Nature-based solutions for Slope Stabilisation and Landslide Precaution

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Nature based Solutions

Introduction to Nature-based Solutions (NbS)

International Union for Conservation of Nature and Natural Resources (IUCN): *"Actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits."*

Societal challenges (Cohen-Shacham et al., 2016)

Nature based Solutions

The importance of NbS are highlighted in the Sendai Framework for Disaster Risk Reduction 2015-2030 as an **effective technique to reduce disaster risk, adapt to climate change and strengthen community resilience**.

The application of nature-based solutions for **slope stabilization and protection** is now used world-wide as an efficient, cost effective and eco-friendly approach.

The **role of plants** in improving slope stability and minimizing soil erosion can be divided into two categories; **hydrological and mechanical mechanisms**.

NbS Options for Landslide Mitigation - Overview

Category - Physical process	NBS measure
NBS for surface protection and erosion control - Living Approach	Hydroseeding
	Turfing
	Tree bushes direct/pit planting (live transplanting)
	Live/intert fascines and straw wattles
	Bush mattresses
	Bush layering
	Live Stakes (live poles)
	Live smiles
NBS for surface protection and erosion control - Combined Living/Not living Approach	Geotextiles (Rolled Erosion Control Products)
	Drainage Blankets
	Beach replenishment/nourishment
	Rip-rap
	Rock dentition

Source: www.larimit.com, cited in Kalsnes & Capobianco, 2019, Klima 2050 Report No 16

NbS Options for Landslide Mitigation - Overview

Category - Physical process	NBS measure
Modifying the slope geometry - mass distribution	Terracing
Modifying the surface water regime - surface drainage	Vegetation - hydrological effects
	Live pole drains
	Live/rock check dams
Modifying the mechanical characteristics of the unstable mass	Vegetation - mechanical effects
Transfer of loads to more competent strata	Soil nail and root technology (SNART) - Hybrid
Retaining structures to improve the slope stability	Vegetated gabions (Hybrid)
	Live crib walls
	Vegetated slope gratings
Passive control works for dissipating the energy of a landslide	Afforestation
	Live gully breaks

Source: www.larimit.com, cited in Kalsnes & Capobianco, 2019, Klima 2050 Report No 16

Stabilisation Options:
Surface Protection and Erosion Control

Surface Seeding

Hydroseeding is suitable for steeper or smooth slopes in mild climate conditions

Forest track

Figure source: Florineth, 2008
(Universität für Bodenkultur, Vienna, Austria)

Surface Seeding

Noise barrier

After 1 year

After 7 years

When using algae products as adhesives, newly planted hardwoods can be sprayed

Rock embankments or quarries can only be greened with hydroseeding

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Surface Protection – Turfing / Pieces of Vegetation

Lifting off pieces of vegetation
Forest path

Forest road 1 month after
placing the vegetation pieces

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Surface Protection – Tree Planting

Forest path
5 year planting

Forest path
9 year old planting
with green alder

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Erosion Protection Mats – Geotextiles

Fabric as erosion protection (coconut, straw, jute, grass… and artificial)

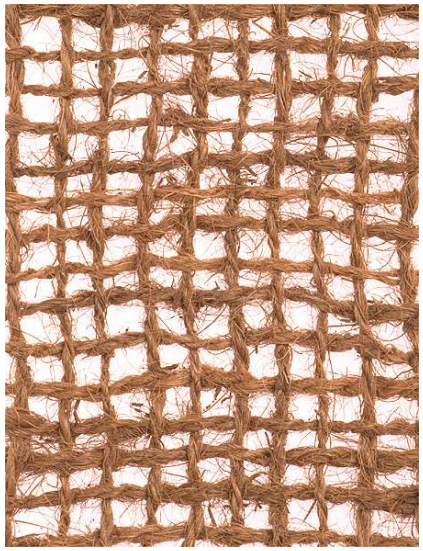


Figure source: GLAESERgreen

During the first (1-6) years these fabrics **secure the vegetation-free slope** or embankment. The vegetation can sprout under the coconut net and slowly grow through the fabric so that complete green cover can be established. If necessary, trees can also be planted in the embankments.

Slope inclination 50-70° requires anchoring (ground spikes, e.g. wood)

Criteria	Coconut fabric 400g	Coconut fabric 700g	Coconut fabric 900g
Material	Coconut	Coconut	Coconut
Mesh sizes	20mm	10mm	8mm
Recommended for slopes	0-30°	30-50°	50-70°
Lifespan	2-3 years	3-4 years	4-5 years

Stabilisation Options:
Technical and Biological Dewatering

Technical Dewatering

Drain pipe covered with stones

Alpine path Passeier

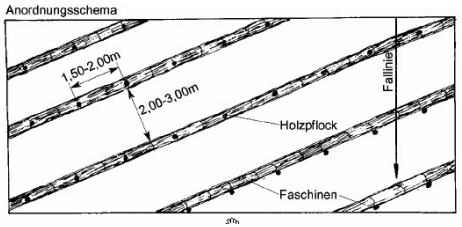
Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

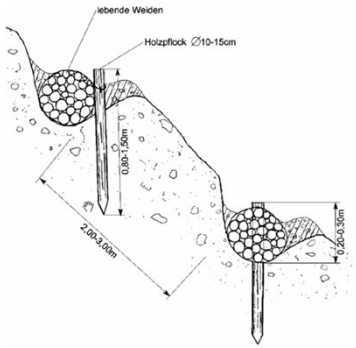
Technical Dewatering

Stone drains on the highway

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Biological Dewatering through Drain Fascines





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Function: Securing 10-20 cm soil layers and drainage

