AGENTURA OCHRANY PŘÍRODY A KRAJINY ČESKÉ REPUBLIKY

Česká zemědělská univerzita v Praze Fakulta životního prostředí

NATURE AND LANDSCAPE MANAGEMENT STANDARDS

WATER IN LANDSCAPE	RIVER MANAGEMENT INCLUDING BANK VEGETATION	SPPK B02 004: 2022
SERIES B		

Péče o vodní toky včetně břehových porostů
Wasserflusspflege Einschliesslich Bankbestände

This standard contains both basic and specific approaches, management principles and practical recommendations for protection of natural watercourses and regeneration of near-natural watercourses.

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Act no. 114/1992 Coll. on Nature and Landscape Protection, as amended

Decree no. 178/2012 Coll., laying down the list of major watercourses and method of implementation of activities associated with watercourse management, as amended

Decree no. 257/2009 Coll. on use of sediments on agricultural soil, as amended

Standard development:
NCA CR in cooperation with Czech University of Life Sciences Prague, Faculty of Environmental Sciences , 2022.

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1. Standard purpose and contents

The standard "River management including bank vegetation" represents a comprehensive concept of watercourse management in the form of environment-oriented management approaches. It formulates specific goals for achieving a good status of watercourses and river territories in the morphological and associated biological aspects. It specifies management principles and recommendations in the area of protection of natural watercourse channels and restoration of near-natural status of watercourse stretches affected by technical modifications of riverbeds and other hydraulic structures in the river space.

2. Legal framework

Act no. 254/2001 Coll. on Waters and on amendment of certain acts (Waters Act)
The jurisdiction of the Standard is derived most importantly from:

- Section 44 – the definition of a natural watercourse channel includes its ability to change direction, gradient and transverse profile;
- Section 45 – creates a path towards stabilization and use of favourable changes in watercourse channels occurring during floods;
- Section 46 – prohibits disturbing interventions in watercourse channels; currently most importantly in the sense of restricting interventions that damage the natural status of watercourses;
- Section 47 – assigns watercourse managers to restore natural watercourse channels, particularly in specially protected areas and territorial systems of ecological stability, and design remedial measures for human interventions leading to restoration of natural watercourse channels;
- Sections 50 and 51 – assign owners of watercourse channel land plots and adjacent plots to tolerate both bank vegetation and natural watercourse channel on their land.

Act no. 114/1992 Coll. on Nature and Landscape Protection
The jurisdiction of the Standard is derived most importantly from:

- Section 3 – defines prominent landscape features (PLF), including hydraulically relevant features, i.e., watercourse, floodplain and fishpond;
- Section 4 – specifies that PLF are protected from damage and destruction; any disrupting interventions require a binding position statement of a nature protection authority; PLF protection requirements applies to both natural and modified watercourses;
- Section 5 – defines general protection of plants and animals;
- Section 44 – specifies that water treatment permits, hydraulic structures, certain activities or approvals under the Waters Act in national parks and protected landscape areas require a binding position statement of a nature protection authority;
- Sections 48, 49 and 50 – apply to cases where specially protected species of organisms are present in a watercourse or its floodplain.

Decree no. 178/2012 Coll., laying down the list of major watercourses and method of implementation of activities associated with watercourse management.
Besides a list of hydraulically important watercourses, it contains some general provisions on watercourse management.

Decree no. 257/2009 Coll. on use of sediments on agricultural soil.
Defines possibilities for placing sediments excavated, among others, during watercourse maintenance, on agricultural soil.

3. Overview of terms

Throughout the document, the term "river" is used even if the watercourse in question is categorized as a brook.

Accompanying vegetation – woody plant vegetation around a riverbed that participates in the watercourse functions, i.e., within the river corridor; in a broader sense, it may encompass vegetation in the entire floodplain (river space).

Bank vegetation – vegetation on the banks of a riverbed; woody plant vegetation in water management practice.

Debris – solid particles carried by a watercourse, mostly originating from earth and rock, from clay particles to boulders; in terms of the motion mechanism, it is divided into floating solids (carried in the flow) and bottom debris (moving in contact with the bottom by way of sliding, rolling or bouncing); it is heavier than water, is laid in the riverbed to form sediment.

Debris dam – a wooden, masonry or gabion transverse structure, used mainly in traditional damming of mountain streams to catch debris and local disabling of gradient.

Driftings – natural and artificial material carried by a watercourse, not heavier than water; mostly wood and herbaceous material, and unfortunately also drifting waste.

Dynamically stable riverbed – in terms of the debris regime, a stable stretch has a balanced floating solid ratio (output equals input); in terms of morphology, the stretch has natural evolution, such as rerouting of meanders, but the basic shape and dimensions of the riverbed and its hydraulic and ecological function do not change; a basic aspect of a dynamically stable riverbed is that its overall depth does not increase (which does not rule out separate bottom depressions).

Hardwood riparian trees – vegetation dominated by longevous hardwood trees such as oaks, elms and ashes; their existence is bound to river alluvium of varying thickness but more distant from the riverbed and only rarely affected by flood waves, or only occasional short-term flooding with fast water drainage; the key factor is a permanently increased water table, typically oscillating within 1–1.5 m below the soil surface.

N-year flow rate – a flow rate in a watercourse that is achieved or exceeded in the long-run hydrological statistics once very N years (Q_5 = one-in-five-year flow rate: a flow rate achieved or exceeded once every five years in the long run).

Natural watercourse (factually) – an ideal watercourse not influenced by human activity, flowing in a natural riverbed; since such watercourses no longer exist in our cultural landscape, we settle for considering any watercourse not affected by technical modifications or swelling caused by transverse structures to be natural.

Polykormon – a biological woody plant individual that forms multiple trunks (typically European black alder, for example).

River corridor (brook corridor) – a strip of territory along a watercourse the character of which is primarily dictated by hydraulic and ecological functions of the watercourse.

River space – the broadest definition of a territory affected by a watercourse; typically the riverbed and the whole floodplain.

River wood – living and dead wood material present in various forms and sizes in a watercourse channel – tree root tangles, deposited wood debris, fallen and drifted tree trunks.

Softwood riparian trees – vegetation dominated by softwood trees such as willows and poplars; the key factor is the existence of fresh bank alluvium, where the water level is above or just below the soil surface throughout the year; another necessary factor is periodic flooding, including long-term.

Trough – the part of a watercourse channel carrying and filled with normal flow.

Water accumulation (in surface areas and soil layers within a catchment area, in reservoirs, watercourse channels, floodplain earth, etc.) – ordinary retention of water, significant over a season, year or several years; the quantity of water accumulated in catchment areas is important for water supply, in terms of droughts, etc.; an essential element of water storage in catchments is the retention of water in aquifers of soil, earth and rocks.

Water retention – surface water from precipitation being held in catchment areas, floodplains, watercourse channels and retention reservoirs, most temporally important during a precipitation/runoff event.

Watercourse potamization – modification of a watercourse with swelling structures whose swellings (stagnant water above the structure/dam) adjoin one another, so that the watercourse practically loses swifter stretches (riffles and fords).

Watercourse flood perimeter – the area of a watercourse and its surroundings in which flood flow rates occur; compared to the entire floodplain, it can be limited, e.g., by constructing levees, buildings or landscaping.

Watercourse renaturation (spontaneous) – in terms of morphological and ecological status, mostly desirable processes of degradation and spontaneous return to natural status of technically modified watercourse channels – disintegration of technical fortifications, loosening of the watercourse channel by sideways erosion, sediment fouling, overgrowing by herbs and woody plants, flood riverbed alterations, beaver damming, etc.

Watercourse with a natural riverbed (pursuant to Waters Act) – a watercourse that is not burdened by any structures in water management or property registers; under current regulations, these may include not only natural watercourses under the above paragraph, but also watercourses that were historically burdened by modification and factually may still carry some of its influences, but the structure was never discussed by water management authorities as a hydraulic structure or has ceased to exist in the administrative manner (disappeared from water management or property registers, has been declared non-existent or annulled by a water management authority decision) – such a watercourse is managed as a natural one.

4. Watercourse status and natural functions

4.1 The ecological status of a watercourse is an expression of the quality of its structure and functions of its aquatic ecosystems. It is described in terms of morphology (defined by the shape and dimensions of the riverbed, structure and substrate of the bottom, structure of the river corridor, size and dynamics of flow rates, connections to groundwater bodies, character of the flow rate and debris regimes, migration passability for aquatic animals), water quality (chemical and physical quality indicators) and biology (quantity and species diversity). The biological aspect is defined by the river space morphology and water quality.

4.2 Good status of a watercourse is the more favourable the closer it is to the natural status of the stretch (adequate hydromorphological pattern and ability to perform natural hydraulic and ecological functions).

4.3 Natural hydraulic and ecological functions of a watercourse refer primarily to:

- biotope functions (existence of river space biota, including conditions for biota survival in unfavourable situations);
- undisturbed water accumulation in the riverbed and adjacent rock, earth and soil strata);

- natural water retention in the riverbed and the floodplain, active action of natural mechanisms attenuating occurrence and severity of floods;
- natural water drainage from the area (not accelerated compared to natural conditions);
- provision of water quantity and quality necessary for watercourse functioning as a water source and receiver for wastewater;
- improving water quality, self-purification, downstream purification;
- provision of a stay and recreation space for people.

4.4 When evaluating watercourse status, determining requirements for status and proposing methods of achieving the requirements, the character of each evaluated stretch of the watercourses is taken into account. It is especially important to distinguish between open country and built-up areas or areas where the watercourse may affect development or infrastructure.

4.5 In open country, the framework objective is naturally authentic watercourse status. Desirable flow conditions there are characterized by a naturally shallow, naturally low-capacity and sufficiently varied watercourse channel, accompanied by vegetation and a river corridor of near-natural condition, supportive of flood overflows into the floodplain.

4.6 In stretches in and near built-up areas, the priority is local protection of areas and buildings from flood overflows. Desirable flow conditions there are typically characterized by a riverbed, or defined river space, with adequate flood capacity and mostly stable in terms of shape.

4.7 Natural watercourse functions associated with good status exclude functions conditioned by technical interventions in the watercourse with unfavourable effects on its morphological status, such as enabling energy production and navigation.

5. Ecologically oriented watercourse management (EOPVT)

5.1 EOPVT represents a holistic notion of watercourse management (detailed in the "Ecologically oriented watercourse management towards good morphological status" methodology; Just, 2016), which systematically aims at good status as described in 4 above as part of provision of natural and societal needs associated with watercourses and river territories.

5.2 EOPVT applies primarily the following approaches:

5.2.1 Consistent protection of extant watercourse and floodplain status from deterioration. Status deterioration refers to changes and interventions that move watercourse and floodplain status from the natural or near-natural status and disrupt natural functions.

5.2.2 Respect, adequate protection, support and land ownership conducive to spontaneous evolution of watercourses with natural riverbeds with the concept of dynamic stability of riverbeds and natural debris regime.

5.2.3 Restriction to interventions for riverbed management, maintenance and repairs that are not reasonably effective and may damage the watercourse status: notably removing debris and wood matter from riverbeds, repairs of ripped banks, repairs that invalidate effects of spontaneous renaturation.

5.2.4 Justified, effective, considerate and economic performance of routine maintenance of watercourses, demonstrably beneficial in terms of society-wide interests, with a view to actual needs and based on rational interpretation of watercourse management obligations. Differentiated maintenance based on distinction of different conditions and potential objectives of watercourse stretches in open country and built-up areas.

5.2.5 Prevention of hydraulically, ecologically or landscape-adverse interventions and activities in the river space, the necessity of which is not well justified (e.g., construction and landscaping that inappropriately restrict the course of and moderating overflows during floods).

5.2.6 Prudent measures after floods and adequate utilization of positive flood changes with respect to different conditions and potentials in open country versus built-up areas.

5.2.7 Application of a rational comprehensive flood protection system effectively combining technical and nature-based approaches.

5.2.8 Protection and restoration of natural passability of watercourses for migration of aquatic animals and passability of river territories for terrestrial animals.

5.2.9 Revitalization of technically modified watercourses.

5.2.10 Respect, utilization and support to spontaneous renaturation processes of technically modified watercourses.

5.2.11 Support to near-natural bank and accompanying vegetation as an important component of the river space.

5.3 The EOPVT principles should be applied primarily to watercourses with a significant nature and landscape protection interest, such as those in specially protected areas and on Natura 2000 sites and those significant as biotopes of important plant and animal species (specially protected, endangered as per Red Books). In light of the general jurisdiction of watercourse protection and status improvement requirements, however, these principles need to be recommended throughout the watercourse network.

5.4 The EOPVT concept follows its objectives and applies its approaches in the area of design and planning, administrative and executive watercourse management.

5.5 Separate documents elaborated for determination of suitable target status of watercourses and designing of adequate measures under the EOPVT for applicable watercourse stretches are as follows:

- hydromorphological analysis;
- hydraulic analysis;
- biological assessment.

They serve primarily comprehensive decision-making in more complex cases and situations. The contents and method of discussing the documents are recommended, for example, by Just et al. (2020).

