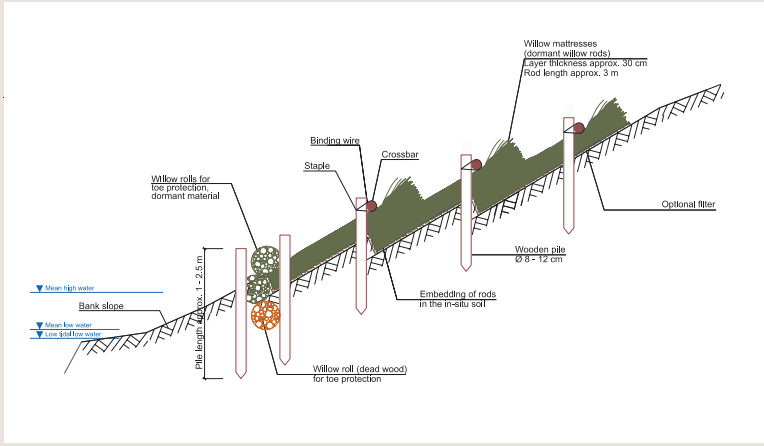
Example of a willow mattress on the River Elbe (BAW)



Schematic diagram of a willow mattress (BAW)

OVERVIEW

Brief description

Willow mattresses consist of living material, unlike brushwood mattresses, they are made of dormant, flexible willow rods. Similarly to brushwood mattresses, they are laid across the streambank to cover the ground, and are fixed with piles, crossbars and wire.

Willow mattresses provide direct and extensive bank protection against surface erosion and translational failure. Once the willows have developed shoots, the root system reinforces this effect, while the above-ground vegetation reduces the hydrodynamic loads acting on the bank.

Willows are pioneer species naturally occurring on the banks of watercourses. They perform key ecosystem functions, such as stabilizing banks, providing habitats and forming a protective buffer.

In tidal areas, they usually only develop shoots above mean high water and can be used as material for bank protection measures. As exposure to waves, currents, wind, salinity and ice increases, the suitable elevation for establishing willow mattresses shifts further above mean high water. Like all nature-based bank protection measures, willow mattresses are classified as WFD-relevant measures (type 73) for the improvement and/or maintenance of waterways, as they enhance bank habitats by replacing hard engineering measures with bioengineering techniques [1].

Ensuring bank protection

Direct protection against translational failure and slope erosion

Covering the surface with willow mattresses that enable rooting helps to protect the slope against surface erosion. Fine roots additionally act as a filter and prevent the loss of soil. Moreover, root growth into the ground increases the shear strength of the soil and thus the protection against sliding failure.

Direct protection against slope erosion through current and wave attenuation

The roughness of the above-ground willow vegetation provides a high degree of surface coverage and is highly effective at reducing the impact of waves and currents. Locally, this promotes sedimentation and siltation.

OVERVIEW

Advantages and disadvantages

compared to a direct bank protection using riprap, concrete or steel

Advantages

- Planting of native vegetation provides high ecological benefits.
- Material can be harvested regularly by cutting back the willow mattress.
- Comparatively low material costs, as renewable and native resources are used, ideally sourced from own trees or bushes.
- No or negligible disposal costs
- In small or difficult-to-access areas, installation and maintenance can be carried out manually without the need for large or special machinery.
- Rapid greening: fast-growing and vigorous willows quickly lead to changes in the landscape features characteristic of natural environments.
- Lower risk of widespread neophyte invasion
- Increased substrate diversity through dead wood, fallen leaves, root development, and enhanced deposition of fine sediments
- Retention of greenhouse gases through carbon storage in woody biomass

Disadvantages

- Construction phase is time-limited (collection of willow material during dormancy; installation in spring).
- Tall and dense woody vegetation can affect flow conveyance.
- Young willows in particular may be subject to browsing by game (usually requiring protective measures) or can be damaged or destroyed by drought or ice scour.
- During the critical initial state, bank protection remains incomplete until roots and shoots have developed.
- Depending on the boundary conditions, regular maintenance may be required, e.g. by cutting back woody vegetation or restoring vegetation cover during the growing season after extreme events.
- Damaged areas in willow mattresses are difficult to repair. Repairs are conducted by installing new plantings, which then compete with the adjacent established vegetation for light and nutrients.

