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NATURE AND LANDSCAPE MANAGEMENT STANDARDS

WATER IN LANDSCAPE	RENATURISATION OF THE WATER REGIME OF MIRES AND SPRINGS	SPPK B02 002: 2022
SERIES B		

Obnova vodního režimu rašelinišť a pramenišť
Erneuerung der Wasserregelung von Torf und Quellen

This standard contains principles for optimum peat bog and springhead hydraulic regime restoration. The standards set and procedures recommended here cannot be treated as a dogmatic manual for implementing all revitalization. Each project needs individual preparation with respect to terrain, available techniques and other local specifics. Responsible setting of revitalization goals and respecting the principles specified here are seen as crucial.

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Development of the standard made use of experience of long-term revitalization projects. It used text of the publication in preparation “Manual for revitalization of peat bogs and wetlands in mountain areas”, one of the outcomes of the project LIFE for MIRES.

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Documentation for the standard development is available in the NCA CR library.

Standard approved on ....

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1. Standard purpose and contents

The standard "Peat bog and springhead hydraulic regime restoration" contains principles for optimum design, construction and efficiency monitoring of revitalization measures for the hydraulic regime of peat bogs and peat wetlands. The standard is intended primarily for applicants for support from landscape creation subsidy programmes, owners of forest and non-forest land on which peat bogs are present, as well as designers, contractors and public administration and self-government employees.

Legal framework

Act no. 114/1992 Coll. on Nature and Landscape Protection (hereinafter, ANLP), as amended, deals with the hydraulic regime in landscape, aiming at maintaining natural conditions for life of aquatic and wetland ecosystems while retaining natural character and near-natural appearance of watercourses, waterbodies and wetlands.

Act no. 254/2001 Coll., on Waters, as amended (hereinafter, "Waters Act"), defines protection of surface water and groundwater. From the perspective of this standard, it is relevant with respect to water management regulation (defining the obligation to obtain a water management permit also for accumulation or damming of surface water and groundwater) and regulation of hydraulic structures, water management and landscaping. Before implementation, the water management authority can be asked for a statement whether the execution is possible from the point of view of interests protected by the Waters Act, and under what conditions if any (Section 18 of Waters Act).

Act no. 183/2006 Coll., the Building Act, as amended (hereinafter, "Building Act"), sets requirements for location and permitting of structures and landscaping as activities that may be necessary for implementation of springhead and peat bog revitalization. That said, the Building Act is a general legal regulation under the Waters Act, and applies in water management if the Waters Act refers to it explicitly or if the decision-making concerns hydraulic structures, unless the Waters Act specifies an separate procedure.

Decree no. 499/2006 Coll. on Building documentation, as amended,

The contents and form of project documentation for construction (including for the purposes of peat bog and springhead revitalization) are defined in Annex 1 to Decree no. 499/2006 Coll. on Building documentation. If a building permit is required, it is advisable to develop project documentation for issuance of a joint permit (DUSP) as part of a joint proceeding, involving both the applicable zoning decision and building permit.

Act no. 289/1995 Coll., on Forests, as amended, defines procedures for changing forest functions and putting revitalization implementation in accordance with forest management plans and territorial forest development plans in force.

2. Definition of peat bog, springhead, anthropogenic influence

2.1 Peat bog

A peat bog is a wetland biotope comprising peat-forming vegetation, which due to extreme habitat conditions have weaker decomposition of organic matter, resulting in accumulation of poorly degradable organic matter (humolith). **Peat bog microrelief** is the rugged, uneven surface of a peat bog comprising bumps, dips, pools and tables. Peat bogs are divided into ombrotrophic (raised bogs) and mineratrophic (quagmires, peat spruce woods). An overview and explanation of basic terms are shown in Annex 1.

2.2 Springhead

A springhead is a set of springs located on a single site. Springhead biotopes are affected by groundwater raising towards the soil surface and characterized by relatively stable physical and chemical conditions of a mosaic character. They occur in every climate zone.

2.3 Main anthropogenic influences damaging hydraulic regime

2.3.1 **Surface drainage.** The most common type of drainage in peat bogs. Typically built using machinery or explosives. Causes the most serious degradation changes (due to erosion and bank washout). Serious damage is caused by grooves dug down to the mineral subgrade and large grooves that are the most difficult to block due to the high risk of regressive erosion of the bottom drain.

2.3.2 **Tubed drains.** Used mainly in industrially exploited peat bogs and farmland; they locally damage hydraulic regime of springheads and mineratrophic non-forest peat bogs of the quagmire type. Drainage pipes can be made of hazardous materials, such as asbestos. This has to be considered when defining revitalization procedures.

2.3.3 **Minor watercourse modifications.** Peat bogs often occur in a mosaic with other wetland biotopes or are hydrologically connected with other water elements (springheads, watercourses, stagnant waters). A revitalization project design has to consider the fact that minor watercourses play a fundamental role in territorial hydraulic regime.

2.3.4 **Peat digging.** Before excavation, peat bogs were drained, and peat digging led to the formation of dry raised blocks (strips of thicker peat layer, usually fast drying) and lower waterlogged depressions, known as basins. Large areas of exposed peat with surface erosion runoff channels occur in patches. The heterogeneous environment and varying degrees of degradation have to be considered when determining revitalization procedures.

2.3.5 **Industrial peat mining.** Thorough drainage before mining and repeated cutting of a thinner layer of peat from large areas leads to permanent damage or even destruction of a peat bog. If the minimum residual peat layer thickness is not observed, the mineral subgrade is exposed and the potential for spontaneous renewal is minimal. Determination of the residual peat depth and the hydraulic regime are necessary preconditions for revitalizing very strongly affected biotopes.

2.3.6 **Inappropriate road network.** Causes strong linear drainage along the road in peat wetlands, destabilizing the hydraulic regime in the area. The more steeply sloping the area, the stronger the effect. Handling drainage along roads is crucial for hydraulic regime revitalization in many places.

3. Information for planning hydraulic regime restoration

3.1 Setting hydraulic regime restoration objective

3.1.1 Generally, the objective of peat bog revitalization is restoration of habitat conditions and ecosystem functions as close as possible to a state that the site would experience before any damaging influences.

3.1.2 The basic goals when restoring peat bog hydraulic regime include:

i) increasing water table to a level corresponding to the natural state,
ii) restoration of natural water movement around the peat bog,

iii) restoration of natural state of hydrological elements/structures functionally connected with the peat bog (e.g., springheads, watercourses, floodplains).

3.1.3 The target community/biotope type has to be recognized and defined.

3.2 Determining revitalization method

3.2.1 Setting of goals and procedures for restoring hydraulic regime is based on thorough analysis of the current state and historic development of the area.

3.2.2 Study area integrity. Peat bog hydraulic regime restoration is handled for entire sub-catchment areas, even if they are very small in size. Recognizing hydrological connections with the surroundings is important for the revitalization result. Separate solving of only specific sections (e.g., raise bogs only) without hydrological linkage is usually insufficient.

3.2.3 In the case of industrially mined peat bogs, it is necessary to decide whether the objective of hydraulic regime restoration is:

i) starting the raised bog restoration process via early mineratrophic stages, or
ii) promotion of direct restoration of raised bog biotope or communities, or
iii) restoration of wetland in order to improve area hydrology and reduce greenhouse gas emissions.

3.2.4 Selection of revitalization procedures and methods, including setting of quantitative indicators (e.g., target water table) for specific measures is determined in accordance with the selected revitalization objective and based on detailed technical documentation containing proposal and description of measures.

3.2.5 The basic revitalization project objectives can be modified for the specific situation of the study area (e.g., additional anthropogenic influences such as eutrophication or requirements for use of surrounding areas) or specific requirements for protection of species or communities (creation of microbiotopes, follow-up management, etc.). When developing the project design, access to revitalized areas has to be ensured so as to eliminate movement of machinery and workers in peat bog parts in good condition.

3.3 Degree of waterlogging, target water level concept

3.3.1 The method of restoring waterlogging of the revitalized site reflects differences in water table height and fluctuation. A basic measure when restoring hydraulic regime of drained peat bogs and springheads is to block drainage grooves with cascading dams with earth backfill combined with filling the grooves with earth or a natural material.

3.3.2 The hydraulic regime restoration is grounded in the target water level concept (CHV), which assumes returning the water table to a level close to the natural state, or the state before draining (target level). CHV can be expressed as the maximum permitted water level drop below the exposed wall of the damming (Annex 3, Fig. 1).

3.3.3 CHV is an important parameter for the technique of blocking drainage ditches, particularly on slopes (including very gentle ones). CHV values are determined based on field measurement or analysis of available data from literature.

3.3.4 The CHV value has to be determined for each groove segment. It is a function of the peat bog type, or peat bog vegetation type crossed by the groove segment. Recommended CHV values for peat bogs are specified in Annex 2, Table 1.

3.3.5 CHV determines the correct number of dams and their distribution over the drainage groove segment so as to restore the water level to the original level along the entire length of the drainage system.

3.3.6 The basic design can work with the available layer from Natura 2000 biotope mapping, but technical calculations require more accurate data. The accurate CHV determination requires detailed mapping of present biotope or vegetation types. Even the smallest springheads are mapped, as they are extremely important for revitalization.