6. Goals of EOPVT

6.1 Protection and restoration of near-natural floodplain status

6.1.1 Near-natural floodplains are protected and restored most importantly as

- spaces for natural functioning and development of near-natural river corridors;
- spaces for natural water accumulation and retention (accumulation of shallow alluvial water table and retention of flood overflows);
- spaces for alluvial plant and animal communities and natural wetlands;
- stay and recreation spaces for people.

6.1.2 In open country outside built-up areas, the priority is a near-natural character of floodplains, whereas in and near built-up areas, the priority is reasonably harmless passage of floods with a growing importance of visitor stay and recreation functions of the floodplain (river flood park concept).

6.2 Restoration of naturally large spatial extent of riverbed, river corridor and natural flood overflow areas:

- restoration of natural riverbed width compared to artificially narrowed technically modified riverbeds;
- restoration of meander strips or near-natural river corridors;
- restoration of naturally flooding perimeters.

6.2.1 The division of the river space is shown in Fig. 1 (Annex 1). The most ecologically valuable parts of the riverbed are the trough filled with normal flow rates, bankside shallows and occasionally flooded flat areas that accompany it. Maximization of extent of these elements is a major goal.

6.3 Restoration of natural shapes and dimensions of watercourse channels in terms of adequate hydromorphological pattern

6.3.1 One of the EOPVT goals is to protect and restore natural shapes and dimensions of riverbeds, including flow capacity, corresponding to the relevant hydromorphological pattern.

6.3.2 In hydromorphologically extant stretches, this goal is achieved primarily by making no disrupting intervention in the watercourse.

6.3.3 In hydromorphologically degraded stretches (most commonly by technical modification), revitalization reconstruction is carried out, designed based on knowledge of the relevant hydromorphological pattern and the derived shape and dimension parameters of the riverbed, which parameters it follows as much as possible. For designing of shapes and dimensions of a revitalized watercourse channel in accordance with the relevant pattern, see B02 003: 2022 Revitalization of watercourses and their floodplains.

6.3.4 For better understanding of fluvial processes and prediction of changes associated with natural behaviour of river systems, watercourses are classified into types. The most common approach to defining types of watercourse is respecting the continuum of the river pattern (simplified as the flow path) and assessment of riverbed shape (Thorne 1997). In the Czech Republic, only a handful of river patterns suffice: riverbeds that are naturally straight, undulating, meandering and running wild, or migrating (branching gravel-bearing riverbeds). Riverbeds with stable branching (anastomosing) are exceptional. The basic types of river patterns applicable in the national conditions are shown in Fig. 2 (Annex 1).

6.3.5 The meandering watercourse type is usually preferred in broader floodplains at lower elevations, filled with alluvial earth, with valley line longitudinal gradients approximately up to 2%. The path comprises alternating to deep bends, sometimes interlaced with shorter straight stretches. The riverbeds tend to have a natural capacity up to Q_1 (“one-year flood”) or more often lower. The riverbed is usually relatively shallow, with pools typically at the steeper impact banks in bends, which can be significantly deeper. Shallowed, stony fords occur typically in the transition area between bends. As such, the riverbed is characterized by alternating pools and swifter stretches, aligned with the alternating bends within the path.

The typical shapes of a meandering riverbed are shown in Fig. 3 (Annex 1).

6.3.6 As for the transition conditions between the meandering type and the straight riverbed watercourse type, the undulating path watercourse shall be preferred.

6.3.7 The wildly running watercourse type is preferred in mountain and submontane areas with higher longitudinal gradients, with a rich transport of debris and highly variable flow rates. The riverbed is relatively straight, wide and shallow, and may occupy the whole width of the valley bottom. The riverbed bottom comprises a cover of gravel and coarser fraction substrate. Normal flow rates do not fill the entire riverbed area but tend to unravel into multiple flow threads amid unstable gravel banks or gravel and stone islets. Only capacity flow rates, typically ranging between Q_1 and Q_2, fill the whole riverbed. (The flow capacity is higher compared to a meandering flow, but is realized in a relatively broader and shallower riverbed shape.)

6.3.8 The straight riverbed watercourse type is preferred in more inclined and narrower valleys providing no room for meandering. The riverbed running wild is precluded by the smaller valley width and the presence of less sedimenting debris – the rocky valley bottom frequently crops out in the riverbed. A relatively regular alternation of swifter areas with coarser riverbed substrate and deeper backwaters is usually established in the riverbed bottom, which is an analogue of alternating pools and fords in meandering riverbeds. The flow capacity of a straight riverbed is typically approximately between Q_1 and Q_2.

An approximate comparison of the usual flow capacities of typical watercourses is shown in Fig. 4 (Annex 1).

6.3.9 So-called high-gradient riverbeds are a special case in watercourse channel classification for the Czech Republic. They are often riverbeds of mountain streams of lower orders, showing high variability in morphological and hydrological characteristics. The differences of high-gradient, mountain watercourse channels with greater longitudinal gradients are detailed, for example, by Montgomery and Buffington (1997). Mountain riverbeds are typically directly connected with adjacent slopes in terms of supply of sediments, and the restricted spatial conditions of mountain valleys usually do not permit formation of a floodplain (mountain watercourses may have naturally straight riverbeds). Therefore, mountain riverbeds have to be viewed in the context of the entire catchment area (particularly in terms of sediment supply and river continuum). The hierarchical classification of valley segments and mountain riverbed stretches (Montgomery and Buffington 1997) is based on morphological characteristics related to sediment supply and transport capacity of the stream. The authors distinguish 3 basic riverbed types: rock, alluvial and colluvial. Within alluvial riverbeds, they describe 5 morphological types: cascades, sequence of terraces and pools, planar morphological riverbed type, sequence of pools and rapids, and riverbeds comprising dunes with ripples. The characteristic features of the different morphological types are shown in Table 1.

Table 1: Characteristic features of morphological types according to Montgomery and Buffington (1997)

Morphological type	Bottom material	Bottom structural pattern	Dominant coarseness elements	Dominant sediment source	Sediment deposition elements	Sinking	Distance between pools (channel width)
Colluvial channels	variable	variable	substrate grain size	slope processes, rockslides	bottom	sunken	unknown
Rock channels	rock subgrade	irregular	interface (bottom and banks)	fluvial, slope processes, rockslides	pockets	sunken	variable
Cascades	boulders	random	substrate grain size, banks	fluvial, slope processes, rockslides	before and after obstacle	sunken	below 1
Sequence of terraces and pools	stone-boulder	vertically variable	bottom shapes (terraces, pools), substrate grain size, banks	fluvial, slope processes, rockslides	bottom shapes	sunken	1 to 4
Planar morphological channel type	gravel-stone	no obvious bottom structure	substrate grain size, banks	fluvial breeches, rockslides	flood sediments outside the channel	variable	none

Sequence of pools and rapids	gravel	laterally variable	bottom shapes (banks, pools), substrate grain size, sinuosity, banks	fluvial breeches	flood sediments outside the channel, bottom shapes	unlimited	5 to 7
Channels comprising dunes with ripples	sand	multilayered	sinuosity, bottom shapes (dunes, ripples, banks), substrate grain size, banks	fluvial breeches	flood sediments outside the channel, bottom shapes	unlimited	5 to 7

6.3.10 The fluvial-morphological status of mountain stream channels depends on communication with the surroundings (slopes: source of sediment, landscape coverage of catchment area and catchment area hydrological status are reflected in flow rate fluctuation, etc.). One absolutely fundamental factor is the condition of forest stands (monocultures vs. near-natural spatial, age and species structure) in close surroundings of the mountain stream. Presence of river wood then may decide whether the mountain stream has a sufficiently developed alluvium, or a continuous or discontinuous floodplain, albeit small in extent, or whether the different elements of the debris regime are in dynamic equilibrium. The problem with the national conditions is that there are very few near-natural forest stands that would enable the existence of reference mountain streams.

6.3.11 The watercourse type with stable branching (anastomosing watercourse) can be preferred in less inclined stretches of low-lying river valleys with a wide floodplain filled with deeper layers of alluvial material. A highly developed meandering leads to the riverbed branching among larger isles, which are usually so stable that they may be covered with tree vegetation.

6.3.12 Real-life watercourses may represent various transitions between these types or various level of type degeneration due to anthropogenic influences.

6.4 Restoration of natural watercourse shape diversity

6.4.1 Shape diversity creates conditions for hydraulic diversity and produces surfaces, habitats and shelters necessary for naturally occurring watercourse life. The naturally high shape diversity in the hydraulic aspect of coarseness is involved in creation of desirable flow rate conditions in watercourse channels outside built-up areas (notably naturally slow progress of flood flow rates and their frequent attenuating overflowing into undeveloped floodplains).

6.4.2 A significant factor of restoration of riverbed shape diversity is restoration of its natural shallowness and flat shapes. In this way, a space is restored that enables development of ecologically valuable shallows and sediment structures, areas of water level fluctuation and bank stretches.

The advantages of a naturally flat riverbed are shown in Fig. 5 (Annex 1).

6.4.3 The typical shapes of a meandering riverbed are a steeper impact (concave) bank (river cliff) and a gentler convex bank where debris is deposited (point bar); see Fig. 3 (Annex 1). Vegetation interfering with the water columns (such as root systems of woody plants) is important for the shape diversity of banks. The frequency and regular alternations of the different shapes are also important.

6.4.4 Natural accompanying water elements in a floodplain include primarily various types of river branches, pools and wetlands providing important habitats for aquatic and water-bound biota, representing accumulation of surface water and shallow groundwater and hydrologically and hydraulically communicating with the watercourse channel.

6.4.5 Different riverbed shapes directly constitute habitats for biota. The generation and restoration of the shapes is directly dependent on the erosion-accumulation process; its reduction leads to the shapes disappearing (fading away).

6.4.6 A spatially extensive and diverse riverbed provides the best conditions for self-purification. The intensity of downstream water purification in watercourses depends primarily on the intensity and duration of contact with contaminated water and the active surface of the riverbed. Self-purifying processes also significantly occur underneath the riverbed (in the hyporheic zone); thus, a natural or near-natural, naturally permeable riverbed bottom is important for their intensity. The ability of a watercourse to retain solid particles, notably by sedimentation, is also significant. Conversely, watercourse channel simplification by technical modifications usually worsens the conditions. Concentration of gradient in riverbeds (e.g., by building weirs) in order to aerate water to promote self-purification is ineffective.

6.5 Restoration of natural watercourse hydraulic diversity

6.5.1 The hydraulic diversity of a watercourse comprises diversity of water depths, directions and velocities of flow.

6.5.2 Hydraulic diversity depends on the riverbed shape diversity, including natural geodiversity and natural flow rate fluctuation. Insufficient hydraulic diversity has a direct negative impact on the biota (too high speed, insufficient depth, etc.).

6.5.3 The hydraulic diversity has to be assessed for different flow rate conditions. The following set is advisable: Q_{330d}; Q_{180d}; Q_{30d}; Q_1; Q_5; Q_{20}; Q_{100}.

6.6 Restoration of ecological habitats and shelters

6.6.1 A rich supply of habitats and shelters for river biota is immediately connected to the natural morphology of the watercourse, notably its shape and hydraulic diversity.

6.6.2 Watercourse biota is endangered and damaged by drying and overheating of watercourses in dry and hot weather, rinsing by floods, silting by fine-grained sediments (from fishponds and fields) or excessive pollution, be it accidental or chronic. The impacts of these generally natural processes are significantly aggravated by morphological degradation of watercourses due to technical modifications and operation of hydraulic structures, particularly hydropower facilities.

6.6.3 The goal is to reduce impacts of technical modifications to riverbeds and artificial swelling due to transverse structures, which mostly reduce diversity, simplify the environment for river biota, destroy diverse habitats, significantly disrupt the debris regime, reduce food and reproduction opportunities and shelter possibilities.

6.6.4 The emphasis is on protection and restoration of specific habitats in the river space, notably as follows:

- root tangles of woody plants growing in the banks (basic habitats, shelters);
- river wood (shelters, important biotope for many specific insect species, etc.);
- gravel bars (spawning ground for some fish species, biotope of many benthic species, etc.);
- steep slopes in impact banks (bird nesting, solitary bees, etc.; material from eroding banks becomes the foundation for silting, sand or gravel banks, etc.);

- organic debris deposited in calmer parts of the riverbed and deep fine-grained sediments (food source, development of insect larvae, lampreys, etc.);
- zone of normal water level fluctuation, flat sand or gravel banks (biotope for a wide range of often specialized plants and animals);
- exposed flat surfaces on the sides of the riverbed, maintained mostly free of vegetation by normal water level fluctuation or progress of more frequent small floods (crucial space for many often specialized organisms);
- banks and riverside channels, activated by floods – occasionally flooded surfaces, maintained at least temporarily free of vegetation, including covering with various debris fractions, sorted by flood flow (important biotope for many species of organisms);
- side branches and floodplain wetlands (habitat for specific and highly endangered plant and animal communities for which the main watercourse with a faster flow is not attractive but serves their proliferation);
- normally overgrown surfaces of the river corridor and floodplain, exposed to more frequent flooding (specific plant and animal communities);
- periodic pools along the watercourse (specialized organisms requiring, e.g., drying of eggs, such as tadpole shrimps, fairy shrimps, etc.).