ECOLOGICAL BENEFIT

compared to direct bank protection using riprap, concrete or steel

Hydromorphology

The shoots and leaves of the willow mattresses increase the surface roughness of the bank, which reduces currents and promotes sedimentation. This results in small-scale differences in relief, which provide additional habitats.

Habitats and their connectivity

Promoting the development of a native woody vegetation can enhance structural and species diversity along the watercourse (see *Habitat conditions* below). The evolving structures provide valuable habitats for terrestrial fauna (e.g. birds, bats and insects) as well as refuges for aquatic organisms (e.g. macrobenthic organisms, fish).

Vegetation

Banks that are flooded with varying frequency are natural places for willows to grow. The elevation at which willows become established depends not only on the duration of flooding, but also on the wave, current, wind, salt and ice loads (see *Habitat conditions* below). In the establishing phase, willows are fast-growing, with a high capacity to grow shoots, and they are elastic and capable of regeneration. In just one to two years, they form a dense willow scrub as a shrub layer and are therefore particularly suitable for brush mattresses.

ECOLOGICAL BENEFIT

compared to direct bank protection using riprap, concrete or steel

	Native species include in particular *Salix alba, Salix cinerea, Salix fragilis, Salix triandra* and *Salix viminalis* and, in locations with sandy soil, also the *Salix purpurea* [2]. Willows have a high ecological value as they provide habitat in the root, trunk and crown area, create a diverse microclimate and serve as a source of food. Branches and fallen leaves provide settlement substrate for fungi, plants and animals. The ecological value of the biotopes and their genetic diversity increase if the seeds germinate in open, humid places at the time of seed maturity and can successfully spread generatively. The shade provided by the willows promotes the development of an ecologically valuable herbaceous layer with the following native species: *Lythrum salicaria*, *Senecio paludosus, Caltha palustris, Stachys palustris, Lycopus europaeus, Bidens frondosa* [2]. On the tidal Elbe, the willows also provide a habitat for the strictly protected Elbe water dropwort (*Oenanthe conioides*) which is threatened with extinction.
Fauna	Willow mattresses can provide valuable habitats for many animal species, some of which are specially or strictly protected under the Federal Nature Conservation Act. Among other functions, they serve as a food source for wood-dependent beetles, flower visitors and beavers and provide habitats and foraging grounds for a wide range of spiders, insects, birds and bats [3]. The older and more structurally diverse the willow mattresses, and the lower the need for maintenance, the higher their ecological value (see *Supplement to the data sheet*).
Ecosystem services	Over time, willow mattresses can provide the following ecosystem services compared to protection with riprap, slab revetments or similar structures: • Increased habitat provision for riparian vegetation and fauna as well as for soil organisms due to greater substrate diversity • Carbon regulation and storage resulting from the development of riparian vegetation • Additional erosion protection as vegetation becomes established. • Improvement of the water balance (resources provision) through natural retention, leading to enhanced water storage • Shading of the bank and protection against wind improves the microclimate. • Enhanced recreational value as the area is perceived as a more natural landscape.

RANGE OF APPLICATIONS, DESIGN AND DIMENSIONING

Range of applications	Willow mattresses are suitable as direct, extensive protection measures on banks and slopes in tidal areas. For this purpose, they must be installed at an elevation where they can grow shoots and develop roots (see *Species-specific material properties*). The elevation varies with the prevailing Habitat conditions at the site; it is generally above mean high water. Isolated measures using willows to stabilise banks have been documented for the intertidal areas of the rivers Elbe and Delme (banks facing towards and away from the navigation channel), cf. the collection of measures online at: https://ufersicherung-baw-bfg.baw.de/aestuarbereich/en/massnahmen

RANGE OF APPLICATIONS, DESIGN AND DIMENSIONING

Design and dimensioning

The bank protection measures with willow mattresses that have been installed to date in tidal areas show that a layer thickness of the willow rods of approximately 0.3 m and a pile spacing of 1.5 m are effective. Depending on the available crossbar lengths, the pile spacing may have to be adjusted on site when the crossbars are fastened to the piles. To enable good root development, full contact of the willow mattress with the ground has to be ensured and, if necessary, smaller distances between the piles and crossbars have to be chosen. The pile lengths need to be selected so that the piles are sufficiently embedded in the in-situ soil. As a rule, piles with a length of approximately 2.5 m are used. For a mathematical estimation of the required pile length, see data sheet *Direct Bank Protection: Brushwood Mattress*, section *Range of applications, dimensioning and design.* If only piles with a shorter length are available, e.g. because material from own trees or bushes is used, these can be installed at a right angle to the slope in order to obtain the best possible installation depth in the ground.

