no means be narrowed down to the responsibilities of water management and the water sector - agriculture and the farmers who cultivate the land also have a prominent role in it. However, unfortunately it is less well known among today's farmers and lawmakers that one of the most effective ways to reduce the erosion of agricultural land and surface runoff would be the proper application of agricultural production and management methods. Underestimating or ignoring the importance of agrotechnics is one of the roots of the destruction caused by erosion and flash floods (Kohut 2020). Without the application of agricultural methods aimed at preventing water erosion, most of the hydrotechnical solutions for reducing runoff discussed in this study only provide "symptomatic treatment"- albeit a significant portion of these issues could be treated at the source by choosing the correct agricultural practice, thus reducing the need for interventions on a catchment or watercourse level.

The soil is the most important water-storing and moisture-buffering medium, but if this function is reduced as a result of soil degradation, the extreme distribution of precipitation can easily cause periodic water shortages or water surpluses in the affected areas. It is important that the local examination of the soil alone does not provide an answer to the cause of the problem in all cases; water management issues must also be examined in their spatial and topographic contexts. For example, problems related to infiltration and excess water caused by soil degradation often appear on the surface not at the site of the degradation, but in places defined by surface water confluence systems caused by the topography – even in an urban area of a settlement.

Stopping soil degradation is not only necessary for preserving the integrity of residential areas in the vicinity of agricultural areas but is also essential for the success of agricultural production, since the basic condition for plant cultivation is the existing humus layer. Since runoff water carries away the most valuable segment of the soil, the humus-rich layer – taking with it some of the applied plant protection agents and fertilizers (Győri 2018) – it is not only a safety and environmental risk, but also an economic loss.

The causes of soil erosion, destruction and wash off in agricultural areas are complex. In addition to natural geographical factors, human factors also play a significant role, since – unfortunately – our agricultural society today is organized in such a way that farmers strive to maximize the areas under cultivation for the highest possible profit. In many cases this involves the elimination of former ditches, grassy and wooded areas, by plowing and seeding (Győri 2018), and eliminating the roads between the fields. Without going into details, the agrotechnological reasons behind the increased erosion of agricultural land can be, for example, the wrongly chosen type of cultivation, inappropriate field size, lack of soil protection cultivation methods (slope ploughing, lack of deep ploughing, over-cultivation, lack of sectioning, etc.), absence or bad location of protective strips, overgrazing, and the poorly assembled planting structure. In addition, large-scale cultivation tools are now widely used in agriculture (Kohut 2020), which are harmful not only due to the formation of hardpan and trampling, but also due to the unnecessary disturbance and rotation, i.e. over-cultivation and – as an indirect effect – the use of fertilizers and chemicals that became necessary. As a result of the successive chain of negative effects caused by over-cultivation or soil cultivation intervention – carried out at the wrong time and soil condition – structural elements are shattered, disintegrated, the soil is pulverized, and soils that have lost their elasticity and resilience are compacted. The structural degradation of agricultural soils is a very significant problem on a national scale; today 70-80% of Hungarian fertile soils are characterized by increased degradation of the upper layer and, as a result, a significant deterioration of the water absorption capacity (Dobos 2022). In the absence of the appropriate water absorption capacity thus developed, stagnant water also leads to significant damage in crop production. Therefore the current bad practice is that the farmer tries to get rid of excess water as quickly and efficiently as possible. However, this water is later missed and desired in production, and its replacement requires a lot of resources. Retaining it in soils would not only be in our economic, but a crucial environmental and climate protection interest. As climate change further increases the negative effects in our structurally degraded soils, this vicious circle escalates further.

**Figure 2 Examples for soil compaction (left: https://soil4life.eu, right: own photo)**

**Figure 3 Soil erosion on cultivated land (https://www.nak.hu)**

Dealing with the problems listed above would require extensive measures from the decision-making, agricultural sector and social sides, starting with legislation, expanding farmers' knowledge and providing technical assistance. It should also be borne in mind that the transformation of the soil does not take place overnight, so the effect of the changes made in tillage will appear later in time. For positive effects on water management (water conductivity, water capacity) to prevail, approximately 3-5 years of reduced tillage or direct seeding are necessary. With reduced tillage, for example, runoff can be reduced by approximately 50%, while erosion by 90% (NAK 2019).

From the above, we can see that as part of the water demand management interventions, a change in agricultural technology should be carried out in parallel with the water construction interventions, i.e. a change in the structure of horticulture in order to ensure that water retention can be effective and efficient in the long term.

# II. HYDROLOGICAL CHARACTERISTICS AND RIVERBED SHAPES OF SMALL WATERCOURSES

In water catchment areas – based on topography – watercourses are formed from the arrival of groundwater to the surface (springs) and the collection and drainage of falling precipitation, which join to form the drainage network and system of a given area. The system develops from the starting point and reaches the final receiving point. Within the drainage system, individual parts, connection points and branches belong to the sub-catchments, the totality of these covers the examined area.

The water running off from the catchment area initially flows down the field like a sheet, then the collected water forms smaller ditches using the local depressions or flows towards the receiver using the existing ones. It can be observed that 30-50 m from the watershed ridges, water-conducting ditches and furrows naturally form, depending on the composition of the soil. The catchment areas are extremely diverse. It can be stated that practically no two catchments are the same. Due to the difference of the slope of the terrain, the composition of the soil, the vegetation, land use, the orientation of the catchment, etc., each catchment has a unique characteristic. These local characteristics significantly influence the volume and dynamics of the runoff water and, accordingly, the watercourses that form in the catchment.

The classification and grouping of watercourses can be done in several ways, and the individual categories can also change depending on the purpose for which the watercourses are grouped (e.g.: water management, geometric characteristics, operation, ownership, use, etc.). It can be concluded that the classification methods are primarily suitable for orientation and that it is not always possible to define sharp boundaries between the individual groups. Watercourses are also characterized by countless time-varying and constant factors, which is why the category of watercourses may change over time. (See Table 1 for possible criteria for the classification of watercourses.)

Considering the surface runoff examination, natural watercourses are the primary ones to be taken into account – i.e., on which human intervention has not taken place or only to such an extent that the watercourse has not lost its natural state.

Natural watercourses can be divided into two large groups:

**Permanent watercourses** that carry water throughout the year. The discharge of these usually comes from precipitation falling on several sub-catchment areas, possibly one or more springs, or permanent snow, or by a glacier. In most cases, the ground water level is higher than the bottom of the water course bed, so during low water the water course is also fed by ground water. In the case of a longer period without precipitation, it may happen that there is no surface influx and only the ground water provides a supply, which is called the base flow.

**Periodic watercourses** carry water only during certain times of the year. Considering the runoff and the water management balance, they are completely similar to those of permanent watercourses, however, defining water transport periods and reasons is essential. The other significant difference is that the bottom level of the bed of periodic watercourses are usually above or close to the groundwater table. The reason for drying up is not only the lack of rainfall or the fact that it is not constantly fed (e.g., a spring), but also the lack of groundwater replenishment, or is the result of infiltration into the soil.

**Table 1 Possible aspects of watercourse characterization (Szlávik 2013)**

| Natural | Artificial |
|---|---|
| **watercourses** | |
| **Permanent watercourses** | **Fully regulated** |
| by geographical characteristics | **Canalized** |
| geographical location | **Artificial canals** |
| catchment size | by geographical location |
| length | only connected to one water course |
| by hydrology | side canal |
| volume of discharge | branching canal |
| water regime | connecting water courses |
| source | deep profile |
| by hydraulic characteristics (morphology) | shallow profile |
| slope | by function |
| velocity | flood protection |
| sediment transport capacity | by-pass |
| sediment composition | parallel |
| riverbed condition | cross channel |
| by hydrology and hydraulic characteristics | agricultural water management |
| by geomorphological and riverbed data | irrigation |
| **Periodic watercourses** | excess water |
| mostly wet throughout the year | hydropower – power channel |
| mostly dry throughout the year | navigation canal (waterway only) |
| torrent (during floods, volatile water level) | |

Natural watercourses can be classified into the following categories based on their main hydrological characteristics:

**Table 2 Categorization of watercourses based on hydrological parameters, KÖQ: average discharge (Szlávik 2013)**

| | By catchment size (A, km²) | By length of watercourse (L, km) | By average water discharge of the watercourse over many years (KÖQ m³/s) |
|---|---|---|---|
| grand river | > 500 000 | > 1 000 | > 500 |
| big river | 25 000 - 500 000 | 250- 1000 | 50-500 |
| small river | 500 - 25 000 | 50 - 250 | 15-50 |
| stream (small watercourse) | < 500 | < 50 | < 15 |

Small watercourses can be further divided into three subcategories based on their water flow with a frequency of Q 10%:

I. Category: $50 m^3/s < Q_{10\%} < 70 m^3/s$
II. Category: $3 m^3/s < Q_{10\%} < 50 m^3/s$
III. Category: $Q_{10\%} < 3 m^3/s$

Distribution of Hungarian small watercourses between the specific categories:

I. Category 6,6%,
II. Category 27,0%,
III. Category 66,4%

## II.1 Classification of watercourses and water bodies according to WFD

According to the European Water Framework Directive (WFD), watercourses with a catchment area larger than 10 km² must be designated as an independent water body, as a significant element or elements of the water network. When determining the types of watercourses in Hungary, the following mandatory typological elements prescribed by the WFD were considered:

- altitude,
- catchment area,
- geology,
- and as a chosen characteristic: riverbed material.

Based on these, 25 types were designated, of which three are Danube water body types defined at the level of the Danube River Basin District.

1031 watercourses were designated as water bodies, taking into account the lower limit of the 10 km² catchment size. The total length of the designated water bodies is 18,800 km. Due to the merging of smaller watercourses into one water body (e.g. Aranyos stream and its tributaries), 869 water bodies were identified from the 1,031 designated rivers, streams or canals. Among them, 373 can be classified as water bodies of the natural category, the rest are highly modified (350) or artificial (146) water bodies.

## II.2 Development of watercourses and riverbed formations

Watercourses flow partly in well-recognizable riverbeds and partly in less defined (e.g. dry conditions) riverbeds. The form and shape of the riverbed is determined by the range of water level fluctuation and dynamics of the rivers and is shaped by the energy of the water to be drained. Watercourses are constantly shaping their beds, eroding them, partially grabbing certain amounts of the bed material, and partially depositing material brought from higher sections. The moved material is transported partly as rolling, partly as suspended sediment.

The bed-forming activity of watercourses can be explained by the dragging force. Depending on the magnitude of the dragging force and the resistance of the soil and rock, watercourses form their beds either by slow erosion (rivers with rocky riverbeds in the mountains) or by breaking up the bed material by erosion (in granular sedimentary rock). Abrasion and dissolution is a slow process, the bed can be considered unchanged, while the beds in the sedimentary layers change quickly and are usually so called moving beds.