A schematic comparison of the usual footprint extents of basic ecologically important environment types in a natural meandering riverbed and a corresponding technically modified riverbed is shown in Fig. 6 (Annex 1).

6.7 Restoration of natural watercourse flow regime and flooding of undeveloped river space is done primarily with a view to:

- sufficient supply of the riverbed and floodplain area with water and flow rate fluctuation to secure common ecological functions of the river space;
- maintenance of acceptable rates of dilution of discharged wastewater or treated wastewater;
- ensuring the best possible conditions for biota survival in drought periods;
- maintenance of natural flooding of hydraulic floodplain elements;
- maintenance of natural dynamics of watercourse hydromorphological evolution (riverbed-forming flow regime and debris motion).

6.7.1 Flow rates considered capable of reshaping the riverbed or the floodplain are Q_{60d} (once-in-60-days flow rate) or higher. The most important are flow rates from Q_{30d} to approx. Q_5, the natural progress of which has to be respected also when planning major water management structures.

6.7.2 Most commonly, the loss of natural riverbed-forming flow rates is caused by excessive transformation of flow rates in reservoirs, including dry and semi-dry flood reservoirs.

6.8 Restoration of natural material character of the riverbed and its communication with surrounding aquifers

6.8.1 Restoration of natural material character of the riverbed refers primarily to restoration of natural substrate of the bottom and banks (in terms of size categories and arrangement of particles) and a near-natural state of the riverbed towards a natural extent of the biologically active wet surface and hydric and ecological communication between the riverbed and the surrounding environment.

6.8.2 Natural bottom structures, notably natural bottom paving, are an important factor of riverbed stability, and their disruption, e.g., by removing debris deposits or other mechanical intervention in watercourse channels, may contribute to depth destabilization of riverbeds.

6.8.3 The material character of the riverbed and the related watercourse behaviour are negatively affected in particular by:

- technical fortification and, in special cases, deliberate technical sealing of the riverbed;
- geometrization of the riverbed as part of technical modification – loss of hydraulic diversity suppresses bottom substrate diversity; the riverbed bottom is continuously covered with fine material and loses ecologically important gravel bars;
- presence of swelling structures (weirs, dams), which intercept sediment and cause so-called hungry water effect farther downstream;
- clearing of debris from watercourse channels;
- clogging of the bottom by settling fine-grained material of erosion origin, long-term severe organic water pollution or discharging of sludge (causing so-called bottom felt), industrial mineral pollution, etc.

6.9 Maintenance and restoration of natural watercourse evolution

6.9.1 In stretches outside built-up areas, where not precluded by particularly serious reasons, related, e.g., to use of adjacent areas, the preferred status is that the watercourse can naturally evolve under conditions of dynamic stability and a respective hydromorphological type.

6.9.2 Such watercourse evolution proceeds with natural erosion, transport and accumulation of debris and driftings and horizontal shifting of the riverbed, which do not significantly alter the shape and dimension pattern of the riverbed (notably depths and widths and their mutual ratio) and the associated hydraulic and ecological functions of the watercourse.

6.9.3 In more complex situations, the acceptability of riverbed evolution and its limits are determined as part of a hydromorphological and hydraulic analysis of the given stretch. A precondition for setting target condition and predicting the expected natural watercourse evolution is to take into account the historic evolution of the watercourse (including response to human activity), its current conditions and evaluation of the watercourse evolution potential with respect to the current limitations (for more details, see Just et al., 2020; for an international approach, see River Styles Framework, Brierley a Fryirs, 2005).

6.10 Promotion of near-natural bank and accompanying woody plant vegetation

6.10.1 Woody plant growths are an important component of river space, as they fundamentally influence the status of watercourses and entire floodplains and significantly contribute to performance of their natural functions.

6.10.2 Natural bank vegetation is frequently characterized by adaptation to higher water table, ability to tolerate short-term inundation, resistance to mechanical damage, high regeneration and rejuvenation capacity (notably softwood riparian trees). Woody plants of natural bank vegetation are usually short-lived. Shrubs are more highly represented in bank vegetation.

6.10.3 Besides the direct effects of the watercourse and fluctuating water table, natural accompanying vegetation (notably hardwood riparian trees) is usually characterized by an adequate presence of long-lived competitors (e.g., oaks, elms, ashes) and other woody plants adapted to drier and less disrupted habitats. The species composition and structure of accompanying growths may differ significantly from bank growths.

6.10.4 One EOPVT priority is protection and management of bank and accompanying vegetation, restoration and promotion of their near-natural character and their widest possible range of natural functions.

6.10.5 Among the natural functions of bank and accompanying vegetation, the most crucial are as follows:

- natural riverbed stabilization – they may fully replace artificial fortification on smaller watercourses, can be used in renaturation;
- contribution to natural shape and hydraulic diversity of the riverbed and floodplain;
- directing and slowing of flood flow, promotion of attenuating overflows into the floodplain;
- interception of flood driftings (which might be caught elsewhere at a risk);
- filtration (reducing input of nutrients and other pollutants from surrounding agricultural areas into the watercourse);
- absorption (water retention in the floodplain, reduced flood waves on minor watercourses);
- soil improvement (e.g., alder) – symbiotic bacteria capacity and nitrogen-rich leaf shed significantly contribute to the nitrogen cycle at both local and landscape levels;
- source of energy and nutrients in watercourse ecosystems (often a key food source for communities of decomposers and detritivores, on which other communities depend, including fish);
- refreshing stock of river wood in the riverbed and the floodplain;
- shading of watercourses and water temperature control; important for the whole watercourse ecosystem, including improved conditions for biota survival in dry and hot weather (reduced water evaporation and temperature increases, reduced algal bloom and subsequent eutrophication, leading to fundamental changes in communities of micro and macroorganisms and, ultimately, fish mortality);
- habitats and shelters for aquatic organisms (notably root tangles extending into the water) and terrestrial organisms (particularly in intensively farmed or inhabited landscapes);
- plus, for example, soil protection from wind erosion, landscaping, recreation, etc.

6.10.6 Woody plants growing directly in the bank (level) lines of riverbeds play a particularly important role. They are most actively involved in generating shape and hydraulic diversity of the riverbed and typically initiate appropriate lateral riverbed evolution. They therefore also play an important role in renaturation of watercourse channels.

6.10.7 Near-natural growth formations are characterized by a natural species composition, dense cover and well-developed spatial, age and structural diversity.

6.10.8 For more details on establishment and management of near-natural bank and accompanying woody plant vegetation, see 7.11.

6.11 Protection and restoration of watercourse migration passability

6.11.1 EOPVT protects migration passability of watercourses as one of the fundamental existential needs of animals, natural life in the ecosystem and maintenance of population quality.

6.11.2 The purpose of watercourse management is to eliminate or at least compensate for artificial obstacles to migration, such as:

- transverse gradient structures, i.e., terraces, weirs and dams (for some species starting from a height of 0.2 m);
- riverbed stretches that technical modifications have made unfavourable for animal living and migration (absence of shelters, fast-flowing water over a flat bottom, etc.);
- riverbed stretches artificially swollen, unsuitable as living environment for rheophilic animal species;
- stretches affected by excess water consumption and peaking of hydropower plants;
- inappropriately designed culverts and bridges;
- through water reservoirs.

6.11.3 Migration connection of individual stretches is beneficial, extending, depending on the watercourse size, over hundreds of metres or single kilometres. The potential efficiency of intended measures should be considered.

6.11.4 The degree of necessity of migration passability of watercourse stretches is assessed based on biological needs of the concerned species identified by study of available documentation or ichthyological or biological surveys.

6.12 Restoration of debris regime

6.12.1 Transport of debris, including its formation (erosion) and deposition, is a natural behaviour of a watercourse, fundamental for the functioning of fluvial morphological processes. Minor watercourse within larger catchment areas play an indispensable role as sources of debris, supplying lower-lying parts of a river with sedimentary material, thus ensuring stability of their channels (preventing the hungry water effect). For more details, see Krejčí et al. (2021).

6.12.2 Reducing movement of debris by technical channel fortification, construction of transverse structures (e.g., terraces, weirs, debris dams) or water reservoir dams disrupts the debris regime of the watercourse; lack of natural debris material can then manifest itself as the hungry water effect – undesirable increase in channel erosion in parts of the river downstream.

6.12.3 Understanding where debris originates and what are its sources (e.g., tributaries, bank erosion, massive material input from valley slopes, as well as washoff from farmland in the case of floating solids), how often it moves and where along the watercourse path it is deposited (and for how long) is crucial for setting goals that can be achieved realistically as part of restoration of the debris regime. Identification of hungry water stretches and those with excess sediment is critical. Field survey is a necessary precondition for understanding the movement of debris and an input for debris analysis for the specific catchment area. For more detail, see, e.g., Brierley and Fryirs (2005); for Czech conditions, see Krejčí et al. (2021).

6.12.4 Reducing the natural debris regime by measures such as damming of mountain streams and other types of debris dams may be permitted only in justified cases based on previous assessment and consideration of nature-based alternative solutions.

6.12.5 The watercourse with its functions, including transport and deposition of debris, is a space that irreplaceably contributes to performing forest functions. Forest soil protection is therefore not considered a reason for damming mountain streams.

6.12.6 The justification of individual damming measures has to be assessed in the context of potential disruption of fluvial morphological processes and damage to the morphological and ecological status of the watercourse, in particular:

- reduction to natural gradients and the associated habitat composition of the riverbed;
- reduction of the watercourse shape and hydraulic diversity;
- deprivation of the watercourse of debris material, which will manifest itself adversely on the fluvial morphological process farther downstream, up to the risk of undesirable riverbed erosion and depth destabilization;
- reduced passability for migration of aquatic animals.

6.12.7 Deposition of debris material is another natural process. The necessity and justification of interference with the sediment is assessed individually depending on the character and needs of each specific watercourse stretch and the nature of the sediments in that area (biotopes for the freshwater pearl mussel require special care). The assessment has to consider negative impacts, in particular:

- damage to habitats and shelters in the watercourse (notably gravel banks, side shallows, spawning grounds and transition habitats);
- direct mechanical damage to river biota when making interventions;

- damage to biota by artificial induction of turbidity;
- reactivation of nutrients and pollutants bound to sediments;
- mechanical damage to bank vegetation (including admission of infection in injured woody plants);
- possible starting of undesirable erosion processes.

For more details on EOPVT goals, see the methodologies of Just (2016) and Just et al. (2020).

7. Management principles, recommendations and specific approaches of EOPVT

7.1 Consistent protection of extant watercourse status from deterioration

7.1.1 Interventions impairing the morphological and ecological status of watercourses with natural channels (pursuant to the Waters Act) are undesirable. They are in particular as follows:

- new technical modifications of channels;
- restoration or renovation of channel modifications in stretches that have been factually modified in the past but are currently successfully renaturing, or are understood by water management authorities as stretches with a natural riverbed;
- establishment, restoration or renovation of transverse gradient structures (weirs, terraces, dams, transverse dams);
- construction of water reservoirs (particularly in stretches of morphologically, naturally and landscape-wise valuable watercourse channels and valleys);
- water consumption causing significant flow rate decreases or peaking;
- removal of natural diversity elements or natural swellings, including river wood and beaver dams;
- removal of natural debris deposits (with the exception of management of biotopes for the freshwater pearl mussel).

7.1.2 The status and functions of watercourses and river territories are damaged, in particular, by the following interventions and activities, which are considered undesirable in every single case:

- location of structures, dump sites or backfills, adversely affecting flow conditions or threatening with water pollution, riverbed clogging, etc., in the river space;
- location of reservoirs for breeding fish or other animals at an intensity that may adversely affect watercourses, e.g., by silting, changing physical or chemical water parameters, intrusion of undesirable animal species, affecting flow rates, etc.;
- making new technical modifications of riverbeds;
- construction of new transverse swelling structures.

7.1.3 Such interventions are only permissible in exceptional cases, where provable reasons of public interest, such as protection of roads, spaces under bridges, etc., clearly outweigh the significance of negative impacts on watercourse status. Then, the adverse impacts of interventions have to be minimized and reasonable compensation measures are to be taken.

7.1.4 Restoration of technical modifications of riverbeds and transverse swelling structures should be done only to the absolutely necessary, justified extent.

7.1.5 Watercourses affected by technical modifications or transverse swelling structures should be restored to a more near-natural state as much as possible, effective and cost-tolerable.

7.2 Performance of necessary adverse interventions

7.2.1 Necessary adverse interventions in a watercourse or floodplain (specified in 7.1.1, 7.1.2, 7.5.5, 7.5.7) can only be made in exceptional cases and under the following conditions:

- the necessity of the intervention outweighs the need to protect the watercourse and floodplain from the adverse effect has to be convincingly documented;
- the effective extent and method of the intervention and minimization of adverse impacts have to be proven;
- the intervention has to use nature-based procedures and elements as much as possible (for example, bank stabilization with rip-rap or rock armour);
- the intervention shall be reasonably compensated for by other improving measures if possible (for example, removal of inappropriate technical fortification from another bank section, where it is unnecessary);
- an intervention plan shall be made before the implementation; a proper project design in the case of construction work, including adequate justification and proposals of measures to minimize and compensate for any damage; it shall be discussed adequately with water management and nature and landscape protection authorities.

