Sustainable Architecture, Urban and Landscape Planning, Lecture WS20/21

Integrated Water Resources Management
Integrated Flood Risk Management

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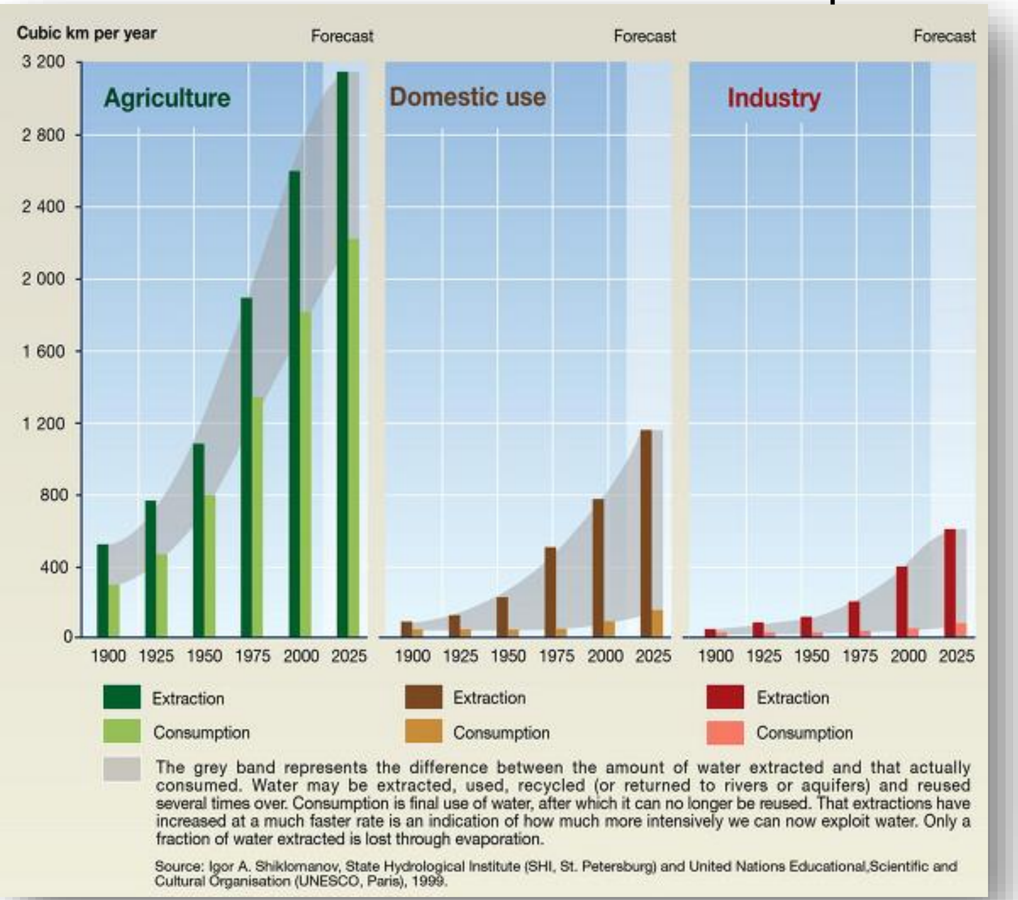
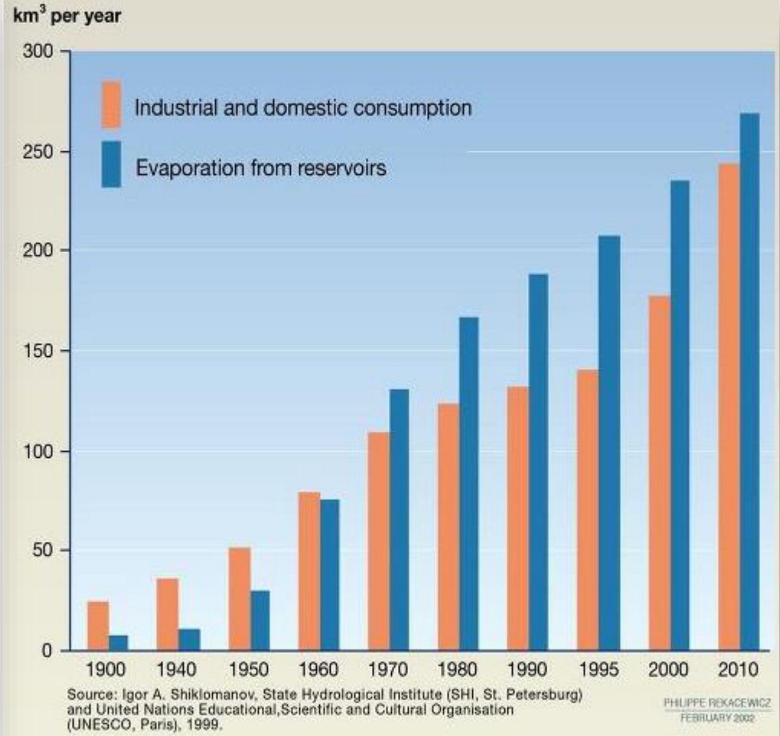
DRIVING FORCES ON WATER RESOURCES