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

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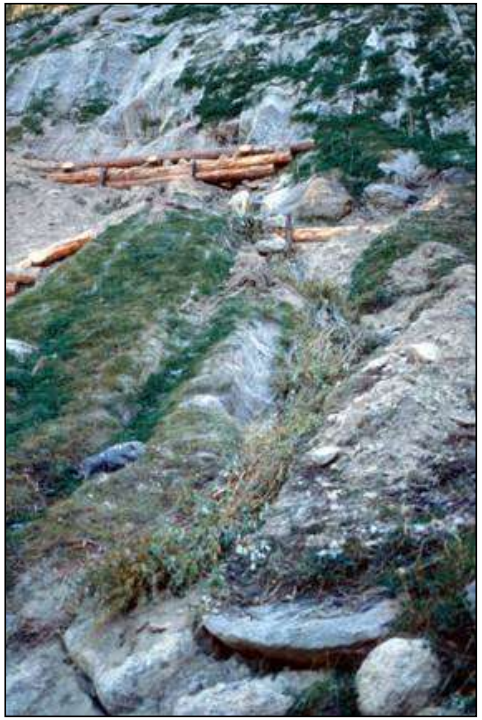
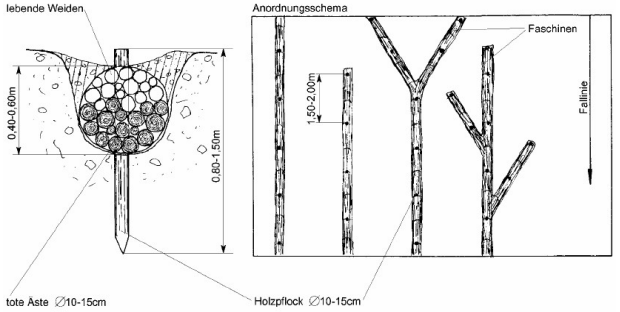
Biological Dewatering through Drain Fascines



During construction

After 1 year

Drain fascine construction
Prünsterlahn, Schenna



After 19 years

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Biological Dewatering through Drain Fascines

Construction of drain fascines

After 1 year

After 3 years

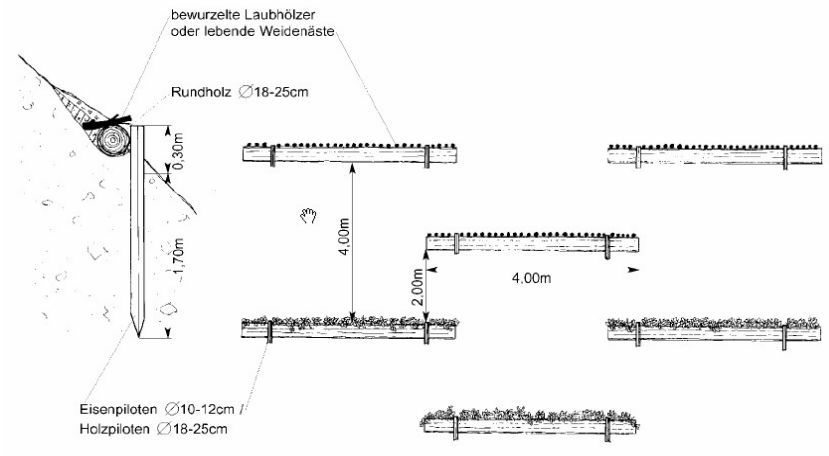
After 7 years

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Stabilisation Options:
Securing 10-20 cm ground instabilities

Stabilisation Pilot Walls

rupture



Pilot wall, planted, meadow

Just built pilot Walls

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Stabilisation Pilot Walls

After 4 years

After 8 years

After 16 years

3 year old planted pilot walls

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Stabilisation Pilot Walls

Planted pilot wall just built

Planted pilot wall after 6 months

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Living Slope Grate

embankment demolition

under construction

Securing with living hanging grate

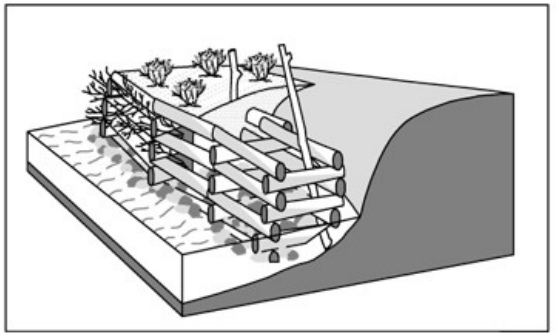
After 6 months

planted with green alder after 4 years

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

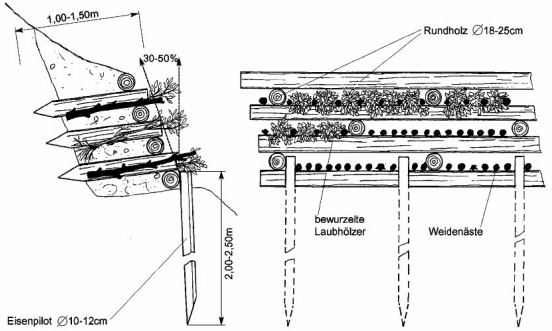
Stabilisation Options:
Securing 30-200 cm ground instabilities

Live Crib Walls



Simple live crib wall, just built

after several years



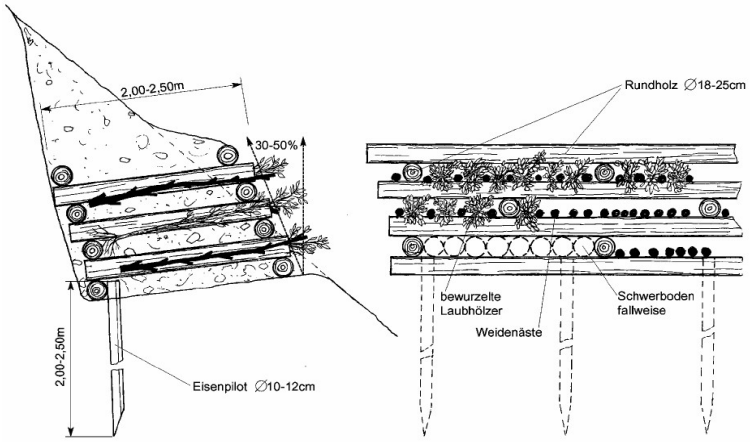


Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Live Crib Walls (Wood)

Planted double wooden live crib wall just built

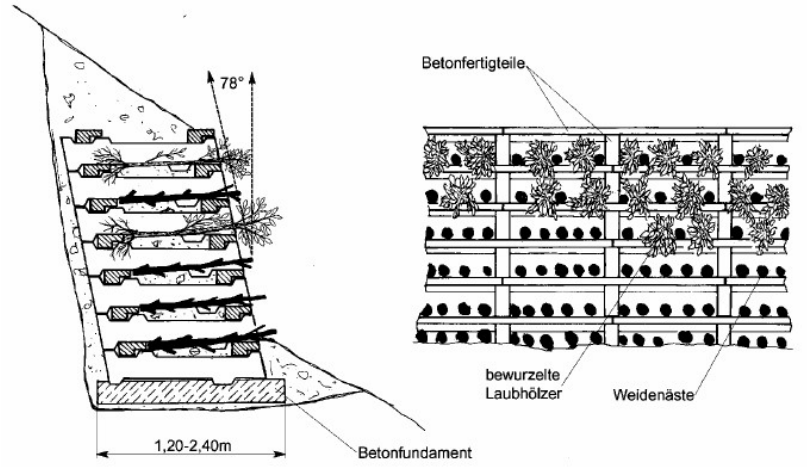
Securing a slip slope after the failure of gabions