3.3.7 The correct placement of dams and their number per groove is calculated as the length of the hypotenuse of a right-angled triangle where the leg and opposite angle are known. The distance between dams must not smaller than 4 m. If shorter distances are calculated, 4 metres are set as default.

3.3.8 In springhead areas, dams are located so that the water level is at or just above the ground surface. I.e., CHV is 0–5 cm. Sections in between dams are filled with earth.

3.3.9 Placement of dams based on technical calculations if eventually usually adjusted depending on the situation on site. The positions of some dams have to be moved slightly in the field due to difficult installation (feet of tall trees, aerial root systems or large boulders in the banks) or presence of precious plant species at the point of installation. The adjustments have to be made so that the resulting distribution of dams, with the exception of (usually short) problem sections, ensures raising the water level to the original CHV.

3.3.10 CHV need not be used in flat, level areas. It is enough to place dams or compacted earth dykes in key positions as per specific terrain configuration. The maximum distance between blocks is 50 m to divide retained water volumes into multiple segments. If ditch segments between blocks are, even partially, filled with earth, the distances between blocks can be many times greater.

3.4 Field survey

3.4.1 <u>Surface drainage type</u>

3.4.1.1 Knowledge of current state and routing of the drainage system on the site is necessary.

3.4.1.2 It has to be determined whether a groove is a drainage ditch collecting groundwater, or a minor watercourse routed as an artificial channel. The distinction between a mere drainage ditch and a channel substituting for a watercourse is crucial, as each case is handled differently:

- Surface drainage ditches are filled and blocked off.
- On the contrary, streams routed as channels must not be blocked, and the revitalization procedures are different (see chapter 4.9.).

3.4.1.3 Revitalization of streams is done first, and only after than can channels collecting groundwater be blocked.

3.4.2 <u>Hydrological conditions in the territory</u>

3.4.2.1 Hydrology of the area comprises a description of the current state, maps with accurate location of watercourses and other water elements (groundwater outlets, pools) or their updates based on actual state, as well as current maps of the secondary hydrological network (drainage) and other hydraulic structures.

3.4.2.2 Hydrological surveys are developed in the following structure:

- Description of basic parameters of drainage systems (drainage type, width, depth – a simple value scale can be used).
- Assessment of functional condition (clogging with earth, erosion, flow capacity, etc.).
- Field mapping and revision of the drainage network based on available data (maps of Research Institute for Soil and Water Conservation, maps of hydraulic structures, forestry maps, cadastral and historical maps, aerial photos, lidar images, etc.).
- Assessment of impact on area hydraulic regime and analysis of runoff conditions, including identification of preferred runoff routes.
- Identification of places with groundwater outlets and probable movement of water under the surface, if significant.
- Identification of initial situation of hydrological network, including natural runoff conditions existing before interventions in hydraulic regime.
- Verification of watercourse registration status in the national database (IDVT), identification of deviations of actual field situation and proposal of changes in locations of affected watercourses after revitalization.

3.4.2.3 Monitoring of a drained peat bog starts already when planning the revitalization. Setting of monitoring and initial data acquired during project planning are an annex to the revitalization project design. For more on monitoring, see chapter 5.

3.4.3 <u>Topographic conditions</u>

3.4.3.1 With a view to local topography, the current water distribution and movement in the study area is assessed, including preferred runoff routes.

3.4.3.2 Knowledge of topographic conditions is crucial for:

- Identification of method of blocking drainage ditches (target water level concept) and initial setting of water distribution in the revitalized area with a view to the target state.
- Planning of landscaping works aimed at promoting water accumulation, preventing undesirable surface runoff and promoting development of peat-forming vegetation.
- Identification of original beds or runoff routes of modified and relocated streams.

3.4.4 <u>Soil characteristics</u> are an input for determining the area degradation and revitalization potential.

3.4.4.1 It identifies the distribution of humoliths in the area, basic peat types and their thickness, level of degradation (decomposition, sinking, structural changes, etc.).

3.4.5 <u>Environmental trophism</u>

3.4.5.1 Basic information on trophic conditions on the site is important for determining the probable initial situation, level of habitat degradation, basic revitalization objectives, identification of various water sources (groundwater outlets, effect of occasional floods, etc.).

3.4.5.2 If anthropogenic influences changing the environmental trophism in mined peat bogs exist, they are crucial for definition or modification of specific measures.

3.4.5.3 As needed, a coarse scale of oligo-, meso- and eutrophic suffices. Alternatively, detailed identification is done using chemical analysis of soil or water samples.

3.4.6 <u>Current vegetation</u>

3.4.6.1 Detailed maps of current vegetation (or at least biotopes) are made, crucial for assessment of hydrological conditions, soil properties, trophic conditions on the site, evaluation of intensity of anthropogenic influences and degree of biotope degradation.

3.4.6.2 The vegetation maps are crucial for determining revitalization objectives and specific measures (target water level, placement of blocks and dams in drainage grooves, method of water distribution in the revitalized area, surface modifications, promotion of peat-forming vegetation, identification of original stream beds, etc.).

3.4.7 Species

3.4.7.1 Current presence of specially protected and important species (see Annex 4) and potentially risky invasive species is identified already during project preparation. Ecological demands of such species are reflected in selection of measures and implementation logistics on the site.

3.4.8 Area protection status

3.4.8.1 Project planning shall reflect classification of the area in different area protection categories.

3.4.8.2 Project planning shall adhere to management plans or other adequate planning documentation, if any exists.

3.5 Revitalization design

3.5.1 The revitalization design is a fundamental and necessary document for hydraulic regime restoration in the study area.

3.5.2 Revitalization planning involves two fundamental steps:

- Analysis of the study area and setting of goals.
- Development of detailed technical documentation with proposals and descriptions of measures.

3.5.3 The revitalization design is based on a thorough analysis of the study area. The analysis includes an assessment of the current state of the site (habitat conditions and biota), present and historic anthropogenic influences, their interactions and impacts on the study area. It involves identification and assessment of negative effects on the study area.

3.5.4 The revitalization design has a clearly defined objective and purpose. It specifies whether the revitalization will lead to a return to a natural state or a partial compromise.

3.5.5 The design includes a current land use map with basic land use categories, including the current state of LPIS on farmland, existing road and other transport networks, location of utility networks, etc.

4. Revitalization technical solutions and work procedures

4.1 Transverse blocking of drainage ditches

4.1.1 Blocking of ditches of a basic measure for (i) increasing and stabilization of groundwater level, (ii) reducing water loss due to concentrated and fast runoff, and (iii) water redistribution and subsequent absorption in the peat bog area.

4.1.2 In sloping terrain, cascades of solid transverse wooden dams, well anchored in the banks and bottom, are built. The dams have to be backfilled with local earth or peat.

4.1.3 Transverse blocking of channels is combined with subsequent filling ditches in between the dams and promotion of fast overgrowing with wetland vegetation.

4.1.4 In flat areas, backfill with earth or compacted earth blocks (peat or earth dams) are enough to block the channels.

4.2 Wooden dams and their installation

4.2.1 **Dams made of horizontally laid** planks, logs or half-logs are used of grooves dug down to the mineral bottom or if the peat thickness at the channel bottom is not sufficient (min. 50 cm). They are the main type of transverse blocking of channels in mineratrophic peat bog such as peat spruce woods and moss bogs and non-peat biotopes.

4.2.2 The dams can be built using half-logs, edged and unedged planks (for dimensions, see, 4.2.5), and logs in justified cases (see 4.2.3).

4.2.3 In justified cases (e.g., site not accessible for bringing more suitable material, material cannot be transported even by hand, and channels, see 4.2.13), log timber dams can be built (Annex 3, Fig. 3). It is necessary to consider greater demands for backfill, sealing and functionality checks during construction and in the first years after completion.

4.2.4 **Horizontally stacked dams** (Annex 3, Fig. 2). They are normally made of two layers of half-logs or planks.

4.2.5 Generally, dams are made of half-logs or planks laid horizontally in two or more layers with overlapping joints (Annex 3, Fig. 2). Typically, they use planks 15-20 cm wide, 1.5-2 cm thick, and half-logs 10-15 cm wide; the length is adjusted to the groove width. The standard lengths are 2m, 3m, 4m (up to 7 m in places), cut to fit as needed on the spot. Earth backfill is always necessary.

4.2.6 Geotextile is inserted between the two plank layers, ideally made of biodegradable natural material (hurds). The geotextile must be inert and tested for harmlessness to the natural environment.

4.2.7 When anchoring plank dams, cuts are dug in the banks and the bottom for anchoring the dams. For channels up 0.6 m deep, an overhang of 0.3 m is enough; 0.5 m or more is necessary for channels deeper than 0.6 m. The overhang is increased depending on the channel size, ground slope and technique used.

4.2.8 Afterwards, the dams are mounted in the prepared cuts and sealed well. The wooden dam sits tight against the cut.

4.2.9 At the bottom of the dam, the geotextile extends beyond the planks and is laid on the channel bottom upstream of the dam (about 0.3-0.5m long), where it is buried in bottom sediments. At the top edge of the dam, the geotextile ends below the overflow.

4.2.10 The exposed face of the dam is reinforced with perpendicularly rammed log stakes 10-20 cm in diameter.

4.2.11 On highly sloping ground (above 20°) and in large grooves deeper than 1.5 m or wider than 3 m, however, dams can be built of three layers of planks (with a single layer of geotextile) and reinforced on the exposed edge with more stakes.