## II.3 Periodic watercourses (gullies)

On mountains or hillsides, if the dragging power of the surface runoff water is so great that it disrupts the soil surface, stronger rill erosion can start, and gullies develop. For the development of gullies, therefore, it is necessary that the dragging force be greater compared to the resistance of the soil surface. This can happen because the grass cover that protects the soil is weakened somewhere (e.g.: excessive grazing, use of incorrect agricultural cultivation, etc.) or the dragging force increases locally, because a dirt road or slope-oriented plowing leads the water into concentrated furrows and thus the depth of the runoff water and, with it, its energy locally increases, which initiates the gully formation.

Once the erosion has started, the developed ditch rapidly deepens and lengthens, the vegetation cover no longer provides protection, because the water collected in the ditch washes away the banks, and the side slope collapses together with the vegetation. The concentrated water most strongly attacks the upper end of the ditch, since this is where the slope is steepest, and in this way the bed of the gully rapidly lengthens upwards with so-called retrograde erosion. See the figure below.

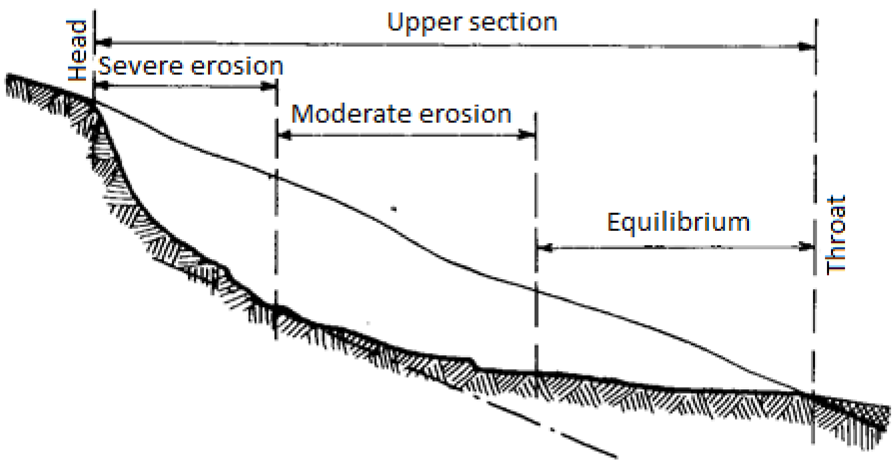


**Figure 4 Gully formation, shape (Sabathiel 1966)**

It can be seen in the figure that the drop is the largest at the head of the gully and decreases downwards - a parallel - to this, the production of sediment also decreases, and a state of equilibrium already prevails at the lower end, i.e., here the amount of incoming and outgoing sediment is approximately equal, the ditch is no longer being deepened here, there is no sediment production. After that, however, sediment deposition begins in the section below. There is no permanent water flow in the gullies, at most the water from a few springs makes the bottom of the gully damp. The magnitude of the erosion depends on the amount of incoming water, but it also depends on the extent to which the vegetation on the banks and bottom of the ditch grew between two floods; and whether there was a restoration or control intervention between the two floods.

At the lower end of the gully, below the throat, the most part of the large amount of sediment produced in the upper part is expected to be deposited. At this stage, the water already loses its sediment moving energy and thus deposits most of its sediment. A smaller part of it reaches the nearest permanent watercourse (the so-called receiver) in the form of suspended sediment and most of the time chokes it.

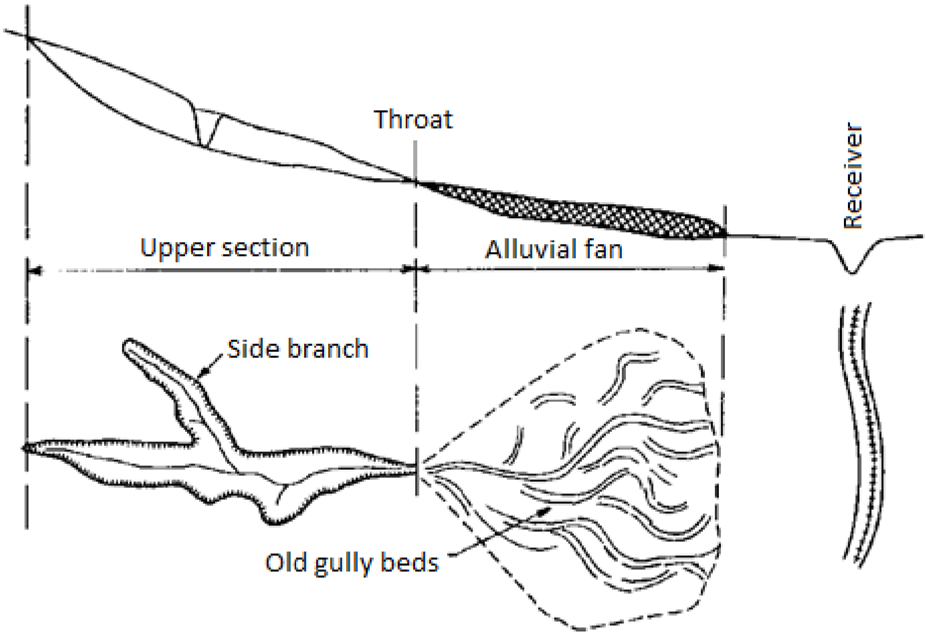


**Figure 5 Formation and shape of alluvial fan below the gully (Sabathiel 1966)**

With the decreased water discharge - after the rain - sediment is deposited in the previously existing bed in such a quantity that the bed usually becomes clogged and during the next rain - if it is not cleaned out - the water usually makes a new bed for itself on top of the deposited sediment. As a result, water migrates from one gully bed to another after a flood, and the cone-shaped sediment deposit always advances further towards the receiving watercourse. The surface of this alluvial fan is not suitable for agricultural cultivation, nor for the construction of roads, houses, or railways, since any structure built here can be covered by new sediment after every rain.

The cross-section of the gullies is characterized by a steep cross-section with stepped walls. The water mainly deepens a narrow trench at the bottom of the cross-section, the washed-out banks break into this depression and the vegetation and even larger trees can slide into the depth along with the banks. The upper section of the gully often cuts through several layers, and the slope of the side slopes and the slope of the longitudinal section show changes according to the resistance of the layers. The remnants of the more resistant layers are chipped off from the sides and block the watercourse bed for a while, however, the next rain digs a new bed next to the obstacle and thus the development of the gully continues.

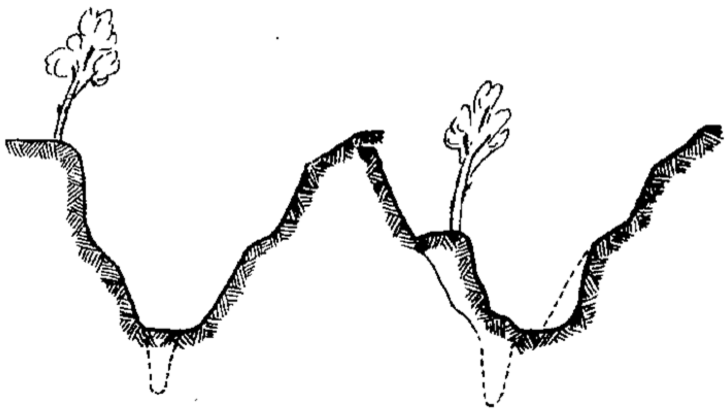

**Figure 6 Shapes of gully on cross-section (Sabathiel 1966)**

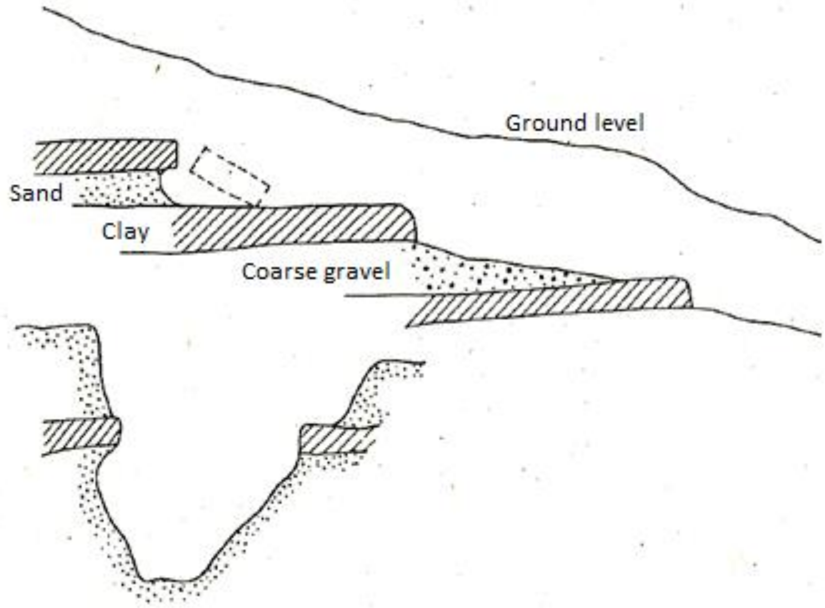


**Figure 7 Gully formation in layered soil (Sabathiel 1966)**

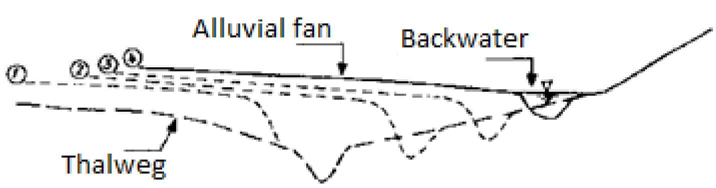


**Figure 8 Bed migration on the alluvial fan (Sabathiel 1966)**

# III. MANAGEMENT OF SMALL WATERCOURSES, FLOOD MITIGATION AND DELAY WITH NATURAL AND NATURE-BASED SOLUTIONS

Since runoff is influenced by several factors, if we want to achieve significant results in water retention, it is essential to examine the possibilities of intervention in a complex manner, covering the entire catchment area. The definition of the methods for slowing down the runoff must also cover conditions predicted based on climate change. It is not enough to simply increase the storage capacity at the water catchment level, but early on, in the upper water catchment sections is it necessary to implement smaller retentions – either in the form of retaining structures, natural and artificial dams, or in the form of reservoirs and lakes (VGT3 JVK Discussion Material).

Accumulation, retention and storage of water in rainy and wet periods and then its utilization in dry periods should be considered the most basic method of protection. Obviously, this cannot be done everywhere and under all circumstances, but we have to recognize the possibilities of relatively inexpensive opportunities.