After 4 months

After 6 years

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Rock Crib Walls (Concrete)



Steep concrete crane walls as supporting bodies: subsequent planting is difficult to carry out

After 3 years

Detail: with sticks

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Rock Crib Walls

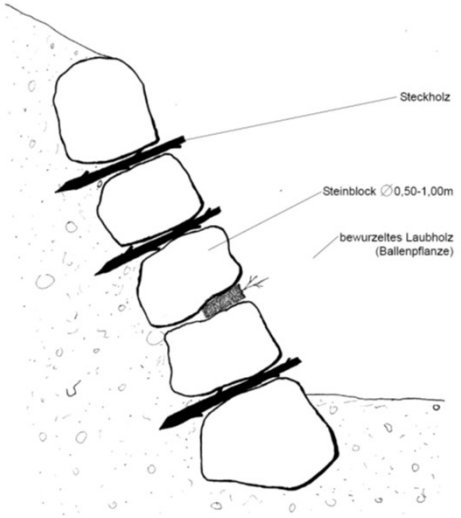
Construction of a rock crib wall

Planted with climbing plants, after 2 years

After 9 years

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Planted Rock Wall Using Plants Sticks



Block stone wall planted with hydroseeding after 17 years

Details of planting after 17 years

Block stone wall planted with various hardwoods after 6 years

Block stone wall planted with green alder after 7 years

Figure source: Florineth, 2010 (Universität für Bodenkultur, Vienna, Austria)

Gabions – Planted Wire Stone Baskets

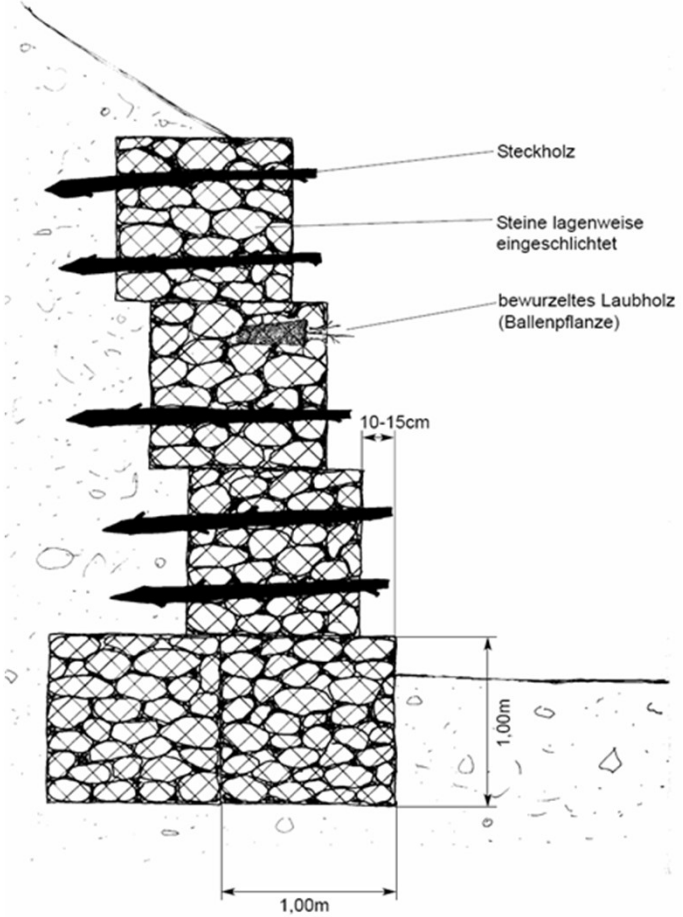


Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Construction of Gabions

Insert the willow cuttings through the galvanized grid down to the natural soil

Gabions – Planted Wire Stone Baskets

Building up gabions: the cavities are filled with earth

Gabions planted and grassed with lawn tiles after 5 months

After 2 years

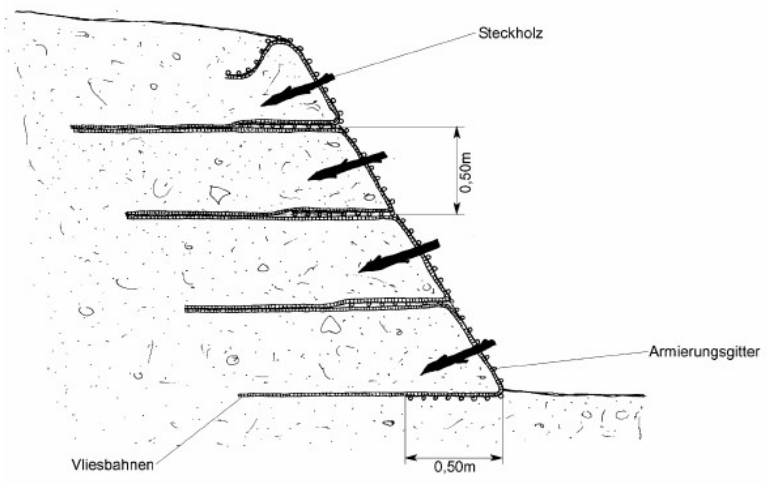
Detail of gabions

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Reinforced Earth Walls

Function: Valley or slope side retaining wall, protective dam (noise, rockfall, avalanches), slope protection

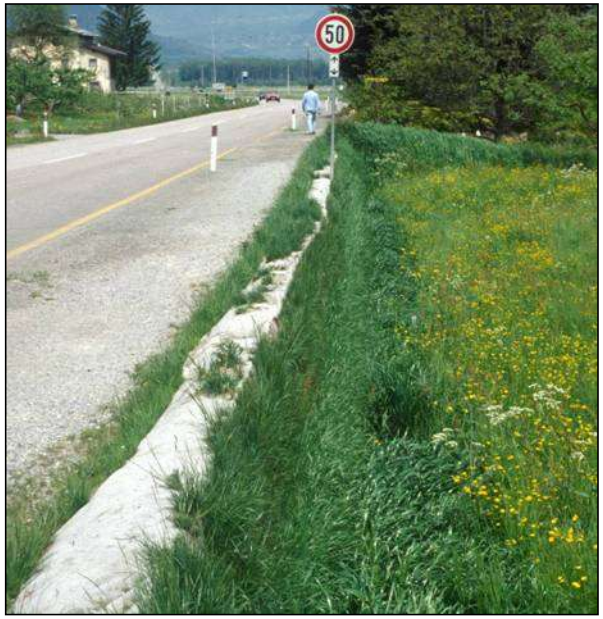
Use/Purpose: Traffic infrastructure construction: road/railway construction, footpaths/cycle paths; Foundation and civil engineering, garden and landscape design, hydraulic engineering