7.2.2 Even justified adverse interventions must not lead to a complete loss of the natural or near-natural character of the watercourse, its significant deviation from its natural hydromorphological type or breakage of its migration passability for aquatic animals (unless the stretch is considered insignificant in terms of migration based on an ichthyological assessment).

7.3 Promotion of spontaneous evolution of watercourses

7.3.1 In watercourse stretches with a natural riverbed, the watercourse manager generally shall not make any interventions that adjust the flow capacity or other aspects of riverbed evolution, such as changes to the direction, gradient and transverse profile, mentioned in the definition of a natural riverbed in Section 44 of the Waters Act. In natural watercourse channels, it is in order to maintain flow conditions adequate to the watercourse hydromorphological type and to remove only such obstacles to the flow that demonstrably constitute serious, potentially dangerous defects.

7.3.2 Protection of natural watercourse channel evolution is achieved by a land plot delineation of the river corridor that provides permanently collision-free progress of fluvial morphological processes.

7.3.3 An important aspect of promotion of natural riverbed evolution is provision of protection and promotion of natural flow and debris regime (see 6.7 and 6.12). If they are disrupted, it is necessary to take measures to provide at least minimum necessary parameters (e.g., by supplying debris, arranging for flow rate dynamics by controlled flooding, particularly in the case of branching gravel-bearing riverbeds).

7.3.4 All fluvial sediment (particularly high-quality river gravel) that is removed from the riverbed for any reason, e.g., as part of necessary post-flood works or as part of routine maintenance, excavated from reservoirs or weir swellings, should be returned into the riverbed in order to provide a debris equilibrium, or placed within accessible source zones from which the river can wash it away afterwards. It should always be observed, however, not to transfer, e.g., crayfish plague or invasive plant species with the gravel.

7.3.5 If technical restriction to watercourse freedom is necessary, then any major stabilization over a necessarily short stretch (such as an embankment wall) is hydromorphologically and ecologically less adverse than a relatively more natural fortification over long stretches of the riverbed that blocks its evolution (such as a stone footing with rip-rap).

7.3.6 In stretches that require stabilization, it is advisable to define a strip where the riverbed can have at least limited evolution and to stabilize the watercourse at the edge of the strip.

7.4 Approaches to restoration of near-natural watercourse stretches according to EOPVT goals

7.4.1 An increase in the spatial extent of individual water elements of the river space (see 6.2) can be achieved particularly by:

- near-natural freeing (widening) of the riverbed;
- replacing an existing narrow riverbed with a new, wider, near-natural riverbed;
- replacing an artificially straightened riverbed with an undulating or meandering one;
- creating or restoring parallel near-natural river branches.

7.4.2 Restoration of a natural flood perimeter of a watercourse can be achieved particularly by:

- restoring a naturally low flow capacity of the watercourse in order to promote flood overflows into the undeveloped floodplain area;
- removing obstacles to flood overflows, such as levees lining the riverbed;
- removing structures that inappropriately take up space in the overflow area.

7.4.3 Restoration of shape diversity (see 6.4) proceeds particularly in the following aspects:

- riverbed routing – restoration of a natural river pattern;
- longitudinal profile – restoration of a natural sequence of detailed stretches with various flow speeds, e.g., sequence of terraces and pools for mountain riverbeds or pools and fords for meandering riverbeds;
- cross-section shapes – restoration of natural variability in riverbed cross-section along its length; restoration of natural supply of bank and riverside surfaces at various inclines, various levels of normal waterlogging, including surfaces activated by oscillating flow rates and flood progress;
- detailed bottom and bank structures – related to restoration of natural material character of the riverbed;
- bank and accompanying vegetation – restoration of natural composition, structure and layout of growths.

7.4.4 Restoration of hydraulic diversity (see 6.5) proceeds alongside restoration of shape diversity, geometry and capacity of the riverbed. The measures can take particularly the following directions:

- overall revitalization reconstruction of the riverbed into near-natural shapes;
- elimination of artificial swellings (weirs, terraces, sills, dams);
- near-natural riverbed freeing by widening it sideways;
- digging of pools;
- reducing the riverbed depth and increasing its diversity by inserting bottom stone banks, boulder-stone bottom covers, bottom ramps;
- increasing the riverbed and flow diversity by inserting offset structures of stone aggregate and river wood, construction of centre cleavers, banks and isles;
- promotion of river wood (leaving it in the riverbed, inserting it as part of implemented measures);
- insertion of other nature-based elements causing local dynamic swelling and diversification of the flow, as well as providing habitats for biota, e.g., boulder clusters.

7.4.5 Insertion of natural bottom stabilization and diversification elements should not lead to potamization of the watercourse – loss of flowing sections by creating continuous swelling.

7.4.6 The nature-based measures to promote hydraulic diversity should not reduce the migration passability of the watercourse compared to conditions natural to the watercourse (by creating difficult-to-overcome places of concentrated gradient or unnaturally increased flow speeds).

7.4.7 The occurrence of beaver dams is regarded as a part of spontaneous restoration of natural watercourse hydraulic diversity.

7.4.8 River biota can be promoted by special measures promoting supply of habitats and shelters (see 6.6), such as:

7.4.8.1 Pools dug in the riverbed bottom – increases species and size valence of watercourse population, notably of fish, supply of wintering depths during freezing.

7.4.8.2 Side inlets (coves) connected to the riverbed but situated outside the main flow in the riverbed – among other things, protects biota from wash-out during floods.

7.4.8.3 Inserted gravel structures – islets, gravel banks, blanket bottom cover. Gravel or stone material, obtained, e.g., when digging pools or during necessary riverbed maintenance, can be used to build small temporary isles in the flow, gravel banks near edges, etc. This will lead to a desirable diversification and shallower riverbed and establish new biotopes for numerous plant and animal species.

7.4.8.4 Offsets made of poured gravel or stone, laid stones or boulders or wood material diversity the flow, promote its undulation, establish dynamic water swelling in the riverbed and affect the movement and deposition of debris, establish shelters and wake habitats.

7.4.8.5 Addition of gravel aggregate or wood material in the form of a near-natural, partially permeable dam up to 0.2 m in height. This measure is justified notably in smaller watercourses with presence of rare aquatic organisms (crayfish, lampreys, some fish species, etc.) where drying is a risk – it can be an important factor enabling survival of populations of target species in extreme situations. Damming must not produce migration obstacles and it must not use stone excavated from adjacent parts of the watercourse – it would damage the shape diversity and eliminate potential shelters, frequently from large areas of the riverbed.

7.4.8.6 Ecological reprofiling of an artificially level riverbed bottom – mechanical ruffling and shaping of more diverse bottom structures; they need not be hydromorphologically authentic, as they are made as an intermediate step for further spontaneous riverbed evolution.

7.4.8.7 River wood structures inserted in the riverbed – create shelters and wake habitats, typically also perform stabilization and hydraulic functions; presence of biofilm on river wood is a food source for invertebrates, increases species diversity and promotes self-purification processes.

7.4.8.8 Resting and fishing places for kingfishers – leaving or installation of inclined trees and long branches, protruding above the water level, ideally over pools.

7.4.8.9 Deliberate leaving of detailed diversity established during technical interventions in the riverbed and floodplain – ruts left by moving machinery, etc.

7.4.8.10 Wintering sites – can be built in floodplains along watercourses using material produced, e.g., by riverbed maintenance. It can use a mixture of stones and organic matter, such as tree stumps, branches, etc. The mixture can be simply piled in a pit dug into freezing depth (pit must not be flooded with water). Similar sites are then used by many animal species as permanent or occasional shelters throughout the year.

7.4.8.11 Piles of organic material in the riverside and floodplain – shelters for invertebrates and small vertebrates (amphibians, birds, mammals); a decaying layer of organic material is highly suitable, e.g., for incubation of reptilian clutches (e.g., dice snake and grass snake); piles of branches can be used by some bird species for nesting (e.g., jenny wrens); it can be a suitable wintering site for many species, etc. Some of the material produced by watercourse maintenance can be left like this (mowing of grassland, bush removal, etc.).

7.4.8.12 Deposition of stone aggregate in the floodplain as habitat for small animals, or leaving of flood deposits in suitable parts of the floodplain.

7.4.9 Structures of the above types that can be washed away by floods shall be placed near the watercourse in the minimum river wood management zone as per 7.9.

7.4.10 Bottom pools are excavated particularly in hydromorphologically natural locations between fords, in meandering and undulating riverbeds at the apex of the path curve, by the impact bank. Pools in less favourable locations, such as excavated in the bottom plane of a hydromorphologically unstructured riverbed, may be threatened by fast silting; bottom planation leads to loss of shape diversity. The durability of such pools can be boosted by placing one or two large boulders at the upper head of the pool – turbulent flow in the wake reduced sedimentation.

7.4.11 Biota survival under unfavourable conditions (see 6.6.2) and subsequent repopulation of the river space can be improved particularly by:

- maintaining minimum residual flow rates and promotion of ecological flow rates;
- maintaining the possibility of natural overflow into the floodplain, including flooding of old river branches, pools, floodplain wetlands, riparian forests and meadows;
- migration passability of the watercourse in order to repopulate affected stretches;
- a natural riverbed bottom permeable for water and passable for animals diversified with pools, in which water remains for some time after the surface flow is lost;
- protecting root tangles of trees extending into the water;
- presence of river wood, leaves shed by trees, etc.;
- shading the water surface with bank and accompanying vegetation.

7.4.12 The theory of biota surviving along the line of an artificially deeply carved riverbed, in which the declining flow is concentrated until the last moment at the lowest bottom flow line, is regarded as erroneous. Such a riverbed offers very little shelter space, excessively drains surrounding earth layers, and thus limits the ability of the riverbed drawing additional water from the surroundings in peak droughts.

7.4.13 The main directions of measures for protection and restoration of the natural flow regime (see 6.7) are as follows:

7.4.13.1 restoration of natural watercourse morphology, starting in the upper parts of catchment areas, in order to restore a more natural character of drainage into downstream parts of the river;

7.4.13.2 promotion of flooding of undeveloped river space by way of naturally small riverbed capacity, lowering ground in the floodplain and restoring natural attenuation of flood drainage in existing floodplains;

7.4.13.3 reduction to excess water consumption, including transfer of water between catchment areas, which might have significant negative impacts on the watercourse ecology and morphology (revision and changes to water management permits, has to be assessed individually);

7.4.13.4 elimination of operation of run-of-river hydropower plants, which would cause undesirable water losses in watercourse stretches, up to constituting a stretch with insufficient water as an obstacle to aquatic animal migration (revision and changes to water management permits);

7.4.13.5 setting the range and time regime of peak water discharge from reservoirs acceptable in terms of watercourse ecology (revision and changes to water management permits, change to water treatment rules);

7.4.13.6 reduction to excess adverse aspects of transformation of watercourse-forming flow rates in the range from Q_{30d} to Q_{10} by reservoirs, unless it is immediately necessary in terms of justified flood protection objectives or other important water management objectives (changes to water management permits when restoring reservoirs, new water treatment rules);

7.4.13.7 controlled flooding of selected watercourse stretches (water treatment in reservoirs, use of requirements/changes to treatment rules).

7.4.14 Restoration of natural riverbed material character (see 6.8) is done, depending on the conditions of the specific watercourse stretch, primarily by:

- removing inappropriate technical bottom and bank fortifications; if necessary for riverbed stability, they are replaced with nature-based stabilization elements (primarily rip-rap or rock armour);
- restoring shape and hydraulic riverbed diversity;
- removing riverbed materials that have been clogged; in such cases, it is desirable to eliminate adverse effects on a catchment area level.

7.4.15 In spatially constricted conditions of built-up areas, where the technical design of riverbed banks cannot be abandoned, up to their stabilization with walls, at least the natural material character of the riverbed bottom should be restored.

7.4.16 Natural riverbed evolution (see 6.9) can be promoted particularly by:

- removing excessive technical stabilization and adequately reducing the riverbed depth (if overall revitalization of the stretch is impossible);
- property and organizational provision of a near-natural space for the river corridor in which the evolution can proceed;
- eliminating artificial swellings in the riverbed and removing other factors limiting supply of natural debris material from upstream stretches;
- measures to reduce supply of fine erosion debris from upstream stretches (e.g., grassed protective strip along the watercourse, erosion prevention measures at the catchment area level).

7.4.17 Limits for horizontal riverbed evolution can be stabilized, for example, with hidden stabilization elements (e.g., rip-rap structures covered with earth, laid along the perimeter of the delineated river corridor.

7.4.18 The watercourse manager, or the revitalization system manager, shall inspect watercourse evolution notably as follows:

- for any undesirable continuous deepening of the riverbed; if it occurs, measures shall be taken, e.g., inserting stabilization rip-rap or rock armour strips in the riverbed, boosting riverbed path diversity by placing offset structures of stone and wood;
- for any disruption of land on which riverbed evolution is not permitted for property or other reasons; if it occurs, further riverbed evolution shall be prevented, e.g., with stabilization rip-rap or rock armour of the bottom and banks or offset structures with a diverting effect.