Below – according to their area of applicability – we present the mountain and hilly nature-based solutions (NBS), which we consider to be the most widely applicable in Hungary in adapting to climate change. In this chapter, we do not cover the solutions that can be achieved by changing farming or agricultural technologies, or changes in plant cover and land use (such as the use of low-cut forestry, afforestation, the installation of field protection forest strips, strip cultivation following the field level, tillage without rotation, soil protection with cover crops, etc.). However, their simultaneous application is just as important an element of water retention as hydraulic structure technologies.

Given that a significant part of the problems are - directly or indirectly - caused by rainwater, the following solutions also apply natural water management. An important aspect is the need for technical solutions that are simple and easy to implement, but at the same time can be very effective responses to both extreme rainfall events and increasing water shortages.

Recommended types of intervention:

- Wave ditch
- Grass drainage ditch
- Small lakes, reservoirs
- Grass infiltration pool
- Gully control with dam
- Gully bed stabilization
- Brushwood and log dams
- Restoration of the natural state of stream beds
- Restoration of meandering
- Floodplain restoration and management (in case of flood peak reduction reservoirs)

In the next chapters we go into the details of the listed technical solutions.

## III.1 Wave ditch

An artificial landscaping that forms a dike parallel to the terrain contours, thus preventing and delaying the terrain flow.

**Figure 9 Wave ditch**

Its purpose is to keep precipitation in place and gradually drain it away. A facility – perpendicular to a slope – that reduces runoff from the terrain, primarily from agricultural areas. This way, it forms a barrier that protects the areas below it from washing out and erosion. Its design and maintenance are extremely simple because it consists only of landscaping. It is the first pillar of local protection, which anyone can easily apply on their own property. If the embankment built as a dike breaks through, it must be restored. The ditch in front of the dike, from which the filling material is extracted, is easily saturated with alluvium. Continuous monitoring of this is necessary, dredging is essential in case of filling.

Its distinct advantage is that it only consists of earthwork, no other building materials are needed for its construction. Virtually anyone can build it. Its implementation and maintenance do not require expertise, neither design nor construction experience. Maintenance is minimal. In addition to the interventions mentioned above, lawn care imposes a negligible task on the owner/operator.

## III.2 Grass drainage ditch

A grass drainage ditch means more than a wave ditch in that while both can be solved with landscaping, the vegetation planted in a grass drainage ditch chemically and physically filters the collected rainwater and helps it infiltrate into the ground. It functions as an infiltration trench.

**Figure 10 Grass drainage ditch (https://www.chesapeakebay.net)**

In simpler cases, it is made only with earthwork involving landscaping, followed by turfing. It is possible to carry out more serious planting, which promote infiltration and drainage, and also plays an important role in biological filtration.

Its maintenance is not complicated. Similar to the wave ditch, sediment can deposit in it, which requires constant monitoring and dredging. Mowing the vegetation also provides an operational task.

Its advantages are similar to the wave ditch, no building materials are needed for construction, it does not require design and construction expertise, but in addition to these, it also has an important ecological role, which is significant in terms of water, soil and wildlife protection in agricultural areas.

## III.3 Small lakes, reservoirs

In the sections of streams that affect inhabited, urban areas, and agricultural areas, protection against floods is primarily possible through prevention, which can be done by building the riverbed to the appropriate size or by establishing reservoirs to reduce flood waves. In hillside water management, the utilization of storage and lake construction opportunities is of particular importance, since in many cases there is no other solution for the security of settlements and various high-value facilities due to being in dense, built-in areas. The amount of water collected in the reservoir is discharged in a controlled manner, taking into account the drainage capacity of the bed section below.

In dry weather conditions a water collection pool is free of water, while a lake (e.g., retention ponds, flood storage reservoirs, shallow water reservoirs) contains water even in dry weather. Their application is primarily effective from the point of view of flash floods, but in addition to water management tasks, they also have a significant role in forestry, agriculture, and ecology.

In the case of watercourses in mountain and hilly areas, reservoirs are most effective in the upper reaches of the catchment. That is why it is important that retention should start already on private properties, at the residential level. Later, this should be continued at the settlement level, on municipal watercourses and public lands. Finally, at the state level, it is also advisable to establish reservoirs and retention ponds on hydrologically managed watercourses, so this unified system can significantly reduce the flood risk. Even expanding the capacity of existing smaller reservoirs is also possible solution to design such structures.

From an operational point of view, it is extremely important that the reservoirs are regularly reviewed. Lack of inspection and maintenance results in a deterioration of the facilities' defensive ability (maintenance of water levels above the operating water level, neglected structures, installation of flood barriers, etc.) Stormwater reservoirs built specifically to decrease the peak level of high waters, and for periodic storage, should not be utilized for other purposes.

## III.4 Grass infiltration pool

**Figure 11 Grass infiltration pool (https://www.stormwaterpartners.com)**

The difference from grass drainage ditch is that these facilities do not function as draining ditches, but by drainage ditches rainwater is collected in a reservoir, stored there temporarily, and most of it is infiltrated into the soil and groundwater. The sediment that collects in the ditches and is transported to the pool is collected in these basins. Its design is relatively simple. It can be created by earthworks, humus treatment, and lawns, no other building materials are required. The maintenance is also simple. Similar to the previously presented facilities, the operators must occasionally carry out mowing, sediment removal, dredging tasks. The advantage is that it can be used to protect against flash floods, because it has a significant role in reducing flood peaks due to its large surface area. However, it does not provide complete safety in case of large volume of intense precipitation. It is advisable to use it in combination with other retention facilities.

Another advantage is that it is favorable from an ecological point of view. It increases the diversity of the landscape and offers food and hiding places to certain living creatures. It also has a favorable effect in cooling the air close to the ground, so it can also be used against heat waves. In addition to the above, its role in water management is that it effectively participates in the improvement of water balance. It promotes the replenishment of groundwater, thereby also playing a part in drought damage protection.

## III.5 Gully control with dam

**Figure 12 Gully control with dam (Tardío, García 2016)**

Despite the best efforts, it happens that erosion makes its way and a gully develops in a relatively short time. The harmful mechanism of gullies must be stopped and – if possible - the process must be reversed. This technical intervention is called a gully control, which can be implemented with gully control dams. In the case of larger gullies, it is necessary to build a dam system, where the uppermost is the head dam, the others are intermediate dams. The structural design and construction of dams can be made of earth, brushwood, stone, concrete, and prefabricated elements.

Concurrent to the technical installation of the drainage system, biological protection must also be taken care of (shrub, tree, lawn planting).

The structures built on the bottom of the bed of the watercourse slow down the water flow, thus reducing the erosion of the bed by lower flow velocity, and the transported sediment starts to deposit.

The hydraulic and static sizing of hydraulic structures of the gully control is a very important hydraulic engineering task. In any case, it is advisable to use local building materials, without the use of binders. It must be designed for durability and trouble-free operation.

Monitoring is an important part of operation. On the section of the riverbed behind the dam, the sediment formation increases – which must be removed in order to ensure uninterrupted functionality.

Another advantage is that - due to its efficiency - flash floods do not occupy areas outside the riverbed, the watercourse remains in its original bed. Due to the reduction in velocity, the infiltration of the minimally stored water can have a positive effect on the water balance of the soil.

## III.6 Gully bed stabilization

It differs from gully control dams in that the steeper riverbed is transformed into steps and, in some cases, some parts of it are paved. This method also slows down the water flow and prevents erosion. However, it also prevents sediment deposition, because on the paved bottom it is rolled further, and this prevents its accumulation.

Its construction requires precise, competent designing, which is especially true for the design of large dams. The advantage is that the fixed bed bottom prevents washing out and erosion, so the bed does not deepen any further. The construction of rock-lined bottom dams is relatively simple. The disadvantage is that it requires gradual maintenance. In the case of a cross dam design, sediment removal requires substantial attention.

**Figure 13 Gully bed stabilization / check dams (https://www.appropedia.org/)**

## III.7 Brushwood and log dams

Brushwood dams are mostly small dams made of driftwood and brushwood, which partially let the water through. When the water level is low, all the water can flow through, but when the water flow is increasing, a significant part of the water is diverted to the flood plain of the river, only letting as much water through, that does not cause flooding in the settlement. This increases the concentration time and reduces the flood peaks, thus protecting the built environment and infrastructure from floods.

Log dams are facilities similar to brushwood dams, built from logs, which ideally are built from locally cut wood.

Both solutions are one of the easiest water retention facilities to create. Absolutely close to nature, as it can be made from local materials. They can be used most effectively in the upper reaches of watercourses, where the watercourse has a significant floodplain to form backwater. Their task is to regulate the water flow, to stop large waters, but to allow the small water flow and small water life (e.g., fish) to pass through undisturbed. In a basic case, it does not form any barrier or obstruct the natural flow, but as soon as an emergency event occurs, it holds back the incoming water surplus extremely efficiently. In such a case, a small reservoir is formed behind the dams.

A log dam can only create a small reservoir capacity (a few hundred, a maximum of a few thousand $m^3$), so the construction of several dams is recommended. Creating a runoff model can help determine their ideal location, as poorly placed dams can even increase flood risk.

**Figure 14 Log dam in Püspökszilágy (https://life-climcoop.hu)**

## III.8 Restoration of the natural state of stream beds - removal of dams and other longitudinal obstacles

The bed of the stream is formed by the bottom bed and the riverbank. In the past, many riverbeds were artificially lined with concrete elements or paving, thus modifying the parameters of the flow and reducing the local fauna and the diversity of the vegetation. The aim of the interventions was usually to prevent flooding and to serve agricultural interests.

During the restoration of the beds to their natural state, the concrete base and all artificial structures are removed. At the same time, the starting of erosion processes must be prevented by the application of various near-natural stabilization techniques. The greatest effect can be achieved if the vegetation and the naturalness of the stream bed are restored during the intervention. This is usually done by planting.

## III.9 Restoration of meandering

A river bend is a U-shape taken by the river, which allows the velocity of the water to be reduced. In the past, rivers were regulated in many cases by cutting their bends. In Northern and Western Europe, many rivers have been straightened and corrected to (e.g.) facilitate log hauling and/or to speed up water flow, as well as to control/limit channel spills. The regulation was also profitable because this way valuable land was acquired for agricultural cultivation. The restoration of meandering of watercourses means creating a new meandering bed or reconnecting cut off bends, thereby slowing down the flow of water. The new shape of the riverbed creates new flow conditions and very often has a positive effect on sedimentation and biodiversity. Newly formed or reconnected meanders also provide a habitat for a wide range of aquatic and terrestrial plant and animal species.

## III.10 Floodplain restoration and management

The floodplain is the area bordering the watercourse, which provides a natural space for the retention of floodwater and rainwater. In previous water management practice, floodplains were separated from the watercourse by dikes, dams or other water flow regulating structures. In the case of these areas, the goal is to restore and reconnect them to the watercourse, thereby keeping their former properties and ecosystem functions. In our case – from the mountain and hill area protection aspect – we are talking about the existing areas, which were previously used and are suitable to decrease flood peak levels. Their reuse is of prime importance.

