# Natural embankments

- *Type: uses natural forces and organisms;*
- *Application: in regional waters, rivers. Salt and fresh waters are suitable. Types of vegetation vary depending on the type of water;*
- *Contributes to:*
  *- Natura 2000 habitats [7]: 'Sandbanks which are slightly covered by sea water all the time', 'Estuaries', 'Mudflats and sandflats not covered by seawater at low tide' including the associated vegetation, 'Large shallow inlets and bays', 'Hard oligo-mesotrophic waters with benthic vegetation of Chara spp', 'Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation', 'Rivers with muddy banks with Chenopodion rubri pp and Bidention pp vegetation', 'Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels', 'Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)';*
  *- Natura 2000 species [8]: among others, fish, birds, insects, amphibians and mammals;*
  *- Water Framework Directive (WFD) [9]: transitional waters, river banks and lakes;*
  *- This measure can contribute to the National Ecological Network (EHS).*

Many nationally managed waters and regionally managed waters have hard banks with materials such as rock cladding, deposited rock, concrete or asphalt. Where this protection is not in place, the absence of any significant water-level variation results in steep, eroded banks. This leads to the loss of mud flats, salt marshes and river lowlands, adversely affecting water quality and bankside biodiversity, and preventing the establishment of flora and fauna. Steep river banks are also obstacles for animals that want to cross a water. These animals may drown. As a result, banks of this type fail to comply with the objectives of the Water Framework Directive, the National Ecological Network (EHS), Natura 2000 and regional water plans. Furthermore, banks of this kind detract from the perception of the landscape from the land and the water.

The construction and maintenance of hard river banks is expensive but nature can do the job in specific cases. That is why this BwN measure focuses on 'softening' these hard dikes and banks by building a natural embankment. A hard forebank will sometimes be necessary to prevent the erosion of the banks. This forebank will be smaller than the usual hard bank. The negative effects of a hard bank will therefore be absent or negligible.

A natural embankment is a gradual transition from water to land that is at least 5-10 m wide and that is made up of a succession of different vegetation zones with aquatic flora in the deeper water (such as pondweed and water lilies), bankside flora on the embankment (reeds and rushes, for example) and river and marsh woodland (willows and ash) on the drier banks.

A natural embankment contributes to:

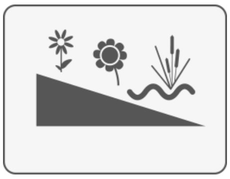
1. bank protection;
2. water storage;
3. enhancing biodiversity;
4. improving water quality;
5. cutting management and maintenance costs;
6. other benefits such as the absorption of particulate matter, capturing greenhouse gas, the improvement of the quality of the residential environment, improvements in public health, and so on.

Specimen projects:

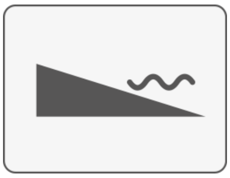
- Construction of 100 km of natural river banks - Nature-Friendly Meuse River Banks project (PNOM) of Rijkswaterstaat and the Dienst Landelijk Gebied;
- Construction of nature-friendly river banks in the Delta, WFD programme River Banks and Flood Plains West - Rijkswaterstaat South Holland;
- Kallang River, PUB Singapore.


## Spatial aspects

*Flowering season: spring & summer*



*Different vegetation zones*



*1 in 10 incline*

## Services [10, 11, 12]

Ecosystem services generate benefits if people can exploit the services and capitalise them.

### Bank protection

Particularly in regionally managed waters, natural embankments can replace hard banks in terms of protection as long as they are wide enough. In larger waters (tidal waters, rivers and lakes), the impact of waves produced by the wind and shipping is generally such that foreland protection will be required.

### Cleaning

Nutrients are captured and removed during mowing and harvesting (277 kg N/ha/year; 20 kg P/ha/year). Floating material sinks to the bed as a result of the lower flow velocity in shallow areas and between plants. Organic material is decomposed. Water and bankside vegetation serve as spawning grounds and nurseries for plant-loving fish and fish predators such as pike. The burrower fish population declines and that enhances the transparency of the water. This effect is promising when at least 10% of the water has been colonised by bankside vegetation and when there is a low nutrient load.

### Biodiversity

A suitable habitat is created for a range of flora and fauna. In particular, the development of submerged aquatic flora and bankside vegetation (reeds especially) has a positive effect on the robustness of the system in terms of withstanding the impact of waves, wind and nutrients. If more than 10% of the aquatic area is covered by vegetation, this will have a positive effect on the light climate and therefore on the development of submerged aquatic flora and associated species.