7.4.19 Restoration of migration passability (see 6.11) is possible primarily by:

- complete removal of a transverse gradient structure and artificial swelling (preferred method particularly for weirs and terraces);
- replacement of a transverse gradient structure with a gradient structure with longitudinal gradient favourable for migration (e.g., replacing of a weir with a bottom ramp or chute); can be combined with reducing structure height (suitable where the structure is not backed by a major swelling, which constitutes a form of migration barrier to many organisms);
- construction of a fish ladder (unless above measures are implemented);
- revitalization of a watercourse stretch of unsatisfactory shape;
- prevention of excessive water consumption from the stretch (water management and civic supervision over SHPP operation, etc.);
- optimization of culverts (under roads, etc.) and areas under bridges in terms of migration of aquatic, semiaquatic and terrestrial species (sufficient clearance, natural bottom substrate, dry land strips by the riverside, bridges, etc.). The issue of animal passages is described in detail in Hlaváč et al. (2020); optimization of migration structures is fundamental for maintaining a landscape passable for animals.

7.4.20 Fish ladders are designed, built and operated according to Nature and Landscape Management Standard B02 006 Fishpasses (Vrána et al., 2014). Assessment of fish ladder efficiency shall follow the methodology Biologické hodnocení rybích přechodů (Musil et al., 2020).

7.4.21 Plans for construction, restoration or renovation of water reservoirs, including dry and semidry flood reservoirs, have to be assessed in terms of importance of migration passability of the watercourse in question. If migration passability of the watercourse is found to be necessary and its provision as part of the construction project effective, the water reservoir shall be fitted with adequate equipment, such as a fish ladder inserted in the spillway. Dry or semidry flood reservoirs shall be fitted with a trough for migration passability during normal flow rates, inserted in the outflow and regulation structure. The execution of such equipment is generally governed by fish ladder construction principles.

7.4.22 An individual approach is required for watercourses with populations of crayfish, both autochthonous and invasive. In order to prevent contact between invasive crayfish and autochthonous crayfish populations, it may be desirable for some watercourses to retain a functional migration barrier to restrict upstream progress of invasive crayfish. However, each such specific situation has to be professionally assessed in a collaboration between a water manager and a biologist-astacologist.

7.4.23 Another EOPVT goal is to maintain or restore migration passability of river territories for amphibians and terrestrial animals. For this purpose, passage strips are built notably at crossings of watercourses with road structures, or side walkways or platforms in constricted conditions. Entrances to and exits from such structures have to be passable as well. Animals should not be directed from exits towards dangerous places (roads, wells, etc.). (See methodology for reducing negative effects of traffic on the river otter: Hlaváč et al., 2011; and methodology describing suitable parameters of culverts and areas under bridges for different categories of animals: Hlaváč et al., 2020.)

7.4.24 In watercourse stretches suffering from a lack of debris material or its inappropriate composition (see 6.12), measures to protect and promote a natural debris regime can be executed, involving, for example:

- not permitting excavation of gravel material or its removal as part of so-called riverbed clearing;
- after assessment of sediment suitability and impacts on the watercourse ecosystem, bottom rinsing of reservoirs and swellings;
- excavation of sediment from reservoirs or weir swellings and its transport to places farther downstream;
- measures to promote greater erosion of banks (directing offsets made of stone or river wood);
- addition of gravel debris above all into the watercourse, e.g., insertion of gravel piles in the riverbed, alternately near one bank and the other, to be slowly washed away (also promotes flow undulation), gravel scattered on the bottom, etc.

Approaches to restoration of near-natural watercourse stretches according to EOPVT goals are elaborated in more detail in Just (2006) and Just et al. (2020).

7.5 Recommendations for protection of prominent landscape features (PLF) watercourse and floodplain

7.5.1 The PLF watercourse represents the space delineated by the upper bank edges of a watercourse in an open or built-up landscape. It does not matter whether it is a watercourse with a natural riverbed or a riverbed comprising a hydraulic structure (modified watercourse).

7.5.2 When unsure, an area belongs to a watercourse PLF if its land plots is registered in the Cadastre in the categories water body, watercourse or watercourse channel. Binding decision-making on the extent of a watercourse PLF is up to the applicable nature protection authority (OOP).

7.5.3 A floodplain refers to the entire area of a flat valley bottom, formed and affected by the progress of floods, regardless of its use. The functions of a floodplain as a natural landscape component are suppressed in continuously built-up areas, particularly in areas that are divided from watercourse overflow by levees or other flood protection elements; this is taken into consideration by the applicable nature protection authority when unsure and deciding whether an area belongs to a floodplain PLF.

7.5.4 If floodplains for Q_{100} are delineated along a watercourse, potential uncertainty about defining the extent of the floodplain as a PLF can be reduced by assuming that at least the areas available for overflow at the Q_{100} level are a part of the floodplain PLF.

7.5.5 A watercourse PLF may be damaged or destroyed, its ecological stabilization function endangered or reduced particularly by any activity restricting the natural spatial extent of the water feature, its shape and hydraulic diversity, migration passability, flow and debris regime, adversely changing the character of bank and accompanying vegetation and generally disrupting biota existential conditions. In particular, the following need to be perceived as endangering or damaging effects:

7.5.5.1 interventions in the riverbed surface and material of greater-than-negligible extent (evaluation up to OOP), notably rearranging or excavation of sediments or removal or river wood;

7.5.5.2 piling of riverbed material towards the banks and dumping of sediments at the riverbed banks and generally in the river corridors;

7.5.5.3 any technical modifications of riverbeds and generally simplification of riverbed shapes;

7.5.5.4 performance of unnatural riverbed stabilization, such as stabilization using unnatural features and structures or unjustified fortification of riverbed banks with rip-rap, rock armour or stone walls (compared to generally acceptable stabilization of riverbed bottom with stone);

7.5.5.5 artificial riverbed swelling with built structures (sills, terraces, weirs, dams);

7.5.5.6 establishment and operation of hydropower facilities to the detriment of the energy balance of natural fluvial morphological processes, natural flow conditions or debris regime;

7.5.5.7 disruption of natural watercourse channel structures produced by floods;

7.5.5.8 interventions in bank and accompanying vegetation that reduce the naturalness of their horizontal and vertical structure, species, age and shape composition and the associated hydraulic and ecological functions (adequate thinning that does not change the character and functions of vegetation may not be regarded as endangering and damaging effects);

7.5.5.9 construction of roads, footpaths and cycling trails directly in the river corridor, particularly near riverbed banks;

7.5.5.10 disruption and restriction of river space by unauthorized expansion of farmland (ploughing nearer and nearer riverbed banks);

7.5.6 The construction of a fish ladder cannot be regarded as full, complete compensation for damage to a watercourse or floodplain PLF caused by the action or construction of an artificial swelling obstacle with all its adverse impacts on natural migration passability and diversity of the watercourse and its flow and debris regime.

7.5.7 The following, for example, can be seen as effects endangering or damaging a floodplain PLF:

7.5.7.1 ecologically unfavourable changes to vegetation cover in the floodplain (such as replacement of near-natural vegetation with a crop culture, including energy wood plantations);

7.5.7.2 drainage of floodplain areas;

7.5.7.3 damming in order to restrict flooding in undeveloped floodplain areas;

7.5.7.4 construction of structures and landscaping in the naturally floodable floodplain;

7.5.7.5 reduction of naturally floodable areas by constructing small side water reservoirs;

7.5.7.6 dumping of earth and waste backfill in the floodplain;

7.5.7.7 interventions adversely changing the character of floodplain woody plant growths (e.g., continuous felling causing a spatial reduction to the vegetation, reduction of favourable structural, species, shape and age diversity of vegetation);

7.5.7.8 construction of paths and cycling trails on embankments and in areas where they would block potential revitalization of a technically modified riverbed by way of near-natural loosening, or where they would cause the need for undesirable intervention in tree vegetation for safety reasons;

7.5.7.9 restriction of flow capacity and backfilling of old and lateral river branches;

7.5.7.10 dumping of excavated sediment along the watercourse channel or river corridor and in other places in the floodplain;

7.5.7.11 ecologically and landscape-architecturally inappropriate afforestation, notably of permanent grassland areas, as well as other parts of the floodplain, including planting so-called energy crops based on unnatural monocultures.

7.6 Promotion of riverbed stability in light of actual needs of the watercourse

7.6.1 If the riverbed is at a risk of deepening, it should be stabilized by inserting nature-based stabilization features in the riverbed bottom, which also contribute to shape diversity of the riverbed and supply of ecological habitats. Such features include, in particular:

- nature-based, irregularly structure bottom stone cover, ideally using a wider range of sizes;
- transverse or oblique bottom strips made of stone (rip-rap, rock armour, armour with a row of boulders as the core), ideally at transitions between curves in an undulating or meandering riverbed, thus imitating a natural ford;
- stone or boulder slide in the bottom with a coarse surface;
- bottom ramp comprising a succession of boulder strips, accompanied by stone of smaller sizes;
- installation of wood material – for example, depth stabilization and reduction in a minor watercourse channel is achieved by inserting a tree with branches on longitudinally, weighed down with stone as necessary.

7.6.2 Stabilization of the bottom with gradient structures such as sills, terraces or dams is generally undesirable due to protection of migration passability and natural gradient and flow of the watercourse. It may only be performed exceptionally, in particularly justified cases.

7.6.3 If, for some reason, sideways riverbed evolution cannot be permitted at a certain location of stretch, nature-based stabilization of the endangered bank is performed only over the absolutely necessary riverbed length, e.g., with stone rip-rap or rock armour, or stone plane in more demanding situations.

7.6.4 In different stretches of the watercourse, different degrees of return to natural dynamic stability are possible as part of the process of restoring the natural character of watercourses. As a framework, the following concept of the riverbed stability requirement is recommended depending on the character of the surrounding areas:

- Built-up areas, road structures nearby, etc. – depth and sideways riverbed stabilization is acceptable. Even under the most seriously spatially constricted conditions (where, e.g., the riverbed has to be defined by bank walls), at least a near-natural bottom type is required, including removal or compensation for migration barriers.

- More intensively farmed areas – the historical level of stabilization of technically modified riverbeds may be accepted, if adequate to the local conditions, legitimate requirements of land owners, cultivation intensity, etc. However, the objective is at least a gradual return to a near-natural watercourse status, consisting notably in replacement of inappropriate materials and structures with more nature-based ones and provision of migration passability. For example, stabilization with concrete paving elements can be replaced with more diverse rip-rap or rock armour structures.
- Undeveloped areas farmed extensively or unused areas that are near-natural, including forest areas – the objective is a return to a near-natural state, including natural morphological evolution of the watercourse and attenuating flooding within floodplains. Nature-based riverbed bottom stabilization is performed to promote shallowing and dynamically stable evolution. As for areas owned by the state or municipalities, development of natural ecological and hydraulic functions of the river space has to be regarded as these owners' interest.

7.7 Flood protection system effectively combining technical and nature-based approaches

7.7.1 The flood protection system (FPS) is based on the following principles:

- in undeveloped areas of catchment areas, in floodplains and watercourse channels in undeveloped areas, retain flood water, slow down and attenuate the formation and progress of flood waves – in particular using nature-based approaches and measures;
- through built-up areas, channel flood flow rates without damage if possible, using an efficient combination of technical and nature-based measures while maintaining an acceptable ecological status of the watercourses.

7.7.2 The main devices for nature-based FPS approaches are as follows:

- promotion and restoration of natural and near-natural status of watercourses and floodplains – revitalization, support to renaturation and associated water management measures (e.g., removal of ineffective old dams, relocation of levees farther towards the edge of the floodplain);
- promotion and utilization of natural attenuating flood overflows in floodplains;
- water retention in dry and semidry reservoirs (flow-through) and polders (lateral beside the watercourse), in old mining pits and similar depressions, the inundation of which is near-natural; dry and semidry reservoirs do not reduce migration passability of watercourses for aquatic animals.

Application of nature-based FPS approaches is elaborated in more detail in standard B02 003: 2022 Revitalization of watercourses and their floodplains.

7.7.3 Measures as part of maintenance and repairs of modified watercourse channels generally aim at removing excessive countersinking of normal water levels in relation to surrounding land. The necessary flood flow capacity of the riverbed is provided largely by its width compared to its depth. This applies, for instance, to justified riverbed clearing.

7.7.4 Justified increases of flood flow capacity of riverbeds in and near built-up areas shall be made, as much as possible, by means of near-natural sideways loosening, which will remove fertile earth layers and ruderal vegetation from the riverbed and expand ecologically valuable shallows and bank areas that are deficient in modified watercourses.

7.7.5 Necessary riverbed stabilization shall prefer near-natural, malleable structures based on stone rip-rap, rock armour, layered stone, boulder-stone bottom strips and offsets or river wood.

7.7.6 Repairs and renovations of damaged transverse gradient structures in watercourse channels (sills, weirs, dams) shall not be carried out if the conditions allow. Such structures shall be replaced with nature-based structures, which have migration passability and distribute the gradient more naturally along the riverbed length, such as stone and boulder bottom layers, bottom strips, slides and ramps.

7.7.7 Repairs and renovations of damaged watercourse stretches in pipes shall not be carried out if the conditions allow. Such watercourses shall be opened up and revitalized into a near-natural state if possible.