Restoration of flood plain function requires measures such as:

- sediment, alluvium removal,
- creation of lakes and riverbank buffer reservoirs on the floodplain,
- a shift in agricultural utilization,
- afforestation, planting native grasses, shrubs and trees,
- removal of invasive species,
- creation of wetlands habitats, grass pools and marshes.

Figure 15 Crop transformed to wetland, Australia (https://www.greeningaustralia.org.au)

# IV. INTERNATIONAL REVIEW

## IV.1 Main international practices and experiences in the field of hillside water management

**River widening and protective structures, Salzburg, Austria**

“In the 1980s, the Mur was regulated in the Salzburg Lungau to improve agricultural production conditions. The river was left mostly devoid of structure. Additionally, the capacity of the regulation profile was exceeded during larger floods, which put the valley floor at risk of large-scale flooding. According to the 2008 hazard zone plan, 110 residential and industrial buildings were exposed to a 100-years flood. The municipality, therefore, decided to create a flood protection project. It comprised linear protective structures as well as widening river stretches and was implemented in 2013-2017. Today, the Mur is up to three times wider on a total length of 2.5 km. The population benefits from accessible local recreation areas around the river. The municipality’s spatial development concept was also adapted to the hazard zone plan and the flood protection project in order to minimise the damage potential.” (FMST 2018)


**Figure 16 River widening and protective structures, before-after photos (FMST 2018)**

**Combining longitudinal measures with flood retention, Styria, Austria**

“In the past, the Lauslingbach repeatedly flooded the municipal area of Obdach. Aside from infrastructure, it also threatened 43 residential and office buildings as well as 10 businesses. Planning needed to consider the lack of space in the village. A flood retention basin combined with longitudinal protective measures along the Lauslingbach proved the best solution for protecting against a 100-years flood. Parts of the linear structures were built along with the street bypass for Obdach. They prevented from significant damage during the flood event of 2012. The flood retention basin, which was built as a bypass has a retention volume of 150,000 cubic metres. Its main element consists of an earth dam with a height of 13 m and a crest length of 300 m. A gravel trap and a driftwood rack precede the basin. The bottom outlet regulates discharge during flood events and during normal water flow allows fish and water animals to migrate unimpeded. By now, the structure has been greened and is well-integrated into the landscape." (FMST 2018)

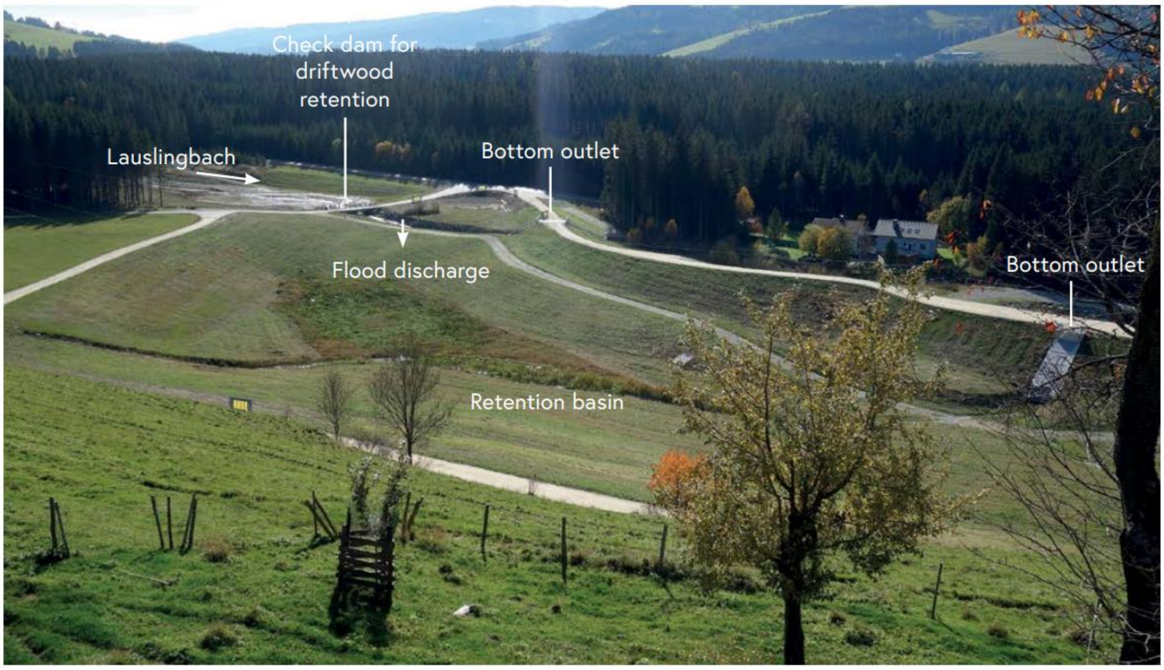


**Figure 17 Flood retention basin of the Lausingbach (FMST 2018)**

### Overland flow areas, Slovakia


**Figure 18 Ditch for overland flow, Slovakia (http://nwrm.eu/measures-catalogue)**

"Overland flow areas are most commonly associated with peatland forestry in Finland but could be applicable in other areas of Europe. Overland flow areas collect some of the excess sediment produced during ditch maintenance and other forest management operations such as road building or harvesting. Overland flow areas are created by building a semi-permeable dam in a forest ditch. Upstream of the dam, lateral ditches are constructed to transport water into the surrounding catchment. During periods of high flow, water will overflow the lateral ditches and travel across land to reach the receiving lake or stream. As the water travels across land, its velocity will be slowed and much of the sediment being carried will be deposited. At periods of low flows, the permeable dam will slow water flow and cause deposition of sediment. Existing wetlands may function as overland flow areas but the use of ecologically valuable and endangered mires should be avoided due to possible changes in vegetation composition. Overland flow areas can also be part of more complex system for water treatment from agricultural areas and landfills.” (http://nwrm.eu/measures-catalogue)

**Stream revitalization, South Bohemia, Czech Republic**

The restoration of a formerly channelized small submontane stream consisted of excavating a new channel to restore the historic meandering pattern. Besides the positive hydrological effects, the conducted biological analyses showed a substantial increase in species richness. This increase was not only due to the creation of lentic habitats, but was even observed at every single sampling site of the stream. (http://nwrm.eu/measures-catalogue)

**Figure 19 Restored stream, South Bohemia, Czech Republic (http://nwrm.eu/measures-catalogue)**

**Sediment capture ponds, Slovakia**

The sediment capture ponds are engineered ponds placed in networks of forest ditches to slow the velocity of water and cause the deposition of suspended materials. Sediment capture ponds are most useful for managing the effects of ditch construction and maintenance, road work and final feeling. While used primarily in forests, sediment capture ponds may be a useful temporary measure for preserving water quality in and around construction sites or mines. They may also be useful for capturing sediment in agricultural runoff. Sediment capture ponds have a limited lifespan, depending on how much suspended material is in the inflowing water. However, ponds can be maintained by removal of accumulated sediment. As most water protection methods, sediment capture ponds function well during base and moderate flow events. Catchment area, hydraulic properties of ditches, discharge rate and soil characteristics are among factors influencing functioning of sedimentation capture ponds. Effective functioning largely depends also on expertise and skill of professionals designing and implementing this and also many other measures. (http://nwrm.eu/measures-catalogue)


**Figure 20 Sediment capture pond, Slovakia (http://nwrm.eu/measures-catalogue)**

## Peak flow control, Slovakia


**Figure 21 Peak flow control basin in forest, Slovakia (http://nwrm.eu/measures-catalogue)**

Peak flow control structures are designed to reduce flow velocities in networks of forest ditches. Peak flow control structures are engineered ponds designed to limit the rate at which water flows out of a ditch network. Because the structures slow water flow, they will contribute to sediment control and can reduce the size of flood peaks. Peak flow control structures will have a limited lifespan as sediment will eventually fill in the upstream detention pond. However, ponds can be maintained by removal of accumulated sediment.
(http://nwrm.eu/measures-catalogue)

## Natural water retention by beaver weirs, The Podspády – Protected Area Bor, Slovakia

„Beavers naturally build dams, and thus slow down the water flow in the catchment area where they live. One area where this has occurred is the protected area Bor, which is located near the village Podspády. Beavers living on the side of the tributaries of Javorinka created weirs, which slowed surface runoff and allowed the water to saturate the surrounding soil profile. Beavers, and the structures they create, occur naturally in nature without causing serious problems. They can thus be encouraged in protected areas where it is impossible to implement technical solutions that change runoff patterns.

The benefit of reducing the water runoff is that the risk for drought would be lower, which would lead to a more stable habitat, and thus more favourable conditions for flora and fauna.

Because this is a naturally occurring phenomenon, the constructions did not need any legal permission. These constructions have no time limit, but depend on the community of beavers and access to woody materials in the river basin. These measures could be seen as a non-technical water retention measure. It is an example of changing conditions in a protected area, and creating more favourable conditions for the flora and fauna in the surrounding area." (Global Water Partnership Central and Eastern Europe 2015)

**Figure 22 Beaver dams in basin Javorinka (Global Water Partnership Central and Eastern Europe 2015)**

**Complex stabilisation system of the Haluzice Gorge, Slovakia**

„Haluzice Gorge is situated 260 meters above sea level bordering the Haluzice Village in Western Slovakia. The Gorge was formed by deep erosion activity of the Haluzice Stream. In the upper part on dolomite-limestone flysch bedrock, erosion gradually excavated a 30 m deep, and a 100 m wide gorge, mostly without vegetation that gradually expanded. Due to weather conditions, fine sandy material from the steep sidewalls eroded and formed embankment cones on the foot of the gorge walls. Heavier surges of water transported material to lower parts where the debris created silt that clogged fertile land in the village Štvrtok and retroactive erosion threatened the Haluzice part of the village. On the slopes, ridges and ditches were formed that created new gorges.