4.2.12 In channels deeper than 1.5 m or wider than 4 m, where high water pressures occur, double dams are used. There, two wooden dams are embedded at a distance of 0.5-0.7 m from each other, and the space between them is filled with earth material. Careful backfilling is necessary.

4.2.13 **Single horizontally stacked dams** (Annex 3, Fig. 4, 5) are used for shallow channels (max. 0,6 m deep), on sites with minimum gradient (up to 5°) and for channels strongly overgrown with wetland vegetation (more than 2/3).

4.2.14 The design of single dams is identical to the plank dam type described above, only the geotextile is fastened to 1 layer of planks are well sealed. The embedding in the banks and bottom is smaller (about 30 cm). The earth backfill of the dams is limited to material from the excavation for the dam embedding.

4.2.15 **Dams made of vertically rammed planks.** Dams made of rammed planks are used in raised bogs or poor fens with sufficient peat depth. A necessity precondition is minimum peat thickness of 50 cm for embedding the dam in the channel bottom.

4.2.16 The dam is produced by ramming individual planks vertically into the groove bottom (Annex 3, Fig. 6a, b). The planks are prepared in advance for tongue-and-groove joint (Fig. 6a), or a joint with two grooves with an inserted slat (Fig. 6b) and are jointed while being rammed in. The planks are cut to fit as needed on the spot.

4.2.17 Assembled dams are reinforced in the transverse direction with tie beams on both sides. The tie beams are placed no more than 5 cm below the overflow.

4.2.18 Plank dimensions: width at least 15 cm, thickness 5-6 cm, length adjusted to groove depth. The standard lengths are 1.5 m, 2 m and 2.5 m, cut to fit as needed on the spot. Dimensions of tongues and grooves in planks: thickness 2 cm, width 2 cm. Tie beam dimensions: width at least 15 cm, ideally 20 cm, thickness 5-6 cm, length to be adjusted to groove width.

4.2.19 **For all types of dams**, they have to be impermeable and sufficiently embedded in the bottom and banks of the groove. The dams are vertical and perpendicular to the longitudinal groove axis.

4.2.20 Suitable materials for dam construction is spruce or Douglas fir wood. Pine or black locust wood is not suitable. Fresh, raw wood is used for dam construction.

4.2.21 The minimum embedded length (overhang) of a rammed plank dam is 50 cm in the bottom and 50-60 cm in the banks of the channel. The overhang is increased depending on the channel size and ground slope.

4.2.22 The top edge of the dam is flush with the surrounding banks. The lower bank is the defining parameter for the dam top edge.

4.2.23 On sloping ground, dams have an overflow cut in the middle of the top edge to guide excess water. The overflow is about 15-20 cm wide and up to 2 cm deep. A moderating surface (spout) is attached below the overflow to disperse the water. The bottom below the overflow/spout is stabilized with laid stones, gravel or pieces of wood to attenuate the erosion force of the falling water and prevent scouring of the bottom below the dam.

4.2.24 Material excavated when installing the dam or from close surroundings can be used to backfill around the dam to improve its insulating properties and durability (Annex 3, Fig. 7). All dams are backfilled around with earth material. The backfill width is usually 1 m on both sides of the dam (at the crest). It may be more for large channels (see 4.2.12) and on sloping ground. For shallower channels with a max. depth of 0.6 m on flat or only gently sloping ground, the backfill width can be reduced to at least 0.5 m on either side. Any bottom clay layers of the soil profile are laid at the channel bottom, and peat in the upper part of the backfill and on its surface.

4.2.25 Starting from a minimal ground slope, all dams are installed gradually from the top of the groove downstream.

4.2.26 The one-way rule must be observed at all times: machinery must not travel back and forth. The work logistics shall ensure one-way movement of machinery along the channel.

4.2.27 On poorly accessible, vulnerable and valuable sites or their parts, all work is done exclusively manually.

4.2.28 Dams cannot be installed at times of increase water flow down the groove. Any earth works must be stopped during strong torrential rain and lasting precipitation (usually, work shall be suspended after 3 days of continuing precipitation).

4.3 Peat dams

4.3.1 Peat dams are the most natural way of blocking drainage ditches in peat bogs, but in the overwhelming majority of cases there is not enough peat to make the dams. Mere material from channel embankments is not sufficient for this measure.

4.3.2 Peat dams are massive: thickness at least 1-2 m and raised at least 0.5 m above the channel bank level. The dam extends beyond the channel banks (at least 5-10 m).

4.3.3 The distance between dams depends on the ground gradient (albeit minimal in these cases) so that it ensures complete filling of the area between them with water, permitting sideways overflow. Swelling of water up to the bank level or about 5 cm below the surrounding surface is permissible, but not less.

4.3.4 The peat has to be compacted while building the dam. The peat may be sourced by excavation from remaining channel embankments or newly created smaller shallow depressions near the channel (3–5 m^2 of area, up to 0.6 m deep).

4.3.5 No new linear depression, however shallow, must be created along the channels, that might produce a parallel drain.

4.3.6 When building peat dams, it is advisable to use machinery: lighter machines up to 3-7 t (depending on ground carrying capacity) or heavier machines with wide tracks, or walking machines with expanded pads.

4.4 Filling of drainage ditches

4.4.1 Dammed ditches have to be additionally filled with earth (peat only in raised bogs) or other autochthonous material, e.g., earth from adjacent embankments remaining since the drainage system construction.

4.4.2 If enough earth is available and the ditch is filled completely, a shallow water column is left on the surface (approx. 30 cm) for overgrowing with peat-forming vegetation.

4.4.3 If material is lacking, a part of the space between the dams is filled with mats made of pruned tree branches. The branch diameter is up to 2 cm, branches are tied together tightly with thin uncoated wire. Mat size is about 0.7 m long and up to 0.5 m wide. The mats should not be laid on a stony bottom: an earth or peat foundation is always needed. The mats are placed side by side longitudinally; they can be placed transversely in narrow channels up to 1 m in width.

4.4.4 In non-forest areas, the fill is made using turf with quaking sedge (*Carex brizoides*), tufted hairgrass (*Deschampsia caespitosa*), hard matgrass (*Nardus stricta*), common bent (*Agrostis capillaris*) or pilose reedgrass (*Calamagrostis villosa)* or other local species.

4.4.5 The densest material is laid at the bottom and airier material towards the surface when filling ditches.

4.4.6 Sections between dams in springheads are completely filled with earth. Remnants of embankments left from the drainage system construction, covering the remains of the springhead, are scraped off to the original springhead surface level.

4.5 Promotion of overgrowing of ditches with peat-forming vegetation

4.5.1 Peat-forming vegetation is inserted in between dams if the sections between the dams are not completely filled with earth from the start. Establishment of vegetation is also initiated on the earth backfill of the dams and on top of the dams made from compacted peat.

4.5.2 Spaces between dams with deeper water are filled using bogmoss turfs, which can grow over open water surface. In the Czech Republic, raised bogs can use feathery bogmoss (*Sphagnum cuspidatum*) and *S. majus*, and mineratrophic peat bog mainly *S. flexuosum* and flat-topped bogmoss (*S. fallax)*.

4.5.3 Bogmoss turfs are inserted near banks or on pieces of wood protruding towards the water surface or floating on it. For10 m^2 of water surface, use about 5–8 turfs.

4.5.4 The vegetation is sourced from near surroundings of the ditches. Use of specific species depends on the peat bog type and local flora and vegetation composition.

4.5.5 Spaces between dams with shallower water and up to 0.3 m in depth can also be filled with turfs of sedges (e.g., silver sedge (*Carex canescens*), bottle sedge (*C. rostrata*)) or cottongrasses (hare's-tail cottongrass (*Eriophorum vaginatum)* – ideal for raised bog channels, common cottongrass (*E. angustifolium*) – particularly for non-forest mineratrophic peat bogs).

4.5.6 Mineratrophic peat bogs can be filled with turfs of any wetland plants from near surroundings, e.g., soft rush (*Juncus effusus*), thread rush (*J. filiformis*), black sedge (*Carex nigra*), creeping bent (*Agrostis stolonifera*), velvet bent (*A. canina*), etc.).

4.5.7 More xerophytic species are used for the earth backfill of dams. For raised bogs, use hare's-tail cottongrass (*Eriophorum vaginatum*), and for mineratrophic peat bogs a mixture of some more xerophytic species, including grasses.

4.6 Stopping tubed drains

4.6.1 Stopping the function is possible by exposing and completely removing the draining system, or locally eliminating the drainage function of the tubes.

4.6.2 Complete removal of the drainage system is usually not advisable. The process is costly and highly risky for the remaining fragments of peat bog vegetation.

4.6.3 Local elimination of the drainage function of the tube system is done by interrupting the tube sections (i) by removing partial segments of tubes and backfilling, or (ii) exposing and sealing the drainage tubes; ideally a combination of both methods.

4.6.4 To remove partial segments of the drainage tubes with backfill, make excavations down to the drain level, and remove the tubes over a length at least 2-3 m. The distance between the interrupted sections shall be approx. 5-10 m; it can be more on flat ground.

4.6.5 At the point of interruption, both ends of the adjacent drainage tubes are sealed. To seal interrupted tubes, use wooden lugs, inert plastic caps or insulation with some impermeable material, e.g., clay, and backfill with earth or peat. A wooden dam is placed 50 cm ahead of and behind the seal to block the water flow down the drainage pipe bed.