7.7.8 The river space shall be maintained primarily free of anthropogenic deposits that could be washed away (wood and timber, hay and straw, waste, inappropriately placed objects and small-scale structures, etc.), which would turn into undesirable flood driftings. This activity, which is an important part of flood damage prevention, proceeds in cooperation with land owners, municipalities, watercourse managers and water management authorities.

7.8 Prudent measures after floods and reasonable utilization of positive flood-induced changes

7.8.1 Under EOPVT, changes in the river space caused by floods are divided into:

- damage that has to be eliminated or resolved by measures in the river space and on damaged buildings and other structures;
- changes that are neutral or improve the watercourse status, to be accepted without reservation or with partial corrective measures (notably removal of deposited waste, etc.).

7.8.2 This distinction is made with a view to conditions of specific watercourse stretches and floodplains, maintenance and use of adjacent land and the target status and functions of the watercourse within the catchment area. It takes into account whether the stretch is in open country or in or near built-up areas.

7.8.3 Under a special regime pursuant to Section 83, item m) of the Waters Act (among others, with limited applicability of nature and landscape protection regulations and decision-making influence of nature protection authorities), EOPVT permits elimination of damage to a watercourse that obviously has to be done immediately to prevent danger to people and property and restore societal functions of the landscape space. This damage is eliminated without approximately 3 months of the flood event. The damage may be determined during initial inspections for damage to watercourses, which usually take place under the stressful conditions of an ending flood. Other damage and changes are assessed as usual under applicable administrative proceedings, with full power of regulations and nature and landscape protection authorities.

7.8.4 Elimination of flood damage cannot include effects that are evidently unrelated to the respective flood event (such as removal of bank vegetation directly unrelated to the flood damage at hand, performance of previously neglected repairs of water management structures or elimination of damage suffered due to causes other than the flood in question).

7.8.5 The objective of elimination or resolution of flood damage is not to restore, at all cost, the watercourse or hydraulic structure status existing prior to the flood. An optimum new status is sought, favourable in terms of water management and ecology.

7.8.6 Hydraulic structures in the form of longitudinal technical modifications to the riverbed and transverse structures across the riverbed, destroyed or damaged by the flood, whose further existence is not found to be indispensable, shall be declared destroyed or officially cancelled.

7.8.7 Remnants of hydraulic structures that are not repaired, renovated or restored after a flood, shall be handled, depending on local conditions and needs, in one of the following ways:

- removal;
- modification into a condition that is safe and more favourable for the watercourse functions and the need to improve its status;
- putting in a safe condition and leaving to further spontaneous decay and riverbed renaturation (may concern particularly longitudinal technical riverbed modifications).

7.8.8 Flood-induced changes to watercourses with natural riverbeds (pursuant to the Waters Act) are generally considered not damage, but part of their natural evolution. Elimination of negative flood-induced effects, such as undesirable riverbed deepening or contamination of river space with deposited waste, is regarded as correction of the changes and can be done in the regime of water management modifications pursuant to the Waters Act.

7.8.9 Flood-induced changes to technically modified watercourse channels that are classified as spontaneous renaturation processes due to their prevailing character are acceptable on a large scale in open, undeveloped country, while their possible utilization is limited in built-up areas.

7.8.10 Evaluation of individual flood-induced changes proceeds with the following important questions:

- What is the target status of the watercourse stretch?
- Does it make sense to restore a former technical modification, or is it wiser to support the spontaneously formed more natural status?
- What factual malfunctions or threats does a flood-induced change pose (gravel bank, ruptured bank, riverbed rerouting, drifting barrier, driftwood pile, uprooted tree, etc.)? In relation to what specific interest is, e.g., reduced flow capacity unfavourable?
- On the contrary, what benefits does the flood-induced change bring? These can be various aspects of improved ecological status – a boost to riverbed diversity, renaturation of an inappropriate technical modification.
- What malfunctions or threats will elimination of the change bring?
- What is the ratio of malfunction, cost effects, etc., of the flood-induced change and its potential elimination?
- A question important particularly where flood debris occurred in municipalities: What portion of the riverbed flow profile does the specific gravel bank occupy, what is its ratio to the capacity of the riverbed and the flood flow rate risky for the development?
- What further steps are possible/appropriate based on the comparison of negative and beneficial aspects of removing/keeping the flood-induced change?
- How to perform the necessary remedial actions so that they are effective and economical, minimize damage to the watercourse ecological status and maximize its desirable qualities?

7.8.11 If a flood-induced change to the natural riverbed of a watercourse interferes with other owners' land unacceptably, despite appearing favourable in terms of morphological evolution of the watercourse, the alternatives for further steps should include consultation with the land owners about state purchase under Section 45 of the Waters Act.

7.8.12 Necessary, consulted and approved post-flood interventions in the riverbed have to be implemented carefully, while reasonably observing the following recommendations:

- if removing sediments, then imitate a natural river pattern; for meandering or undulating riverbeds, dig pools at naturally favourable locations, i.e., by impact banks in curves; in straight riverbeds, form a series of dug pools and transverse rows of stones or boulders at a spacing that is twice or four times the riverbed width (as per the adequate hydromorphological pattern); however, digging of bottom pools must not lead to undesirable continuous deepening of the riverbed;

- return any sediment excavated in built-up areas back to the riverbed farther downstream; return any sediment excavated from reservoirs or weir swellings back to the riverbed farther downstream;
- particularly in larger meandering riverbeds, spare morphologically valuable bankside sections;
- do not needlessly damage stabilized natural bank sections, remove their turf cover and damage root systems and trunks of woody plants;
- on the contrary, disrupting bank sections covered with fertile earth and overgrowing with ruderal vegetation, including removal of such earth and vegetation, can be beneficial;
- do not suppress riverbed diversity by ineffective levelling and smoothing of the bottom and banks, but, particularly in larger watercourses, use the potential to spread sediment across the riverbed (e.g., from point bars to concaves);
- for necessary restoration of ruptures and potholes, including necessary repairs to technical riverbed modifications, use nature-based stone rip-rap or layered stone;
- do not restore or establish gradient steps in the riverbed bottom, or no more than low bottom strips and slides; remove damaged old steps (unless ruins of transverse structures are left in place in special cases as features suitably boosting riverbed diversity).

7.8.13 In stretches where flood-induced changes to the riverbed or floodplain are evaluated as generally beneficial, elimination of flood damage usually takes to form of clearing away anthropogenic mess.

7.9 Protection of river space when doing necessary technical and construction work

7.9.1 Movement of machinery in watercourse channels and river territories in general has to be limited to the necessary minimum, because, among other things, they lead to biota damage and death.

7.9.2 Before and during construction and maintenance work in river space, measures have to be taken that minimize the risks of direct death and damage to animals and/or plants that might result, in particular, directly from moving machinery, individuals being caught in drained or backfilled "traps", etc. This risk is reduced primarily by catching and rescue transfer before the works, or repeatedly during them. This can make use of electrofishing (we advise contacting the respective local Czech Anglers Union organization) and other methods for catching present organisms; but temporary drainage of the affected riverbed stretch, followed by collecting present individuals, always appears most efficient. (Rescue transfer of specially protected species can only proceed based on an exemption from the protection requirements under Section 56 of Act no. 114/1992 Coll. on Nature and Landscape Protection, issued by the applicable nature protection authority. The exemption should handle both times and methods of transfer and placement of transferred organisms.)

7.9.3 The technique, equipment and clothing of staff making interventions in watercourses shall be inspected during transfer between different watercourse stretches in terms of potential transfer of infection, notably crayfish plague. Machinery, tools, clothing, etc., can only be transferred from stretches with potential presence of crayfish plague to stretches with potential presence of domestic crayfish species after thorough disinfection.

7.9.4 Sediment shall be excavated and transferred in watercourse channels or reservoirs so as to minimize turbidity carried downstream.

If possible and appropriate, sediment interception areas shall be established, ideally at the lower edge of the intervention stretch, to protect downstream watercourse stretches from debris, ideally in the form of pools. Afterwards, they can remain in place as biotope pools. When draining or removing mud from small water reservoirs, it is possible to place, e.g., straw bales downstream to intercept fine particles.

7.10 River wood

7.10.1 Naturally occurring river wood is left in the watercourse channel as much as possible. That said:

- pieces of river wood should be of maximum possible size (less mobile and hydromorphologically and ecologically more effective);
- effectiveness of wood increases depending on its position within the riverbed – pieces submerged in areas of active flow are most effective.

7.10.2 Handling river wood is differentiated in zones according to danger. They are defined based on distance above dangerous places or stretches, where collision and damage might occur (e.g., clogging a bridge profile with flood driftings).

Table 2: Wood management zones (adapted from Kožený et al., 2011)

Danger zone	Watercourse zone length	River wood handling rules
Zone of immediate danger	2 x B (B = width at bank edges)	wood is removed or very strongly anchored, structure is inspected
Zone of active management	30 to 100 x B	stabilization of larger pieces of wood material, placement of structures for intercepting drifting wood
Zone of minimum management	length of active management zone or more	natural wood dynamics left, unanchored wood placed

7.10.3 Potentially dangerous watercourse stretches in terms of river wood are particularly:

- stretches in built-up areas;
- stretches touching or crossing road structures (bridges, footbridges, culverts);
- stretches from which wood material could be washed down into stretches described above, with a clear risk of undesirable flow capacity reduction, barriers made from flood driftings, etc.

7.10.4 In dangerous areas or stretches, like in the zone of immediate danger, wood material that could become driftings is removed or fastened as necessary, typically according to established custom of watercourse management.

7.10.5 Stabilization of wood against drifting away can be achieved, e.g., by connecting wood materials structures or anchoring each element using ropes, posts, etc. In the zone of active management, it is advisable to use “soft” techniques, which greatly reduce wood mobility but do not hinder its movement entirely, such as burden bags, stone cover, interceptor live trees, etc.

7.10.6 At the interface between the zone of immediate danger and zone of active management, a hydrotechnical interceptor for wood material can be installed and operated to increase safety – a coarse grate for catching flood driftings. An appropriate nature-based watercourse channel modification can also promote flood overflowing into an undeveloped floodplain, where part of the driftings will leave the current due to decreased carrying speed.

7.10.7 In the zone of minimum management, an adequate quantity of wood material in various formats is present; its excess may be removed selectively, similar to maintenance thinning of woody plants growing along the watercourse. In particular, pieces of piles of river wood are left in the riverbed that appropriately diversity the flow, establish valuable shelters for aquatic biota or make the riverbed shallower or direct the flow at the point. Fallen trees and other wood structures that are evidently stable in the long run are not removed.

7.10.8 In watercourse stretches outside dangerous places and stretches, covered by special nature protection interests, interventions in river wood can be abandoned completely with respect to local conditions and protection goals.

7.10.9 Wood material can be inserted deliberately in watercourse stretches where wood material is evidently missing or whose hydromorphological and ecological status is to be improved. The goal may be to promote some of the functions described above. In organizational respect, wood material can be applied as part of routine maintenance, improving water management modifications pursuant to the Waters Act, measures to promote spontaneous renaturation processes or revitalization measures and projects.

7.10.10 Insertion of river wood structures is one of the basic methods of promoting near-natural state of watercourses. Its importance and potential, notably in terms of shape and hydraulic riverbed diversity, creation of shelters and habitats, influencing riverbed dynamics, including depth stability and sources of organic material in the food chain, should be appreciated as much as possible in watercourse management.

7.10.11 Especially suitable are simple, near-natural installations of wood material, such as insertion of trees with branches in the riverbed at offset locations. Various log structures and structures requiring extensive ramming of piles, however abundantly recommended by various publications, are usually quite laborious and less appropriate in relation to the achieved effects of river space diversification and creation of habitats and shelters for biota.

7.10.12 The zone of immediate danger requires structures made of river wood according to the same rules as other hydraulic structures, such as offsets. Such structures have to be subjected to structural analysis and hydrotechnically stable. At the same time, they must meet requirements for hydromorphological and ecological functions.

7.10.13 Fastening of installed wood material against washing away can be done, e.g., by

- insertion and backfilling of trunks in reasonably deep cuts excavated in banks;
- fastening to poles, anchors or sufficiently sturdy stumps using ropes;
- mutual tying of larger river wood features (watch out for the risk of the whole tied pile being washed away);
- poles passing through holes in the fastened trunks and driven into the substrate.

The fastening should work until the fastened wood material structure decomposes into harmless pieces.

7.10.14 Fortification of riverbeds with wattling, logs and so-called stabilized potholes, debris dams and sills made of logs are not regarded as near-natural river wood applications – and generally are not regarded as appropriate watercourse management features under the EOPVT concept.

7.10.15 Appropriate forms of river wood promotion include various applications of rooting willow wood (branches and branch bundles, logs of various thickness, stumps). Living material of all domestic willow species except goat willow should be capable of rooting, if placed in spring in areas with sufficient moisture and sunshine (see also 7.10.14).