For detailed information on the range of usual component dimensions see *Components and installation*.

Willow mattresses can be stabilised by integrating a toe protection. This usually consists of a deadwood roll and two shoot-forming willow rolls with a diameter of 60–70 cm. For a more detailed description of the design of the toe protection see *Installation and components – Work steps*. In locations where riprap is installed under water, the willow mattresses can be integrated in the structure.

Allowable hydrodynamic loads

Specific measurements of the hydrodynamic loads acting on willow mattresses in the tidal area are not yet available. However, practical experience gained from existing measures in the area is available. On the Elbe island of Hanskalbsand, willow mattresses have successfully established on the bank facing the navigation channel, in the shelter of a training wall. On the island's bank facing away from the navigation channel, the mattresses provide reliable protection to the bank of a tidal creek. Shoot-forming willow material sourced from on-site trees and shrubs was also successfully used for willow mattresses along the banks of the River Delme.

In the critical initial state before the willow mattresses grow shoots, they are similar to brushwood mattresses, so that experience with this design can be used as a reference. In tidal areas, brushwood mattresses are frequently used and provide stable protection along banks facing the navigation channel on the tidal Weser and Elbe. Measurements of the hydrodynamic loads acting on brushwood mattresses are available for the River Wümme, although only recreational boats operate here. Maximum flow velocities of 0.9 m/s measured near the banks, have no effect on the stability of the brushwood mattresses.

For willow mattresses in a critical initial state, measurements indicate a capacity to absorb flow velocities close to the bank of up to 1.0 m/s and, based on experience, of up to 2.0 m/s on flowing waters without ship traffic (cf. data sheet *Living Brush Mattresses – Inland Waterways*).

RANGE OF APPLICATIONS, DESIGN AND DIMENSIONING

Habitat conditions	When dimensioning willow mattresses, the following habitat conditions relevant to the target vegetation should be considered. It should be noted that the statements below primarily refer to individual boundary condition in each case. In reality, however, multiple site-specific boundary conditions interact spatially and temporally, so plant tolerances may vary or deviate from the ranges indicated below. As a general rule, higher levels of stress are likely to result in poorer plant growth. In addition, it is important to protect young plants from browsing damage (e.g., by fencing, if necessary, particularly in areas with grazing livestock).
Flooding tolerance	Flooding tolerance varies depending on plant species, wave- and flow-induced loads and the plant's stage of development. As loading increases, plant growth below mean high water tends to decrease.
Salt tolerance	Various willow shrubs, as well as *S. alba* as a tree species (see below) are suitable for willow mattresses in fresh and slightly brackish water [7]. Threshold salinity levels in soil water relevant to willow growth are not precisely known. However, there is evidence that a salinity of 2 ‰ in soil water has no adverse effect on plants' vitality [8] [9] [10]. Biotope mapping of the estuaries indicates the following patterns along the longitudinal gradient towards the sea: • Along the tidal Elbe, willows occur in the tidal marsh on the left side up to Elbe-km 680 (Brammer Sand) and on the right side up to approximately Elbe-km 690 (southern part of St. Margarethen). • Along the tidal Ems, individual willows can be found up to Ems-km 18.5 (southern part of Nüttermoor). • Along the tidal Weser, willows grow on the right side up to approximately km 53 of the Unterweser (UW) (location of the Weser Tunnel) and on the left side up to approximately UW-km 55 (Kleinensieler Plate). • No information is available for the River Eider, with the exception of a willow population in the tidal marsh near Friedrichstadt.
Tolerance towards ice scour	Ice scour can destroy young, low-growing willow plants [10]. At higher elevations, where the soil around the roots is not eroded by water, willow plants are generally not damaged by ice and floating debris, particularly once the branches have reached approximately arm thickness [7]. After thawing, they resprout in spring [10].
Wind tolerance	In coastal areas with frequent exposure to strong winds, willow mattresses may no longer be able to adapt to these loads without maintenance, and their tolerance limits can be exceeded. Regular pruning helps maintain shoot flexibility and reduces susceptibility to wind damage in exposed locations. According to the literature, data on wind tolerance are only available for the tidal Elbe. There, willows tolerate wind exposure up to approximately Elbe-km 691 (St. Margarethen) [10].