### Water dynamic

Natural embankments can be combined with water storage because reducing the incline of steep river banks enhances the water storage capacity.

### Uptake of particulate matter

One hectare of reeds captures 10 kg of particulate matter a year. A natural embankment with vegetation also helps to improve air quality.

### Carbon capture

Reed banks capture approximately 6.8 kg C per hectare a year. In that way, a reed bank can help to mitigate climate change.

### Urban climate

Green areas reduce the urban heat island effect by approximately 0.6 degrees per 10% increase in the green area.

## Benefits and cost savings [10,11,12]

The ecosystem services referred to above generate benefits if people can exploit the services and capitalise them.

### Leisure value

A bank rich in plant and animal varieties enhances the natural experience. The area becomes more appealing for anglers, bathers, skaters, leisure boats without motors and so on, generating income for business and government (through tax).

### More appealing habitats

Natural views improve residential quality and push up property values. The urban climate may improve, and this has a favourable impact on public health. Depending on the number of residents, this can become a major benefit.

### Education

Children and adults come into contact with nature in the immediate vicinity.

### Reed harvesting

Commercially-managed reed marshes produce approximately 900 sheaves of reeds per hectare annually, generating income of approximately 2 euros per sheaf. When managed for nature-conservation purposes, marshes can produce 250 sheaves per hectare annually.

### Maintenance costs

When a nature-friendly bank is in place and working properly, management and maintenance costs may be considerably lower than in the case of banks with traditional supporting elements that require replacement once every six to ten years.

### Nature objectives

The construction of nature-friendly river banks is one of the main measures in the WFD. At the same time, the banks can act as Natura 2000 habitats and serve as important structures that allow various species to migrate through the landscape. In that way, they can act as Ecological Connecting Zones (EVZ) and link nature areas with one another. Combining objectives makes it possible to make savings.

Both costs and benefits are location-specific and difficult to extrapolate. Cost-benefit analyses will therefore have to be conducted for each individual location.

## Implementation costs[5,6]

Most of the costs are generally related to land purchase and earthworks. In places where the water dynamic results in a lot of erosion, measures will have to be taken to create the right boundary conditions. This usually involves manipulating the direction of the current or wave attenuation using groynes or natural breakwaters. Other costs relate to plan development, the introduction of bankside vegetation and management. The precise cost will depend on the location, the design and the potential for completing several operations at the same time.

The Nature-Friendly River Banks Guide[5] assumes € 45 per metre and a bandwidth of between € 20 and € 160 per metre. This corresponds to what has been seen in practice. The Hoogheemraadschap Hollands Noorderkwartier (HHNK) water authority assumes a standard amount of € 60,000 per kilometre without support structures and € 120,000 per kilometre with support structures[6].

However, major cost savings can be made by using nature itself for the creation of the banks: allow wooden support for the bank to rot away, let the bank subside within given limits, and make adjustments to standard management practices (replacing them with ecological practices).

## Management and maintenance

It is possible to distinguish between different phases of management. Immediately after construction, different types of management will be needed than after the target objective has been achieved.

Management should be adjusted in line with the goal of the natural embankment. Is the focus exclusively on protecting the bank, or does it also include biodiversity and water quality? If there are specific wishes relating to vegetation (such as plants with floating leaves, reed vegetation, rushes or woodland, spawning grounds for fish), the appropriate ecological management measures should be put into place. If the aim is to protect the bank, monitoring is advisable after storms and high water. Where the bank has been washed away, one approach could be to fill up the gaps with seed bags.

## Physical boundary conditions [1, 2, 3, 4]

### Wave impact

The aim is to focus on locations where the impact of waves and currents is acceptable for bankside vegetation (reeds and rushes). Where vegetation is lost, erosion may begin and the embankment may be degraded. Sedimentation will result in the extension of the embankment, depending on the local situation. In terms of preserving the vegetation, we assume a maximum wave load for mature reeds (in other words, two years old): 0.25 m daily, 0.4 m occasionally given a maximum of 5000 waves a year and not for an uninterrupted period. Particularly just after construction and when seeds, cuttings or reed root balls are used, the bank and the young vegetation will be very vulnerable to wave impact. The requirements will then be stricter.