4.6.6 The excavated segment is refilled with compacted peat. On sloping ground, a wooden dam extending sideways and into the bottom is installed in the excavation and backfilled.

4.6.7 In the process, check that the sealing does not result in water being redirected to other segments of the drainage network.

4.7 Surface modification of mined peat bogs

4.7.1 The aim of surface modification in areas of exposed peat is to promote water retention in suitable areas on the surface of the mined peat bog and increase water availability for development of peat-forming vegetation.

4.7.2 Surface modifications are made before blocking the channels.

4.7.3 Smaller shallow depressions with a depth up to 0.5-1 m (depending on the thickness of the remaining peat layer) with an area of 20-30 m^2 are left scattered in patches of the mined area.

4.7.4 On gently sloping ground, the deeper part of the depression is higher up the slope.

4.7.5 Sloping ground of industrially mined peat bogs are partitioned by newly built gentle terraces with shallow depressions for water. The terraces run as longitudinal wide beds across the slope, with a flat, non-sloping surface divided by depressions. The height difference between the terraces is no more than 30 cm. The width of terraces is defined by the gradient and the length of the sloping area with exposed peat. For example, a total of 3 terraces can be built in an area 100 m long with a 0.3% gradient. The material obtained can be used to fill in drainage channels.

4.7.6 The surface peat crust on the mined surface (formed by repeated surface freezing and overheating) is scraped off. Additional measures to promote peat-forming vegetation shall be carried out in these places (see 4.8.2).

4.7.7 Dispersion dams made of logs are installed in areas with excavated peat, along small deceleration depressions eliminating water runoff from eroding shallow surface gullies.

4.8 Promotion of wetland vegetation restoration

4.8.1 It is most commonly done in areas with exposed peat left after industrial mining.

4.8.2 Turfs of suitable bogmoss species are placed in small depressions on the peat surface, which are then covered with a layer of plant mulch about 15-20 cm thick of appropriate composition (peat-forming vegetation). The material is sourced from mowed peat meadows from the surroundings.

4.9 Restoration of minor natural watercourses

4.9.1 Revitalization of peat bogs and small-scale wetlands most commonly deals with the smallest watercourses (tiers 1 and 2). Only in lower-lying areas do higher-level watercourses tend to have hydrological contact with peat bogs, fens in this case.

4.9.2 The standards for revitalization of watercourses (mainly medium and large ones) have been developed. Restoration of smaller, first-tier streams in peat bog environment has certain specifics (see 4.10.4).

4.9.3 If the watercourse runs down a drainage ditch (typically the main collecting channel) outside its original bed, it can be returned to its original route in several ways: (i) returning it to its extant original bed, or (ii) building a new stream bed along a natural runoff route. For capillary streams with a flow rate up to 5 l/s, it is also possible, in certain cases, to (iii) let the water flow freely approximately along the original path without digging a bed. Each measure type requires a different technique.

4.9.4 After the streams have been rerouted to their natural paths, the respective channel sections are blocked using the normal method.

4.10 Site access for revitalization

4.10.1 Access for machinery has to be provided when revitalizing forest peat bogs. Normally, a linear strip along the channel is cut as wide as the excavator (on one bank), with only smaller gaps prepared on the opposite bank for installation of dams, if any.

4.10.2 In forest peat bogs, only a highly sensitive path is provided, assuming travel between trees close to the channel, making use of gaps between trees and only cutting woody plants directly in the path and at the points of dam or channel blockade construction.

4.10.3 Before starting work, all trees to be felled shall be marked, along with paths for machinery movement.

4.10.4 Material obtained from the pruning is used to fill the channels.

4.10.5 Pontoon slabs and mats made of pruned trees and branches are used to increase the ground carrying capacity in shorter (max. 10–20 m long) severely waterlogged sections. In severely waterlogged or otherwise vulnerable areas, all work is done manually only.

4.10.6 Tracked machines or ball extenders for walking machines are used. Excavator tracks shall be as wide as possible, undivided and made of rubber. Steel tracks, including divided tracks, are inadmissible.

4.11 Follow-up management

4.11.1 After restoration to adequate abiotic (aquatic) conditions, sites develop spontaneously without any further human support activity. The only exception is some types of non-forest peat bogs, for which long-term maintenance by mowing is advisable in order to promote biodiversity.

4.11.2 Planned follow-up management operations are included in the revitalization design.

4.11.3 Since the installed wooden dams gradually disintegrate and connect with the earth backfill of the drainage ditches, the damming of ditches is only a temporary structure. The original hydraulic structure (drainage ditch) disappears in the process.

4.11.4 In the case of stream restoration, the result is a natural watercourse. It is without any follow-up maintenance as well.

4.11.5 Follow-up management concerns site facilities associated with peat bog effectiveness monitoring, such as permanent areas for vegetation monitoring, meteostations and data loggers.

5. Monitoring of revitalized sites

5.1 Basic monitoring projects, the main objective of which is to identify the degree of degradation of specific drained sites, acquisition of data for setting realistic revitalization objectives, revitalization design development and evaluation of success of revitalization measures implemented, are an integral part of revitalization projects.

5.2 Monitoring of a drained peat bog starts already when planning the revitalization. The monitoring should ideally start three years before the revitalization implementation, and should continue unchanged after the revitalization measures are implemented.

5.3 It is desirable to perform monitoring of an extant peat bog (control site) in the study area using the same methodology.

5.4 The following abiotic factors are monitored: water table, ground and surface water hydrochemistry, and basic chemical composition of peat.

5.5 The following microclimatic conditions are monitored: data on air and soil temperature and humidity at different levels above and below ground surface, precipitation and runoff conditions, and runoff surface water chemistry.

5.6 A minimalist version of monitoring comprises the following monitoring set: a water level probe (enabling water quality sampling too) and a permanent area of 1x1 m in close vicinity (up to 0.5 m) for vegetation monitoring.

5.7 The sets cover main types of peat bog vegetation or environmental gradients, and are placed with at least three iterations in each vegetation type. On drained sites, it is advisable to place probes and permanent monitoring area with a view to the documented drainage.

5.8 Water table measurements are taken manually or using automatic piezometers with memory (data loggers) at least once a month.

5.9 The vegetation composition and structure are recorded in detail in 2 to 5-year intervals.

Annex 1: Overview of basic terms

Humolith: Mostly organic matter produced through a special anaerobic decomposition process (bog formation or **paludification**), primarily from remnants of dead peat bog plants. Depending on the origin, we distinguish raised bog, poor fen (mixed) or fen humoliths.

Peat bog: A wetland biotope where organic matter (humolith) accumulates due to extreme habitat conditions.

Peat-forming vegetation: Communities with a prevalence of plant species that have specific adaptations to thrive in the extreme environment of peat bogs and produce large quantities of difficult-to-decay biomass. Due to their specific properties, these species contribute to the unfavourable conditions in the peat bog, attenuate decomposition of organic matter and significantly contribute to humolith accumulation.

Peat bog microrelief: The rugged, uneven surface of a peat bog comprising bumps, dips, pools and tables.

Bump: A raised mound in a peat bog comprising less hygrophilous plant species, which grow away from the water table.

Dip: A small shallow depression between bumps populated by strongly hygrophilous plant species.

Lagg: A peripheral lower-lying part of a peat bog, severely waterlogged area where water rushes out of the peat bog along gradient and seeps into the surrounding area.

Acrotelm: The aerobic thin surface layer of a raised bog with living plants, easily permeable for water, with a fluctuating water table. Characterized by constant accretion of plant matter and water level fluctuation depending on precipitation. The acrotelm is a crucial layer where the main exchange of water and substances between the raised bog and its surroundings occurs. It is also the primary peat-forming layer: if the plant composition in it changes, e.g., if bogmoss disappears, the peat formation process stops.

Catotelm: The anaerobic, permanently waterlogged environment of the lower layers of humolith in a raised bog with low hydraulic conductivity. It is a layer permanently saturated with water where organic matter accumulates and decomposes under anaerobic conditions. It comprises the main volume of the peat bog, or raised bog, dome and is the reservoir holding the maximum volume of water in the peat bog. Correct functioning of acrotelm is highly dependent on contact with stable water table, maintained with a range of several centimetres below the surface by the presence of saturated and hydraulically poorly conductive catotelm.

Ombrotrophic peat bogs, or **raised bogs** are fed mostly by water from atmospheric precipitation, i.e., water with very low nutrient and mineral content, and accumulate bogmoss humolith. The term “raised bog” derives from the raised loaf shape, because the central part experiences the greatest growth and accumulation of peat. **Mountain raised bogs** are formed in the paludification process, particularly in conjunction with spring systems in shallow depressions or saddles between mountain ridges with low runoff. **Valley raised bogs** are formed in the terrestrialization process, i.e., gradual overgrowing of small stagnant water bodies (e.g., cut-off river branches), contributed to by groundwater, rainwater and surface water.

Mineratrophic bogs, or **fens**, are supplied to a large degree, beside rainwater, with groundwater enriched with minerals. They accumulate mostly sedge humolith and the peat thickness is usually smaller than in raised bogs. They include, e.g., peat spruce woods, peat birch woods, poor fens, moss fens and calcareous fens.