RANGE OF APPLICATIONS, DESIGN AND DIMENSIONING

Species-specific material properties

The habitat conditions suitable for willows are not the same for every species. By evolving specific traits and material properties, willows have adapted to different site types, thereby reducing interspecific competition and the resulting use of energy to a minimum. This must be taken into account when selecting suitable species for willow mattresses at a specific site.

Willows are generally divided into willow shrubs (up to 7 m) and willow trees (7–25 m). Compared to willow trees, shrubs are more flood-tolerant, cope better with pruning, and are more compact and space-saving (also in the root system). They provide more flexible material and are therefore frequently used as living bank protection measures. Willow trees require more frequent maintenance when used as mattresses for bank protection. The species and structural diversity of willow mattresses is increased by combining different willow species.

Information on distinguishing between the individual willow species can be found in the fact sheet on woody plants for waterway maintenance (*Steckbrief Gehölze für die Unterhaltung an Bundeswasserstraßen*) published by the Federal Institute of Hydrology (BfG), and other practical guidelines (in German only):

- BfG: https://www.bafg.de/DE/5_Informiert/2_Publikationen/Arbeitshilfen/arbeitshilfen_node.html
- Meyer, T.: https://blumeninschwaben.de/Hauptgruppen/baum1.htm
- WBW & LUBW: https://pudi.lubw.de/detailseite/-/publication/51092, P. 36
- Dachsel, K. Stowasser, A. & Roloff, A: https://stowasserplan.de/wp-content/uploads/2025/07/Stowasser_Dachsel_Weiden_Verwendung_und_Bestimmung_ProBaum_03-18.pdf
- Gurk, C.: https://www.baumkunde.de/baumbestimmung/

Willow shrubs

Salix viminalis

A willow shrub growing to a height of up to 8 m and a width of up to 4 m, it is suitable for quickly stabilising predominantly sandy, low-salt banks exposed to erosion by wind, currents and waves [11]. Cuttings with a length of 20–35 cm and a diameter of up to 1 cm can form shoots that are up to 3 m long in the first year and thus provide bank protection quickly. Willow rods are very elastic and can withstand being burdened with floating debris. However, they have shallow roots, and their root system will therefore be exposed after heavier storm surges. Rods and cuttings become rigid and inelastic over time. This species should therefore be combined with other willow species to ensure durability of the bank protection measure [10].

Salix triandra

The almond willow forms a strong and deep root system. It takes on a bushy and sparse form, up to 7 m high and 5 m wide. In an experiment with bottom water with a salinity of 4 ‰, it was the only species that survived, however with stunted growth [10]. It is adapted to marsh clay and silt [12].

Salix purpurea

A densely bushy willow shrub that can grow up to 5 m high and 3 m wide. It prefers sand but also grows on silty ground [13]. It develops a shallow root system, is not very salt-tolerant and is therefore more characteristic of inner estuaries.

RANGE OF APPLICATIONS, DESIGN AND DIMENSIONING

Willow trees	***Salix alba*** *S. alba* can grow to a height of 25 m and a width of 20 m, and forms a deep root system [11]. It therefore requires regular maintenance when used as willow mattresses. *S. alba* completes the typical willow zonation (from water to land) with *S. purpurea* and *S. triandra*, and is considered the most wind-resistant willow tree [10]. A common hybrid of the white willow is *Salix x rubens*, which is a cross with the *S. alba* and *S. fragilis*. Its cuttings have good rooting ability [14].
Willow hybrids	It should be noted that willow species often occur as hybrids, i.e. the species interbreed easily and thus become more robust regarding boundary conditions (e.g. *Salix x smithiana* in the tidal Elbe region). However, this species (typically occurring around mean high water +2.5 m) and other hybrids of *Salix caprea* are not typical of riverine environments and unsuitable for mattresses due to their limited capacity for vegetative regeneration.