Reinforced Earth: Supporting structure made of compacted soil layers embedded in plastic mats

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

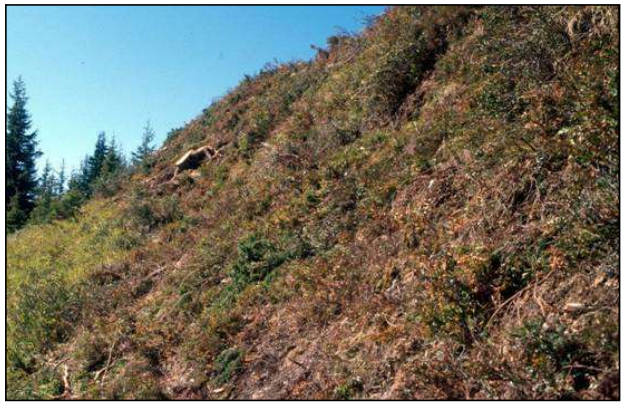
Reinforced Earth Walls

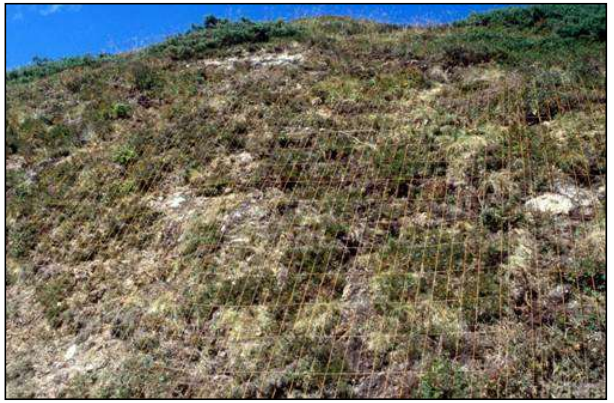


after 10 months
planted with hydroseeding

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Planting the Gabions with Turf



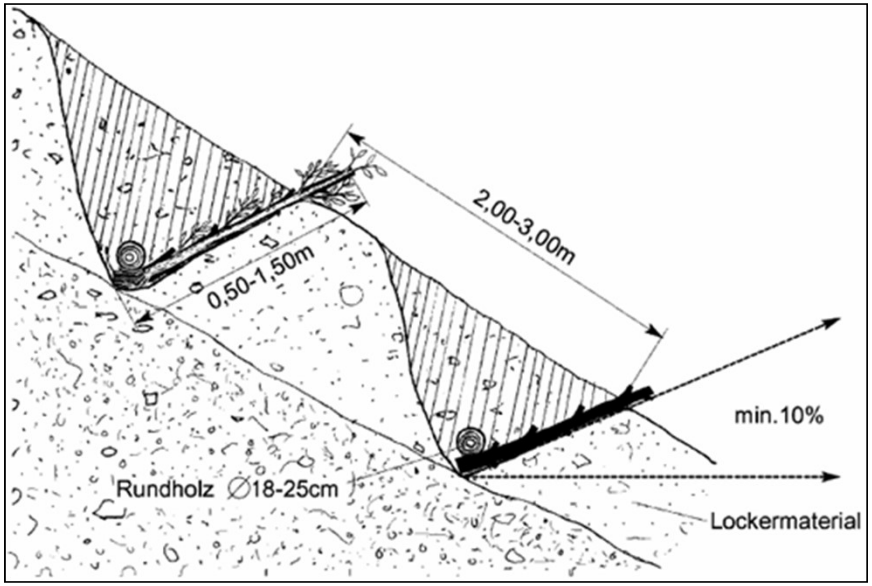


Fixing the lawn sod with a wire mesh

After 1 month

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Hedge Cuts Sticks Layering Living Stabilisation



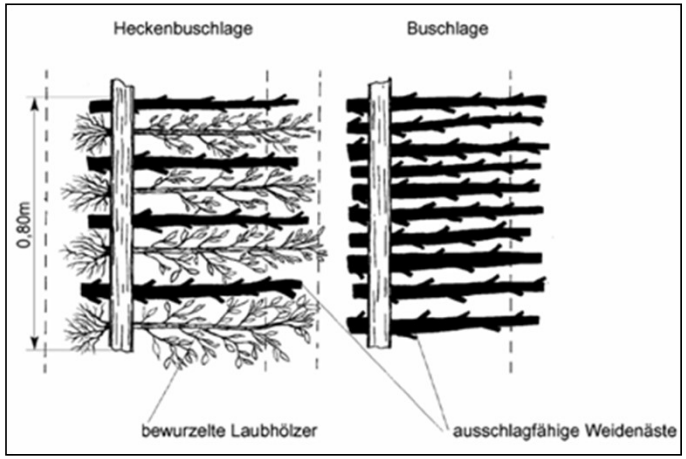


Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

Hedge Cuts Sticks Layering

Securing the loose material with layer construction

After 6 months

After 4 years

After 10 years

After 20 years

Figure source: Florineth, 2008 (Universität für Bodenkultur, Vienna, Austria)

River Bank Stabilisation

Options for River Bank Stabilisation

Function: Pushing the flowing water away from the bank

Bushes to protect erosion holes for sediment retention: For hollow banks and scours, insert branches into the hollow forms and anchor them with stakes (good spruce).

Rough surface trees for erosion protection: natural construction, quickly effective; Fastening and anchoring a well-branched conifer with a good crown at the base of the trunk, orientation almost parallel to the bank with the tip in the direction of the flow.

