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

M&P WATER

Lessons learned from levee incidents and failures of German case studies

Working Group Meeting, 5th September 2023, Interlaken

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Conclusion

Introduction

Flood frequency and damages during the last decades in Germany

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

Monestry Weltenburg during Danube flood1999, Quelle: Bayrisches LfU

Flood on Mulde River 2002 at Weesenstein, Source: www.si-journal.de

Flood 2021 on the River Erft, City Erftstadt Blessem, Source: www.rnd.de

Financial damage [billion €]

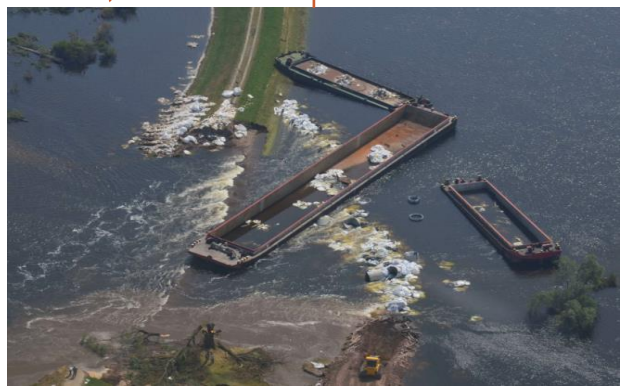
1980 | 1988 | 1990 | 1993/1995 | 1997 | 1999 | 2000 | 2002 | 2005 | 2010 | 2013 | 2020 | 2021

0,2 | 0,3 | 0,3 | 15 | 0,2 | 6,7 | 7,0

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

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)



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

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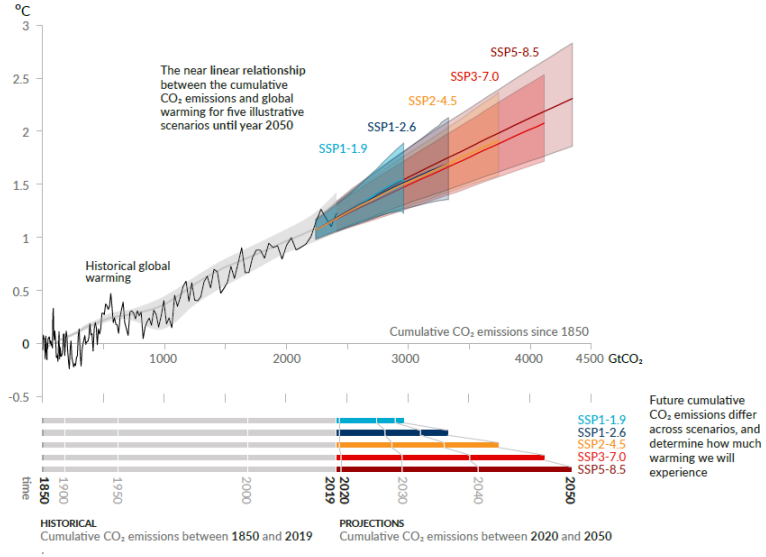
General aspects

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
  - ….

→ 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 Loisach (Loisach) after 1999 flood in Bavaria (Source: WWA Weilheim)