Alternative designs	**Brushwood mattress**
	If the boundary conditions do not permit using mattresses from dormant willow material, brushwood that is not dormant can be used. For brushwood mattresses, the fascine material is laid across the bank slope and fixed with piles and wire. This design also works as bank protection in areas below mean high water where willows do not sprout or sprout only poorly.
	Initial plantings (e.g. to repair defects)
	Initial plantings from willow cuttings can be used to repair areas in a willow mattress where the willows have not grown (sufficient) shoots. Willow cuttings planted at an angle develop more roots. Protection against browsing by game and livestock is recommended. After two to three years, effective bank protection is in place (in selected areas) in the immediate vicinity of the plants. Maintenance effort is low and the landscape quality is enhanced. Initial planting can be combined with various bank protection measures.
	Willow cuttings can be obtained from different parts of the plant [15]:
	• Branch: branched shoot of woody species capable of rooting, minimum length 100 cm, minimum diameter of cutting point 2 cm
	• Brushwood: thin, branched twigs from woody species capable of growing shoots
	• Rod: fine or weak annual or perennial branch, with few or no branches, capable of rooting, minimum length 150 cm, minimum diameter at the cutting point 2 cm
	• Log branch cutting: unbranched part of a strong branch of woody species capable of rooting, dimensions depending on plant species and installation situation, minimum length 100 cm, diameter 4–6 cm
	• Live stake: Perennial unbranched part of a branch that is capable of rooting
	  • Live stake from willow tree: length 60–100 cm, diameter 3–6 cm
	  • Live stake from willow shrub: length 60–100 cm, diameter 2–5 cm
	In addition, pre-grown woody seedlings (e.g. from succession) with a height of 40–100 cm can be planted [16].

COMPONENTS AND INSTALLATION

Components

The material requirements are based on bank protection measures with willow mattresses that have been carried out in tidal areas. The layer thickness of the fascines is approximately 0.3 m and the pile spacing is 1.5 m. Based on these specifications, the material requirement per 100 m2 slope surface is, on average, as follows:

- approximately 30 m³ of willow rods (*depending on diameter, approximately 20–50 willow rods per running metre* [17])
- approximately 50 wooden piles
- approximately 8–12 crossbars (*depending on crossbar length*)
- approximately 100 m of wire
- approximately 50 staples
- soil/sand for covering

The exact design and material requirement can vary between projects. In particular, the spacing of the piles need to be adapted to local conditions; spacings of < 1 m are also possible, with the number of piles and crossbars varying accordingly. Components with the following properties have proven suitable for the conditions prevailing in estuaries [18].

Willow rods

Willow branches and rods that are capable of producing shoots, as long and straight as possible [16]. A mixture of thin and thick branches is ideal: thick branches with stronger shoot-forming capacity, thin branches to ensure the rods are flush with the ground.

Length: 2–5 m [17]

Diameter: at least 3 cm

If the available dormant willow material is insufficient, up to 50 % of material that is not able to form shoots can be added [16]. There is a risk, however, that the vegetation will remain patchy, which may limit the ecological function of the area in the long term and compromise the extensive bank protection function.

Wooden piles

Piles, ideally made of dormant willow material, to secure the willow mattress on the bank slope.

Length: 1–2.5 m (*depending on soil and hydrodynamic loads*) [18][15]

Diameter: 8–12 cm [18]

If no willow material is available, spruce/fir piles can be used.

Crossbars

Crossbars should be as straight as possible to ensure full contact of the mattress with the ground. The material is the same as that of the piles.

Length: 6–8 m [18]

Diameter: 8–12 cm [18]

If no willow material is available, spruce/fir piles can be used.

