ICOLD-CIGB 2019 SYMPOSIUM:
SUSTAINABLE AND SAFE DAMS AROUND THE WORLD
UN MONDE DE BARRAGES DURABLES ET SÉCURITAIRES

Woody vegetation on levees in Germany – Requirements, technical solutions and case studies

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Outline

- Introduction / Motivation
- Occurrence and Effects
- Regulations, Codes, Requirements
- Ecological Aspects and Targets
- Technical Solutions
- Best Practice & Case Studies
- Conclusion

Dike breach during flood incident 1999 at the river Ammer (Source: WWA Weilheim)

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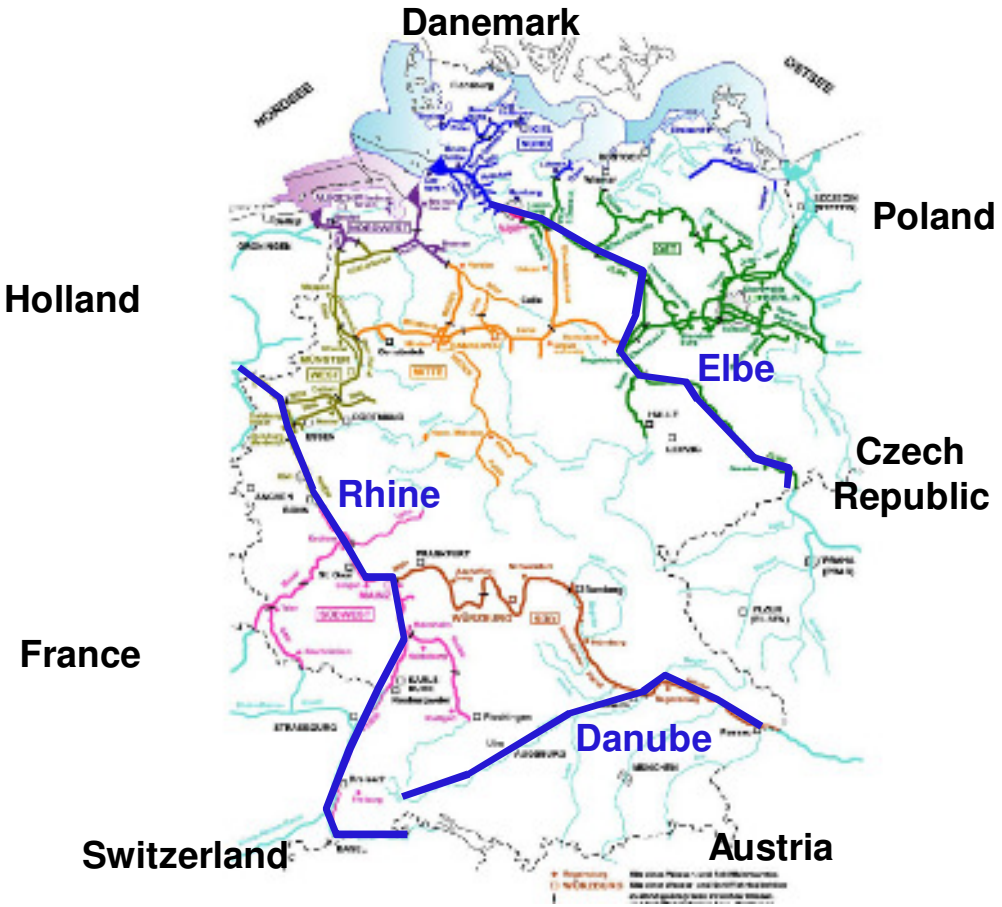
Failed Dike at River Mulde (2002)
(Source: Landestalsperren-verwaltung Sachsen)

Introduction / Motivation → Rivers in Germany

- Rhine
  - Length 1,233 km
  - Flood discharge HQ = 10,900 m³/s
  - Average discharge MQ = 2,090 m³/s
- Danube
  - Length 2,850 km
  - Flood discharge HQ = 3,450 m³/s
  - Average discharge MQ = 637 m³/s
- Elbe
  - Length 1,094 km
  - Flood discharge HQ = 5,700 m³/s
  - Average discharge MQ = 332 m³/s



Source: http://undine.bafg.de

Introduction / Motivation → Floods in Germany

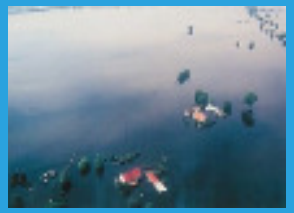
1993

West Germany
Rhine

1995

West Germany
Rhine

1997



East Germany
Oder

1999

Bavaria
Iller, Danube

2002

East Germany
Mulde

2002

East Germany
Elbe

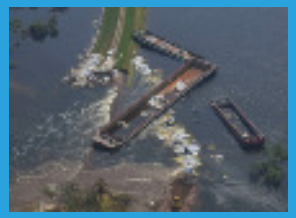
2003

Cologne
Rhein

2005

Bavaria
Isar

2013



East Germany
Elbe

2018

Koblenz
Rhein

Introduction / Motivation → Dike Failures and Trees

Dike breach during flood incident 1999 at the river Ammer
(Source: WWA Weilheim)

Dike break in Eschenlohe (1999)
(Source: WWA Weilheim)

Windthrow at dikes at the Black Magpie during storm Kyrill 2007
(Source: LUA Brandenburg)

Failed Dike at River Mulde (2002)
(Source: Landestalsperren-verwaltung Sachsen)

Dike breach during flood incident 1988 at Höselhurst in Danube (Source: TUM)

Tree failure at a dike in Germany 1999
(Source: StMUVG NRW)

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Lohauser dike with a row of trees on the top of the dike (Source: BezReg Düsseldorf)

Occurrence and Effects

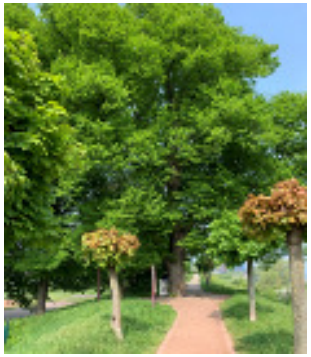
Wooded dike at River Iller (Bavaria) near Altenstadt with a trail on dike crest (Source: TU Munich)

Flood protection dike at the river Koeßnach near with poplars and meadow (year 1985, taken from Hacker et al. 1999)

Flood protection dike at the river Rhine, Orsoy, wooded dike (Source: BCE, 2019)

Complete wooded dike at River Danube near Dillingen in a nature protection area (Source: StMUGV)

Flood protection dike at the river Danube with landside poplar row and waterside bushes and grass/meadow (year 1985, taken from Hacker et al. 1999)

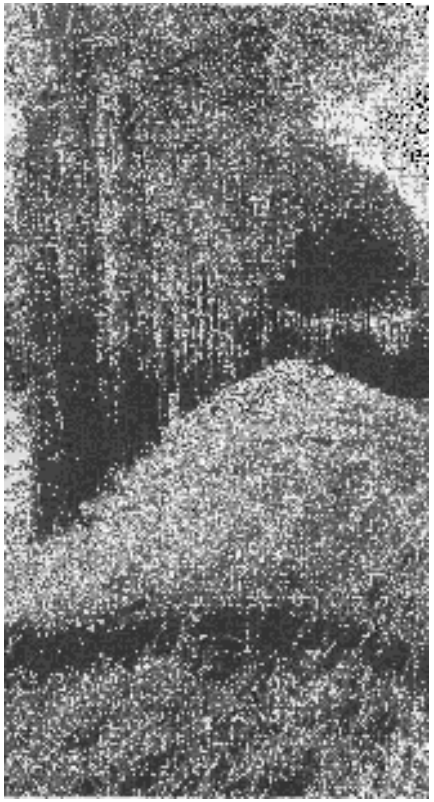


Flood protection dike at the river Rhine, Orsoy, tree on dike crest (Source: BCE, 2019)

Occurrence and Effects

Flood protection dike at the River Ammer (year 1979; Source: WWA Weilheim)

Flood protection dike at the river Mangfall before remediation (Source: WWA Rosenheim)



Poplar row on an backflow dike at the river Danube (taken from Seethaler 1999)

Huge single tree with bushes on waterside slope of a dyke at the river Loisach (Source: TUM)

Alluvial plains completely wooded and agricultural structure at landside dyke toe at river Loisach (Source: TUM)

Wooded dyke in the city of Stuttgart in 2009 (Source: Haselsteiner)

Occurrence and Effects

- Positive Effects

  - Roots may **stabilize slopes** by growing through potential slope failure mechanism. This effect is called natural reinforcement (Seethaler 1999, Schiechtl 1985).