The project included comprehensive technical measures comprising stonewall weirs and stone steps, and its implementation stabilised the slopes of the Haluzice Gorge and its side arms, and prevented flooding and transport of debris downstream. The complex stabilisation system comprised of 8 stonewall weirs, and 17 stone steps in the lower part of the Gorge. The slopes were stabilised by afforestation through terraces reinforced by willow fences. Shrubs, trees and creeper plants were planted on the floor, on the sides and on bare spots. During the following years, trees, shrubs and creepers gradually filled the whole surface of the Gorge. The last 4 m high weir was constructed towards the end in order to stop erosion and protect Haluzice Village, as well as a connecting local road with Štvrtok Village. Total length of modified Haluzický Stream included in the Gorge is 1.5 km. Currently, there are 6 functional weirs in the Gorge on the Haluzický Stream, 4 are in the right side arm. The purpose of the weirs is to retain silt, caused by erosion in the upper part of the steam, as well as retain the high water levels during storms. In addition, 17 stone steps slow runoff and safely drain water.” (Global Water Partnership Central and Eastern Europe 2015)

**Figure 23 The Haluzice Gorge and its ide valley with stone weirs (Global Water Partnership Central and Eastern Europe 2015)**

### Small reservoirs, Poland

Figure 24 Small reservoirs, Poland (left: https://architektura.um.warszawa.pl, right: Majewicz 2016)

The examples above were installed in Poland. However this kind of water retention can be applied anywhere at semi urban/semi-rural/rural catchments, where the terrain and land use is suitable. Reservoirs are typically sited at a lowest point in the catchment where it can receive drainage by gravity. These facilities retain rainwater coming from surface runoff. They must be sized to cope with the 100 years flood volume. Usually these reservoirs have a certain amount of water permanently, but there is extra capacity in case of floods.

The maximum size of the pond should be based on the catchment area, which is up to 10 $km^2$. It requires the 3-7% percent of the upstream catchment size. Maintenance should ensure storage capacity, remove the sediment, and debris occasionally after floods, cutting the grass, and shrubs every year. (Harsányi et al. 2018)

### Brush layers and mats to stabilize marly gullies, French Southern Alps, France

Figure 25 Brush layers and mats to stabilize marly gullies, French Southern Alps, France (https://link.springer.com)

“In the French Southern Alps, where the Mediterranean climate is characterised by hot summers and heavy rainfall events, high sediment yields at the exit of marly catchments cause significant socio-economic and ecological problems downstream.

In 2002, brush layers with or without brush mats on wooden sills were installed in gullies to: i) enhance vegetation development, ii) allow efficient and sustainable sediment trapping and iii) decrease sediment yield at the gully and catchment exits. Plant material used in brush layers was willow (Salix purpurea and S. incana) cuttings. Today, more than 2000 brush layers have been installed in 160 marly gullies and about one third of these structures are surveyed.

Results showed that these bioengineering structures can resist high hydrological forces, even when exposed to intense precipitation events with a return period of almost 100 years. Natural succession of native plants was also initiated on and around brush layers. Significant quantities of sediment were trapped from the first year onwards and continuously. Sediment yield will therefore be substantially decreased at the gully and catchment exits. This case study provides design criteria to guide future restoration actions in both the French Southern Alps and similar regions worldwide." (https://geoikp.operandum-project.eu)

**Stormwater retention basins for the protection of coastal landscapes in Marseille, France**

"In the event of severe thunderstorms, the sewage networks are saturated and part of the water is then directly discharged into the sea without going through the sewage treatment plants. To avoid these phenomena, five new stormwater retention basins will be developed.

The construction of 5 retention basins will allow to regulate the rainwater, to reduce the pollution rate too important, to avoid runoff water ending in the ocean, to preserve the habitat of the aquatic life and their environment." (https://geoikp.operandum-project.eu)

**Figure 26 Stormwater retention basin (https://crowd-geoikp.kajoservices.com)**

**Sustainable Urban Drainage System, Manchester, UK**

Sustainable urban drainage systems (SUDs) are a collection of water management practices that aim to align modern drainage systems with natural water processes. They alleviate flooding problems by storing or re-using surface water at source, by decreasing flow rates to watercourses and by improving water quality.

Dale's Brow in Swinton, Manchester has been transformed into a sustainable urban drainage system. This comes with the installation of two swales, the creation of a new 64 m$^2$ wetland area, a 40 m long beech hedge and hundreds of new plants and trees. Rainwater from the road will be diverted away from the sewers into the swales. With heavy rainfall the water will travel along the swales and into a temporary wetland area. When the swales and wetland area are full, the water will overflow back into the water course via a pipe connection in a clean and safe condition.

The swales and the wetland area contain a variety of different vegetation types that are able to cope with wet conditions. Microbes in the soil and vegetation will trap and help to break down any pollutants into harmless compounds. (https://www.landscapeengineering.co.uk)

**Figure 27 Sustainable Urban Drainage System, Manchester, UK (https://www.landscapeengineering.co.uk)**

**Rain gardens, London, UK**

The Moore Brook is one of London's lost rivers that flows beneath Haselbury's Streets and was rediscovered during a local flood risk investigation. As part of the improvement rain gardens were introduced along the route of the river between Firs Farm Wetlands and Pymmes Park Wetlands where it peeks above ground.

By bringing the brook up to the surface and creating big depressions along it they created wetlands, open water features, ponds and raingardens. These new establishments allowed to store a huge amount of water which reduces the amount of flooding that could occur downstream during an extreme rainfall event. But also the wetlands themselves are incredibly good at cleaning water. On top of that the wetlands create a fantastic habitat for a wide range of wildlife. (https://www.enfield.gov.uk )

**Complex runoff control, Belford, UK**

More than 30 interventions have taken place in the Belford Burn catchment, United Kingdom. The main objective was to reduce the risk of flooding by slowing down run-off and creating artificial ponds, including detention basins and overland flow features, as well as sediment capture measures to improve water quality. This meant a loss of land for farmers, which could be mitigated with good cooperation. Ponds were placed in corners of fields or in wetlands. Natural bunds were built on small watercourses to spread the water and slow down run-off. (OVF 2013)

**Figure 28 Wooden bund, Belford, UK (Wilkinson 2010)**

A wooden bund disconnecting a flow pathway. At full capacity draining slowly through the gaps in the wood and in normal status of the feature, no disruption to farming practice.

**Figure 29 Woody debris and soil bunds, Belford, UK (Wilkinson 2010)**

In the left picture bund built across a major flow pathway (base of a hollow) using local soil. In the right: A woody debris beaver dam constructed in a stream with locally felled Sycamore trees. Tree trunks are placed cross over to avoid bank scour. Coarse woody debris in stream channels has multiple ecological and hydrologic benefits. At one extreme, coarse woody debris can be used to form coffer or placer dams which effectively limit water flow. In addition to its role in slowing streamflow and facilitating sediment accumulation, coarse woody debris can improve aquatic biodiversity by retaining food and providing additional habitat, such as refuges and spawning sites. (Wilkinson 2010)

### Log Erosion Barrier (or Contour Log), USA

30. Figure Contour log
(https://afterwildfirenm.org)

Contour logs are intended to slow runoff, cause localized ponding, and capture and store eroded sediment when arranged in a bricklayer pattern on hillslopes. The logs are partially entrenched or/and staked to soil surface parallel to the contour.

Studies indicated that log erosion barriers may reduce runoff, peak flows, and sediment yields for low intensity rain events (< 45 mm/ hour), but are unlikely to have a significant effect for high intensity rain events. Sediment storage was reported to decrease by 10–15% with each successive rain event. Although the potential volume of sediment stored is dependent on slope, tree size and length, frequency, and use of berm traps, with proper implementation effective sediment storage and creation of microsites can be achieved.

It can be applied on hillslopes with high- and moderate-burn severity, slopes between 25 and 60 percent, soils with high erosion-hazard ratings, and watersheds with high values at risk. (https://afterwildfirenm.org)

### Check dams, Coralville, USA

The photo on the right shows a proactive example in Coralville, where a large rooftop and large parking lot discharge down a little ravine. The solution is a head-to-toe chain of a dozen concrete dams, max 0.9 m high, with a centering notch. The little hole in the bottom center of each dam will allow it to slowly drain down completely. The ravine sides have since been planted with native shade-tolerant shrubs, and the dams will gradually disappear from view. This chain of check dams spaced down the gully, each one momentarily slowing the flow before it spills into the pool of the next one downstream. (https://buroaklandtrust.org)

31. Figure Chain of check dams, USA
(https://buroaklandtrust.org)

### Forest restoration and infiltration ditches in San Salvador, El Salvador

Climate change is increasing the intensity of storms in El Salvador, causing erosion, landslides and flooding. To address these hydrometeorological events, by the UNEP sponsored CityAdapt or "Sponge City" project, 1150 ha of forest and coffee plantations are under restoration. The restoration includes the creation of 62 km of infiltration ditches, to enhance drainage during heavy rains. Such ditches mimic the natural drainage services provided by streams and rivers, and combined with the water holding capacity of trees, are expected to reduce flood risk for 115,000 people. The restoration project also aims to provide direct benefits for local people by planting fruit trees for an extra source of food or income." (https://www.unep.org/ar/node/28425)

**Figure 32 Infiltration ditch in San Salvador, El Salvador (https://www.unep.org)**

## IV.2 Danube Basin review, possibilities for interventions near the border

Intervention close to the border is primarily possible where the cost of the intervention can be provided together with the neighboring partner in the cross-border catchment or watercourse section.

A successful Hungarian example is the restoration of the cross-border section of the Láhn stream near Szentgotthárd. A part of the arable stream landscape was restored between 2000 and 2002. Its purpose was partly to develop the ecological corridor, but mainly to drain the floods of the Lapincs River. The restoration of a cross-border section of the Kerca near the western border was also carried out, which was financed by EU program (INTERREG II/B.). The settlement aimed at improving the ecological condition, protecting plant and animal species, restoring the pre-regulation state and extensifying farming, which meant water resupply, reconstruction of hydraulic structures and planting. (Báthoryné 2007)

Given the basin-like topography of the country, we cannot really count on small watercourses exiting the country's border or on cross-border downstream effects. The interventions carried out on the other side of the borders – which affect the quantitative and quality parameters of the waters entering the country – can affect us all the more.