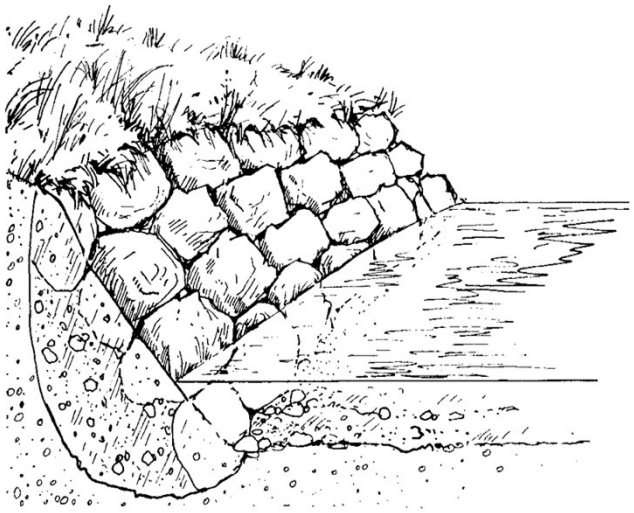
Groynes: Dam bodies protruding from the bank into the water on one side; serve to secure banks, to repel currents or to concentrate runoff at low water levels

Flow Guiding Dams

- **Flow Guiding Dams:** Measures predominantly with dead or living building elements in places with strong attack on the embankment; selection according to purpose and location.
  - Gabions
  - Masonery
  - Stone box: rock crib walls made of wood and stones

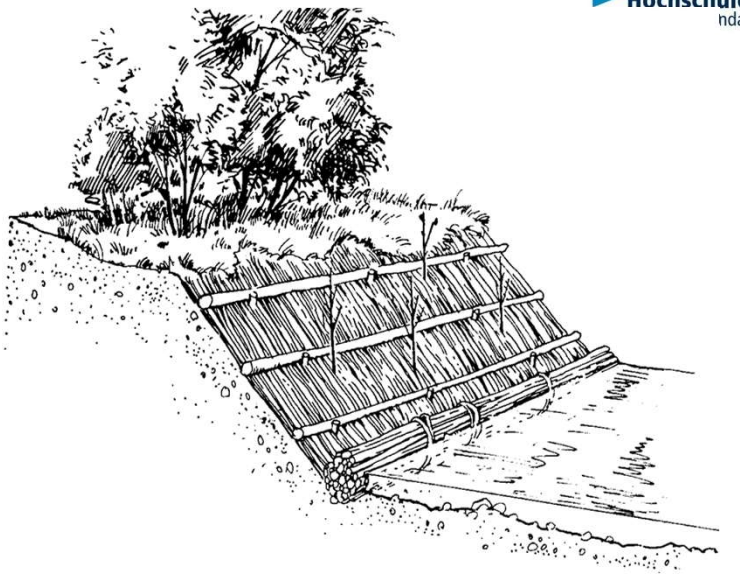
Figure source: Zander, 2013 (TU München, Germany)

River Bank Stabilisation



Stone setting with hydraulic stones

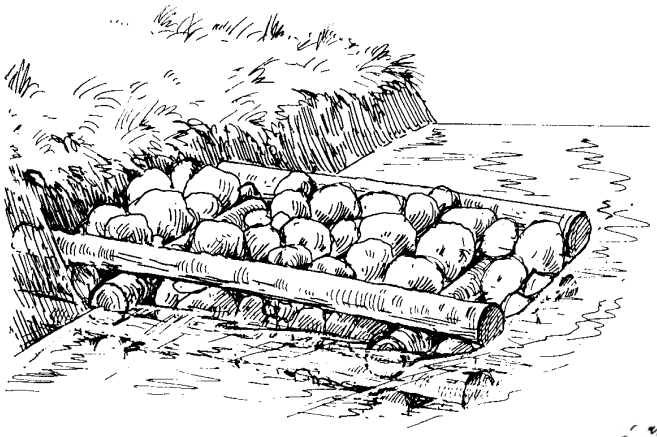
Stone setting with living wood



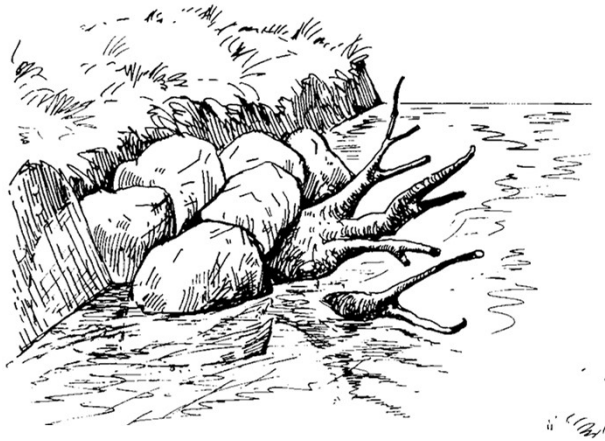
Willow spreading layer with fascine roller to secure the base of the embankment

Figure source: Zander, 2013 (TU München, Germany)

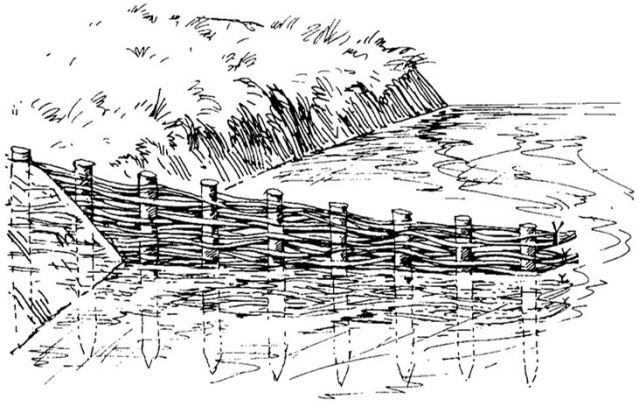
Types of Groynes – Living and Non-Living



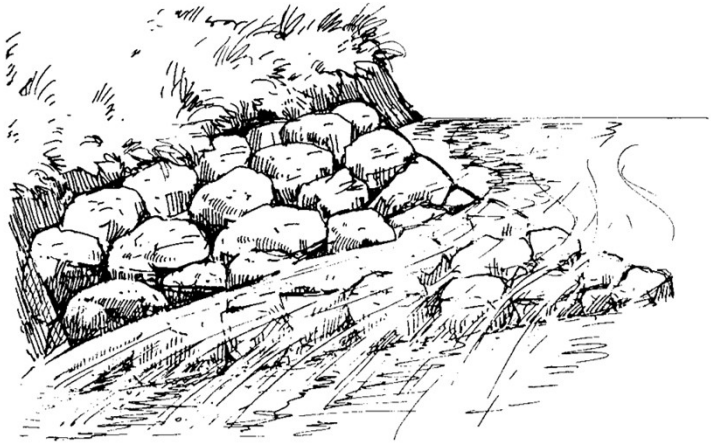
Stone box groyne



Rhizome groyne, weighted with stones



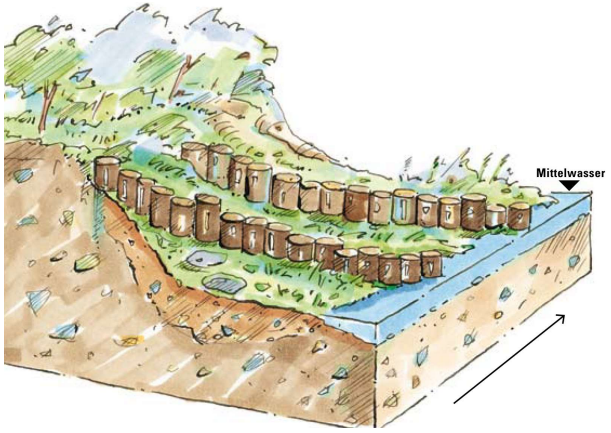
Wattle groyne



Bank spur made of hydraulic stones

Figure source: Zander, 2013 (TU München, Germany)