  - At homogenous dikes that consist of cohesive materials wood roots may **support soil drainage** effects. This causes soil stabilization, too (see Döscher 1999, Marks & Tschantz 2002, Seethaler 1999).

  - Woods, particularly root intensive bushes, may **protect** the surface of a dike **against erosion**.

  - Woods and bushes are **stabilizing the soil** – a kind of **root cohesion** may be respected within stability criteria (BAW MSD 2005) – and they may reduce flow velocity and therefore shear stresses significantly.

  - **Ecological effects** – nature protection → living environment (habitat) – biological diversity

  - **Landscape / urban development**

  - **Local recreation**

  - **Local climate**

Occurrence and Effects

- Negative Effects
  - **Loosening of soil particles** through wood roots because of wind indicated movement
  - **Falling trees causing collapse of slopes** (windthrow) (see LfW BY 1990)
  - **Addition loads** on slope through trees that transfer wind forces to the subsoil
  - **Surface erosion** by flow turbulences and wave action, particularly near single trees
  - **Concentrated leaks** → Inner erosion
  - **Attraction of animals** (food & housing)
  - **Supervision, flood defense and maintenance** are critically **hindered**
  - Lack of grass vegetation by the **shadow** of trees → **surface erosion**
  - Roots penetrate soils and sealing elements → **increase of permeability**
  - **Damages of drainage** elements
  - **Damages of buildings** in dikes (pipes …) (Marks & Tschantz 2002)

Occurrence and Effects

- **Question 1**

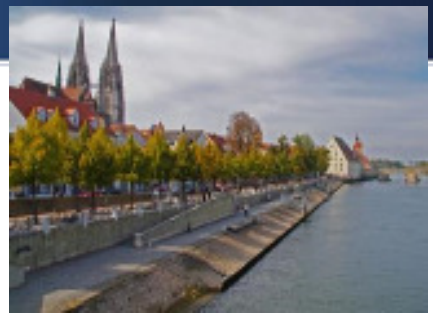
Who is guaranteeing flood safety permanently of levees with trees during the service period of the levee?

- **Question 2**

How much money would you spend for the positive effects for strengthening of the levee?

- **Question 3**

Who is responsible for the safety to traffic on the levee roads and ways covered by trees?



Regensburg
Danube

Source:
Internet

Köln
Rhine

Source:
www.bilder-buch-koeln.de

Krefeld
Rhine

Source:
BCE

Occurrence and Effects

Breakage of the Ammer dike during the Whitsun flood in 1999 (Source: WWA Weilheim)

Breakage of the dike near Höselhurst on the Danube during flooding 1988 (Source: TU Munich)

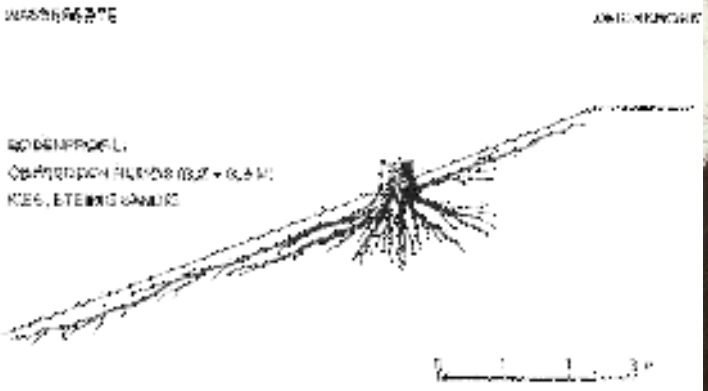
Cottonwood, Lech dike, Bavaria (Source: LfU Bavaria Germany, 1990)

Breakage of Loisach dike in Bavaria during the Spring flood 1999 (Source: WWA Weilheim)

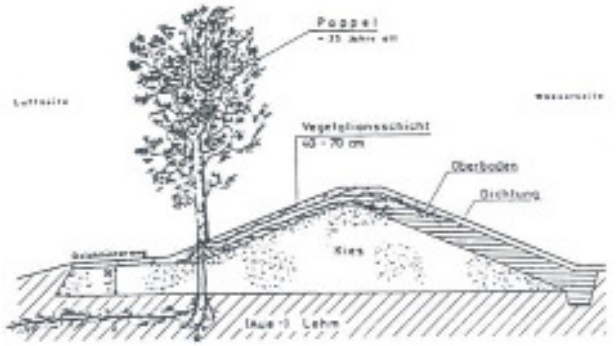
Rooting through embankment Vernalis, California, USA (Source: Berry and Chung, 2013)

Flat Roots (Source: Int. Levee Handbook)

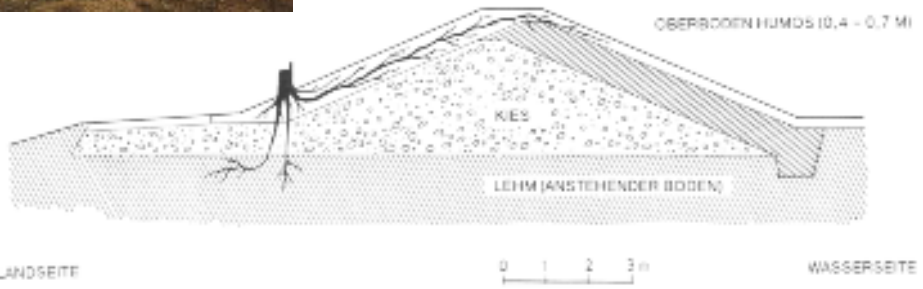
Occurrence and Effects



Birch tree on a dyke at the river Lech
(taken from LfW BY 1990)



Roots of a poplar vertical through gravel layer
and within topsoil layer
(taken from Seethaler 1999)



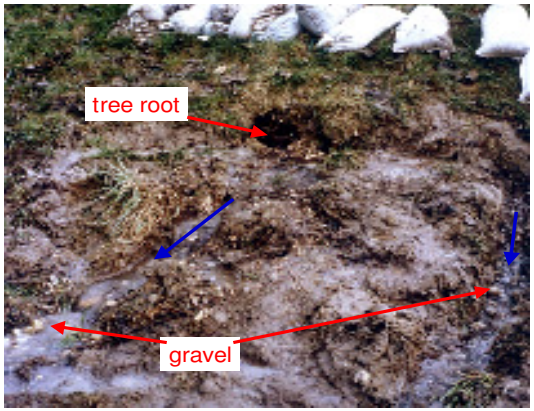
Maple tree with roots in topsoil and
subsoil in a dyke at the river Danube
(taken from LfW BY 1990)