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

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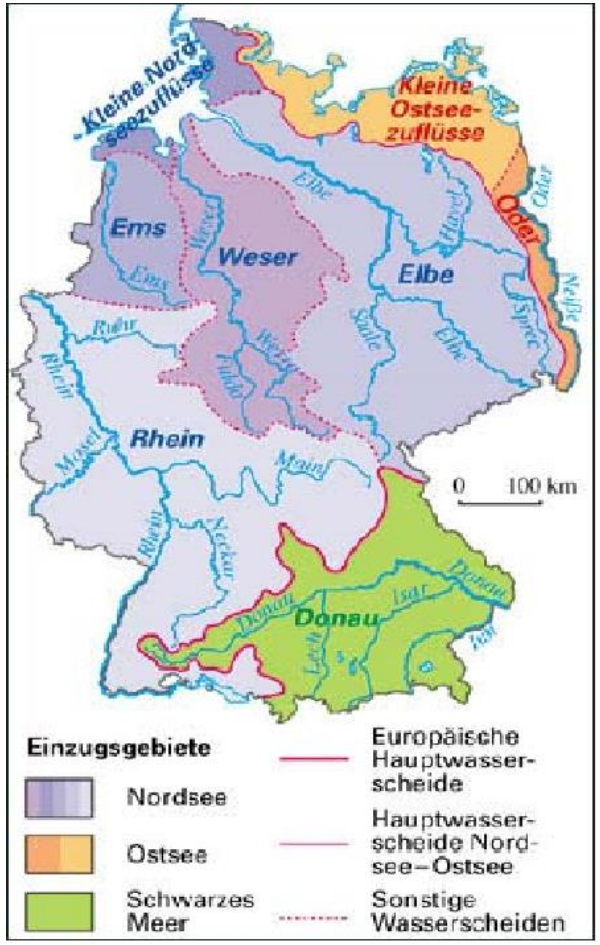
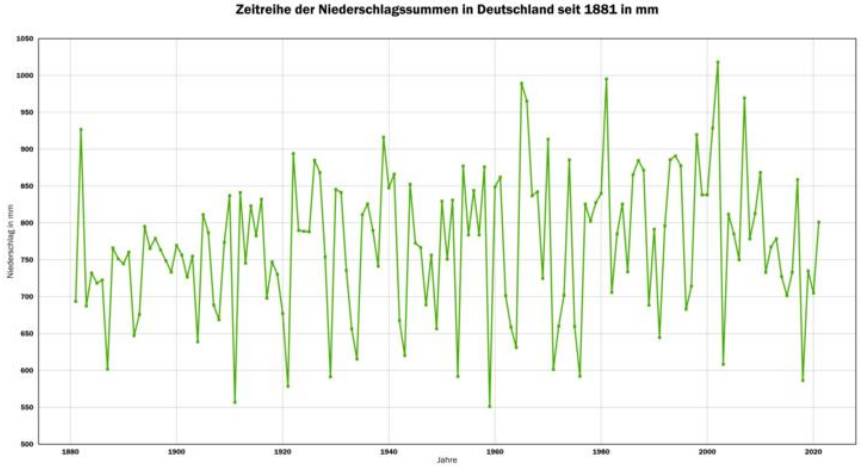
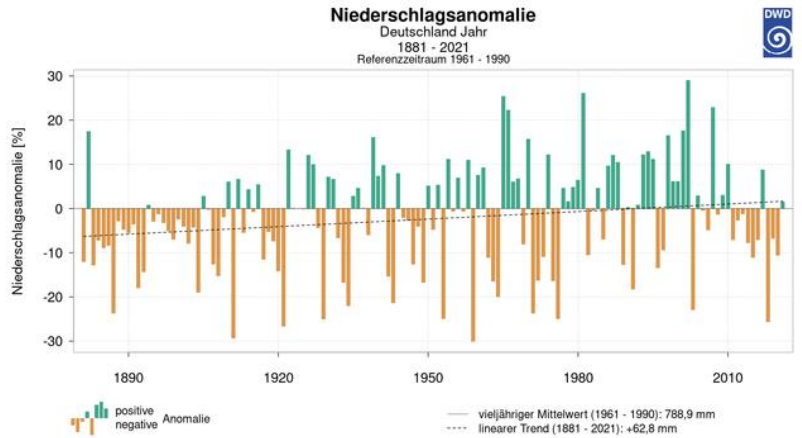
German conditions

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)