River Bank Protection – Living Groynes



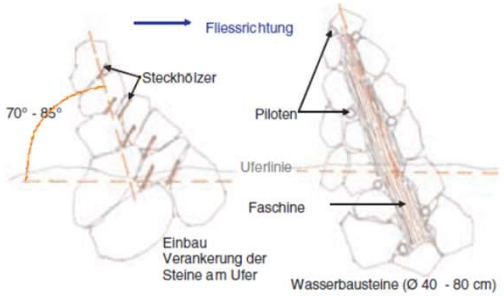


Figure source: Kanton Aargau (2005)

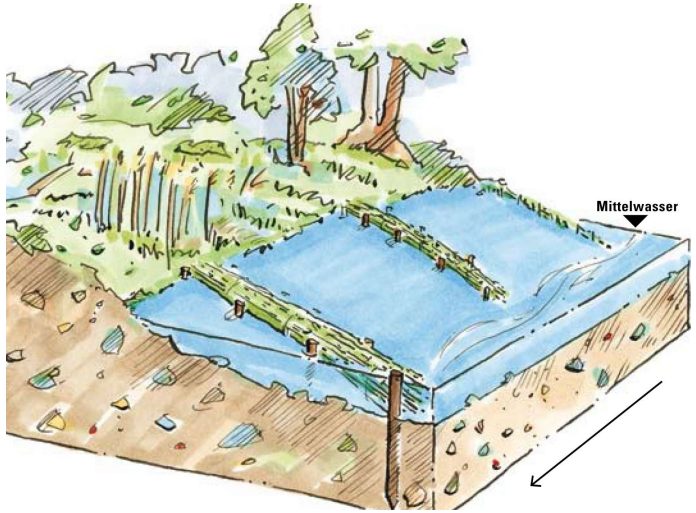


Figure source: WBW /LUBW (2013)

River Bank Protection - Fascines

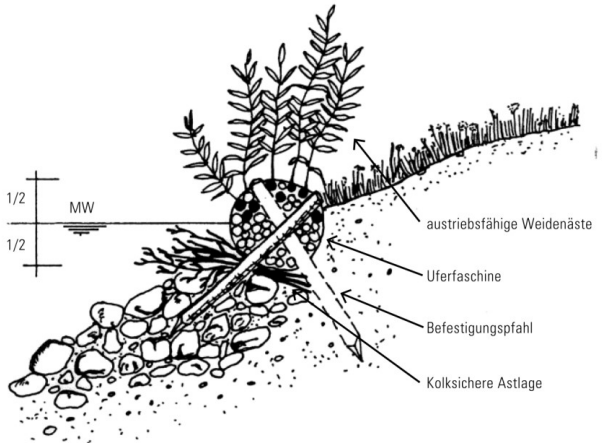


Figure source: WBW /LUBW (2013)

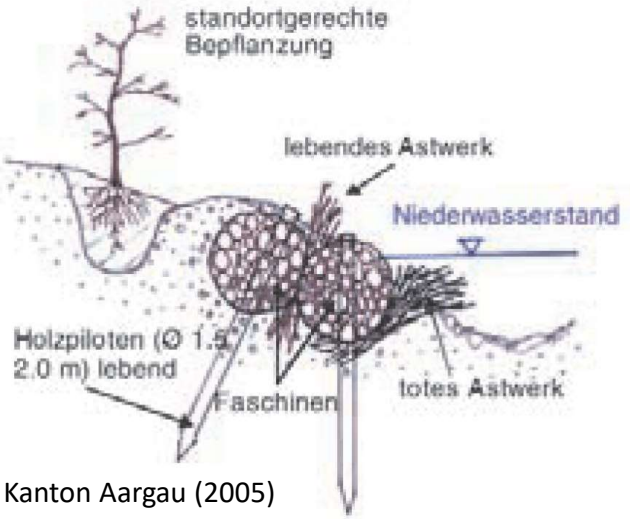
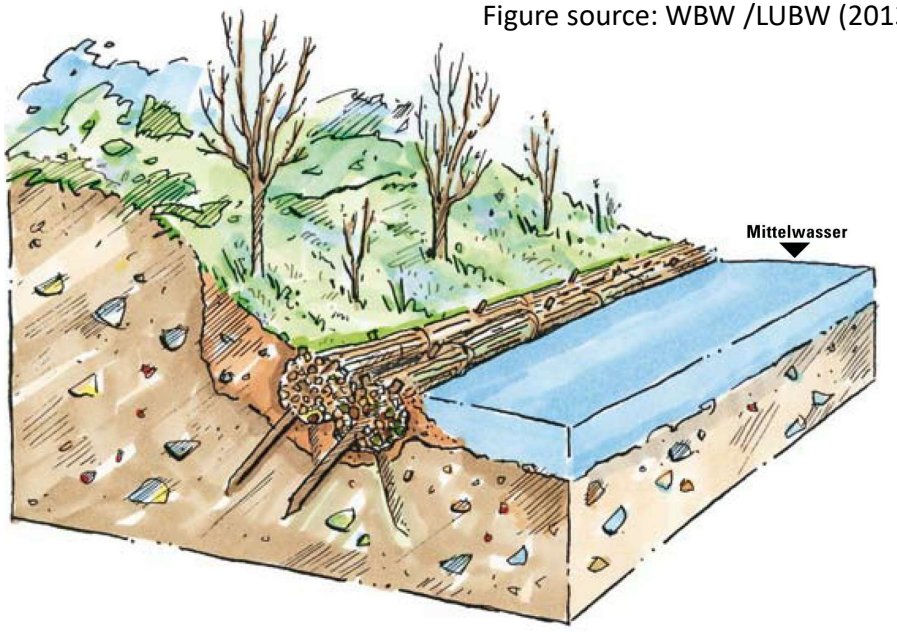