Below we present the watercourses forming or intersecting the state border according to Act CXCVI. of 2011. on national property. These watercourses should be prime subjects of cross-border projects.

| Name of stream forming or intersecting a state border | Receiver | Length of stream [km] |
|---|---|---|
| Arany-patak | Ikva-patak | 2.980 |
| Arany-patak | Sorok-Perint | 14.744 |
| Bánrévei-Névtelen-patak | Sajó | 1.600 |
| Bara-patak | Karasica | 4.150 |
| Beremendi-csatorna | Tapolca-patak | 7.400 |
| Bódva | Sajó | 54.000 |
| Borza-patak | Karasica | 7.473 |
| Bozsoki-határárok | Arany-patak | 0.320 |
| Bozsoki-patak | Arany-patak | 0.500 |
| Brandt-majori-csatorna | Arany-patak | 1.156 |
| Csencsi-patak | Pinka | 18.919 |
| Disznó-patak | Rába | 0.260 |
| Dombó-csatorna | Dráva-holtág | 19.450 |
| Fekete-árok | Dráva | 18.000 |
| Fekete-árok | Pinka | 2.028 |
| Gyöngyös-patak | Gyöngyös-műcsatorna | 17.407 |
| Gyöngyösszeri-patak | Zala | 1.434 |
| Határ-árok | Határ-patak | 1.750 |
| Határ-patak | Kebele-patak | 6.648 |
| Border drainage ditch | Borosnyák-patak | 1.581 |
| Ikva-patak | Hanság-főcsatorna | 51.545 |
| Illocskai (Eastern branch) | Karasica | 1.700 |
| Illocskai-csatorna | Karasica | 0.100 |
| Izidórius-patak | Dráva | 7.640 |
| Karasica | Duna | 34.880 |
| Karasica-szívó | Izsépi(-Duna)-holtág | 17.036 |
| Kardos-ér | Ikva-patak | 45.008 |
| Kebele-patak | Lendva-patak | 8.590 |
| Kecske-patak | Brandt-majori-csatorna | 1.460 |
| Kemence-patak | Ipoly | 2.400 |
| Kerca-patak | Kerka-patak | 6.570 |
| Kerka-patak | Mura | 53.620 |
| Kőhidi-patak | Láhn-patak | 0.500 |
| Láhn-patak | Vörös-patak | 11.844 |

| Name of stream forming or intersecting a state border | Receiver | Length of stream [km] |
|---|---|---|
| Lajta bal parti csatorna | Lajta | 13.656 |
| Lendva-patak | Kerka-patak | 6.803 |
| Locsmándi-határárok | Répce-malomcsatorna | 0.285 |
| Lővöi-patak | Pinka | 0.630 |
| Mindszenti-patak | Csencsi-patak | 0.500 |
| Mogersdorfi-árok | Lapincs-patak | 2.084 |
| Moschendorfi-határárok | Csencsi-patak | 0.200 |
| Nagy-Szuha-patak | Ipoly | 1.000 |
| ÓLendva | Kerka-patak | 4.354 |
| Öreg-Tapolca | Tapolca-patak | 3.512 |
| Pincei-határárok | Ó-Lendva | 0.409 |
| Pinka | Rába | 0.899 |
| Pinka-ág | Pinka | 4.555 |
| Pinkamindszenti-lecsapolóárok | Csencsi-patak | 0.812 |
| Pornói déli árok | Pinka | 0.500 |
| Pornói északi árok | Pinka | 0.510 |
| Pornói keleti árok | Pinka | 0.780 |
| Pornói nyugati árok | Neugraben | 2.707 |
| Rábafüzesi-határárok | Láhn-patak | 1.380 |
| Rákos-patak | Fertő-tó | 9.844 |
| Rátóti-patak | Vörös-patak | 0.500 |
| Régi-Borza | Izsépi(-Duna)-holtág | 0.165 |
| Répce | Rábca | 78.659 |
| Répce-malomcsatorna | Répce | 0.500 |
| Ribnyák-patak | Répce | 1.561 |
| Ronyva-patak | Bodrog | 16.661 |
| Rönöki-patak | Láhn-patak | 0.500 |
| Sároki-vízfolyás | Karasica | 3.515 |
| Sároslaki-patak | Mindszenti-patak | 1.320 |
| Schuszter-patak | Rába | 0.810 |
| Sós-patak | Ikva-patak | 3.848 |
| Steinbach-árok | Tapolca-patak | 1.000 |
| Strém-patak | Pinka | 4.173 |
| Szartos-patak | Hernád | 4.000 |
| Szentgyörgyvölgyi-patak | Kebele-patak | 23.742 |
| Szentpéterfai-határárok | Pinka-üzemvízcsatorna | 0.899 |
| Szív-völgyi-patak | Jáki-Sorok | 0.500 |
| Szív-völgyi jobb parti mellékág | Szív-völgyi-patak | 0.280 |
| Szölnöki-patak | Rába | 0.500 |

| Name of stream forming or intersecting a state border | Receiver | Length of stream [km] |
|---|---|---|
| Tapolca-patak | Dráva | 7.704 |
| Templom-árok | Szakonyi-övcsatorna | 0.500 |
| Topolyás-ér | Bara-patak | 2.500 |
| Vaskeresztesi-határárok | Pinka | 3.060 |
| Venda-patak | Ipoly | 0.900 |
| Vörös-patak | Rába | 17.287 |
| Zsdála-árok | Dombó-csatorna | 26.550 |

There are many places in the country where reservoirs can be built. On the next page, we present the potential hillside water reservoirs sites that are planned on watercourses that intersect the border and therefore can be an important part of interventions close to the border.

**Table 3 Water reservoir possibilities close to the border**

| Name of reservoir | Water management directorate | Settlement | Name of watercourse | Section of closure | Catchment area (km²) | Reservoir volume (tm³) | Preparedness | Recommended utilization | Category of utilization |
|---|---|---|---|---|---|---|---|---|---|
| Tolmács reservoir | KDVVIZIG | Tolmács | Fekete-patak | 2+300 | n.a. | 250 | none | stormwater | stormwater |
| Csörötnek reservoir | NYUDUVIZIG | Csörötnek | Gyöngyös ér | 1+020 | 2 | 24.7 | study plan | complex | multipurpose |
| Soproni I. reservoir | ÉDUVIZIG | Sopron | Ikva-patak | 50+650 | 30.45 | 1260 | establishment water permit plan | stormwater | stormwater |
| Ebergőc reservoir | ÉDUVIZIG | Ebergöc | Ikva-patak | 22+750 | 345 | 2130 | study plan | stormwater | stormwater |
| Borjád tározó | DDVIZIG | Borjád | Karasica | 20+850 | 380 | 9000 | study plan | stormwater | stormwater |
| Máriakéménd reservoir | DDVIZIG | Máriakéménd | Karasica | 30+900 | 220 | 280 | study plan | stormwater | stormwater |
| Ólmod reservoir | NYUDUVIZIG | Ólmod | Ribnyák patak | 2+130 | 4.5 | 405 | study plan | recreation | other |
| Sopron II. reservoir | ÉDUVIZIG | Sopron | Sós-patak | 2+223 | 9.61 | 980 | establishment water permit plan | complex | multipurpose |

# V. TECHNICAL REQUIREMENTS FOR THE CONSTRUCTION OF LOG AND BRUSHWOOD DAMS, MAIN TECHNICAL PARAMETERS, THEIR DESIGN, SAMPLE DESIGN; LOG AND BRUSHWOOD DAM MAINTENANCE AND MONITORING RECOMMENDATIONS

## V.1 Technical requirements for the construction of log and brushwood dams

Log and brushwood dams are such close-to-nature solutions that decrease the slope of watercourses, quiet the flow of water and make partial and temporary retention possible. Depending on their design, these types of interventions can serve as sediment traps and as water retention structures. Placing brushwood dams or logs in the water course in a natural way is not a watertight solution in itself, due to their structural design. Their partial water retention and their ability to regulate flow is ensured by their hydraulic resistance.

The idea of creating log and brushwood dams can be derived from the practice occurring in nature, from the example of spontaneously assembled dams and barriers created from fallen trees and branches, as well as from the experience gained in relation to dams built by beavers. Brushwood dams are smaller, they look more like natural formations. Log dams are larger, they can be considered more like a constructed structure – which can withstand larger amounts of water energy or can dampen it.

Figure 33 Naturally occurring cases affecting water flow (fallen trees, beaver dam)

In the case of **brushwood dams**, water flows through the dam in two ways. Initially, the water passes between the branches. In such cases, damming occurs on the upstream side of the dam due to the resistance between the branches. If the water flow is of such a magnitude, or the brushwood dam is so wide, that the backwater – caused by the resistance of the branches – reaches the upper plane (crest) of the dam, a failure occurs. Flow through and overflow can only be calculated with a rough approximation – based on experience – and therefore can be estimated or given as an approximation. Based on this, after their construction, it is necessary to monitor whether the structure achieves the desired effect and, accordingly, the required modification must be carried out on the dams.

The waterproofing of the structure can change or improve over time, based on the degree to which tree leaves and sediment from the environment clog the openings. If, on the other hand, a larger flood wave causes damage to the structure, its ability to retain water may even deteriorate.

Due to their nature, brushwood dams are only capable of retaining water at a low height. Part of the reason for this is that their material is less dense than water, so in the case of greater water depth, the buoyant force can be greater than the weight of the dam, and the stability of the structure itself is not suitable for holding a larger mass of water. Therefore, their stability must be increased with additional structural elements, otherwise only intertwining twigs and branches ensure stability – making it impossible to determine the proper size the structure. The stability of dams can be increased by using a mixed stone-brushwood structure. The stability is improved, for example, by the installation of large, branching tree branches. However, this may hinder future maintenance.

In mixed brushwood-stone structures, the placement of stone and brushwood braid can be diffuse or layered. By using stone, the stability of the structure is improved, and its elements work better together.

In simple cases, the brushwood dam does not require any particular foundation. The brushwood structure flexibly takes the shape of the natural bed structure. If the structure is higher, the dam may move due to water pressure despite the structural stability. To prevent this, a row of stakes can be used under the brushwood structure, which can be single-row or arranged in several rows. In the latter case, it is advisable to drive the stakes in a triangular system, at a distance of one and a half meters from each other. The stakes may protrude no more than one meter from the bed, but the stakes must remain below the level of the dam crest, as the brushwood dam material will compact over time and the stakes may be exposed to the surface. To prevent this, it is advisable to drive the stakes up to a maximum of 10 cm below the crest.

The stability of the brushwood dam can also be improved by wiring and bundling. On one hand, the wiring can ensure the cohesion of the layers of brushwood – in this case, the wired bundles are placed during the installation – but the brushwood can also be wired to the stakes – in this case by tying them in the form of a horizontal net. Considering that the wooden material will need repair after a few years, the wiring can make it difficult to repair the structure. The repair of mixed brushwood-stone structures is significantly easier without wiring.

A **log dam** is a more rigid structure compared to a brushwood dam. Simply put, it is a robust tree trunk placed horizontally in the riverbed, which blocks, slows down and holds back the flow. Compared to the brushwood structure, the tree trunk is rigid, washing out can occur around it and under it. As this deteriorates further, it reduces the water retention capability.

The size of the dam can be increased by stacking several tree trunks, but in this case, due to the gaps between the trees, the amount of water that can be retained is low. Damming is only significant during high water levels, in which case there is a risk of washing out. To prevent washing out, stone or brushwood (with stone weights) covering can be used on the affected sections of the riverbed, especially on the downstream side, as well as on the side of the riverbed, and where trees are in contact with the bank. The watertightness of dams made of natural logs can be improved by the combination of a log and a brushwood dam, in which case a brushwood dam on the upstream side of the log dam provides a better water seal.