Occurrence and Effects

Dyke breach during flood incident 1999 at the river Ammer (Source: WWA Weilheim)

Erosion damages at dyke crest after windthrow lead to overtopping during flood incident 2002 at river Salzach (Source: LfW)

Overtopping of a dyke at the village Eschenlohe (river Loisach) during flood incident 1999 (Source: WWA Weilheim)



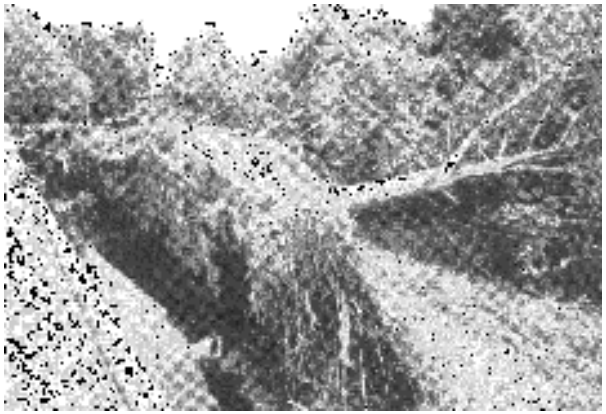
Seepage in the area of dead and partially rotten roots, Danube,1988 (Source: WWA Deggendorf)

Erosion during the flood 1999 at the Danube in the area of Dünzing (Source: WWA Ingolstadt)

Sliding of top soil layer at the landside slope at river Danube 1988 (Source: WWA Deggendorf)

Occurrence and Effects

Thrown spruce at the landside dyke toe at the river Lech (taken from LfW BY 1990)



Thrown poplar at a roadway embankment (taken from Mattheck & Bethge 1999)

Thrown row of poplars at the landside dyke toe (Source: StMUVG)

Windthrow at dikes at the Black Magpie during storm Kyrill 2007 (Source:LUA Brandenburg)

Windfall at a dike at the Ammer during the flood 2005 (Source: Haselsteiner)

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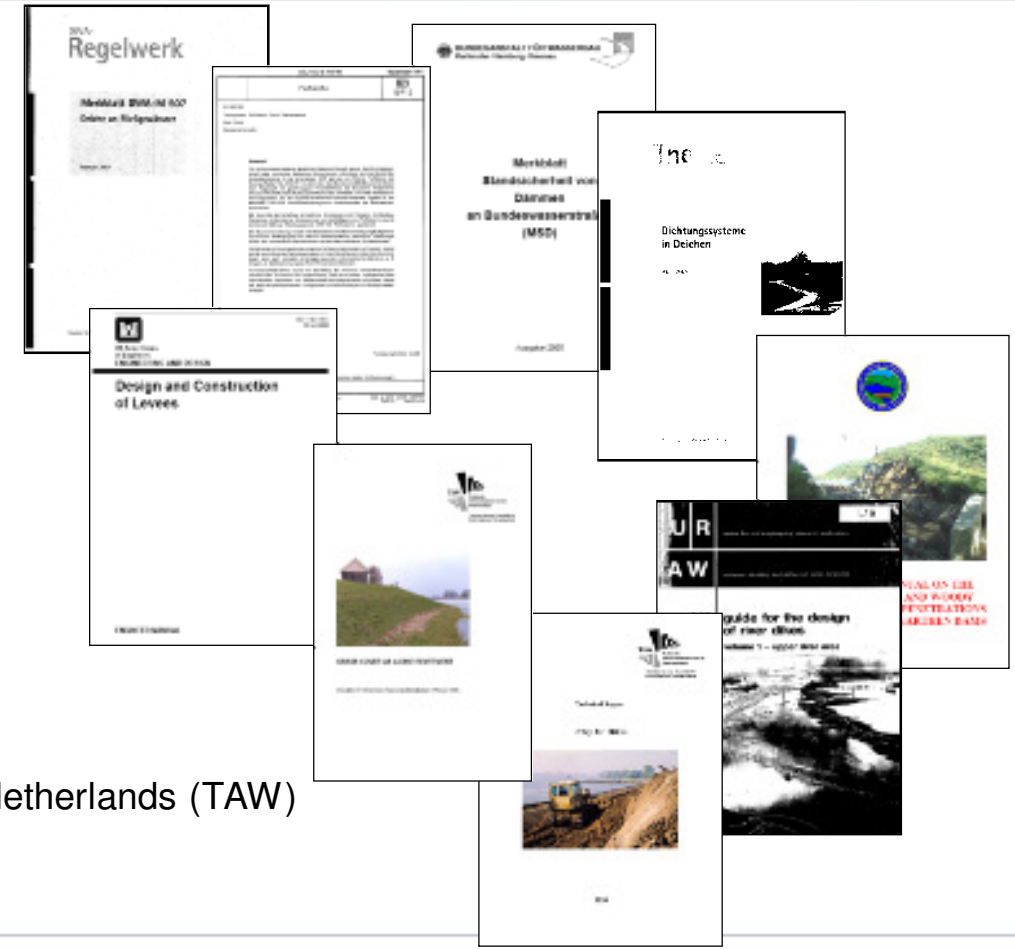
Regulations, Codes, Requirements

- German standards
  - DIN 19712/1997 Levees
    → DIN 19712/2013 “Flood Protection Structures”
  - DVWK 210/1986 Levees
  - → DWA M 507 Part 1 2011 Levees
  - DVWK 226/1993 *(under revision)*
    → DWA 507 Part 2 “Ecological Aspects Levees”
  - DWA (2005) (under revision)
    → DWA 507 Part 3 “Drainage/Sealing Levees”
  - BAW MSD (2011) Dams along waterways
  - DIN 19700/2004 Dams …

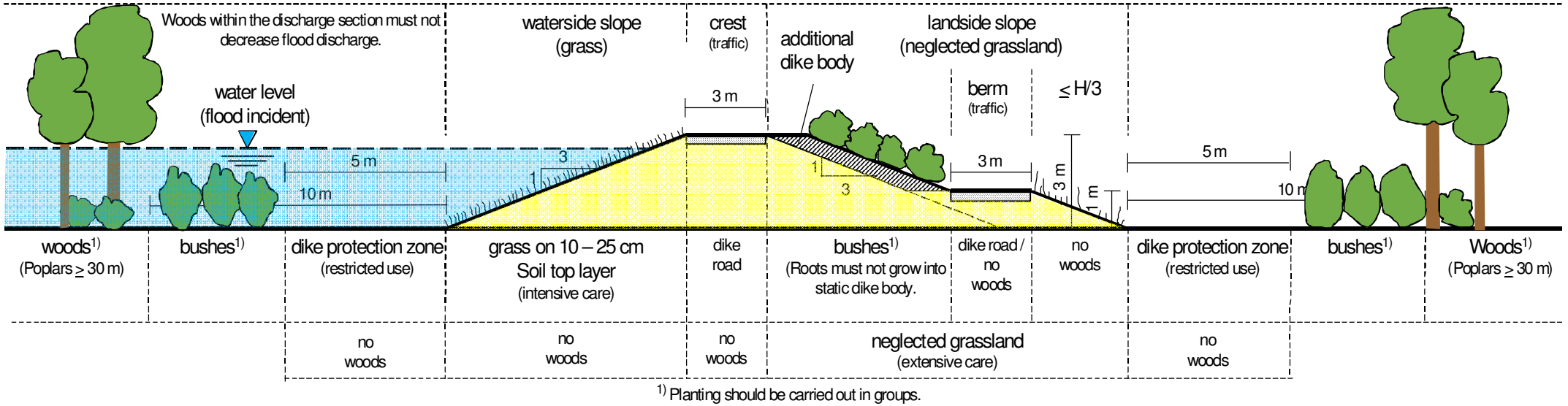
- International Standards
  - US Army Corps of Engineers (USACE)
  - US Bureau of Reclamation (USBR)
  - Technical Advisory Committee for Flood Defense of the Netherlands (TAW)
  - International Levee Handbook (CIRIA) …