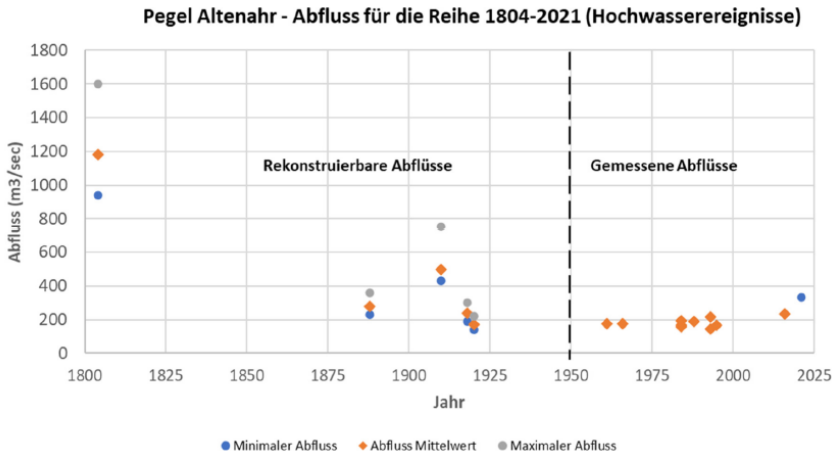


German conditions

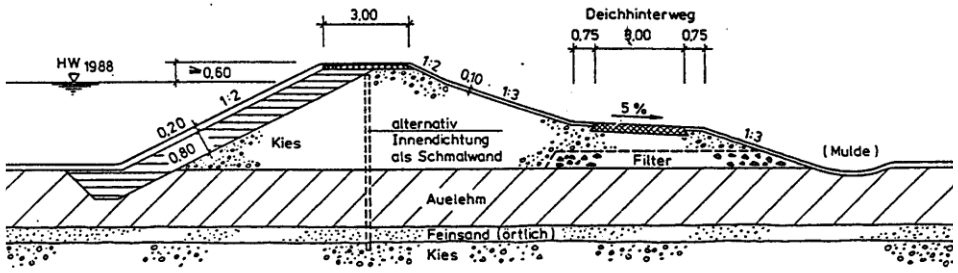
Basins, hydrology, hydraulics and levees

- **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.

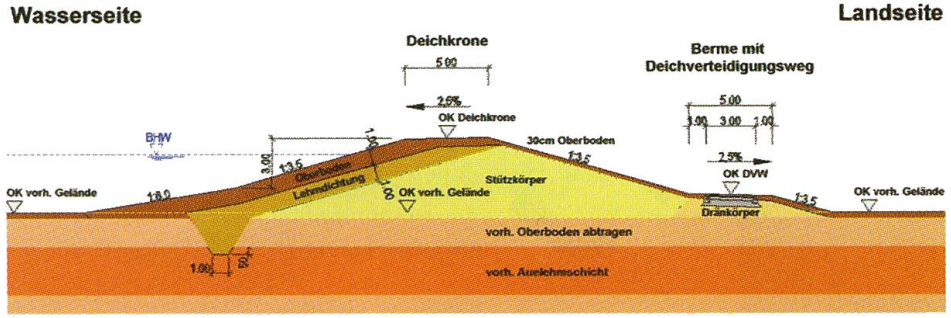
Hochwasser im Ahrtal - Historische Betrachtung und die Flut 2021 Dr. Thomas Roggenkamp Geographisches Institut Universität Bonn



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



„Old" standard dike section of Danube River



Standard dike section of Lower Rhine River

German conditions

Regulations, codes and 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 (published, yellow paper)
  - → **DWA M 507 Part 2** “Ecological Aspects Levees”
- DWA (2005) (under revision)
  - → **DWA M 507 Part 3** “Drainage/Sealing Levees”
- BAW MSD (2011) Dams along waterways
- DIN 19700/2004 Dams …

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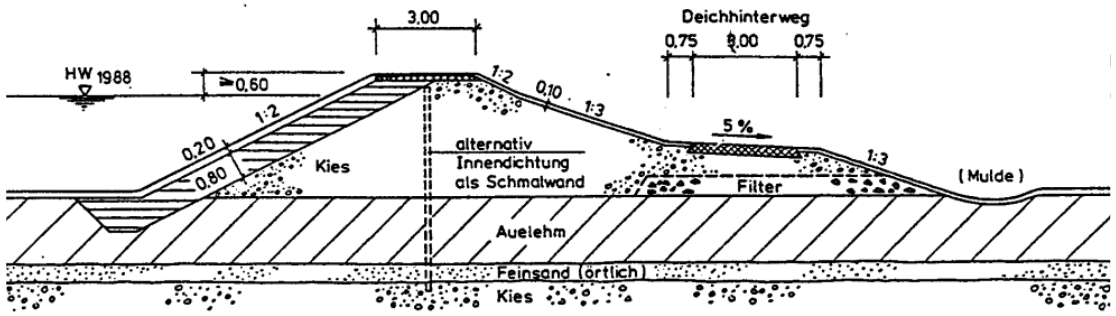
Selected case studies – lessons learned

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

Selected case studies – lessons learned

Levee failure after misleading upgrading of downstream body

- Situation
  - 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 → inhomogenuous levee section