Poor fens are mineratrophic peat bogs with a deeper layer of humolith, which reduces the effect of groundwater on the vegetation on the bog surface. It comprises mainly bogmoss and sedge.

Springheads are biotopes with relatively stable physical and chemical conditions, characterized by temperature stability throughout the year (azonal). They are not homogeneous, the structure is a mosaic comprising numerous different microhabitats.

Surface drainage: A system of surface grooves and ditches built in order to accelerate water runoff from waterlogged areas.

Tubed drains: A system of underground drainage aimed at collecting, intercepting and draining of water from waterlogged areas. They include various types of modern tube drains as well as historic drains.

Drainage: We distinguish surface (i.e., via dug ditches) and subsurface drainage (system of drainage elements laid in the ground). In peat bogs, drainage causes a decrease and fluctuation of the water table and subsequent aeration of the peat profile, interfering with the originally completely waterlogged anaerobic layer, the catotelm. Lower water saturation and presence of oxygen enables activity of microorganic aerobic decomposers, resulting in increased decomposition, particularly of the upper peat layers. Nutrients released by the peat decay are released into the environment and the nutrition environment capacity (trophism) and chemistry changes.

Types of peat biotopes

For the purposes of this standard, only the basic types handled in the text are listed here. For a more detailed categorization and description of the different types, see, e.g., Chytrý et al. (2010) and Verdonshot & Schot (1987).

Mountain raised bogs are ombrotrophic systems formed in mountain areas in conjunction with springheads, classified into sloping and watershed types, most common in shallow depressions or saddles between mountain ridges.

Valley raised bogs (most commonly bog pine woods), formed by gradual overgrowing of small stagnant water bodies (such as cut-off river branches, known as terrestrialization); they are ombrotrophic too, and may have weak local groundwater effects.

Peat spruce woods exist around springheads, peat bogs and in waterlogged depressions and along streams, frequently around the perimeter of raised bogs. A typical feature is a rich moss storey, comprising mostly bogmoss.

Peat pine woods are loose or canopied growths dominated by bog pine (*Pinus rotundata*). They may have admixtures of downy birch, Scots pine and spruce. The herb storey is dominated by shrubs of bilberry, cowberry and heather. Marsh Labrador tea (*Ledum palustre*) is also characteristic.

Peat birch woods are loose woods dominated by the downy birch (*Betula pubescens*), with potential admixtures of other species, also in the shrub storey. The willow-leaved meadowsweet (*Spirea salicifolia*) is typical of South Bohemia. Compared to peat pine woods, this is a more oceanic vegetation type, typically on shallow peat 10-20 cm deep.

Moss fens are mineratrophic systems, supplied mostly with groundwater enriched with minerals. They are characterized by higher pH, low percentage of bogmoss and prevalence of other hygrophilic bryophytes.

Poor fens are mineratrophic peat bogs with a deeper layer of humolith, which reduces the effect of groundwater on the vegetation on the bog surface. It comprises mainly bogmoss and sedge.

Tufa springheads are springheads saturated with groundwater rich in calcium carbonate.

Non-tufa springheads are formed on subgrades of silicate bedrock, where the presence of oxygen prevents fen formation.

Helocrenes are springheads supplied with relatively low quantities of water, which rises into a relatively large, gently sloping area. This produces a waterlogged area rich in wetland vegetation.

Rheocrene springheads result from a point source (spring) and produce a fast-flowing spring gully.

Limnocrenes are springheads where the rising groundwater produces a small lake at the exit point. Such springheads frequently comprise individual or scattered springs.

Annex 2: Recommended target water levels for main peat bog types

Table 1: Recommended target water levels for main peat bog types.

Biotope type	Target level (cm below surface)
Active raised bog (central portion) - (*Sphagnion medii*, *Oxycocco-Empetrion hermaphroditi*, *Leuco-Scheuchzerion palustris*)	5
Active raised bog (peripheral portion) *(Pino mugo-Sphagnetum)*	10
Lagg raised bog	0–5
Peat spruce wood – sedge type (*Sphagno-Piceetum*)	5
Peat spruce wood – shrub type (*Sphagno-Piceetum*)	10–15
Waterlogged spruce wood (*Bazzanio trilobatae-Piceetum, Soldanello-Piceetum*)	20–35
Springhead (all types)	0
Poor fens (*Carici rostratae-Sphagnetum apiculati*)	0–2
Moss fens (*Caricion fuscae*, *Caricion demissae*)	10–20

Note: The values shown are based on long-term measurements of target water levels in the Šumava Mountains. The target water levels will be the same in other parts of the Czech Republic, or differ by no more than single cm.

Annex 3 Illustrations

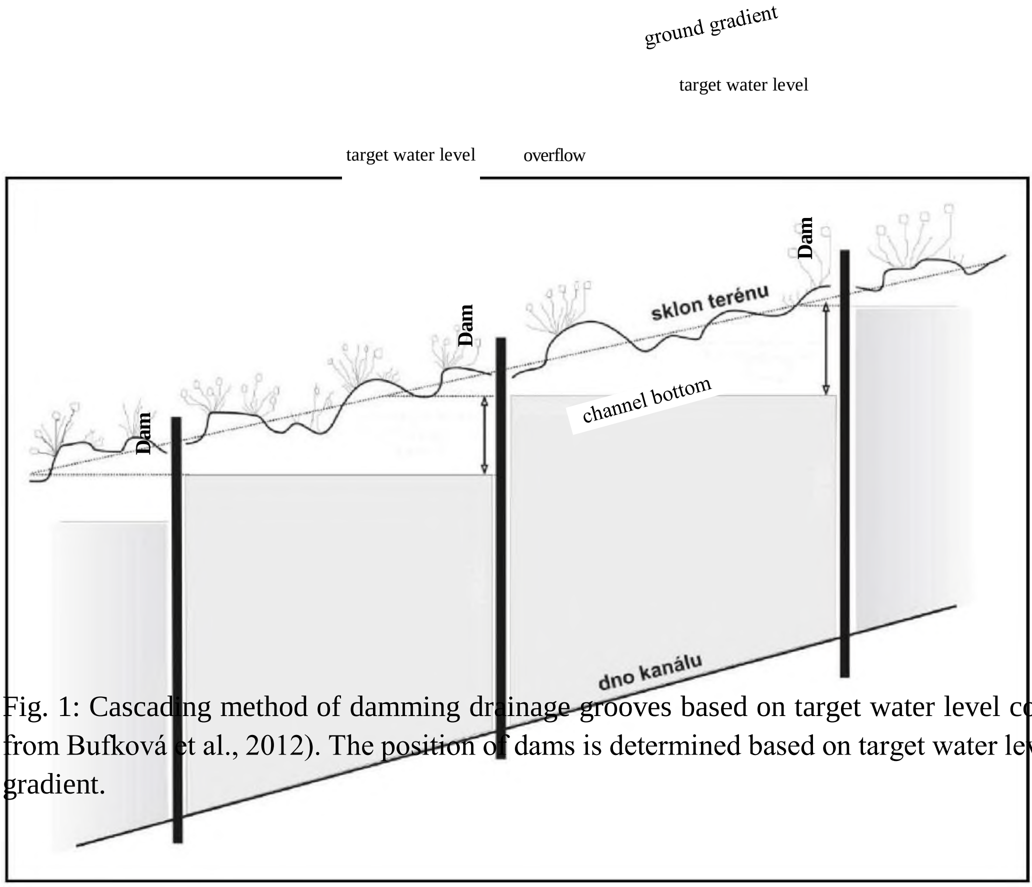

Fig. 1: Cascading method of damming drainage grooves based on target water level concept (adopted from Bufková et al., 2012). The position of dams is determined based on target water levels and ground gradient.