Water consumption change for main water uses

World's population more than **doubled** in the last century,

water consumption **six-folded**!

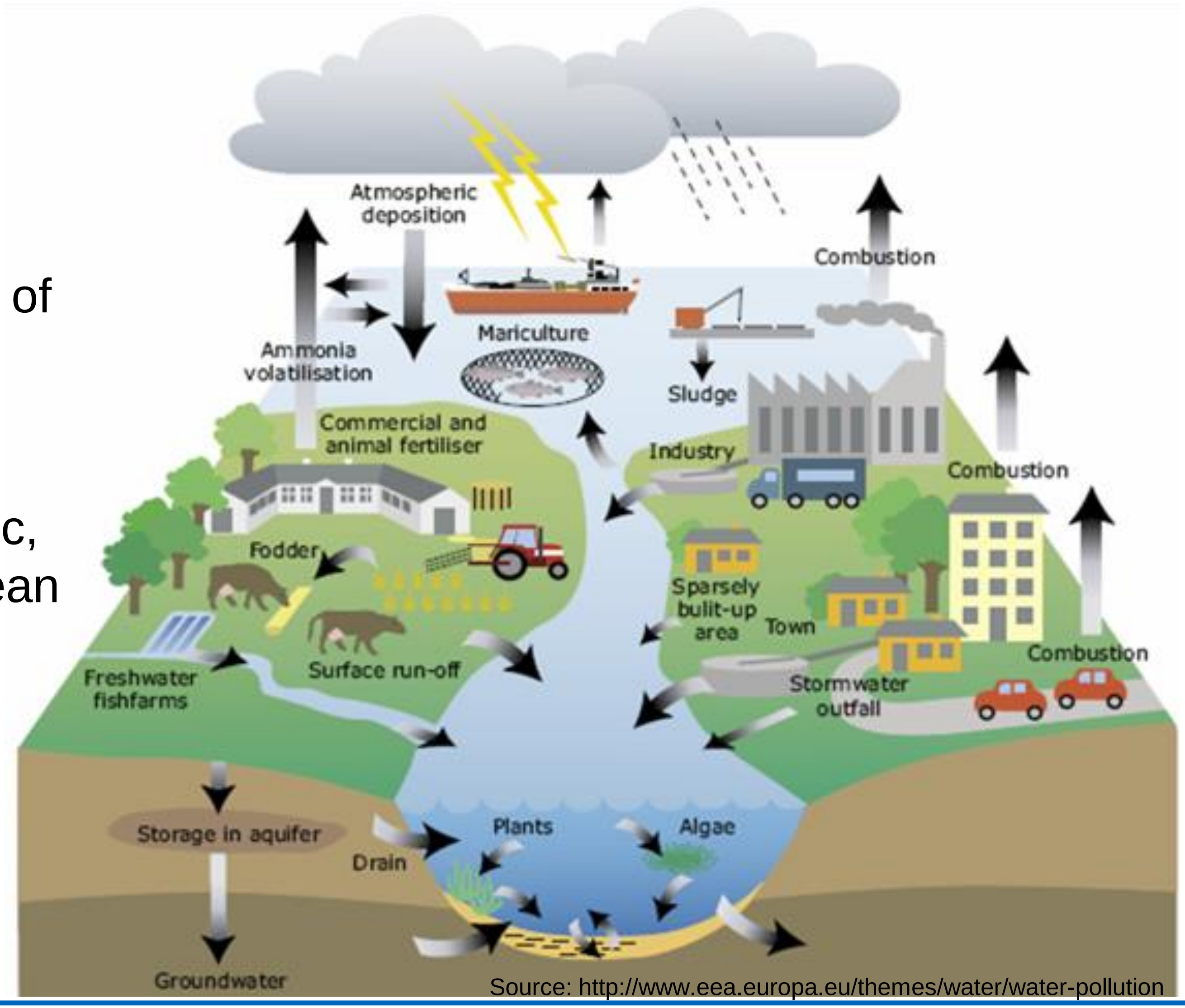




DRIVING FORCES ON WATER RESOURCES

Water pollution

- **Dirty water:** world's biggest health risk
- Threatens both quality of life and public health
- **7 million tons of garbage**, mostly plastic, is dumped into the ocean every year
- Around 70% of the industrial waste is dumped into the water bodies