Filter

The filter stability of the in situ soil must always be checked. If this is not the case, it must be assessed whether a temporary soil loss can be tolerated in the initial state before the roots take over the filter function. If a temporary soil loss needs to be avoided in the initial state, an additional filter can be installed between the willow mattress and the in-situ soil. However, the available empirical data on such measures in estuaries are currently insufficient. The selection and design of a suitable filter material must therefore be carried out on a project-specific basis, with particular attention given to materials that allow subsequent root development and are degradable over the long term.

COMPONENTS AND INSTALLATION

Other construction materials	**Binding wire** 0,3 cm-thick annealed or galvanised corrosion-resistant wire **Soil/sand** Covering with existing substrate **Toe protection** The additional material required for the toe protection varies depending on the type and design (see sections *Design and dimensioning* and *Work steps*)
Work steps	Generally, the following work steps for installing a willow mattress can be distinguished [18] (see technical drawing in appendix 1): 1. Preparing the subgrade, clearing the construction area of any obstacles (armour stones, geotextiles, vegetation cover, etc.). 2. Profiling the slope at a maximum inclination of 1:3. The mattress is laid on the slope starting from the top. The surface of the first layer is profiled to a depth of approximately 0.5 m. On steeper slopes, a trench-shaped depression can be created at the lower end to prevent the willow rods from being washed out and to support their establishment. 3. Dense, continuous placement of the willow rods onto the pre-profiled slope, perpendicular to the flow direction. The rods are placed with the cut ends facing downward into the depression and their shoots pointing toward the top edge of the slope. 4. Inserting the piles into the ground for two-thirds of their length with spacing depending on boundary conditions, typically 1–1.5 m (if necessary, this step may be also be carried out before laying the willow rods). 5. Optional: If the willow rods are embedded in a trench-shaped depression, it must be refilled with soil/sand before placing the crossbars in order to fix the rods in position. 6. Fixing the mattress on the slope by means of transversely placed crossbars. 7. Fastening the crossbars to the piles with wire. 8. Repeating steps 2–7 for subsequent layers. The shoot tips of the next layer cover the base ends of the previous layer by at least one-third. The installation of the mattress can be continued in this way, depending on the slope surface. As a rule, 2–3 layers of willow rods are laid. 9. Driving or pressing the piles deeper into the ground until the crossbars press the willow rods firmly against the ground. Depending on equipment availability and local conditions, this step may also be carried out separately for each layer. 10. If necessary, trimming protruding piles at approximately a hand‘s width above the wire. 11. Construction of a toe protection adapted to local boundary conditions and requirements. It usually consists of a deadwood roll and two dormant willow rolls placed in a prepared trench. A deadwood roll is buried at a depth of approximately 1.3 m to 1.5 m as a lower securing element of the lower part of the toe. Directly above it, a dormant willow roll is placed. The final dormant willow roll is positioned on the butt ends of the lowest brush layer and fixed with spruce/fir piles and diagonal wire to prevent uplift of the mattress and keep it in place until roots have grown into it. If riprap is present underwater, the willow mattresses can also be integrated into the structure. 12. Covering the mattress with soil/sand so that the shoot tips remain visible.

COMPONENTS AND INSTALLATION

13. Saturating the mattress with water (slurry infiltration) and, if necessary, providing regular irrigation during the establishment phase. Optionally, each layer can be watered individually immediately after installation.

Installation instructions

Material collection

Native material must be used. From October to February, during the vegetation-rest period outside the bird breeding season, willow material can be obtained when maintenance measures are carried out. Care should be taken to ensure that willow branches with rooting ability are used and that they have a diameter of at least 3 cm. After pruning, the willow material should be immediately tied into transportable bundles and used promptly, ideally within a few weeks. It is therefore advisable to collect material for living measures during the dormant season. The smaller the diameter of the shoots, the more quickly they dry out. The material for willow mattresses must be installed within a few weeks. All cut material should be stored in a cool and damp place until installation. Material that has been stored for a longer time (e.g. after pruning in the autumn) can be used for bank protection measures with dead wood. If no or insufficient own willow material is available for fixing the piles and crossbars, spruce/fir material can be used instead.

Installation times

Willow mattresses are usually installed between March and May to allow immediate root development after installation. From October to February, installation is not advisable. Weather conditions are often harsh – marked by extreme flooding, storms and ice – and root development is delayed, typically not beginning until spring.