Regulations, Codes, Requirements

Old regulations:

DIN 19712/1997 + DVWK 210/1986 + DVWK 226/1993



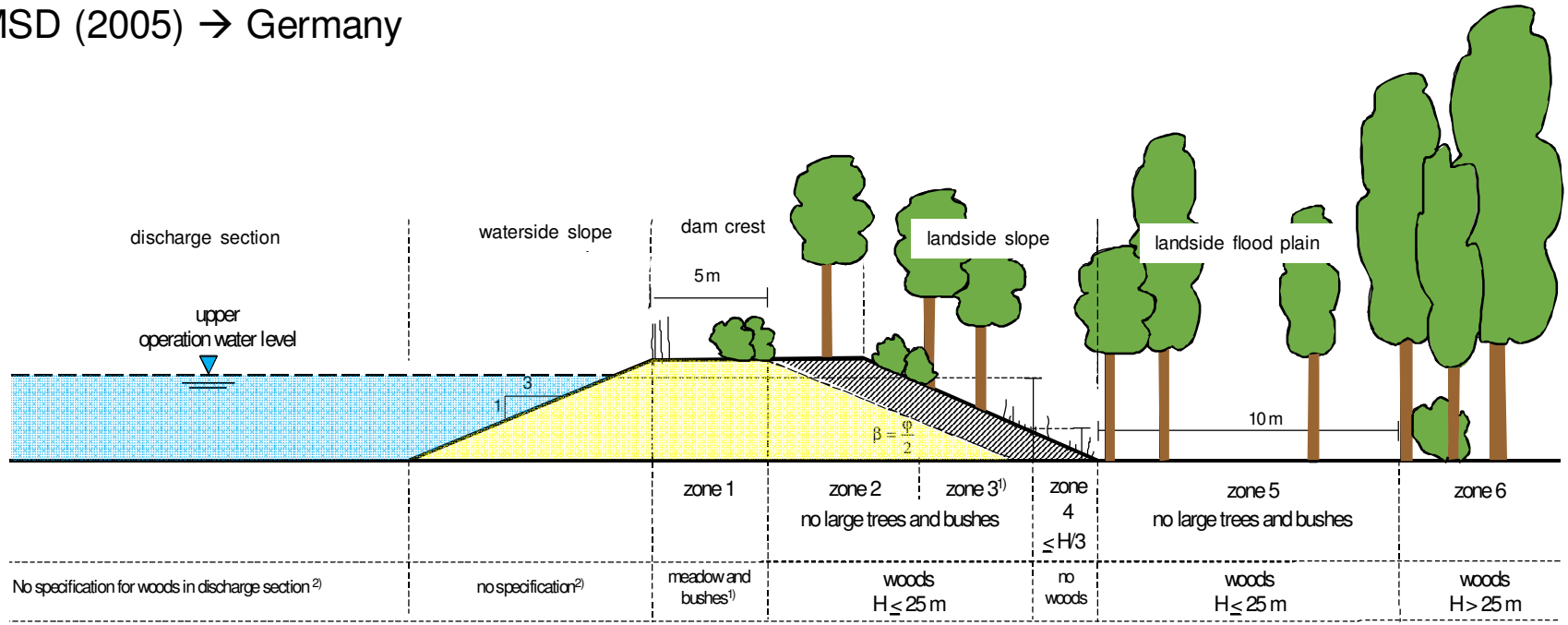
1) Planting should be carried out in groups.

New regulations → "Standard case":

DIN 19712/2013 + DWA-M 507-1/2011 + DWA-M 507-2/under preparation

Regulations, Codes, Requirements

BAW MSD (2005) → Germany



1) Woods should be planted and grown in groups.
2) For a permanent water level no wood growth has to be expected.
3) On dams with centre sealing elements or without sealing elements meadows and single bush groups are allowed. No woods are allowed when surface sealing elements are applied.

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Completed dike construction project in the Mangfall area (Source: WWA Rosenheim)

Ecological Aspects and Targets

- Regulations and Laws, Approach
  - **National Nature Protection Law** (German: Bundesnaturschutzgesetz)
  - Federal Nature Protection Laws (Landesnaturschutzgesetze)
  - Tree Preservation bye-laws (German: Baumschutzsatzungen)
  - Nature Protection Areas (German: Naturschutzgebiete)
  - Natural Monument (German: Naturdenkmale)
  - Alley Protection Statutes (German: Alleenschutz)
  - **Environmental Impact Law** (German: Umweltverträglichkeitsgesetz)
  - …
- Consideration during planning and in design
  - **Environmental Impact Assessment (EIA)**
  - Landscape Management Plan
  - Biodiversity Report, Specific Reports and Studies
  - Compensation Measures

Source: BCE

Ecological Aspects and Targets

- Measures – Mapping, Assessment, Avoidance, Minimization, Compensation
  - Mapping of fauna and flora species → **3 to 5 years validity** of the results
  - Interactive planning and design process → The technical design goes always ahead of the environmental works → Assessment of the design (EcoPoints!)
  - **Principle:** It has to be proofed that **no (better) alternative is available**!
  - Define the compensation measures in the Landscape Management Plan
    - **Compensation of the function and impact close to the impact**
    - Substitution of trees by a factor (min. factor 1.0)
    - Transformation of the type of utilization of the lands
    - Realization of other eco measures (such as renaturation of rivers)
    - CEF – Continuous Ecological Functionality (Measures)
    - Environmental payments (**0,25 € to 15 € per EcoPoint**)
    - Protection of trees during construction works