Source: http://www.eea.europa.eu/themes/water/water-pollution

DRIVING FORCES ON WATER RESOURCES

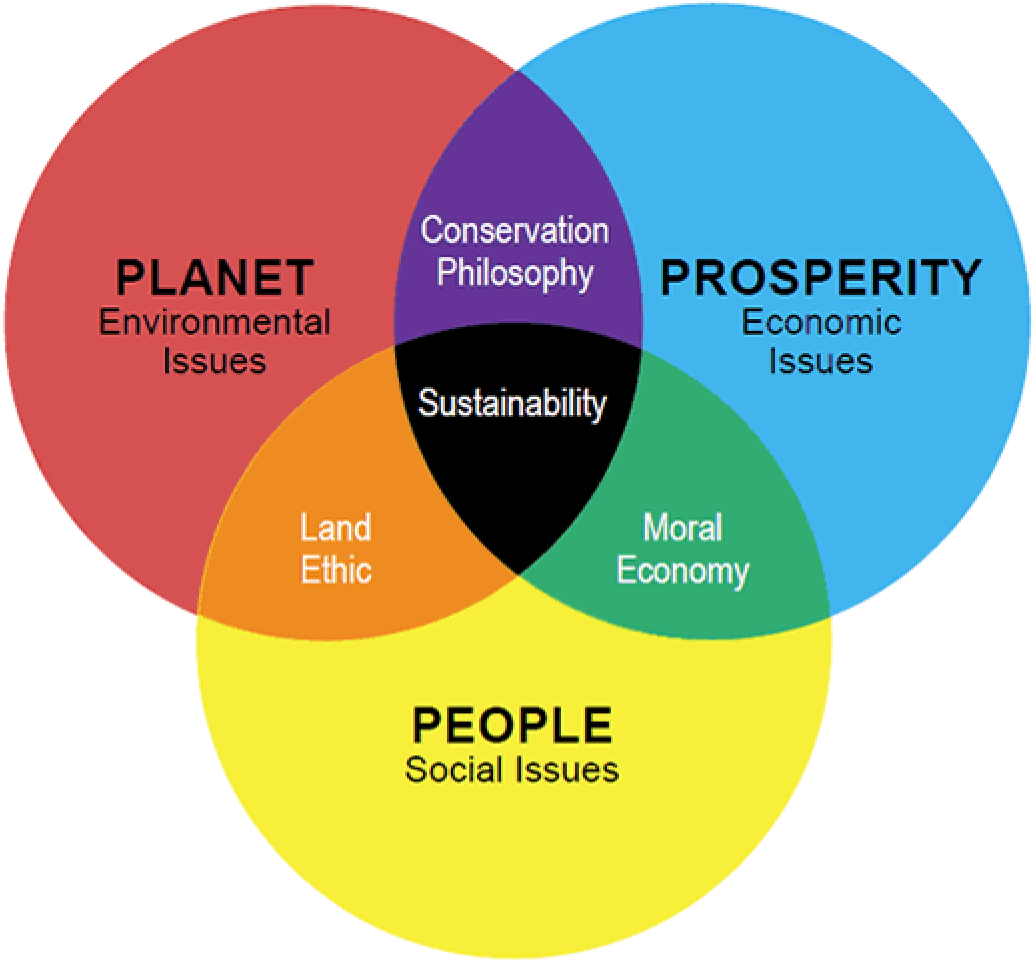
Climate Change/ Variability

- **Fundamental concern:** Impact of climate change on hydrological cycle:
  - changes in precipitation patterns
  - changes in intensity and timing of precipitation
  - changes in partitioning of incoming solar radiation between evapotranspiration and sensible heat due to land-cover change