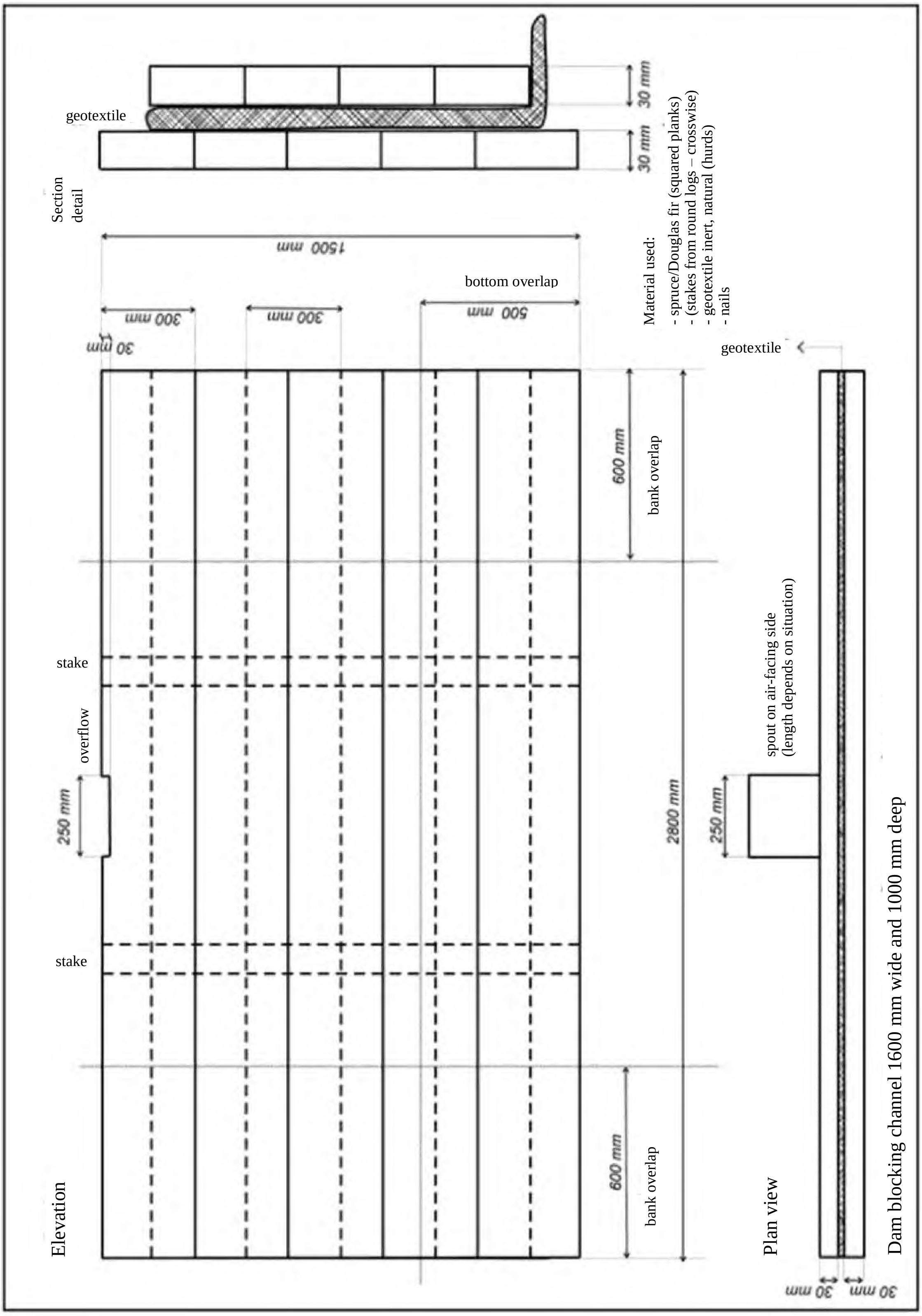

Fig. 2: Schematic of double dam made of horizontally installed planks.
Source: RNDr. Ivana Bufková, Ph.D.

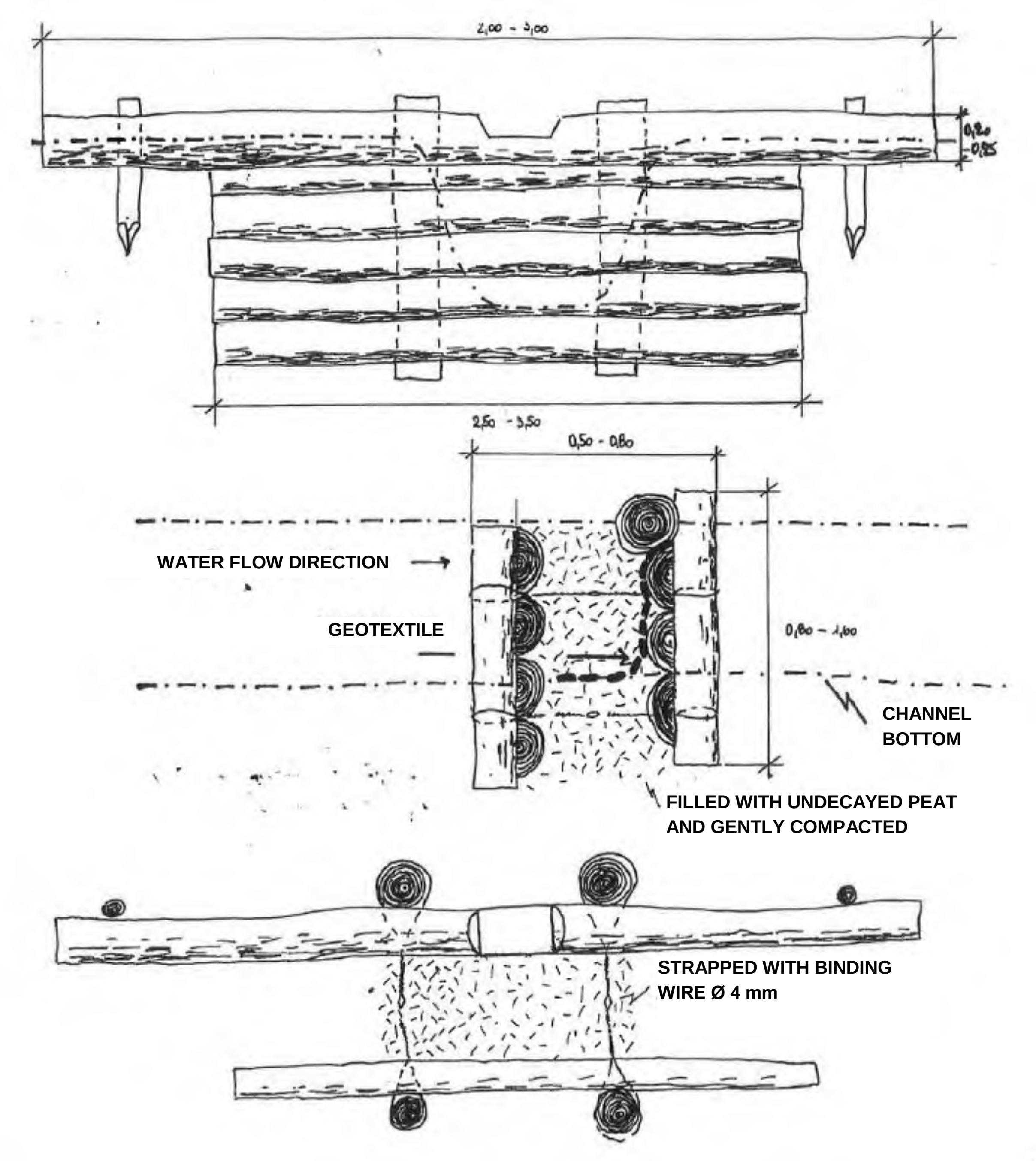

Fig. 3: Double timber dam made of spruce logs. Peat in between is compacted with a shovel or pressed down with an excavator bucket. Source: RNDr. Vladimír Zývaľ sr.

Material used:

- spruce planks, thickness 24 mm
- nails 100-150 mm
- geotextile
- binding wire

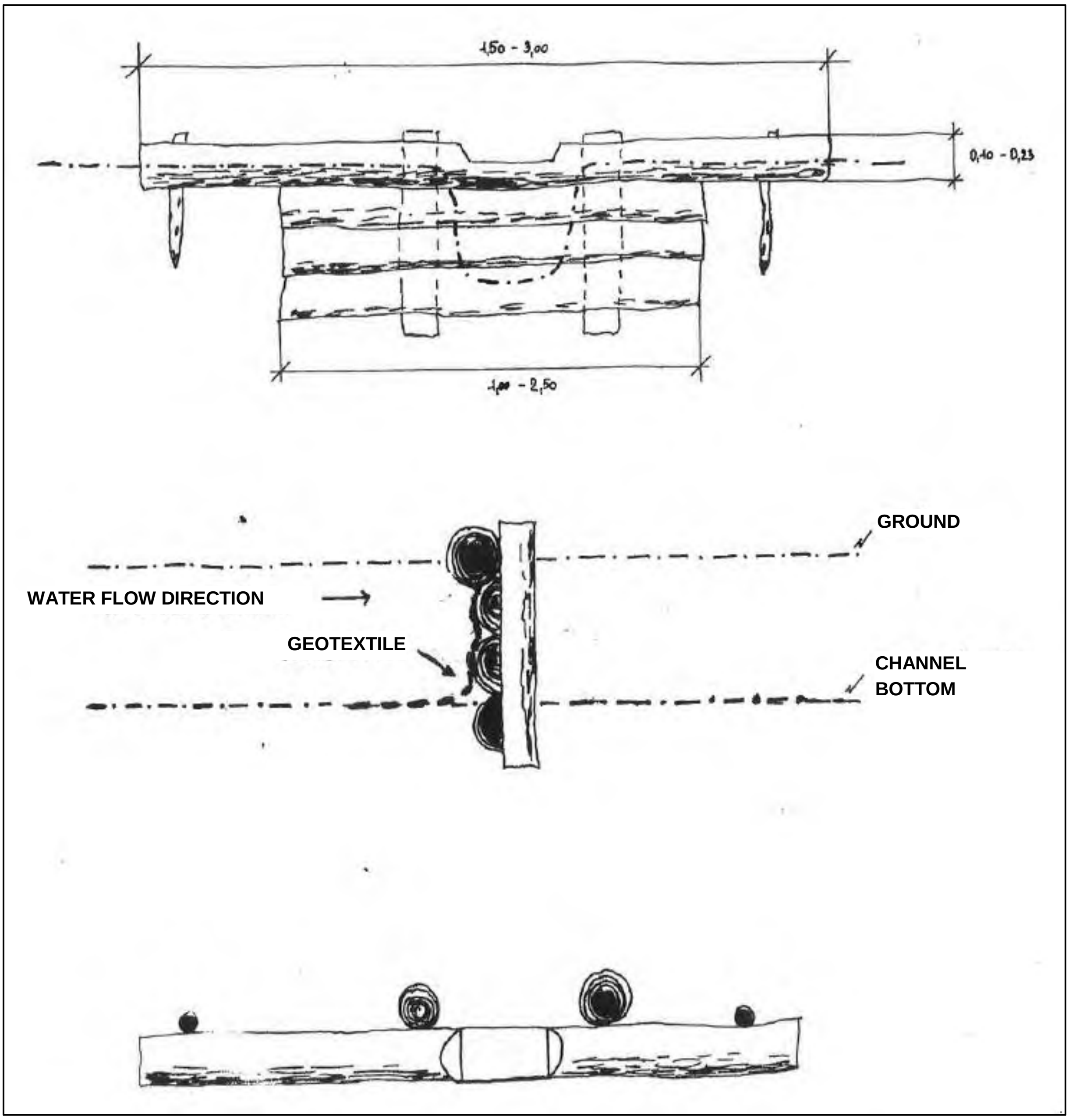

Fig. 4: Single dam made of spruce logs. Source: RNDr. Vladimír Zývval sr.