hazel dormouse

reveller

bat

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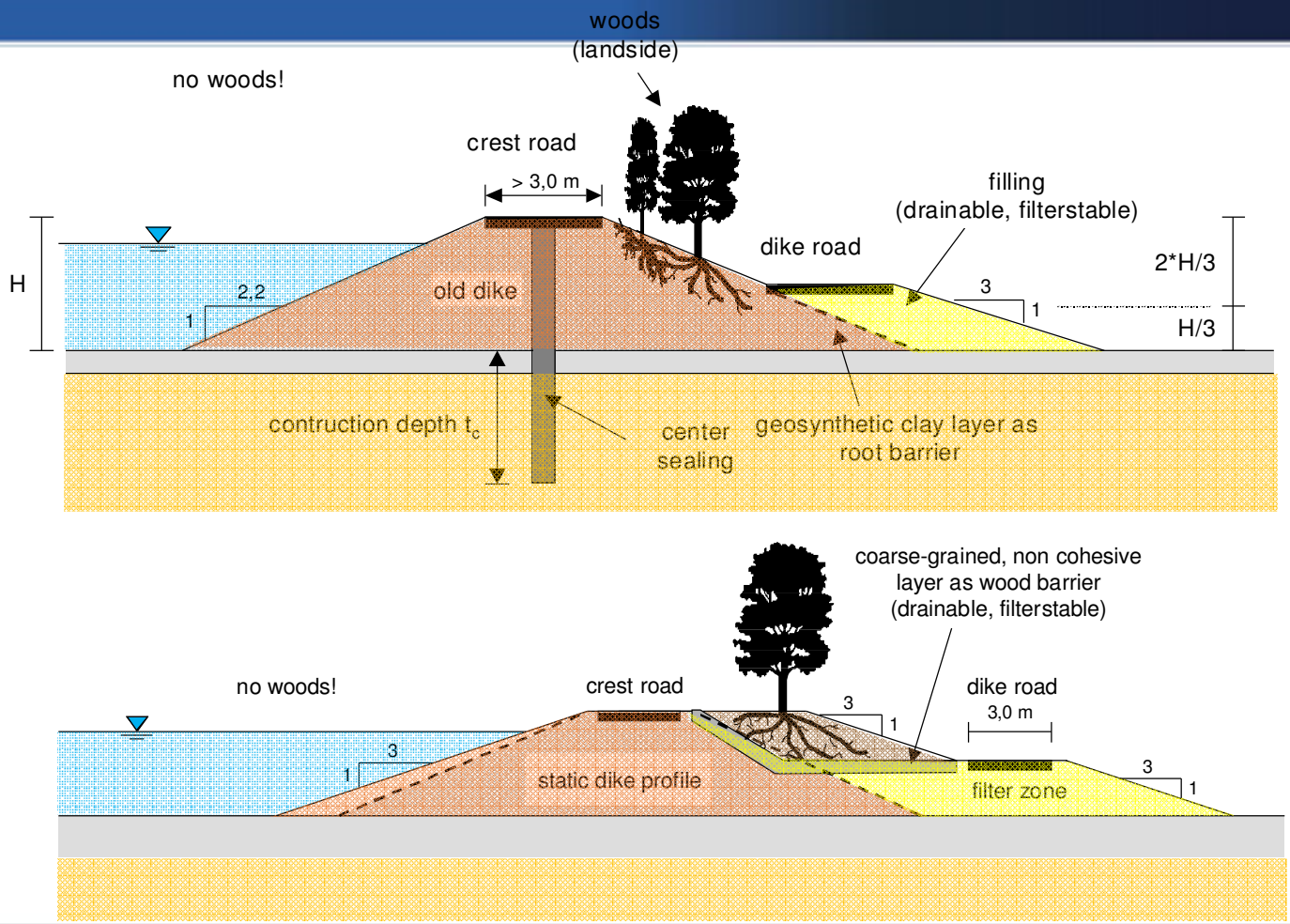
Rehabilitated Isar dike
(Source: WWA Munich, from Haselsteiner & Strobl, 2005)

Technical Solutions

Principle Design Aspects

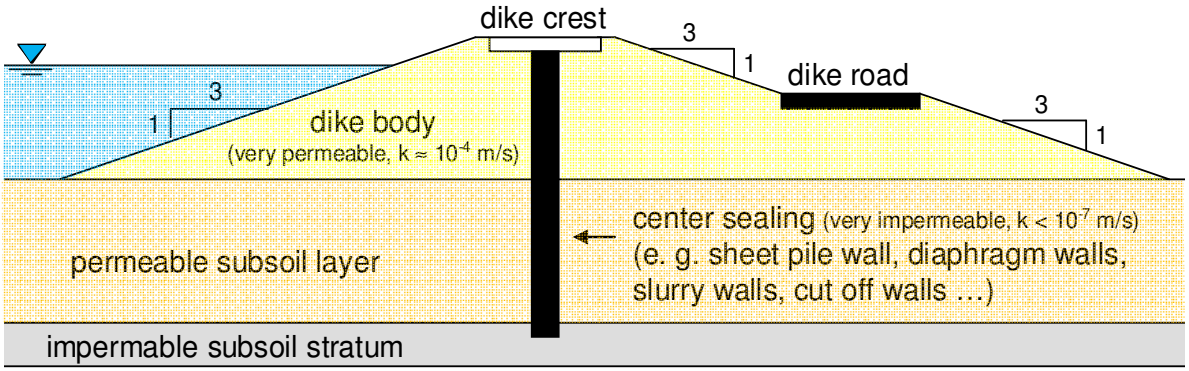
- Avoidance of seepage flow through rooted soils
- Application of root barriers for inner erosion
- Use of root resistant gravely non-cohesive soils
- Application of center sealing



Technical Solutions

Static Center Sealing

- Simultaneous sealing of dike and subsoil
- Reduction of seepage
- Avoidance of or barrier for inner erosion
- Possibility of static properties by reinforcement



PVC Sheet Pile
(Company g²)

Bored MIP wall in dike at
River Danube
(Source: WWA Ingolstadt)

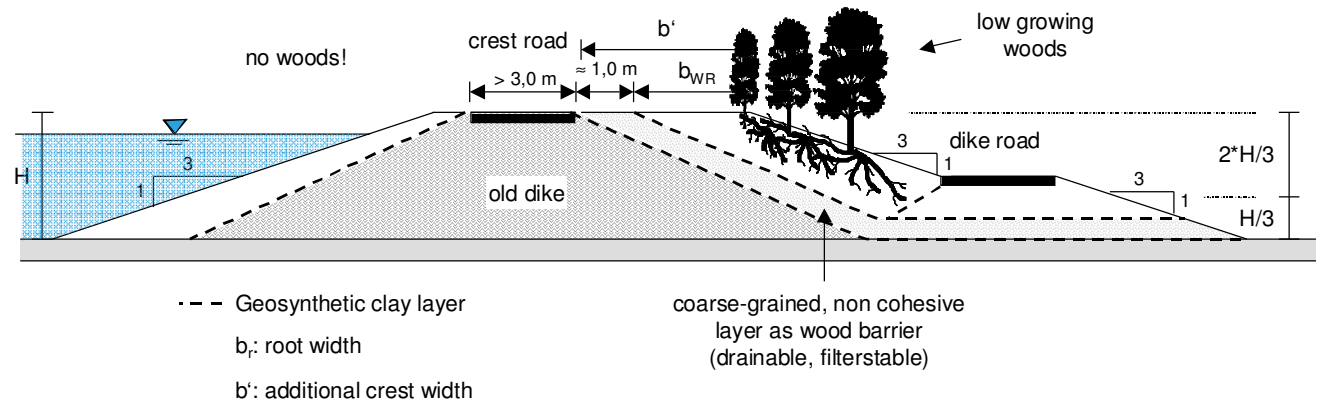
Milled cut off wall in dike at
River Danube
(Source: TUM)

Sheet pile wall in dike at
River Danube
(Source: WWA Ingolstadt)

Technical Solutions

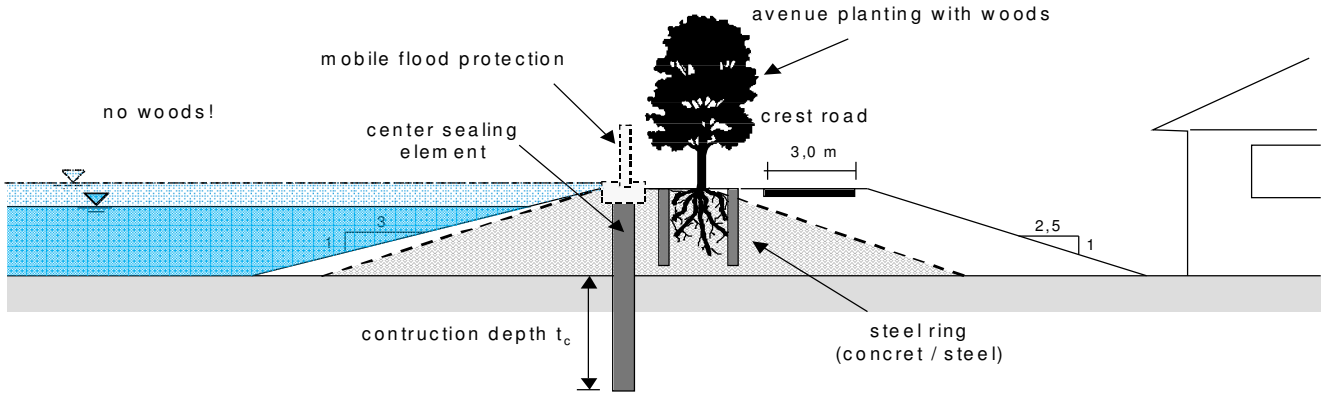
Oversize dike berm ("Eco berm")

- Strengthening of the dike by additional berm
- Avoidance of rooting through the dike body by barriers
- Safety for traffic on roads (!)



