

European Club of ICOLD Working group on Levees and Flood Defences EUCOLD LFD WG



Lessons learned from levee incidents and failures of German case studies

Working Group Meeting, 5th September 2023, Interlaken

M. Sc. Burcu Ersoy, M. Sc. Lucas Werner, Dr.-Ing. Ronald Haselsteiner

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Introduction

General aspects

German conditions

Selected German case studies – lessons learned



Introduction Flood frequency and damages during the last decades in Germany

Quelle: Bayrisches LfU

Monestry Weltenburg during Danube flood1999,

Old town of Cologne1995 with view on the dome, Source: StEB Köln

15 6.7 Financial damage [billion €] (0.2)980 1990 2020 1988 2010 2013 1997 1999 2000 2002 2005 2021 1993/1995

Levee failure nearby Stadldorf during Danube flood 1988 – initial breachign stage, Source: WWA Deggendorf

3

Levee defence works carried out by soldiers during Oder flood 1997 (Source: www.planet-wissen.de)

Flood on the Isar 2005, Beaver caves, Source: WWA Freising (from Kleber-Lerchbaumer, 2010)

Flood on Mulde River 2002 at Weesenstein,

Source: www.si-journal.de

Elbe Flood 2013 – Levee failure near the village Fischbeck, Source: Jüpner (2016)

Flood 2021 on the River Erft, City Erftstadt Blessem,

Source: www.rnd.de

| Working Group Meeting, 5th September 2023, Interlaken - Lessons learned from levee incidents and failures of German case studies – Werner, Ersoy, Dr. Haselsteiner

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German conditions

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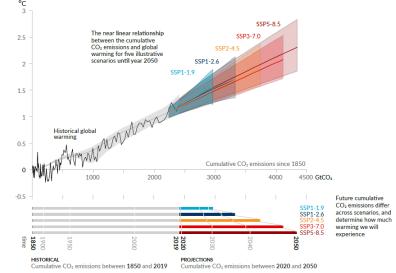


General aspects

General requirements and challenges

- General requirements
 - Levees have to be designed, constructed, maintained and operated so that their **stability and serviceability** are always given.
 - Flood protection works do always have priority over all other uses and requirements; usually compromises need to be established without degradation of safety aspects (stability, defense, supervision, maintenance, access...)
 - Nature and environmental requirements need always to be considered and all measures have to be taken to avoid, reduce and compensate interferences.
- Challenges
 - Climate change → Impact on loads (hydraulic load) and impact on structure
 - Ageing of structures → The smaller the structure, the "harder" the ageing effects
 → levees are frequently relative small structures → long-term perspective
 - Knowledge management → Engineering basics misremember period
 - Long-term financing → Flood misremember period
 - • • •

\rightarrow Resilient and slender designs and structures



Source:

IPCC (2021): Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press.

Legend:

SSPx-y: Shared Socio-Economic Pathway x: Number SSP

y: Level of radiative forcing (in W/m²)

General aspects

Causes and reasons for levee incidents, damages and failures

- Outdated hydrological and hydraulic conditions → inadequate water levels
- Environmental impacts (animals, woods roots) on levee body and underground
- Upcoming of inadequate vegetations (large trees)
- Inadequate design and construction works
- Inadequate structural adaptations and works
- Ageing of materials
- Changes of underground conditions
- Inadequate maintenance
- → Intensification by climate change effects

Levee failure on river Ammer after flood 1999 in Bavaria (Source: WWA Weilheim)

Levee failure on river Loisach (Loisach) after 1999 flood in Bavaria (Source: WWA Weilheim)







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Selected German case studies – lessons learned Conclusion



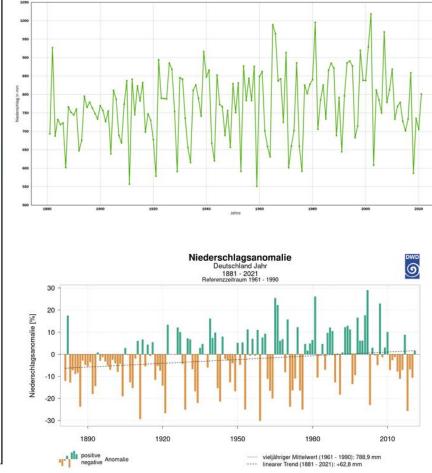
German conditions

Basins, hydrology, hydraulics and levees

- The huge catchments drain via first degree rivers
 - Danube
 - Rhine
 - Weser
 - Elbe
 - Ems
 - Oder
- Annual precipitation ranges from 500 to 1,000 mm/a on average for complete Germany, peaks in the Alps in the south, lows North-East.
- Trend of precipitation is positive, but anomalies are negative during the last decade → Droughts (and floods)



Zeitreihe der Niederschlagssummen in Deutschland seit 1881 in mm

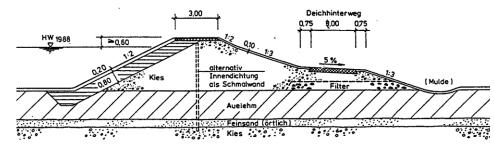


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German conditions

Basins, hydrology, hydraulics and levees

- Floods are not longer dominated by long-lasting continental rains
 exclusively and snow melt but also by stormwater events (flash floods) such as occurred in 2021.
- Uncertainty of the design principles and criteria is increasing → resilient levees need to be designed which also reduce the residual risks and extreme load cases.