7.11 Establishment and management of near-natural bank and accompanying woody plant vegetation

7.11.1 Management of bank and accompanying vegetation employs standard procedures, notably woody plant thinning, additional planting (including adequate management after planting and beyond), promotion of natural regeneration, or renovation of unsatisfactory growths in order to improve their present state – in particular, species composition and its optimum evenness, age, spatial and structural diversity, and at the same time, boost or restore natural functions specified in 6.10.

7.11.2 A zero-intervention regime for bank vegetation is a theoretical ideal state, typically only possible on selected sites and stretches, usually enjoying a high level of protection, in headwaters or on minor watercourses in forests, etc.

7.11.3 The vegetation management goals have to be differentiated according to specific conditions. In built-up areas and near structures, operating safety conditions have to be respected (flood flow capacity). In open country, where the objective is near-natural riverbed and floodplain shapes, near-natural growth formations are in order.

7.11.4 Growth thinning

7.11.4.1 Growth management by thinning is an important part of bank and accompanying vegetation management. Thinning (along with regeneration) appropriately adjusts the species composition and structure of growths, increases their vertical diversity and increases and maintains their stability in space and time. Thinning must not negatively affect the character of the growth and its functions, unless forced by serious operating and safety requirements or otherwise justified.

7.11.4.2 The importance of thinning is crucial notably for growths with unsatisfactory diversity and structure, high share of introduced (especially invasive) taxa and growths significantly affected by invasive pathogens.

7.11.4.3 Recommendations for thinning management:

7.11.4.4 only perform thinning that have no adverse effect on the growth character (up to 10-20% of trunks at once); renovation interventions may be an exception;

7.11.4.5 focus any extensive interventions (renovations) on introduced (especially invasive) woody plants and those inappropriate for the habitat, or their expansive rejuvenation, on sections with prevailing or ageing single age cohort, monocultural sections on sites for naturally species-diverse growths, etc.;

7.11.4.6 use timely and adequate thinning to restrict the spreading and impact of invasive pathogens on woody plants (e.g., phytophthora rot in alders, necrosis in ashes). For more details, see Černý et al. (2013), Bjelke et al. (2016) and Skovsgaard et al. (2017);

7.11.4.7 do not aim thinning at woody plant growing directly in bank lines; conversely, protect them as a valuable and integral part of growths;

7.11.4.8 old, damaged or disintegrating individuals and lying dead wood and torsos, important for biota in the growth, should be left in place, unless they pose a significant risk in terms of operating safety;

7.11.4.9 during thinning, other woody plants and desirable natural regeneration have to be protected from damage;

7.11.4.10 do not thin (unify) tall-growing multitrunks (polykormons, e.g., willows, alders) because of upset natural form and stability of the individual, except interventions quite necessary for operating safety.

7.11.5 Growth regeneration

7.11.5.1 The objective of growth regeneration is to promote adequate species diversity, evenness, structural and spatial diversity and increasing growth stability in space and time.

7.11.5.2 The species composition of regenerated growths has to match the community adequate for the specific region, (micro)habitat and its conditions. Suitable resources in this area are, e.g., habitat classification systems (biotope classification, Chytrý et al., 2010) or phytocenological (Moravec et al., 2000; Neuhäuslová, 2003). It is particularly suitable to apply mosaics of communities structured based on watercourse, river space and floodplain morphology and requirements on the growths.

7.11.5.3 The species composition, share of woody plant species and their locations can be modified based on ecological, biotechnical, operating, safety, phytopathological and other requirements (stabilization of riverbed path, replacement of excess artificial fortification, excessive spreading and development of pioneer or even introduced species, spreading of invasive pathogens, observation of utility networks and structures, etc.; for more detail, see, e.g., Černý et al., 2013). It is also important to assess the effect of stress and expected disturbances on the site.

7.11.5.4 The growth diversity (age, spatial, structural) has to match the specific community; it can be higher than natural (alder woods, willow shrubs) in order to promote biodiversity, growth resistance to negative effects, growth continuity in time, etc. This applies particularly to watercourse stretches in open country and farmland, where other requirements apply to growths as well (e.g., biodiversity at a broader landscape level, protection from wind erosion, slope stabilization, landscape character, etc.).

7.11.5.5 There are two ways of growth regeneration: natural and artificial. Natural regeneration of site-appropriate woody plants has to be promoted wherever conditions allow (available sources of appropriate generative or vegetative material and conditions for young plant development). Artificial regeneration is used where natural regeneration of woody plants cannot achieve the expected goals.

7.11.5.6 Recommendations for growth establishment using natural regeneration:

7.11.5.7 Natural regeneration can be used successfully, in particular, with woody plant species producing larger quantities of easily propagating seeds (e.g., willows, poplars, alders) or easily vegetatively reproducing (notably willows, possibly alder, bird cherry, etc.). Natural regeneration of longevous deciduous trees, particularly in bank vegetation, characterized by dynamic development, frequent disturbances and rampant nitrophilous vegetation, is often more difficult.

7.11.5.8 It is mainly important in regeneration of habitats derived from softwood riparian forests and moister sections of hardwood riparian forests, willow wood and shrub, alder wood, etc., where it can be the main regeneration method in the long run.

7.11.5.9 When establishing (new) growths, a locally available source of suitable material (typically alders and willows) can be used. Its shortage can be compensated with sowing or additional planting of appropriate taxa.

7.11.5.10 A functional measure for promoting natural regeneration is spatially and temporally adequate disruption or removal of top layers or fertile earth and exposure of low-fertility gravelly, sandy or clayey surfaces (but there is a risk of spread of undesirable invasive plants or autochthonous ruderal ones, excessive erosion during floods, etc.). Similarly, if natural regeneration is desirable and possible on the site, surfaces are left bare after construction works or floods. These surfaces are not covered with humus or, unless absolutely necessary, grass sowing. Removal of humus-rich layers is suitable for promoting natural regeneration of the black poplar as an important tree species for larger river floodplains. Implemented improvement measures and watercourse management in open country should do without grass mowing on riverbed banks, berms and in the river corridor. Management of specific biotopes may be an exception. Rules for management and maintenance of river banks and the river corridor are specified in standard B02 003: 2022 Revitalization of watercourses and their floodplains.

7.11.5.11 Growths produced from advance seeding on bare surfaces tend to be species-poor, same-age, not at optimum density, etc., which is why their further development and management should receive considerable attention. A typical next stage is a correction of the structure and composition of the regenerated or newly established growths, and local introduction of additional desirable taxa as necessary.

7.11.5.12 Natural regeneration of target deciduous woody plants of hardwood riparian forests, ash and alder woods, etc. (pedunculate oak, lindens, maples, ashes, elms, common hornbeam, wild cherry, etc.) is difficult in most cases. The sufficient natural regeneration is mostly linked directly to presence of parent trees on the site. These species may be the subject matter of additional planting.

7.11.5.13 It is advisable to connect regeneration to thinning work (or natural loss of individuals), particularly in the overstorey. Conversely, thinning may deliberately follow developing rejuvenation.

7.11.5.14 A risk for successful natural regeneration is posed by intensively developing nitrophilous herbaceous vegetation, making it difficult for establishment and successful growth of seedlings, or overpopulated game. As protection from game, some areas of natural growth regeneration can be enclosed with temporary fencing.

7.11.5.15 Recommendations for growth establishment using artificial regeneration:

7.11.5.16 Artificial regeneration is used in cases where natural regeneration of appropriate species is insufficient or impossible (lack of sources of suitable material, wrong time for spread of seeds or establishment of seedlings), when establishing larger plantings (accompanying vegetation, edges around river corridors or floodplains, revitalized areas), when there is excessive risk of spread of invasive or otherwise inappropriate species in natural regeneration, and to introduce and promote desirable species (increase diversity).

7.11.5.17 The planting uses well developed, undamaged and healthy plants (e.g., ash necrosis, alder phytophthora rot) of taxa appropriate for the site (material origin, ecological and biotechnical parameters, etc.).

7.11.5.18 Areal establishment of larger continuous growth formations of accompanying and adjacent vegetation outside exposed bank areas, etc., typically applies forestry planting in protective enclosures; the choice between bare-rooted and ball-rooted plants is made depending on local soil and moisture conditions and planting season; for dry-prone substrates and during spring planting in particular, ball-rooted plants are recommended.

7.11.5.19 Areal planting has to be in groups, established in irregular and uneven clusters of transplants of different species, chosen appropriately based on soil, moisture and exposure conditions.

7.11.5.20 Artificial regeneration has to avoid chaotic mixing of taxa of various species, growth strategies and forms.

7.11.5.21 Individual planting in riverbed banks usually uses bare-rooted, ball-rooted or containerized saplings or rods (taller trunk shapes are not normally used) of species ecologically and usually also biotechnically appropriate for the specific microsite (see Černý et al., 2013), planted in irregular clusters.

7.11.5.22 If appropriate and if local conditions allow, areal planting of floodplain riparian forest-type vegetation can be preceded by removing the top fertile soil (earth) layer, and the planting is done in the exposed fluvial substrate.

7.11.5.23 Of course it must involve a suitable planting process (date, planting technique, pruning while planting as necessary, fastening and individual protection, distances, etc.), sufficient inspection and after-planting management, including mowing of weeds and freeing of desirable individuals, which is particularly necessary in cases of unrestrained spontaneous regeneration of willows and alders.

7.11.5.24 In smaller, particularly revitalized watercourses, the location (distance from bank line, bank edge), planting distance and species within individual planting of bank vegetation can, to some extent, influence the future morphological riverbed evolution and other parameters (e.g., drainage).

7.11.5.25 Both areal and individual planting has to include an adequate shrub storey (very poorly represented in present-day bank vegetation), which significantly increases the site biodiversity and promotes numerous important functions of the growth. Shrubs tolerating high water table and mechanical damage can be planted in the bank line (typically willows). Creation of a continuous strip of shrubs along the outer edge of the established growth must not be neglected.

7.11.5.26 Establishment of shrub growths can use transplants of the following species, for example: shrubby willow species, European bird cherry, guelder rose, alder buckthorn, common hazel, green alder (where autochthonous), black elder and red elder, European spindle, black-berried honeysuckle, fly honeysuckle, mountain rose, wild privet, common buckthorn, common dogwood, etc. They are again planted with respect to their natural extent, ecology, biotechnical properties, etc.

7.11.5.27 It is advisable to establish growths of willows (except goat willow), both tree-formed (white willow, crack willow, red willow) and shrubby (e.g., basket willow, purple willow, bay willow, grey sallow, almond willow, etc.) by rooting their living parts. Application is assumed in spring, or in autumn as the case may be, in places with sufficient moisture and sunshine (little competition from trees). The establishment may use the following principles, for example: carpets of thrust woody cuttings, bundles of branches laid in excavated trenches, partly buried with earth, branches and brushwood scattered on the ground and partly buried with earth, poles, trunks or stumps embedded in the ground. Shrubby willows can be used suitably for prevention of exposed soil and earth surface overgrowing with inappropriate taxa.

7.11.6 A renovation intervention is made when an unsatisfactory growth has to be replaced completely along a watercourse stretch (ageing monocultures of Canadian poplar, alder growths significantly damaged by phytophthora rot, growths with a high share of invasive taxa, etc.). Renovations are done gradually in shorter sections in order to secure at least partially the integrity of the growth as a whole and its basic ecological, stabilization and landscape-forming functions.

7.11.7 In order to protect bank and accompanying vegetation from spread of infection, machinery work in and near watercourse channels is minimized, as it could cause damage to bases and trunks of trees.

7.11.8 Negative interventions near vegetation, e.g., changes to the hydraulic regime, spraying, etc., have to be reduced.

7.11.9 Restricting spread of invasive plants

7.11.9.1 Watercourses and their surroundings constitute an important communication channel in landscape, which may serve to spread numerous organisms, including introduced invasive species. Bank and accompanying vegetation and watercourse floodplains can serve large-scale proliferation of, e.g., the ashleaf maple, knotweed species, giant hogweed, goldenrods, daisies, Himalayan balsam and other undesirable species. The destruction of these species is difficult and long-term and involves diverse methods; for details, see, e.g., Pergl et al. (2016). Another considerable potential problem is proliferation of domestic species, e.g., on exposed surfaces during revitalization. Appropriate methods of destruction of invasive species include:

- clearing and banding (Canadian poplar, ashleaf maple);
- severing of roots, mowing and removal of inflorescences (giant hogweed);
- extraction combined with mowing (Himalayan balsam, goldenrods, daisies, Jerusalem artichoke), or only repeated mowing (knotweeds);
- for some well-regenerating or difficult species, mechanical destruction methods can be combined with local, targeted (injection, leaf spraying) use of herbicides, of course if possible in terms of water protection, territorial protection, etc..
- Destruction is recommended to proceed systematically from the top downstream, gradually along the entire catchment area.

7.11.9.2 Said principles can be applied, to an adequate extent, in bank and accompanying vegetation of a large majority of watercourses. However, the vegetation management goals have to be differentiated according to specific conditions. In and near built-up areas and many types of structures, adequately cultivated accompanying vegetation is in order, permitting flood flow capacity of the river space, sufficiently large for its protection, etc., and not posing additional operating and safety risks (movement of persons) and appropriately matching adjoining spaces and green areas (flood park concept). In open country, where the objective is near-natural riverbed and floodplain shapes, near-natural growth formations are in order.