Design instructions

For the willow mattresses to develop shoots, full contact with the ground across the entire slope surface is crucial. To ensure this, a smaller distance between the crossbars (< 1 m) may be necessary. Experience along inland waterways has shown that shoots often develop most readily in the area around the crossbars.

Working in intertidal areas

The daily tidal dynamics act as limiting factor for the time available for construction activities. Frequently, construction sites are located on stretches of the bank that are difficult to access from water or land.

Personnel and equipment requirements

The working conditions are very demanding and require skilled staff with the relevant technical expertise and experience in working in tidal areas and knowledge about occupational safety. We recommend deploying trained hydraulic technicians. Hydraulic dredges that can be used both on land and water often save time and work. For small-scale measures in particular, portable manual or power post drivers can also be used.

Obstacles

Obstacles such as stones in the ground may pose problems when the piles are driven or pressed into the ground. Even when the work is carried out very carefully, breaking of the piles can occur.

Regulations

Nature conservation and occupational safety regulations must be observed.

MAINTENANCE

Dense and flexible willow shoots provide the best bank protection. This protective effect can be maintained by regular pruning at intervals of around three to five years. However, the following should be noted: Reduced maintenance of a willow mattress increases its potential to provide ecologically valuable habitats (see *Supplement to the data sheet*). It is therefore advisable to assess, for each site, whether willow mattresses require continuous maintenance or whether the frequency can be reduced. Ecological structural richness can already be promoted, for example, by excluding individual areas from pruning or extending maintenance intervals. Alternatively, annual selective pruning can be carried out to avoid complete pruning over a large area. When assessing the need for maintenance, it must be clarified whether the willow mattress needs to be:

a. preserved or stabilised in its function as a sediment trap or bank protection. In this case, thinning out by cutting 30–50 % of the shoots at different heights is recommended to achieve structural diversity.
b. reactivated or rejuvenated to promote new shoots and stronger rooting; This requires that the mattresses in these bank areas are cut back 20–50 cm above the ground.
c. renewed or replaced because of a loss of material.

Sharp tools and angled cuts promote water drainage and reduce rot. In tidal areas, it is advisable to carry out maintenance activities in late winter after the storm surge season and before the breeding and nesting season sets in.

Ice scour, game and livestock browsing or storm events can cause damage to the willows. In the event of extensive damage, additional protection or maintenance is required, e.g. by planting cuttings.

The dense shrub vegetation formed by willow mattresses also suppresses neophytes, so that no separate maintenance measures are required for their removal.

EXAMPLES

Examples of willow mattresses on German federal waterways

Willow mattresses on the Elbe island of Hanskalbsand, facing towards the navigation channel

Elbe-km 642.3–642.7, left bank

https://izw.baw.de/publikationen/alu-aestuare-massnahmen/0/Elb642li_01_02_EN.pdf

Willow mattresses on Elbe island of Hanskalbsand, breach in tidal creek

HNe-km 6.7–7, right bank

https://izw.baw.de/publikationen/alu-aestuare-massnahmen/0/Hne-007re_01_01_EN.pdf

Willow mattresses on the River Delme

Del-km 0–0.5, right bank

https://izw.baw.de/publikationen/alu-aestuare-massnahmen/0/Del-000re_01_01_EN.pdf