Figure source: Kanton Aargau (2005)



River Bank Protection - Sinking Rollers

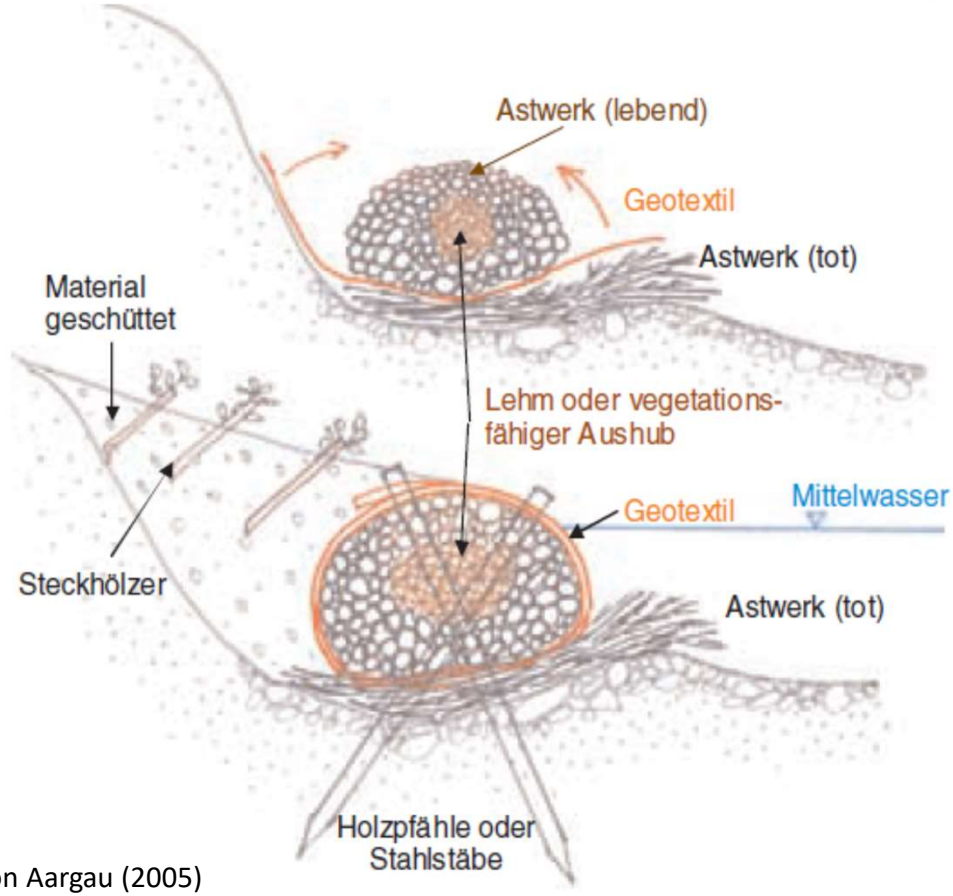
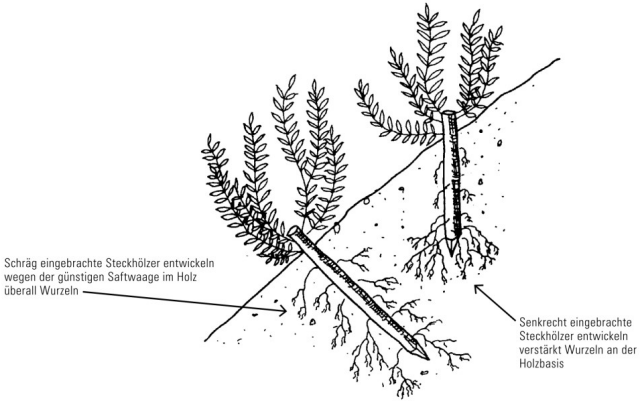


Figure source: Kanton Aargau (2005)

River Bank Protection – Living Wooden Sticks



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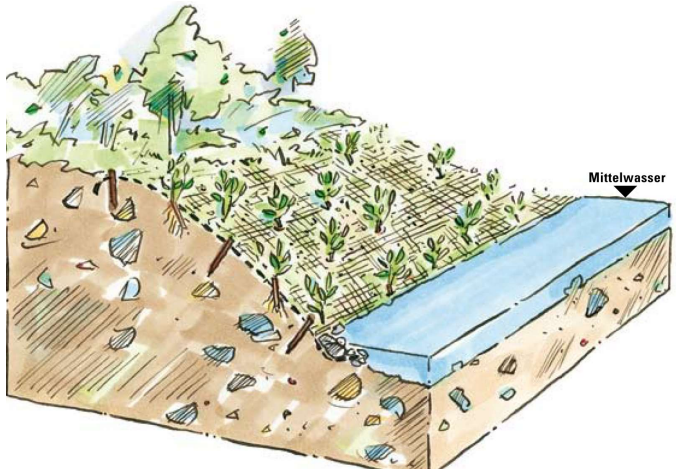

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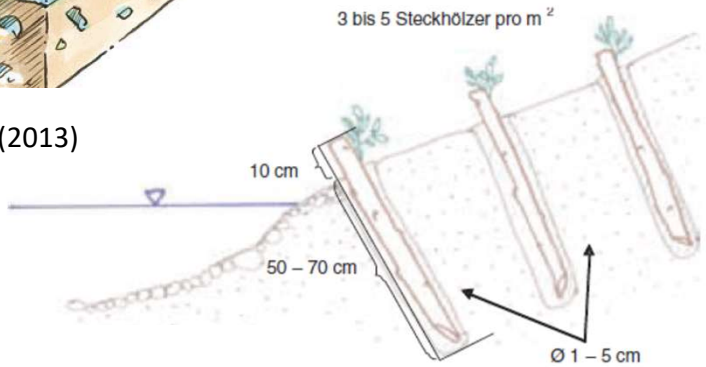