Material used:

- spruce half-logs
- spruce logs
- nails 100–150 mm
- geotextile

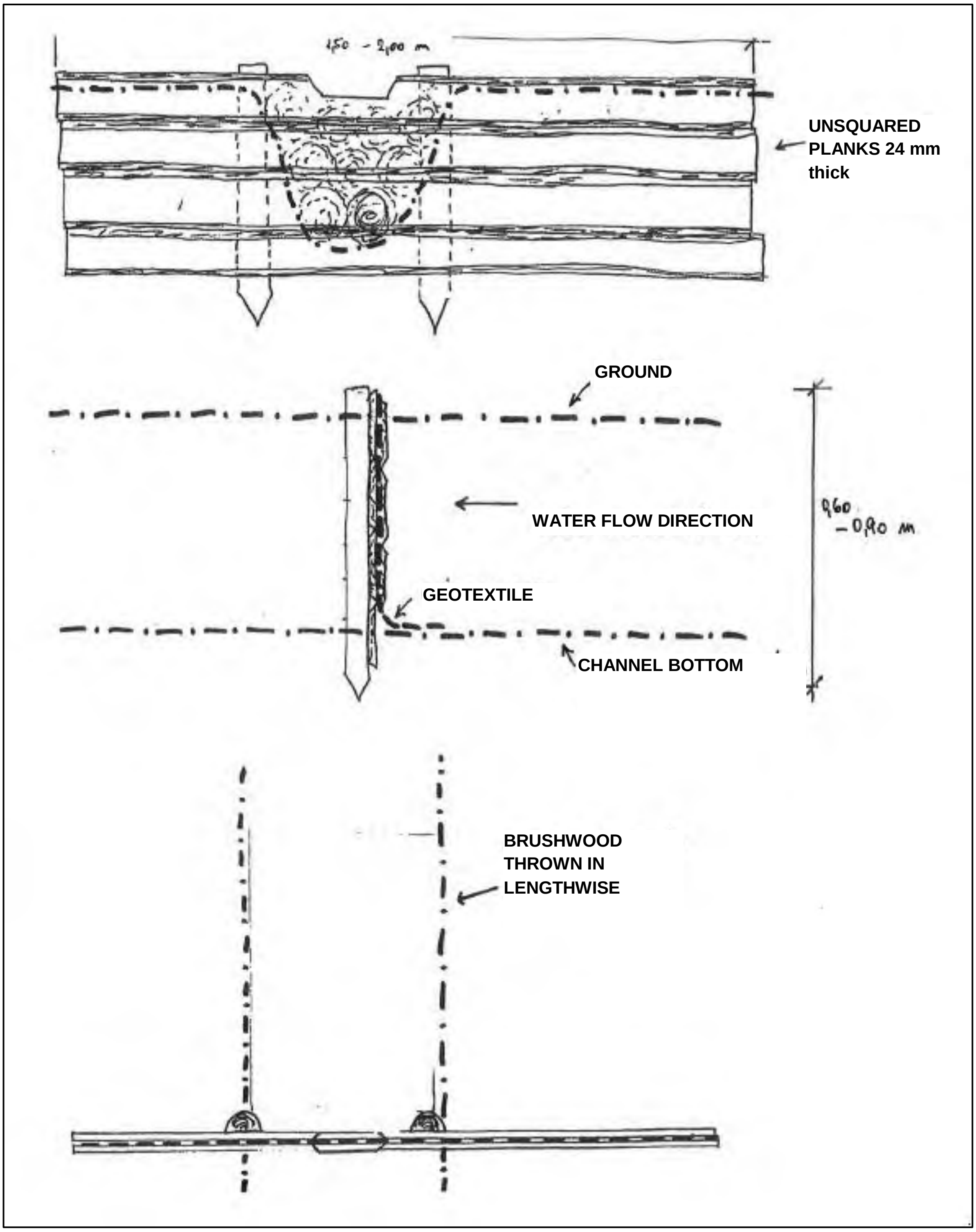

Fig. 5: Single dam made of spruce planks Source: RNDr. Vladimír Zýval sr.

Material used:

- spruce planks, thickness 24 mm
- nails 60–120 mm
- geotextile

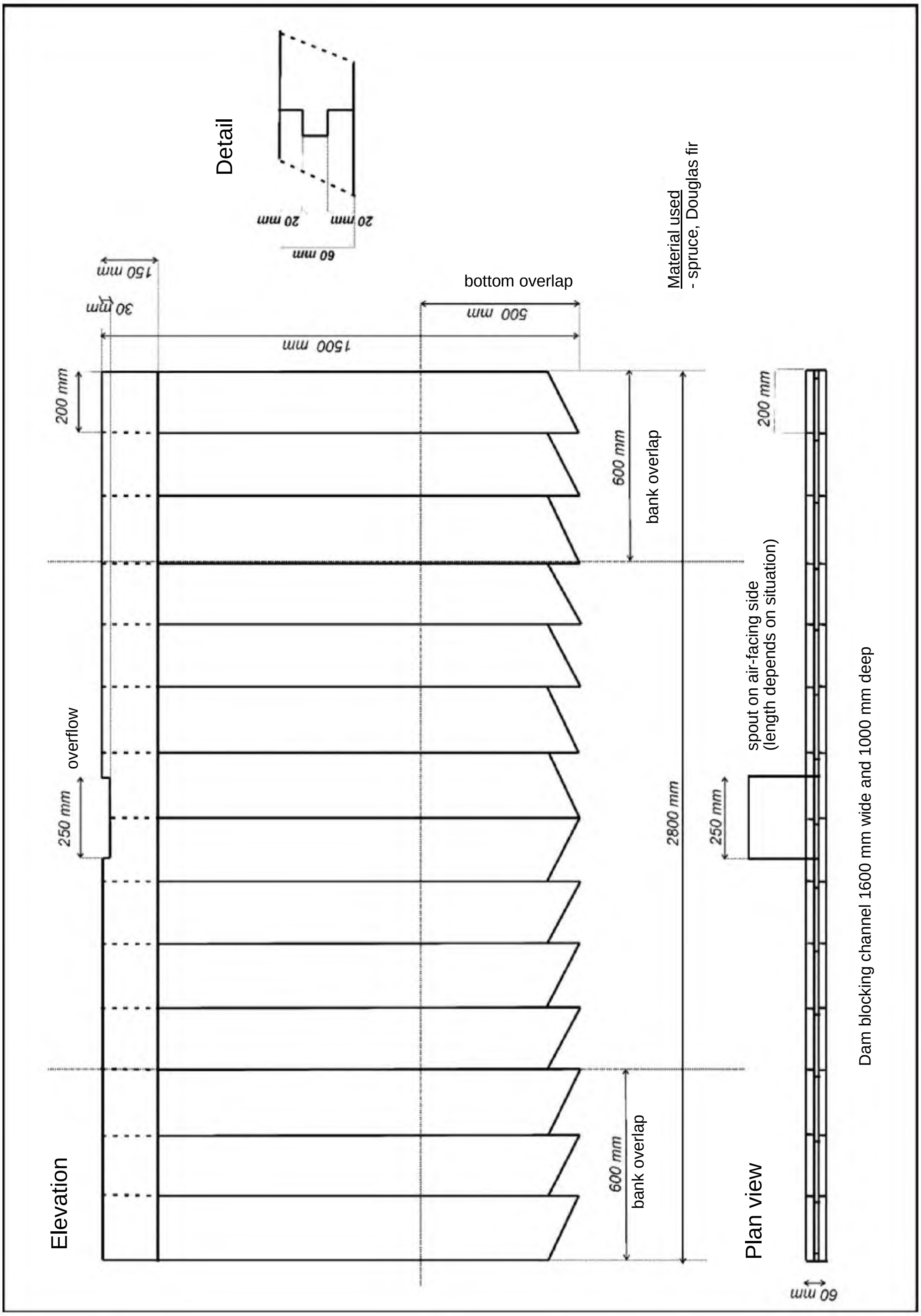

Fig. 6a: Schematic of vertically installed dam made of machined planks, tongue-and-groove joints.
Source: RNDr. Ivana Bufková, Ph.D.