In dynamic systems (wind waves and shipping), a temporary breakwater structure may be needed in front of the natural embankment. That will affect the cost.

### Shadows

Shadows will affect the vegetation in place and therefore, indirectly, the maintenance of the embankment (see wave impact). Steps should be taken to prevent shadow formation by trees. In addition, accumulations of leaves and twigs can cause problems with water quality. Furthermore, they are not suitable as a substrate for the establishment and germination of submerged aquatic flora.

### Embankment and water depth

Generally speaking, the shallower and wider the embankment, the better it is for nature (this results in wider vegetation zones) and for wave attenuation, but the more space is needed. In practice, a narrow nature-friendly embankment can develop when the incline is 1:2, but this is still quite steep. The aim should be an incline of 1:10-1:20. An embankment without vegetation and sediment only will be approximately 1:10. Horizontal embankments are also suitable, and they should preferably be between 0.3 and 1.0 m deep.

The embankment slope and depths should vary along the bank. This creates more opportunities for different species to move in.

From the point of view of biodiversity, a minimum width of 5-10 m is advisable (land + water), but the area for vegetation should be at least 10% of the water surface area in order to have an effect on water quality. This can be achieved using fluctuations in the water level, the embankment incline and the depth[4].

### Water-level dynamic

The water-level dynamic will affect vegetation growth, sedimentation and erosion processes, and therefore have a direct effect on the preservation of the embankment (see wave impact). In freshwater tidal areas, large tidal variations of a few metres will, in the case of a shallow embankment, result in a wide bank zone with a variety of water and bankside vegetation[4]. A naturally fluctuating water level is advisable in polders and channels, with higher levels in the winter and lower levels in the summer and the water level fluctuating by at least 30 cm[2]. In these conditions, a range of physical, chemical and biological processes will be initiated that favour the development of bankside vegetation. As a result, less inlet water will be needed, and this can benefit water quality (because the nutrient load will be lower).

When seeds, cuttings or reed root balls are used, the bank and the young vegetation will be highly sensitive to the water level. It will be important to prevent both drying out and drowning. Shallow water/marshy conditions are generally optimal.

### Salinity

Natural embankments are an option in both salt and fresh water. The vegetation in these two conditions will differ. The boundary conditions above apply in particular to conditions varying from fresh water to slightly brackish water. As water gets saltier, reeds will retreat to the higher sections of the bank. However in that case, they will only be of limited value as a defence for mud flats and shoals. This function can be taken over by oyster reefs and mussel fields (see Oyster reefs and mussel fields fact sheet).

### Food availability in soil and water

High nutrient levels are, in combination with the regulation of water levels, a major threat to biodiversity on natural embankments. Many large plants that protect banks, such as reeds and rushes, are found in the most naturally nutrient-rich waters of the Netherlands (in other words, freshwater tidal areas). The aquatic flora are therefore affected most by eutrophication.

Load and robustness should therefore be determined at the system-specific level in order to determine the potential for submerged aquatic flora[3]. Changes in nutrient levels in the water bed should preferably be made in accordance with demands relating to water quality (now in the future). Local materials (clay, sand and peat) should be used that are not more, or less, nutrient-rich than the water where the natural embankments are located.

Generally speaking, everything is possible but 'moderately nutrient-rich' conditions will favour natural vegetation development most.

## Other boundary conditions

When plans are being made for the replacement of hard banks, it is important to establish a picture of:

1. The minimum discharge profile for the design discharge;
2. The wishes of local residents (such as an unimpeded view of the water);
3. The availability of seeds, cuttings or root balls to further vegetation development.

## Potential sites

This BwN measure is possible where the wave loads are low enough to permit natural bank defences. This primarily means urban waters and regionally managed waters but also sheltered sections of our large rivers and in tidal waters. These areas will often be behind a river training wall or forebank, as in the case of the salt marshes in the Haringvliet and Hollands Deep (Beningerslikken, Blanken slikken, Willemstad Tonnekreek).

Quick wins are possible at locations where, from the point of view of water discharge, there is space for vegetation development in the water and where high banks with vegetation do not disrupt the view. This approach has been adopted extensively in the urban waters of Capelle aan den IJssel. The role of the water authority was crucial here. By making use of space and introducing changes to maintenance and management, natural embankments have been established during the course of time over several kilometres without incurring consultancy and construction costs.

Elsewhere, cost-benefit analyses will be useful to determine whether investments are justifiable to the taxpayer.

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