Annex 1: Illustrations

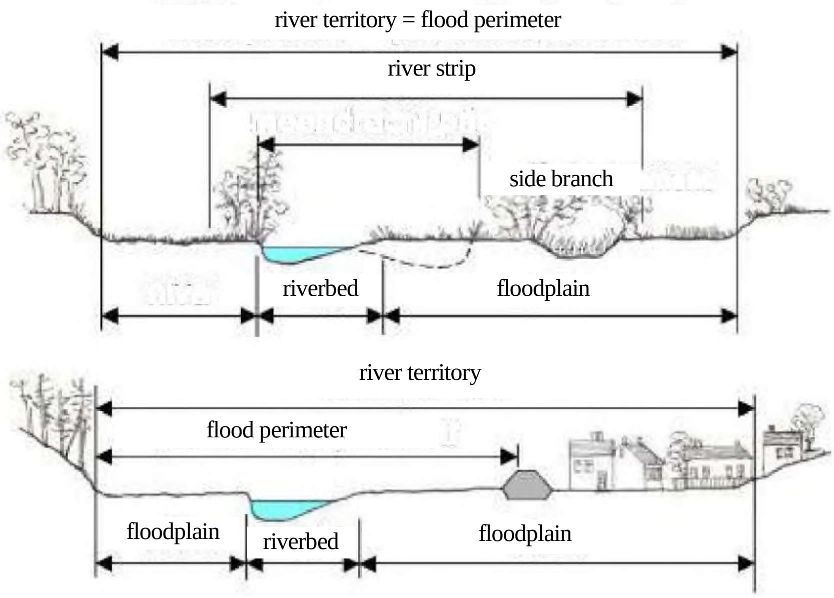

Fig. 1 (for 6.2.1): Division of river territory for a meandering watercourse in a flat floodplain. Top: natural conditions for flood overflows. Bottom: overflows restricted with levees along built-up parts of the floodplain.

Fig. 2 (for 6.3.4): Basic types of river patterns of Czech watercourses (from the left):

- wild-running
- straight riverbed
- meandering
- stable branching (anastomosis)

Right: schematic depiction of technically modified watercourse.

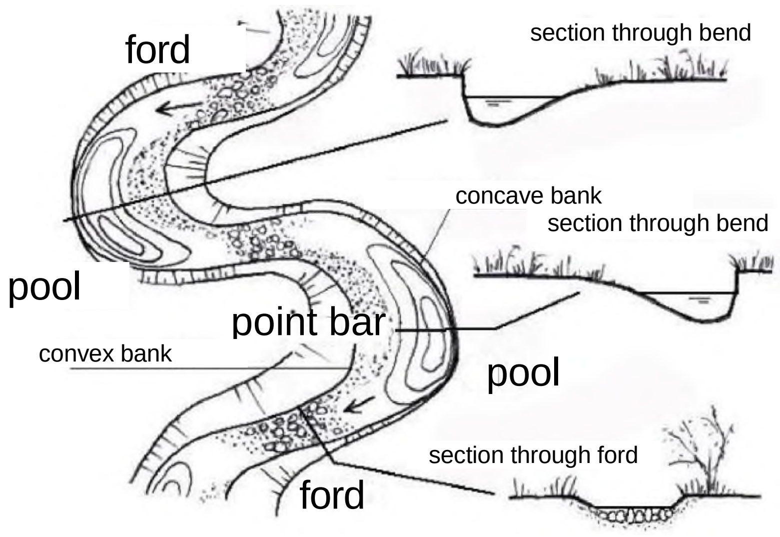

Fig. 3 (for 6.3.5): Typical shapes of a meandering riverbed.

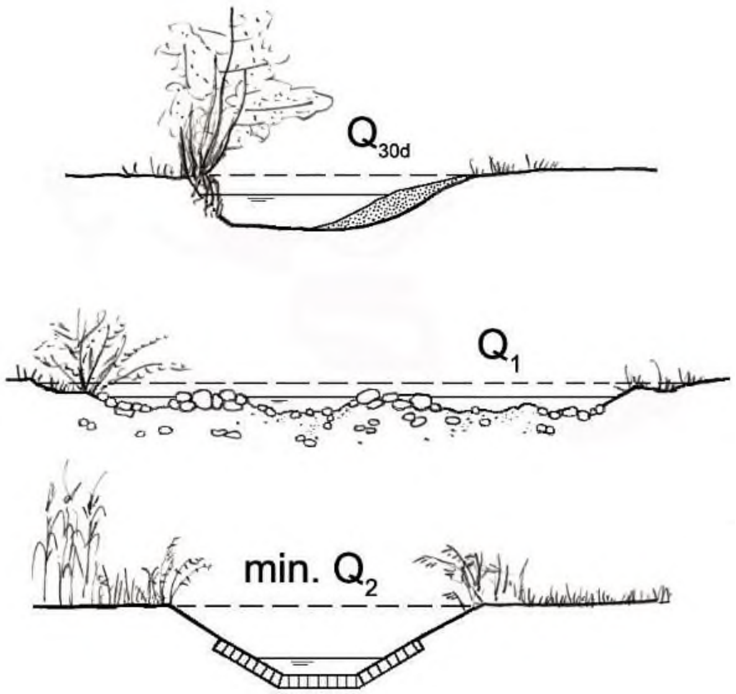

Fig. 4 (for 6.3.8): Approximate comparison of usual flow capacities of typical watercourses:

- meandering or undulating stream (top)
- stream running wild or with straight riverbed
- stream after typical technical modification.

Values shown for natural riverbeds prove useful as design capacities for corresponding revitalization riverbeds.

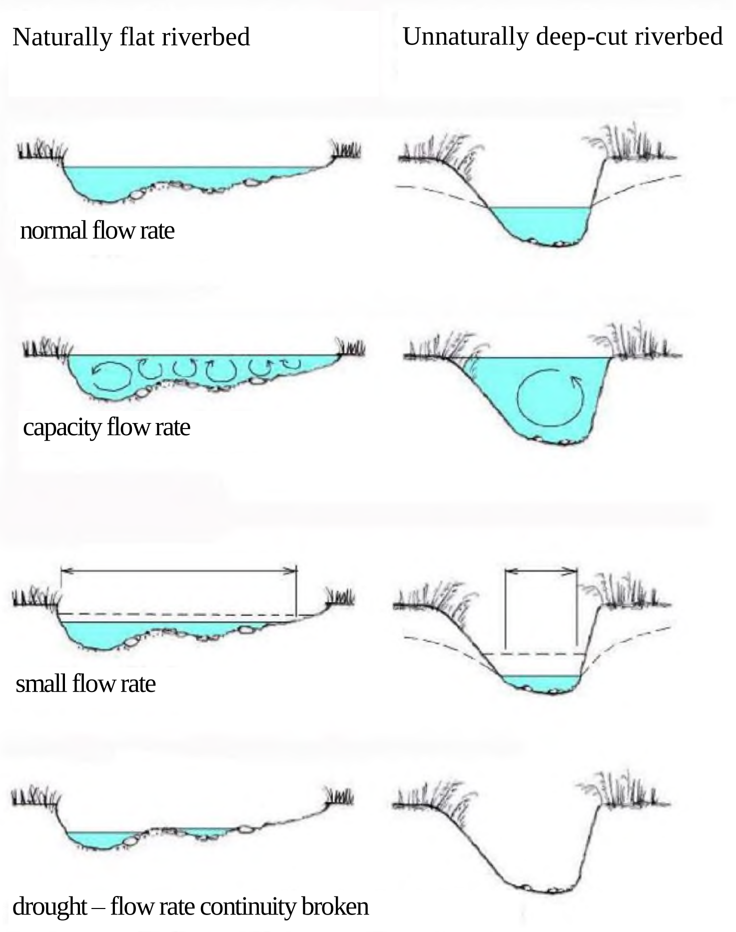

Fig. 5 (for 6.4.2): Comparison of naturally flat riverbed (left) and unnaturally deep-cut, probably due to technical modification (right).

Normal flow rates: The deep-cut riverbed offers limited space for development of shallows and bank sections, excessively draining adjacent earth strata.

Capacity flow rates: The deep-cut riverbed experiences more concentrated longitudinal and transverse flow components – the riverbed is more prone to erosion and deepening.

Low flow rates: Countersinking water surface reduces space for biota survival, continuing to drain adjacent earth.

Drought, obvious flow in the riverbed has ceased: The flat riverbed offers a relatively wide waterlogged strip for biota survival, divided by pools; the deep-cut riverbed offers hardly anything.

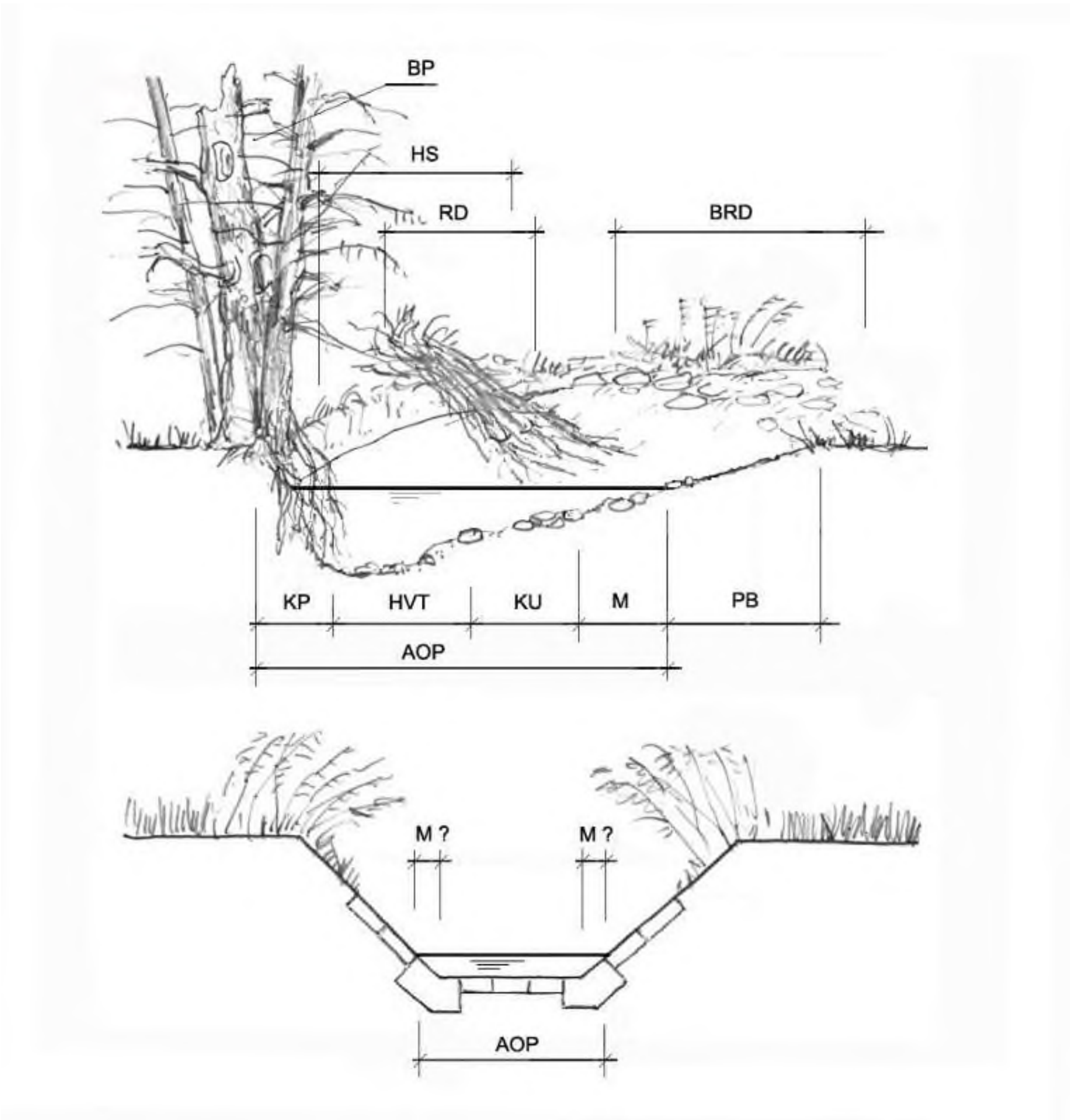

Fig. 6 (for 6.6): Schematic comparison of usual footprint extents of basic ecologically important environment types in a natural meandering riverbed and a corresponding technically modified riverbed.

AOP - active wet surface of the riverbed

HVT - deep pool water

KU - shelters among stones

M - shallows

PB - bank zone (area of water level fluctuation and flood surface disturbances)

BP - bank vegetation

HS - bird nesting slope

RD - river wood structures

BRD - flowing ford environment.

Annex 2: List of Nature and Landscape Management Standards (Water in Landscape)

Series B (Water in Landscape)

02 001 Creation and restoration of pools

02 002 Renaturisation of the water regime of mires and springs

02 003 Restoration of watercourses and their floodplains

02 004 River management including bank vegetation

02 005 Nature-based and friendly fishpond management

02 006 Fishpasses

02 007 Construction and reconstruction of water reservoirs by using nature friendly approach