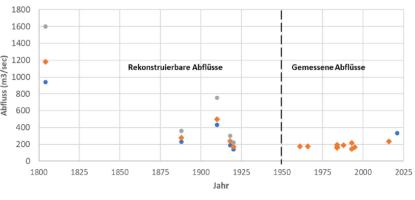


"Old" standard dike section of Danube River



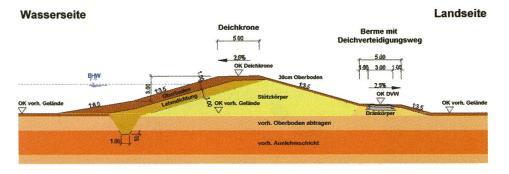
Hochwasser im Ahrtal - Historische Betrachtung und die Flut 2021 Dr. Thomas Roggenkamp Geographisches Institut Universität Bonn

Pegel Altenahr - Abfluss für die Reihe 1804-2021 (Hochwasserereignisse)



Minimaler Abfluss 🛛 🔶 Abfluss Mittelwert 💿 Maximaler Abfluss

CEDIM (2021): Hochwasser Mitteleuropa, Juli 2021 (Deutschland), 21. Juli 2021 – Bericht Nr. 1 "Nordrhein-Westfalen & Rheinland-Pfalz"Forensic Disaster Analysis (FDA) Group



Standard dike section of Lower Rhine River

German conditions

Regulations, codes and standards

- DIN 19712/1997 Levees Ο
 - → DIN 19712/2013 "Flood Protection Structures"
- DVWK 210/1986 Levees 0

→ DWA M 507 Part 1 2011 Levees

- DVWK 226/1993 (published, yellow paper) Ο → DWA M 507 Part 2 "Ecological Aspects Levees"
- DWA (2005) (under revision) Ο
 - → DWA M 507 Part 3 "Drainage/Sealing Levees"
- BAW MSD (2011) Dams along waterways Ο
- DIN 19700/2004 Dams ... Ο

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General aspects

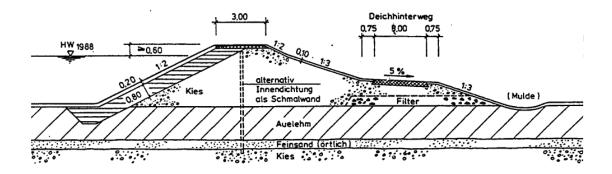
German conditions

Selected German case studies – lessons learned



Old existing dikes with deficits not confirming to up-to-date regulations

- Situation
 - In consideration of actual impacts and flood incidents design fundamentals were adapted
 - For the different rivers and basins different design principles and standard sections were established
- Explanation
 - In Germany the federal states are responsible for the realization of flood protection projects
 - Although general design principles, requirements and specification are available their interpretation strongly varies
 - In addition the effects such as climate change, ageing and a lack of maintanence shows a critical impact on the performance of recommended standard designs
- Damage, deficits, threads, risks
 - Inadequate sealings (clay, thin walls...)
 - Inadequate soil materials
 - Inadequate roads incl. pavements etc.
 - Inadequate maintenance (vegetation...) ...



Standard design section developed by the WWA Deggendorf after flooding 1988 on the Danube (taken from Weiß 1997)

- Lessons learned
 - Adapt project specific designs
 - Detailed study of design variations and solutions
 - Consider long-term performance / Durability during design stage
 - Adaptation of "resilient" designs
 - Read and understand the available codes, regulations and bulletins
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Levee failure after misleading upgrading of downstream body



- During a medium flood indicent in 1988 at the Danube River a levee failed
- The levee was upgrading shortly before the flood indicdent
- Explanation
 - The downstream slope was enlarged by placing the same soil material as used for the overall existing main dam body
 - But, modern compaction works were applied in order to compact the soil layerwise so that the relative density was higher and the permeability was lower than in the main dam body
 - Pore water pressures devoloped so that a geotechnical slipping failure occured
- Damage, deficits, threads, risks
 - Complete levee failure with flooding
 - Inadequate design and construction \rightarrow inhomogenuous levee section



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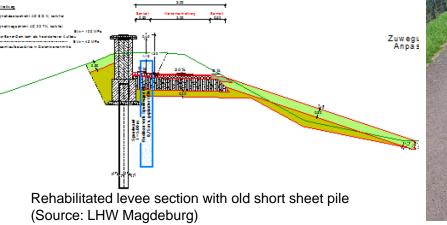
Levee failure at the village Stadldorf during the flood 1988 on the Danubeintitial stage (Source: WWA Deggendorf)

- Lessons learned
 - Rehabilitation and upgrading of levees need to comply the same requirements than a new levee
 - A geotechnical expert need to be consulted; it is not mandatory in all federal states of Germany
 - Read and understand the available codes, regulations and bulletins