Application of root shafts

- Stabilization of the tree by steel shaft
- Avoidance of uncontrolled rooting through the dike body



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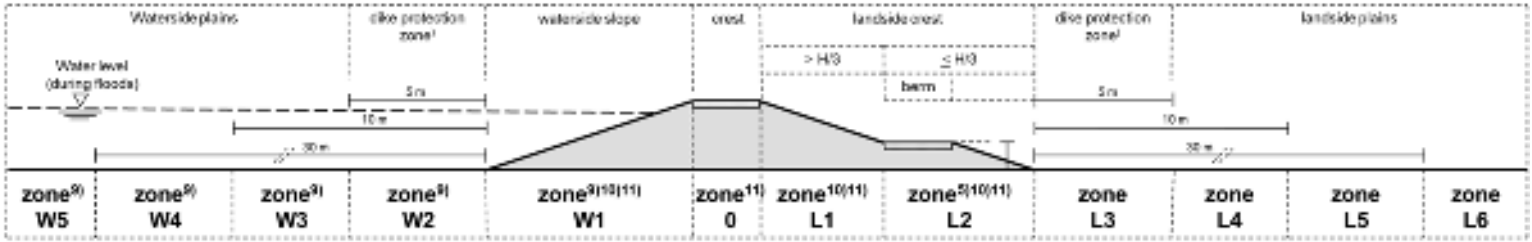
Rows of trees and individual trees at a flood protection wall at the Rhine-Park in Düsseldorf (Source: www.mapio.net)

Best Practice & Case Studies

Admissibility of woods vegetation on dikes regarding risk classes

rc: risk class[7][8]

(classification of woody vegetation mainly after BAW MSD (2005) in consideration of height, root extension and growing velocity)



	protection measures[6][10]	dike-section[2][3]	zone[9] W5	zone[9] W4	zone[9] W3	zone[9] W2	zone[9][10][11] W1	zone[11] 0	zone[10][11] L1	zone[5][10][11] L2	zone L3	zone L4	zone L5	zone L6
	Standard case													
1	none (static necessary dyke section crest)		rc 1	rc 2	rc 3	-	-	-	-	-	-	rc 3	rc 2	rc 1
	Exceptional case													
2	landside oversize section		rc 1	rc 2	rc 3	-	-	-	rc 4	-	-	rc 3	rc 2	rc 1
	Exceptional case													
3	landside and waterside oversize section		rc 1	rc 2	rc 3	rc[4] 4	rc[6][11] 4	rc 4	rc 4	-	rc[4] 4	rc 3	rc 2	rc 1
	Exceptional case													
4	sealing elements with static function		rc 1	rc 2	rc 2	rc 3	rc[6][11] 4	-	rc 4	-	rc[4] 4	rc 3	rc 2	rc 1

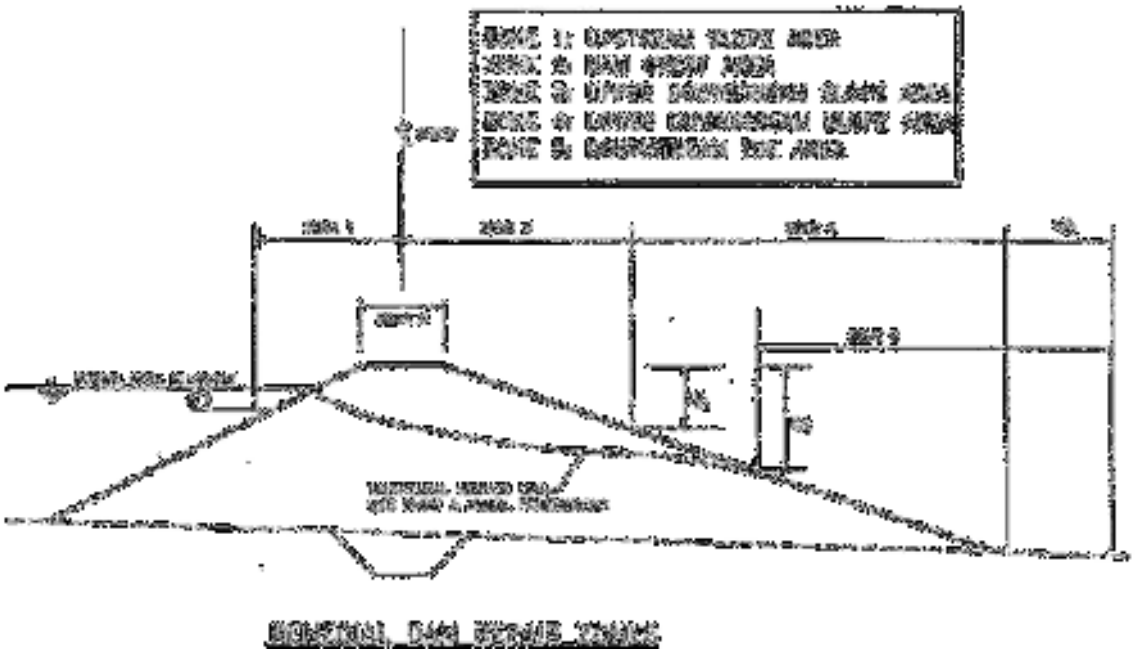
Best Practice & Case Studies

- New Vegetation Concept
  - Need to differ from standards
  - Respect of certain protection measures
  - Respect of vegetation type
  - Roadways and all other ways has to be free from woody vegetation.
  - The **intrusion of roots** into a surface sealing **must be avoided**

risk class	German	English	Botanic
1	Bergahorn	sycamore maple	Acer pseudoplatanus
	Bergulme	wych elm	Ulmus glabra
	Esche	ash	Fraxinus excelsior
	Eßkastanie	chestnut	Castanea sativa
	Stieleiche	common, English oak	Quercus robur
	Weißtanne	white fir	Abies alba
2	Bruchweide	willow	Salix fragilis
	Eberesche/Vogelbeere	sorb, mountain ash	Sorbus aucuparia
	Sandbirke	birch tree	Betula pendula
	Schwarzerle	alder	Alnus glutinosa
	Speierling	sorb-tree	Sobus domestica
	Winterlinde	littleleaf linden	Tilia cordata
3	Grauweide	golden willow	Salix cinerea
	Hasel	hazel	Corylus avellana
	Spindelstrauch / Pfaffenhütchen	evonymus	Euonymus europaeus
	Weichselkirsche	sour cherry	Prunus mahaleb
	Weissdorn (eingriffelig)	hawthorn	Crataegus monogyna
	Wolliger Schneeball	snowball bush	Viburnum lantana
4	Berberitze	barberry	Berberis vulgaris
	Brombeere	blackberry	Rubus fructicosus
	Faulbaum	buckthorn	Rhamnus frangula
	Himbeere	raspberry	Rubus idaeus
	Schlehdorn	blackthorn	Prunus spinosa