**Accordingly, during designing, it is always important to determine to what extent we want to retain water with the given structure, and to reduce the energy and speed of flood propagation.**

The stability and water tightness of the log dam is improved by the vertical, close placement of the logs. During placement, both single-row and multi-row placement can be used. In these cases, 2/3 of the logs are placed below ground level, typically by digging in, and the remaining 1/3 in the bed provides the dam height required for backwater. Such structures can be joined together with horizontal tie beams, so that the individual logs are transformed into a structure that works together. The part behind the log dam can be filled with granular-stone material, or with a suitable mixed brushwood-stone dam.

The solution that ensures greater structural stability of the log dam is the mixed stone-log dam, which is built as a layer-by-layer structure of stones and logs. This solution can only be built into the watercourse as an engineered structure, with appropriate designing and sizing calculation and by using a significant amount of "straight" i.e. certified wood.

The crest of the log dam can be trapeze, "U" shaped, or curved, circular or parabolic. The calculation of the flow rate has less uncertainty than in the case of brushwood dams.

Log dams are more durable structures than brushwood dams, but their maintenance requires significantly more specialist work.

Log and brushwood dams are not watertight structures. To use them in structures specially designed for water retention, additional water proofing has to be made. Both solutions can be used in permanent watercourses, where it is necessary to reduce the flow. Where high velocity is expected, the use of a more stable log barrier is recommended. Both structures can be used to catch sediment, but the log dam is also recommended at sites exposed to significant velocity.

The construction of the simpler brushwood dams does not require special expertise or specialized work. In these cases, the impact on the catchment area and the watercourse must be considered, based on professional knowledge. Assembling vertical and layered log dams, cutting wood to size, and moving heavier materials requires a more detailed design of the structure in advance, as well as the presence of experienced skilled workers for the construction.

Designation of the location and geometric design of the dam should be entrusted to a specialist experienced in river basin management, given that individual interventions may affect each other and have to be taken into account and evaluated accumulated.

## V.2 Sample designs

The brushwood dams are to be built on the basis of the technical specifications presented above and in compliance with them – at the specified location. If the dam is placed in a permanent or periodic watercourse, an establishment water permit is required. Currently, a detailed construction plan is practically not required for the construction of a dam. In this case, the primary designing task is the designation of the location of the dams, which is definitely tied to water management knowledge.

In the case of log dams, based on the complexity of the structure, it is necessary to prepare the designs of the dam at the general design level, or if its static role is significant, a detailed construction design must be prepared for it before implementation.

Below we present a general sample design of some types of dams, as well as photographs of the completed state.

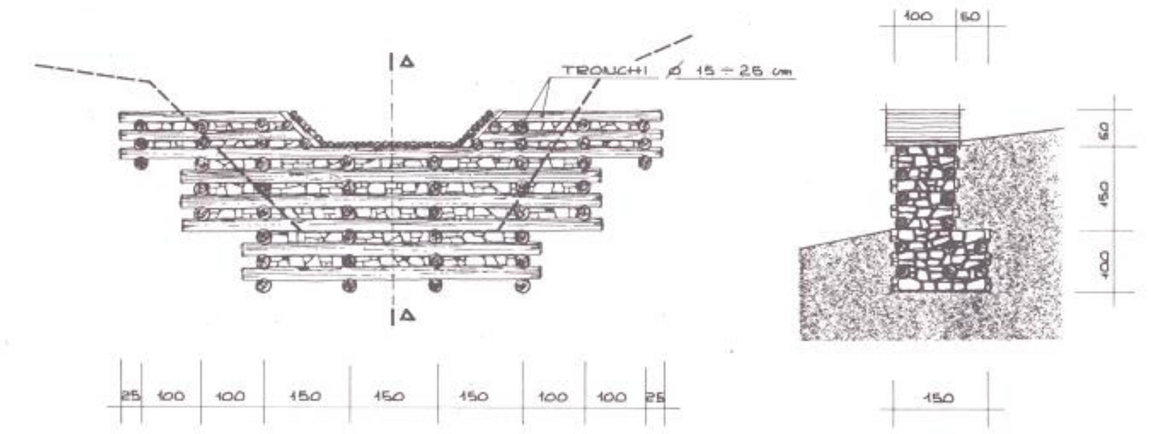


**Figure 34 Layered wood-stone dam (Malaguti 1993)**

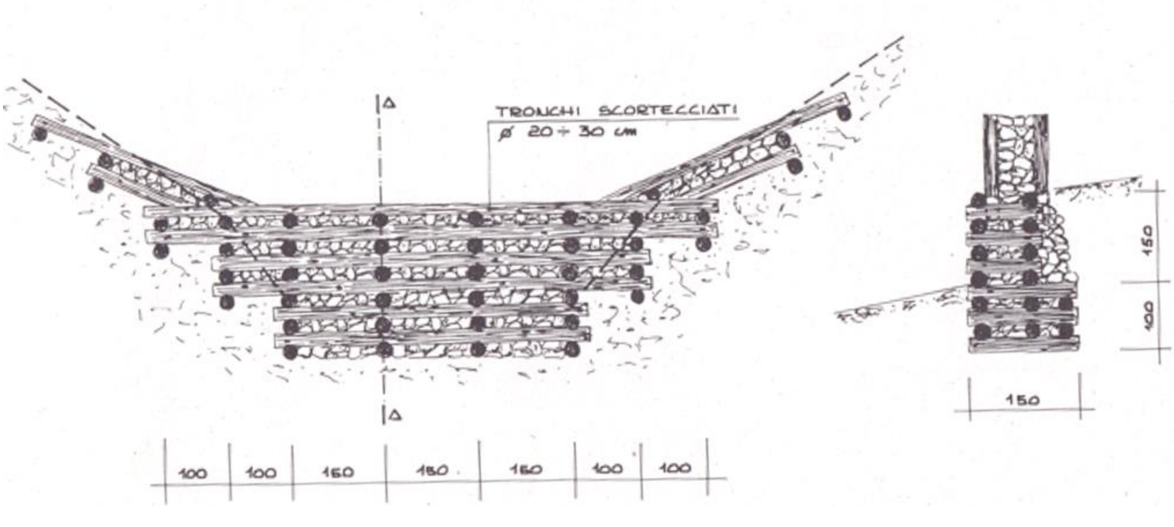


**Figure 35 Layered wood-stone dam (Malaguti 1993)**

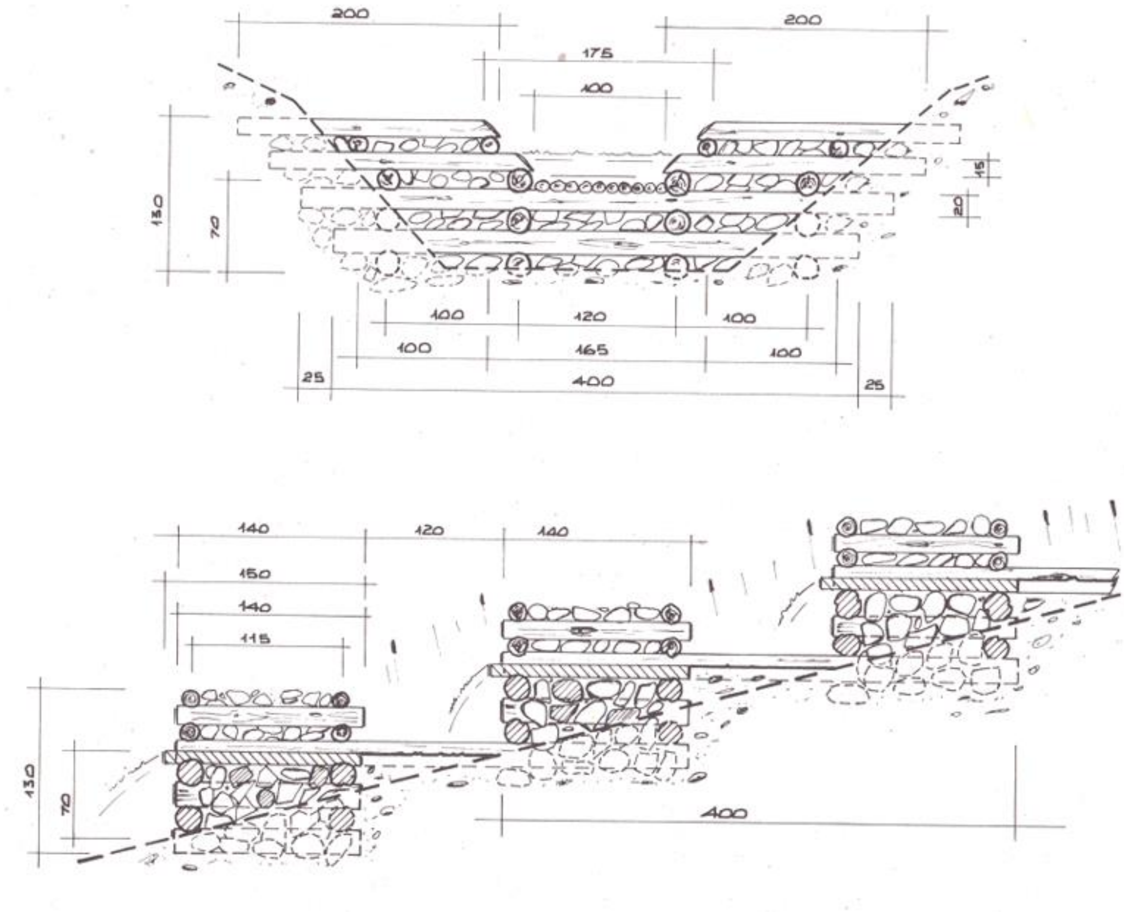


Figure 36 Application of a layered dam for slope reduction (Malaguti 1993)

Figure 37 Construction of a wooden and stone dam (Malaguti 1993)

**Figure 38 Wood and stone sediment trap dam and slope reduction dams (Malaguti 1993)**

**Figure 39 Erosion protection intervention using wood and stone (Malaguti 1993)**

## V.3 Maintenance and monitoring recommendation for log and brushwood dams

The material of brushwood dams is more fragile than that of log dams, so they require more attention, maintenance activities and corresponding repairs. However, dismantling and restoring the structure can be done relatively easily (if the water and weather conditions are suitable). The log dams are more stable, but due to the deterioration (rotting) of the structure, failure occurs periodically, which is why it also needs periodic supervision. In case of repairs, the need for professional work depends on the complexity of the structure.

Since dams can only be partially hydraulically sized during designing, not only their stability has to be checked, but also their role in water management after construction. Based on this – after their construction – it has to be monitored, if the desired effect is achieved by the structure and, accordingly, modification must be carried out on the dams as necessary.

It is necessary to regularly check the condition of the dams in accordance with the expected durability of the materials. It is advisable to carry out the inspection once a year. During this, the condition of the materials (searching for signs of decay) and the geometric conformity (height, shape of the dam crest, etc.) must be checked, as well as traces of possible seepage. After a significant load (flood), it is necessary to carry out an occasional inspection, which has the same aspects and elements as the regular inspection. During the inspections, it is advisable to determine the repair solutions for possible deterioration, as well as setting the deadline for the repair.