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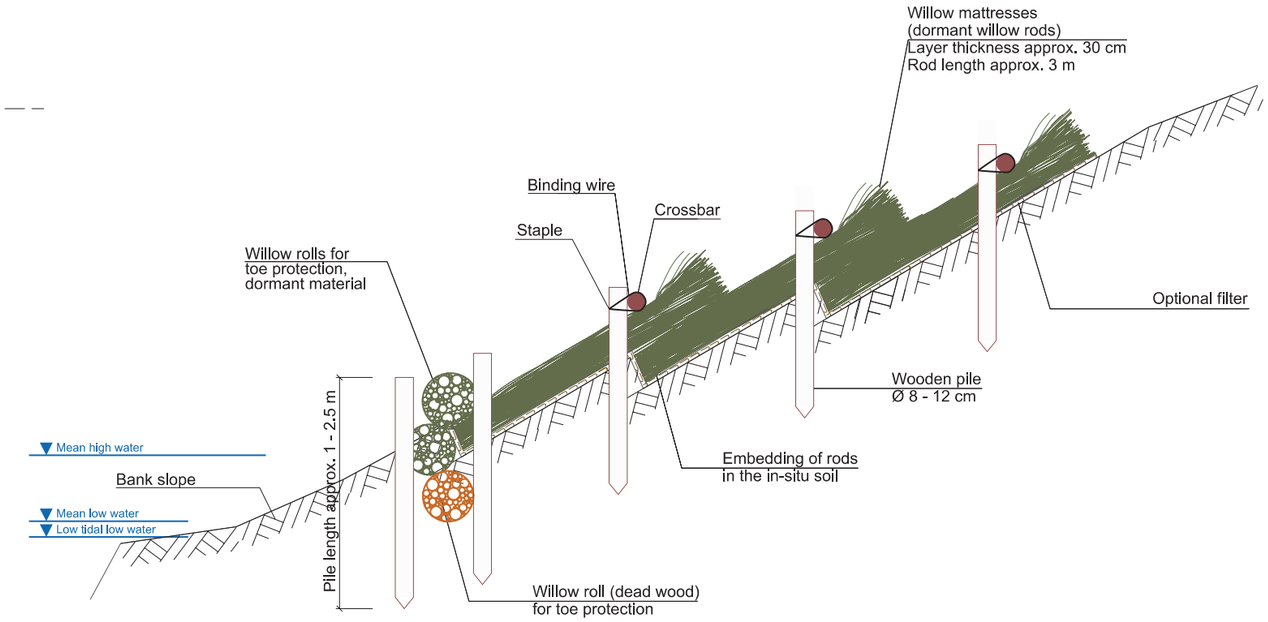
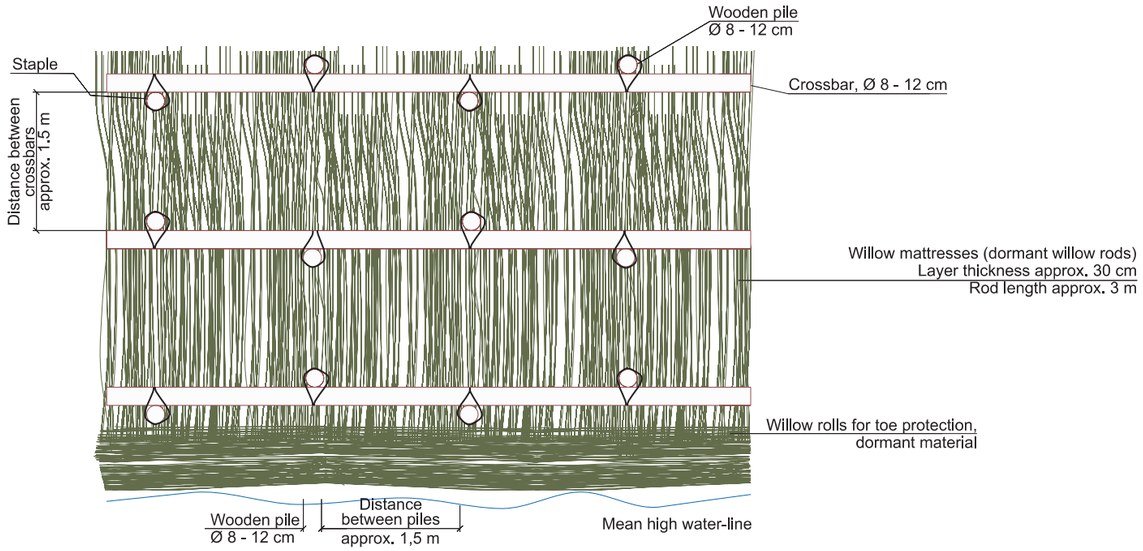
Annex:
1. Technical drawings

Annex 1 Technical drawings

The drawings shown here must be adapted to local conditions.





The willow mattress will be covered with sand/soil after completion, so that only the tips of the rods remain visible.

Illustrative example. All dimensions must be adapted tot he specific site conditions.

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Technical biological bank protection in estuaries
Direct bank protection:
Willow mattresses

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