Best Practice & Case Studies

- **No woody vegetation**, but exceptions
- No vegetation at overflow sections or spillways
- Restricted forms of vegetation at the slopes
- Consideration of hydraulic aspects
- No woody vegetation within seepage exit
- Safety corridor
- Single trees are more harmful than tree groups
- Removal of trees together with the complete roots

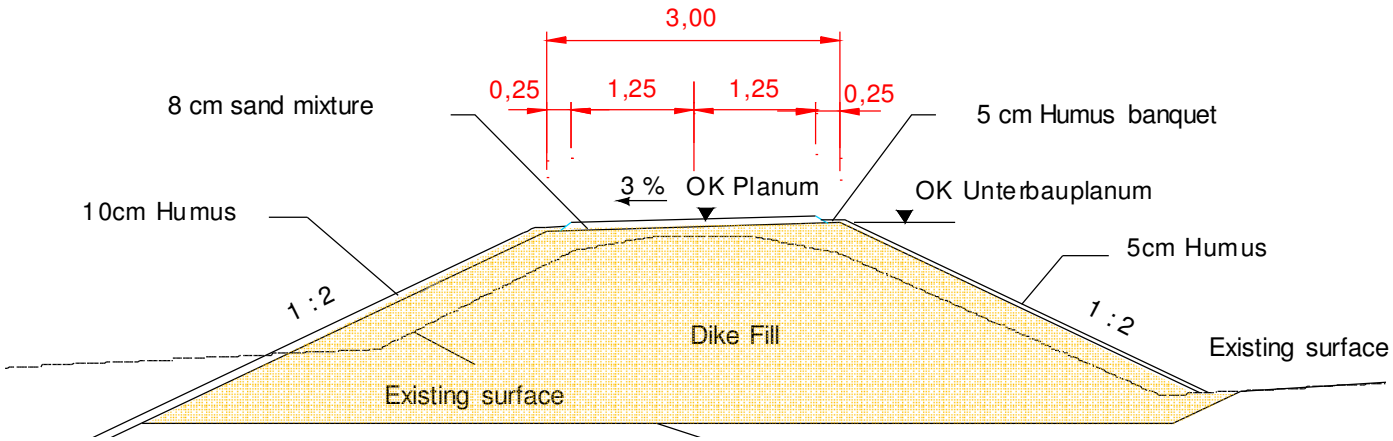


Source: Marks & Tschantz (2002) → USA

Best Practice & Case Studies

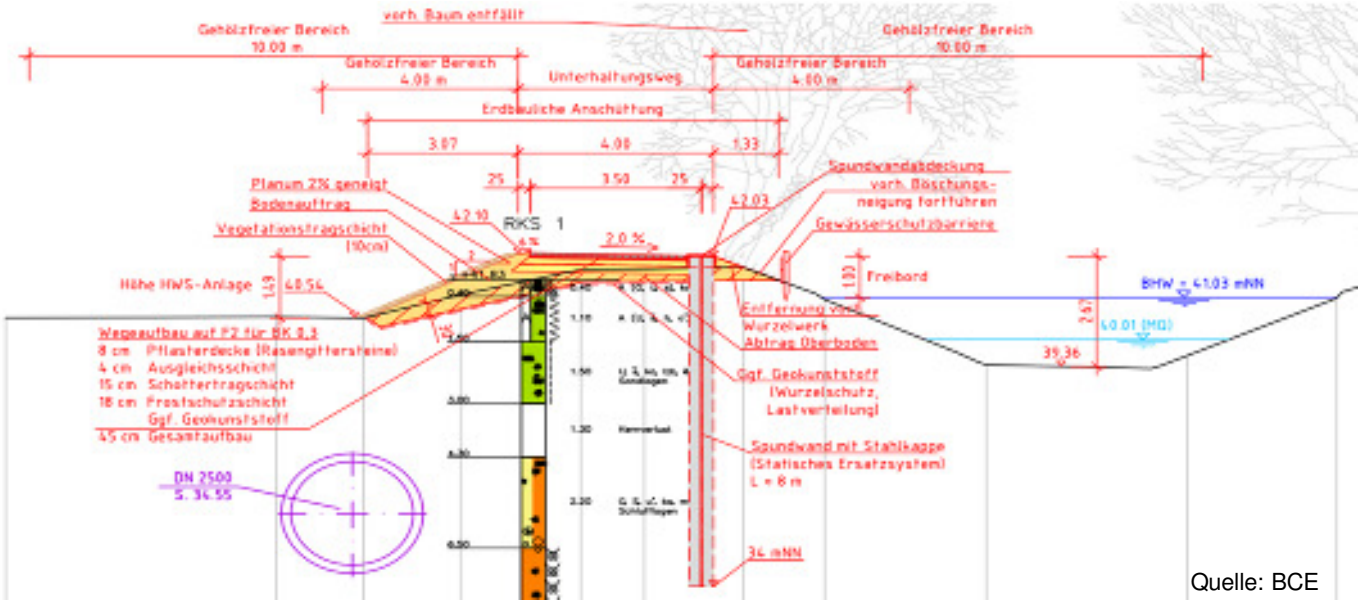
- Dike at the Mangfall near Rosenheim/Bavaria/Germany
  - Inhomogeneous dike body → Complete removal of old dike body
  - Reconstruction of the dike with modified geometry (recycling!)
  - **Complete tree removal**
  - Pure earth works solution

Quelle: WWA Rosenheim



Best Practice & Case Studies

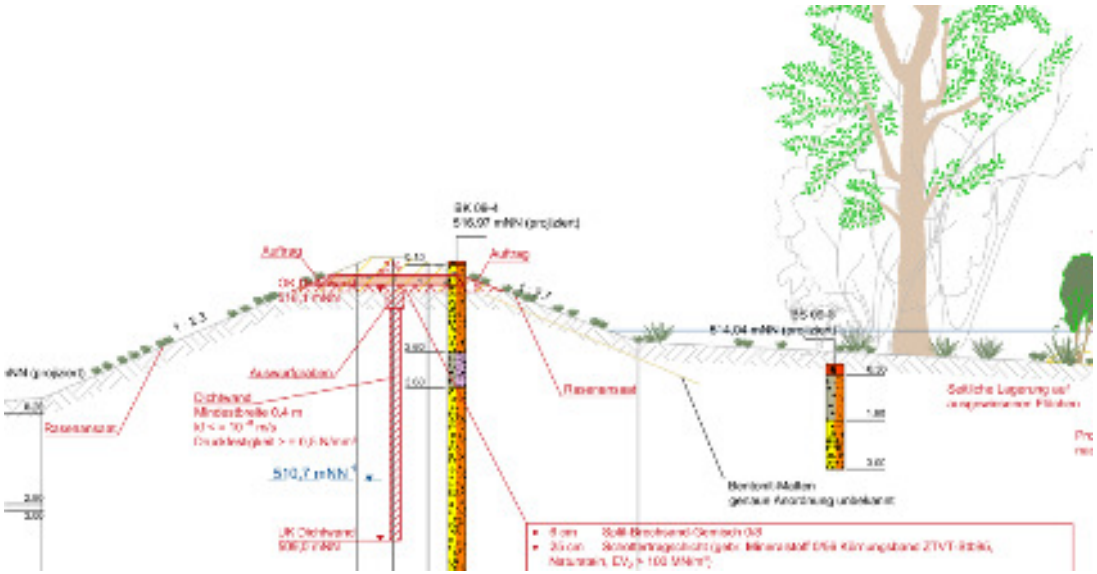
- Dike on Itter in Düsseldorf at the Rhine/Germany
  - No additional area available
  - **Statically effective sheet pile wall**
  - Area by area dike elevation
  - **Complete removal of woody plants** in dike protection zones I and II