# VI. LOG AND BRUSHWOOD DAM LOCATION POSSIBILITIES AND LEGAL BACKGROUND

It is necessary to examine the protection methods not only from the point of view of technical design, but also from the point of view of establishment, construction and operation.

We have to examine the planned location of the structure, its basic purpose, from the point of view of establishment, environmental and nature protection. We also have to check what other permits are necessary to obtain for the implementation of the given facility. Considering financing and operation, clarifying the right of ownership and the possibility of financing the operating costs is also an essential issue.

## VI.1 Water permit

As a first step, it is worth clarifying whether the location of the planned facility is categorized as a watercourse or water facility area based on the current water management legislation, and whether the implementation of the planned facility should be considered water-related activity.

Act LVII of 1995 on water management (hereinafter: Water Management Act) Annex 1 contains three definitions that make the classification of the facility and its site uncertain from a water law point of view.

- watercourse: any natural or artificial terrain formation in which water flows permanently or periodically;
- water-related activity: the activity whose purpose is to alter the drainage, flow conditions, quantity or quality, bed, and bank of the watercourse for the purpose of preventing water damage, utilizing water, monitoring its quality and quantity, conducting mineral and geological research, extracting mineral raw materials;
- hydraulic establishment: facility (water utility), structure, or equipment, whose purpose is to alter the drainage, flow conditions, quantity or quality, bed, and bank of the watercourse for the purpose of preventing water damage, utilizing water - including water utilities service provided by utility activity - for the purpose of preventing water damage, utilizing water, monitoring its quality and quantity, conducting mineral and geological research, extracting mineral raw materials;

The law defines the concepts in such a broad way that the necessity of the water permit procedure cannot be defined based on the location or on the nature of the facility.

According to Section 28/A (1) of the Water Management Act, apart from activities subject to notification by law, a water permit is required;
a) to carry out water-related activities, construction and modification of the water facility (establishment water permit),
b) for commissioning and operation of the water facility, for water use (operation water permit), and
c) to terminate the water facility (termination water permit).

Considering that the purpose of the planned facilities is to change the flow conditions of the water and to prevent damage caused by waters, according to the law on water management, all proposed facilities are categorized as requiring an establishment water permit.

The government decree 72/1996. (V. 22.) on the exercise of water management authority does not define a scope of exceptions in terms of subject, so even based on the decree, it can only be established that the planned facilities are subject to an establishment water permit and fall under the jurisdiction of the regional water authority.

Provisions of the Water Management Act regarding ownership: According to the law, the owner of the property owns the watercourses that originates and flows into the receiver on the property and, the natural stagnant waters within the boundaries of the property (lake, oxbow) that are not directly connected to water located on other property, and the private water facilities within the boundaries of the property and have private purposes. At the same time, from a licensing point of view, the law does not distinguish between activities on one's own land and activities using properties with different ownership.

Besides the water management related legislation, we have to evaluate whether the planned facility falls under the scope of other legislation, and whether another authority can establish its competence or authority in relation to the facility

In this next section, we will only deal with permit process of the gully control dam, gully bed control, and brushwood and log dams in detail, since these facilities are the main topic of the study.

**Gully control dam and gully bed control permit**

From a licensing point of view, the question arises here as to which gullies should be considered watercourses. For example, in the case of a washed-out tourist trail if a "dam" that prevents runoff is placed or steps are created in the slope, do these fall under the water permit obligation?

If the gully is in a dry valley, then the purpose of the gully control dam is primarily to reduce soil erosion, and secondarily to retain water. If the gully can be clearly considered as a periodic watercourse, then the task of the dam is primarily to retain water. In this case, the bed control is still more about reducing erosion.

If the water periodically flows, due to improper practices in the agricultural area, or on naturally formed terrain, it should be considered a watercourse. At the same time, in many cases the resulting gully can even be restored by plowing. In this case, we can only talk about landscaping for agricultural purposes. In an agricultural area, the purpose of the dam in the gully is primarily to protect against erosion, so the construction can also be considered as landscaping for agricultural purposes.

Landscaping for agricultural purposes falls under the regulation of Act CXXIX of 2007 on the protection of agricultural land. Section (2) of §49 states, that landscaping for agricultural purposes must be reported to the soil protection authority.

In the case of a dam built in the forest, it must be examined whether it can be considered a forestry facility. According to Act XXXVII of 2009 (Forest Act) on forests, forest protection and forest management, §15 section (1) point c), a forest facility is a facility serving the purpose of the forest. Since the dam to be created in the gully serves to reduce erosion and retain the forest soil, it can be considered a forestry facility. In this case, it falls under the scope of the Forest Act, and its establishment must be notified to the forestry authority. The question arises as to where a dam can be defined as a forestry facility, and according to what criteria is it classified as a water facility. The current legal regulations do not provide any guidance for the delimitation. Based on this, the authorization takes place according to the decision of the developer and/or engineer. But it is not clear whether the developer can be fined for considering the installation of a dam in a gully to be forestry intervention.

**Brushwood and log dam permit**

In the case of brushwood and log dams, the purpose is primarily to reduce erosion, and secondly to slow down waterflow.

If the dam is constructed in a permanent or periodic watercourse, an establishment water permit is required.

Again, the question arises as to which of the gullies should be considered a periodic watercourse. If a brushwood dam is placed in the forest, can it also be said that it is a forestry facility? According to Act XXXVII of 2009, §15 section (1) point c) a facility serving the purpose of the forest is classified as a forestry facility. Since the dam to be created at the catchment serves to reduce erosion and retain the forest soil, it can even be considered a forestry facility. In this case, it falls under the scope of the Forest Act, and its establishment must be notified to the forestry authority.

A brushwood dam or log dam can be placed anywhere on a steep mountainside where erosion is expected, so it may not be placed in a gully. In this case, it can be said with certainty that an establishment water permit is not required.

In other cases, however, the classification of the gully determines the establishment water permit obligation.

## VI.2 Environmental permit

Like the water permit, the environmental permitting or environmental screening obligation does not apply to all inspected facilities. Due to their volume, the interventions examined in this chapter (brushwood and log dams) are not expected to fall into any of the categories. However, smaller dams established in nature conservation areas or Natura 2000 areas may be activities subject to an environmental permit, depending on the decision made by the environmental protection authority.

Screening is the process of determining whether or not environmental impact assessment (hereinafter: EIA) is required for a particular project. Depending on the location or specific features of the facility a Screening process might be conducted, in which case the environmental and nature conservation authority decides on the need for further assessment. The environmental procedure for Screening/EIA obliged establishments is quite developed, and the required formal standards and protocols are well formulated.

In a protected area, it must be taken into account that according to Act LIII of 1996 on the protection of nature, a nature conservation permit is obligatory even if the facility is otherwise not subject to Screening/EIA:

§ 38 (1) In a protected natural area, the permission of the nature conservation authority is required in particular:

b) for breaking up, renovating, reseeding, irrigating, grazing, mowing of the lawn;

c) or restoring the area, to change its nature and use

(Note: this includes practically everything that concerns the inspected facilities, so in a protected area we have to apply for a nature conservation permit even if the facility is not subject to Screening/EIA.)

j) for vehicle traffic, except for roads designated for agricultural and forestry use, machinery required for the performance of authorized activities, and the vehicles of persons performing their duties - authorized to do so in separate legislation.

According to Act LXIV of 2001 on **the protection of cultural heritage**, the interventions, developments, and constructions associated with earthworks must avoid registered archaeological sites in the cases and in the manner specified by the concerning legislation.

From a **landscape protection** point of view, a separate investigation is required if the activity is subject to an environmental protection procedure. The only exception to this is the felling of trees. If the establishment of a facility involves the cutting of trees, the procedure depends on where the given tree or trees are located and whose property they are. If they are in a forest area, they fall under the scope of the Forest and Forest Protection Act, and if in a Natura 2000 area, then the procedure is regulated by government decree 75/2004 on nature conservation areas of European Community importance. (X. 8.). In addition to these, depending on whether the tree to be cut is on public or private property, in urban or rural area, government decree 346/2008 on the protection of woody plants (XII. 30.), or the provisions of local government regulations must be applied.

Furthermore, the nature of the previous use of the establishment area must be considered, and whether, as a result, there is possible contamination in the soil or subsurface environment. If, for example, the area of the project previously served as an illegal waste landfill, we have to consider that the resulting disturbances or changes in the flow of water – due to the new hydraulic structure – might cause the pollution or waste to mobilize, to enter surface water or subsurface water and spread. In such a case, pollution and waste removal should be the first objective, and after that can the construction of water retention facilities begin.

## VI.3 Ownership, establishment and operation issues

Ownership issues must be taken into account already during planning as some of the planned interventions will take place on a watercourse that is designated as exclusive property of the state by Act CXCVI of 2011 on national property. If a facility is built on these watercourses, or a lake or reservoir is created by damming the watercourse, i.e., the watercourse's bank line is changed, the resulting facility also becomes non-negotiable state property. In the case of properties considered as national property, shared ownership is prohibited.

According to §6 of Act LVII of 1995 on water management, besides the rivers, streams, oxbows, tributaries, natural lakes and water facilities specified in Act CXCVI of 2011, the state's non-negotiable properties also include state-owned areas subject to nature conservation, enhanced protection, or areas planned for protection. The law defines the areas of responsibility and authority. According to §16, the construction, development, maintenance, operation and protection activities of protection facilities are the responsibility of the state, local governments, and those who have an interest in preventing or controlling damage.

The tasks of the state and the tasks of the local municipalities can be clearly delineated, but the scope and obligations of the stakeholders are not.

According to section (2) of §16, the water management organization must prepare a hazard and risk map and a risk management plan for the areas affected by the risk resulting from excess water.

According to section (3) of §16, the task of the water management organizations are to regulate rivers for the purpose of water damage control; the construction, maintenance and development of, and control and protection activities on the water damage control facilities serving more than two settlements - main flood protection lines, water damage control reservoirs, main inland water control facilities (hereinafter: control facilities) -, as well as control facilities exclusively owned by the state; furthermore performing the tasks of agricultural water supply and water damage prevention.

Section (4) defines, among other things, the possibility of professional management of the water damage control activities of local municipalities, and obligatorily assigns the task to the water management directorate.

According to section (5) of §16, the establishment and maintenance of water damage control facilities in the interests of up to two settlements are among the responsibilities of local municipalities.

Section (6) of §16 classifies the activities that do not fall within the scope of state or municipal responsibilities necessary for water damage control as the duty of the concerning owners and those using the property under other legal rights.

Although Act LVII of 1995 on water management does assign tasks to the stakeholders interested in damage control, the task cannot be delimited in terms of stakeholders and facilities. Failure to participate in damage control is not penalized.

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