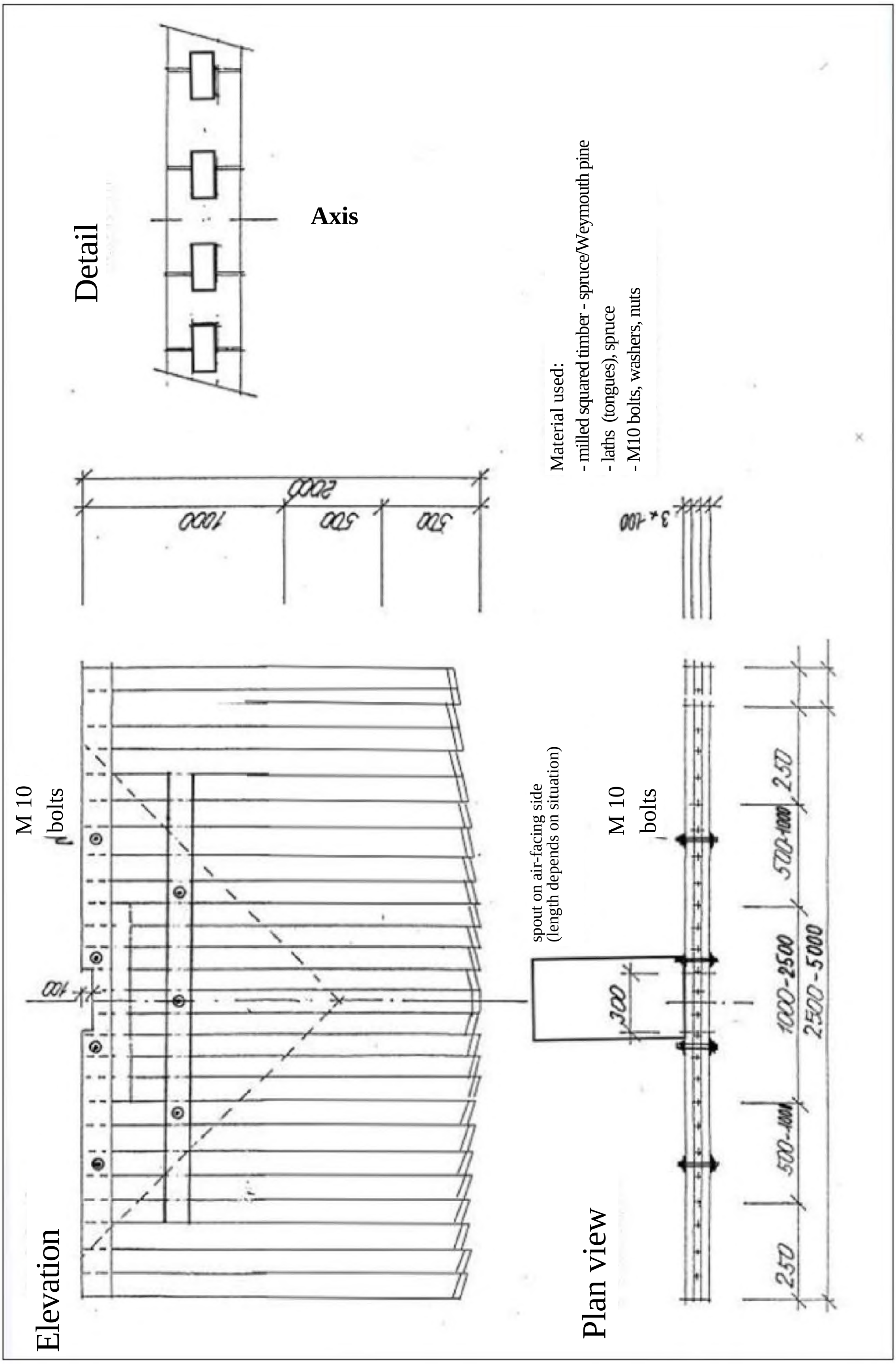

Fig. 6b: Schematic of vertically installed dam made of machined planks, groove-and-groove joints. Source: RNDr. Vladimír Zýval sr.

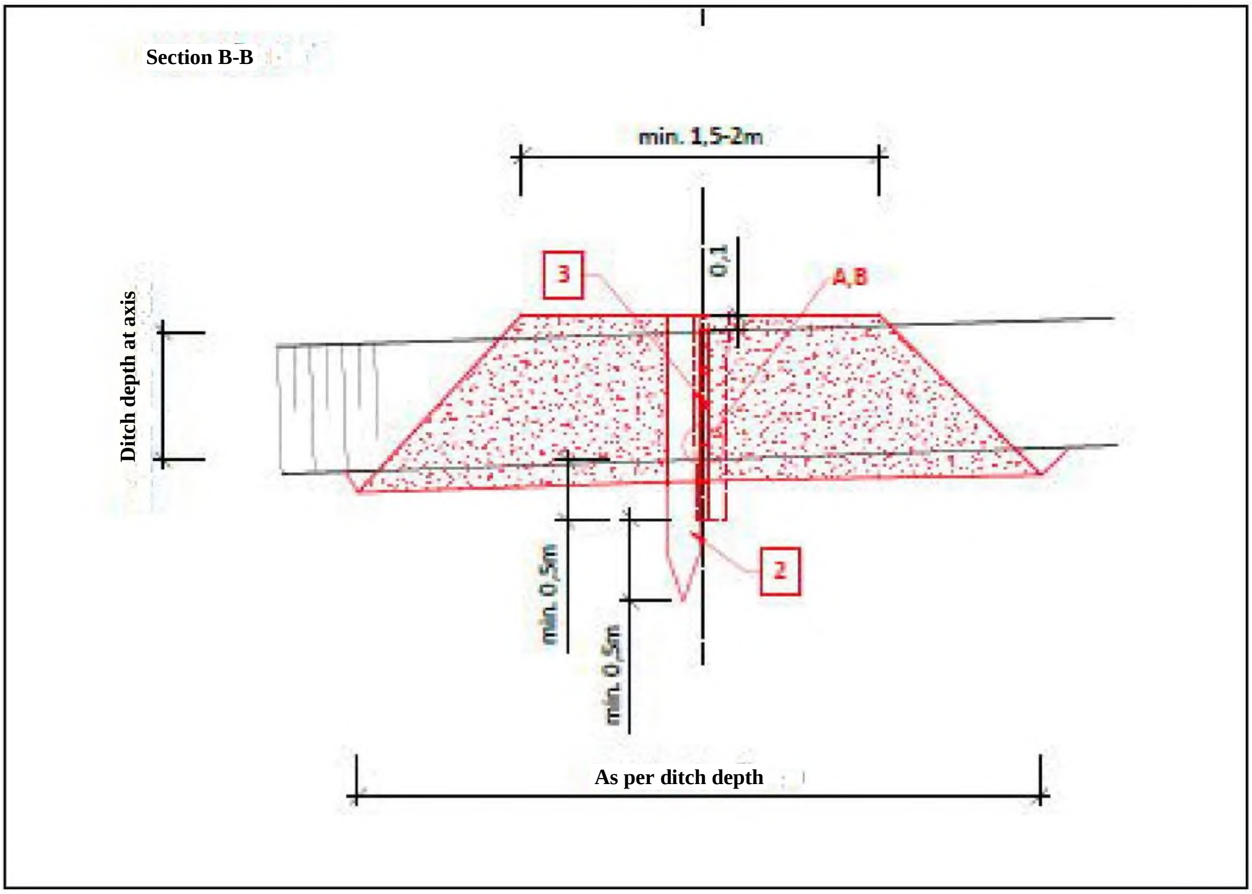

Fig. 7: Schematic of earth backfill around dams.Source: RNDr. Ivana Bufková, Ph.D.

Explanations:
1 - wall made of two layers of half-logs or planks, min. thickness 20 mm. Whole structure thickness min. 150 mm. Geotextile inserted between half-log or plank layers.
2 - stake made of log, min. diameter 15 cm, rammed min. 0.5 m into the soil layer.

Annex 4: Wetland revitalization and species protection

1. Hydraulic regime revitalization aims primarily at the biotope, i.e., restoration of habitat conditions on a site to improve the biotope condition and long-term existence. Along with that, of course, conditions are created for restoration of communities and improvement to the state of local populations of specific significant species bound to peat bogs.
2. Due to the succession development of degraded peat bogs, many of the species tightly bound to peat bogs may only survive in small residual populations. That has to be considered when setting goals for revitalization and planning project implementation. Special attention should be paid to critically endangered, regionally significant endangered species, rare Red Book species and species that are objects of protection of SPA or other type of protected area.
3. A precondition for a successful revitalization project is a detailed site survey and monitoring already during project planning.
4. A survey focused on presence of specially protected species is a precondition for obtaining necessary exemptions from protection requirements under the Nature and Landscape Protection Act.
5. In accordance with the set revitalization objectives, it is possible to diversify the project spatially, define protection priorities for the area, and retain a mosaic of necessary biotopes for the target species.
6. Technical procedures and timing of the revitalization should be adjusted with respect to the biotope demands and phenology of the concerned species (e.g., black grouse or common crane mating and nesting).
7. If specially protected species are present in the project channel sections, they shall be transferred to suitable undisturbed areas in the vicinity, or the dams shall be moved and installed so as not to destroy local populations of said species.

Annex 5: List of Nature and Landscape Management Standards (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