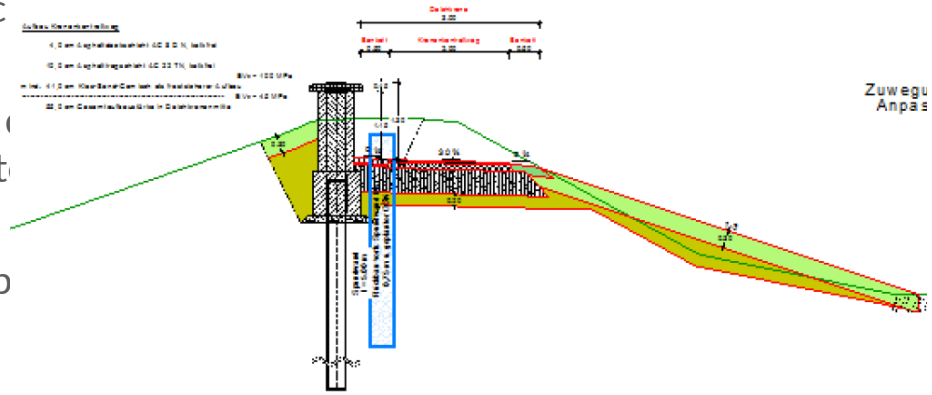
Levee failure at the village Stadldorf during the flood 1988 on the Danube-intitial stage (Source: WWA Deggendorf)

- 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

Selected case studies – lessons learned

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 dike body integrated only in the flood loam layer (limited depth)
  - After placing the sheet pile an crest road with asphalt 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



Rehabilitated levee section with old short sheet pile
(Source: LHW Magdeburg)

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

Selected case studies – lessons learned

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)

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

Selected case studies – lessons learned

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

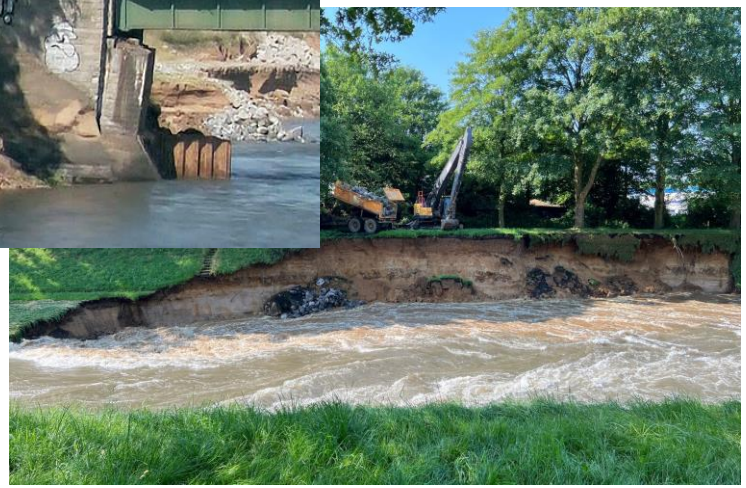
- Lessons learned
  - For new levees also old existing structures should be adapted, or as here shifted and replaced
  - A adequate emergency action plan should be available which also dictates the integration of expert knowledge in emergency situations
  - Read and understand the available codes, regulations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

Selected case studies – lessons learned

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

Source: https://www1.wdr.de/nachrichten/ruhrgebiet/emscherdeich-dinslaken-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

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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.“

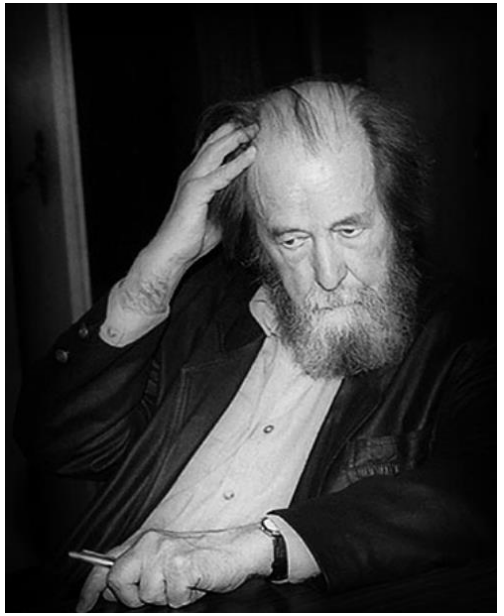
Karl Valentin (* 4. Juni 1882 in Munich; † 9. Februar 1948 in Planegg) German comedian, folksinger, author and movie maker.

“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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Swiss Committee on Dams 2023
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