Quelle: BCE

Best Practice & Case Studies

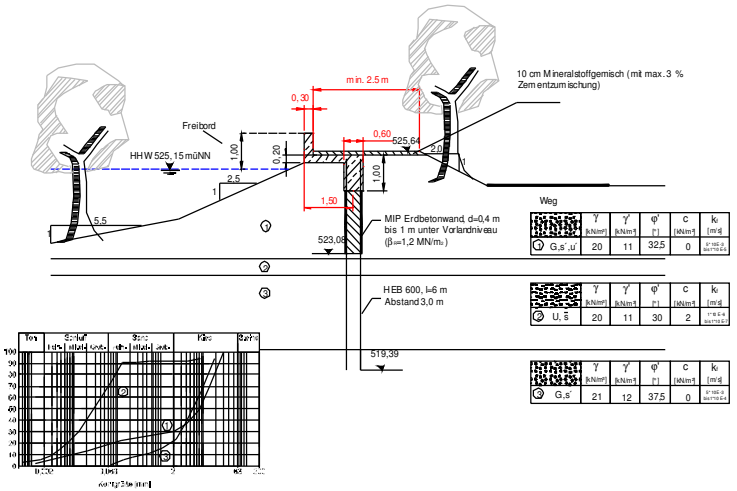
- Dike in Dietenheim/Balzheim Iller/Germany
  - **Statical mixed in place (earth concrete) wall**
  - Adjustment of the dike crest
  - Placement of a crest road
  - **Conservation of the existing tree vegetation**



Quelle: BCE

Best Practice & Case Studies

- Dike in Munich at the Isar/Bavaria/Germany
  - Minimal impact on the existing dike
  - **Static mixed in place (earth concrete) wall**
  - Dike heightening
  - **Conservation of existing tree vegetation**

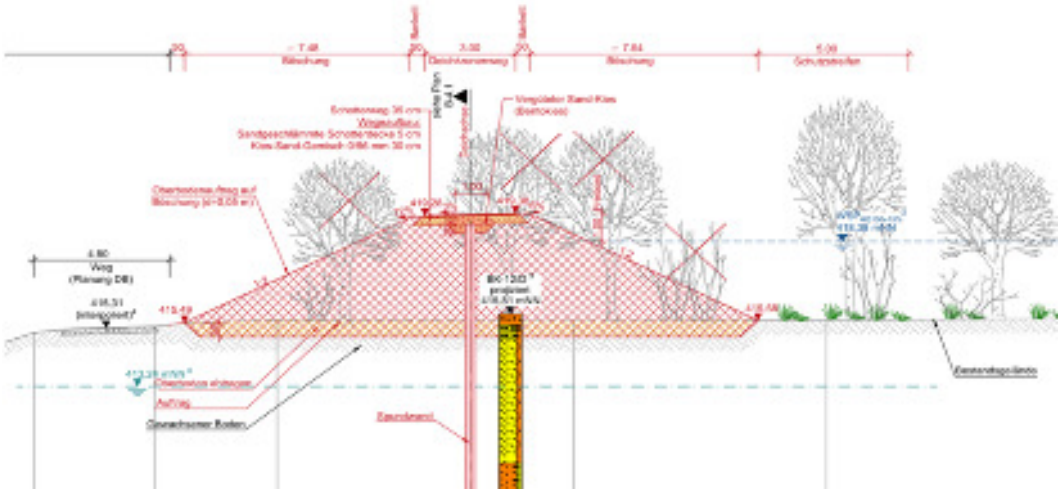


Quelle: WWA München

Best Practice & Case Studies

- Dike on the Saalach in Freilassing/Bavaria/Germany
  - **New construction and rehabilitation**
  - Minimization of the land use
  - Allowance of new trees up to the dike foot
  - **Static mixed in place (earth concrete) wall and steel sheet piles**

  → Effects on groundwater

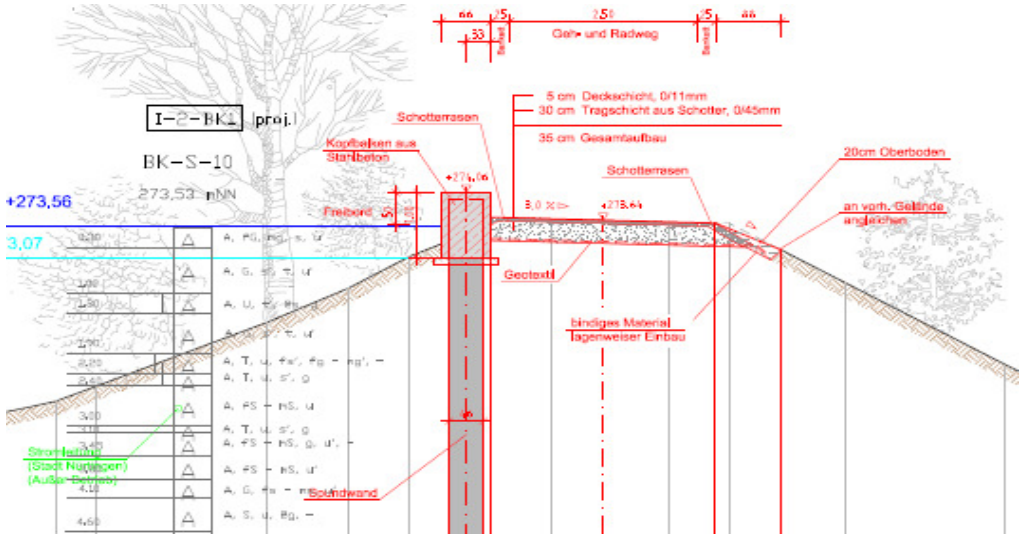


Quelle: www.bgland24.de

Quelle: WWA Traunstein

Best Practice & Case Studies

- Dike at the river Neckar in Nürtingen/Germany
  - Minimization of land use → nature protected areas, biotopes
  - Almost no compensation areas available
  - **Static steel sheet piles by pressing method**
  - **Conservation of most of the existing trees**
  - → **Effects on groundwater**



Levee with trees in Nürtingen at the Neckar in Germany (Source: BCE)

Silent Piler (Hermann Koth Ingenieurbau)

Outline

- Introduction / Motivation
- Occurrence and Effects
- Regulations, Codes, Requirements
- Ecological Aspects and Targets
- Technical Solutions
- Best Practice & Case Studies
- Conclusion

Whittlesey Washes, Peterborough, England (Source: Ogunyoye, 2013)

Conclusion

- The **technical measures** for securing of dikes overgrown with woody plants, especially tall trees, are **complex and expensive**.
- **Detailed, project specific assessment** of actual conditions in consideration of consequences and vulnerability
- **Continuous maintenance** and monitoring is necessary to avoid "surprising" conditions or refurbishment/removal.
- International (and German) **regulations and "experience" available** (Be aware of stricter environmental regulations!)
- Balance of landscape, environmental, recreation, and other aspects
  → **Technical (and economical) requirements dominate (!)**

Outro

Wood-chopping works for a levee rehabiliation at the river Herrenbach during May 2018 (Augsburg/Germany)

Source:
Münchner Merkur
dpa / Stefan Puchner

„"Wood-chopping is so beloved because the success of this work can be realized immediately."

Albert Einstein, German Physician (1879-1955)

„Holzhacken ist deshalb so beliebt, weil man bei dieser Tätigkeit den Erfolg sofort sieht."

Albert Einstein, dt. Physiker (1879-1955)