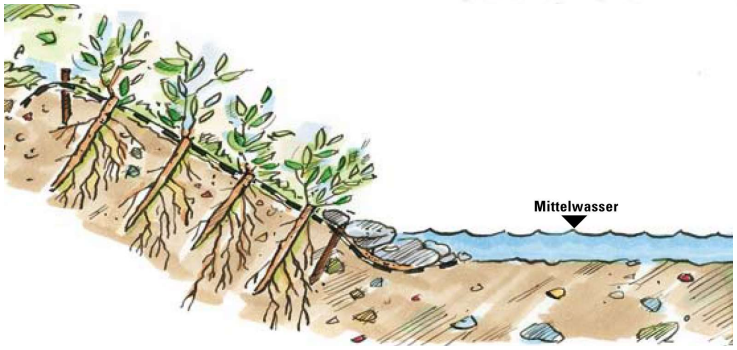

River Bank Protection - Hedge Cuts Sticks Layering

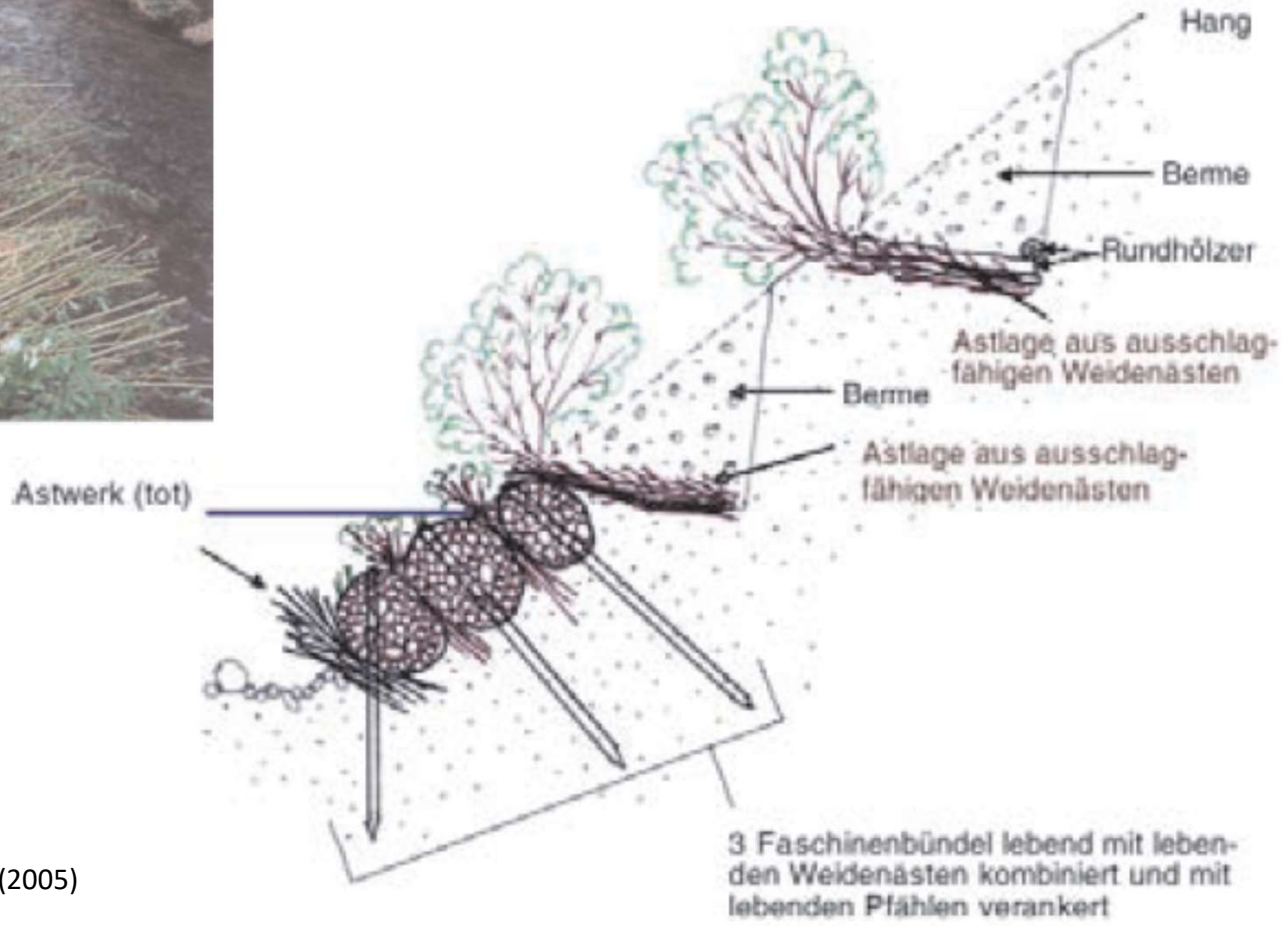

Figure source: Kanton Aargau (2005)

River Bank Stabilisation - Rhizomes

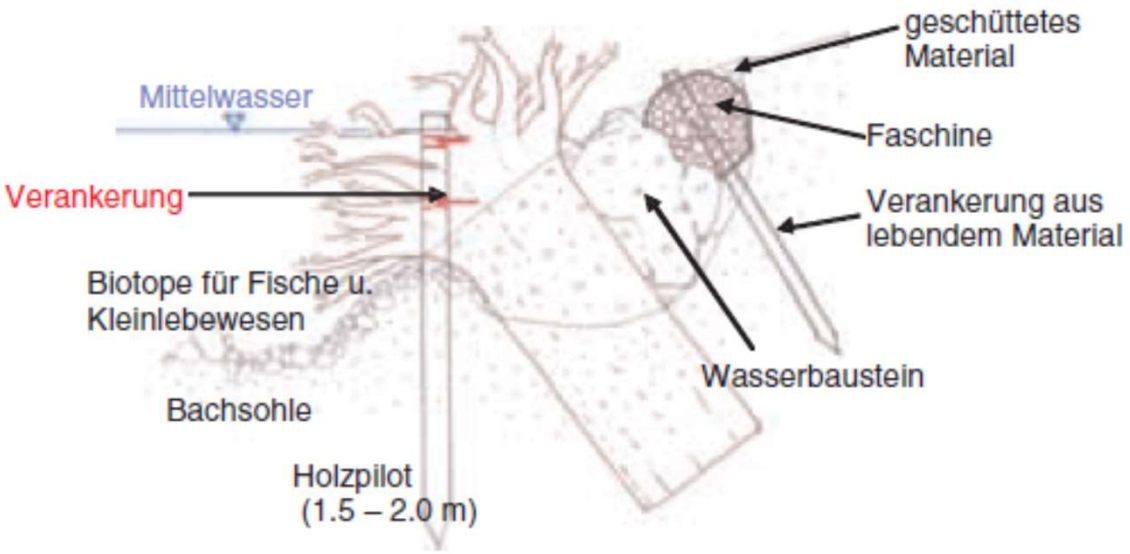

Figure source: Kanton Aargau (2005)

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Questions?