Unfavorable deformation of crest caused by inappropriate sheet piling

- Situation
 - After the 1997 flooding on the Oder river ad-hoc stabilization measures were carried out
 - A steel sheet pile was placed in the center of the body integrated only in the flood loam layer (limit depth)
 - After placing the sheet pile an crest road with asp pavement was carried out
- Explanation
 - During stability problems a center sealing was placed in order to guarantee stability upcoming floods → low costs, immediate effect
- Damage, deficits, threads, risks
 - The dike body showed a low density, after further floods the deformations resulted in cracks and major deformations of the crest
 - The design does not comply to techn. requirements



Source. Haselsteiner

- Lessons learned
 - Short-termed ad-hoc measures should be always rechecked after implementation
 - A combination of ad-hoc and long-term measures should be adapted
 - Read and understand the available codes, regulations and bulletins
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Lost levees in upcoming forest

- Situation
 - Due to lack of floods also maintenance was lacking over years also due to poor financial resources
 - Many levee areas "vanished" in upcoming forests •
- Explanation
 - Before the 1980s serious floods were not occurring for decades
 - The importance of flood protection works was • ranked subordindately
 - After decades those forests became nature protection areas
- Damage, deficits, threads, risks
 - All deficits and risks with large trees regarding stability, supervision and maintenance
 - Realization of flood protection or levee rehabiliaton project difficult if special nature protection zones or protected species are present

Wooded levee at the River Danube nearby (Source: StUGV)



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Wooded levee at the River Iller nearby

Altenstadt (Source: TUM)

- Lessons learned
 - Levees are technical flood protection structure which require strict • supervision and maintenance
 - Forests and large trees contradict all requriements of a flood protection structure
 - Read and understand the available codes, regulations and bulletins
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Pipe failure at a Lower Rhine Dike

- Situation
 - In January 2023 a sink hole occurred within a dike at the Lower Rhine which was constructed some years ago
 - The sink hole developed over night and ad-hoc safety measures were initiated
- Explanation
 - A wastewater pressure pipe leaked and transported soil material from the underground so that a sink hole occured on the surface
 - The operation of the pumping station was stopped and within a few days the pipe section was replaced and the construction pit was refilled
- Damage, deficits, threads, risks
 - The pipe is located under or near the Rhine levee whith does not comply to regulations
 - No protection pipe was applied → The pipe failure caused critical erosion
 - The refilling of the pit was not done according to regulations



- Lessons learned
 - For new levees also old existing structures should be adapted, or as here shifted and replaced
 - A adequate emergency action plan should be available which also dictates the integration of expert knowledge in emergency situations
 - Read and understand the available codes, regulations and bulletins → Clear regulations for refilling were not given



Erosion of levee caused by bridge scour

- Situation
 - During a medium flood indicent in June 2023 a scour occurred a railway bridge of ther Emscher River
 - The bridge suffered serious deformation
 - The adjacent levee suffered considerable erosion of the upstream slope
- Explanation
 - Flow concentration at a bridge section of the Emscher River resulted in high velocities and scouring
 - The scouring/erosion impacted a few hundred meters of the levee
 - A complete failure did not occur thanks to the short flood period
- Damage, deficits, threads, risks
 - Complete erosion of the upstream levee body
 - The risk of breaching was critical





https://www1.wdr.de/nachrich ten/ruhrgebiet/emscherdeichdinslaken-bruch-droht-100.html

- Lessons learned
 - Special structures within a levee always represent a risk
 - Damages on these structures may extend to the levee
 - Structures within a levee/river should consider flood protection safety level
 - Read and understand the available codes, regulations and bulletins
- 17 | Working Group Meeting, 5th September 2023, Interlaken Lessons learned from levee incidents and failures of German case studies Werner, Ersoy, Dr. Haselsteiner



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Flood protection and levee rehabilitation is a Sisyphus work

- Resilient and slender designs and structures meet all requirements best in consideration of future challenges such as climate change and ageing.
- An **open-minded culture** of failure is required paired with the personal and overall will of improvement as part of knowledge management.
- The importance of flood protection needs to be emphasis by **lively "lobby" work** on all fields. This supports the financing issue.

"An Optimist is a human being, who consider the things not so tragic as they actually are."

Karl Valentin (* 4. Juni 1882 in Munich; † 9. Februar 1948 in Planegg) German comedian, folksinger, author and movie maker.

"The struggle itself toward the heights is enough to fill a man's heart. One must imagine Sisyphus happy."

Albert Camus (7 November 1913 – 4 January 1960) French philosopher, author, dramatist, journalist, and political activist.

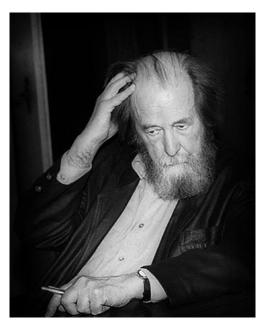






"The solution is always simple, you just have to find it."

Alexander Issajewitsch Solschenizyn (1918-2008), Russian writer and noble prize winner







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