- Intensification and acceleration of future water cycle
  - ✓ Affecting water availability and demand
- Increasing intensity and frequency of floods and droughts
  - ✓ Coping and adaptation

SUSTAINABILITY CONCEPT: THREE ES

ENVIRONMENT



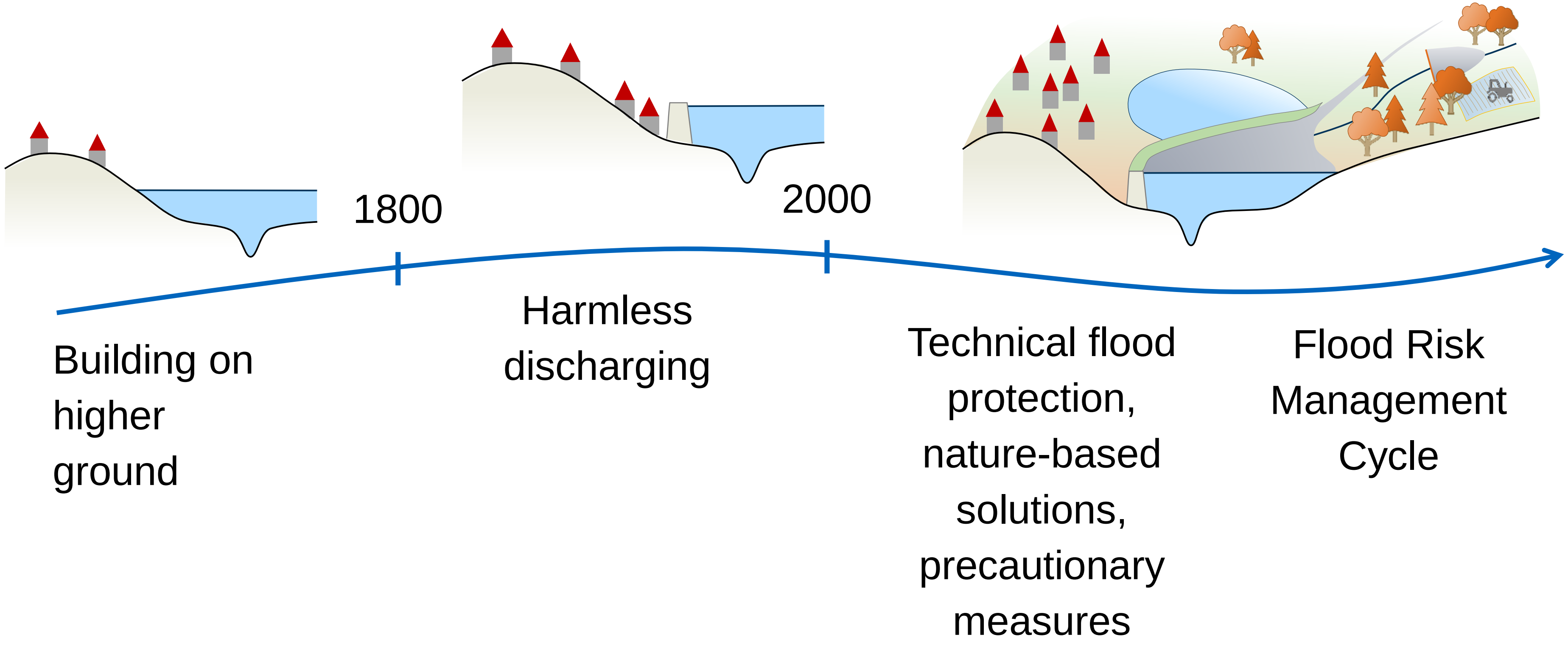
ECONOMY

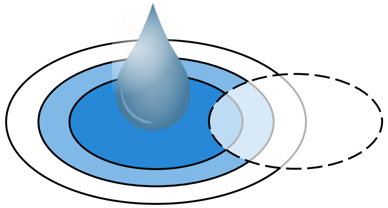
EQUALITY

Source: **(1)**http://www.iasc-culture.org/THR/THR_article_2012_Summer_Yates.php
(2) http://www.gwp.org/en/ToolBox/ABOUT/IWRM-Plans/IWRM-Principles/Integrating-three-Es/

Flood Risk Management

History of Flood Management





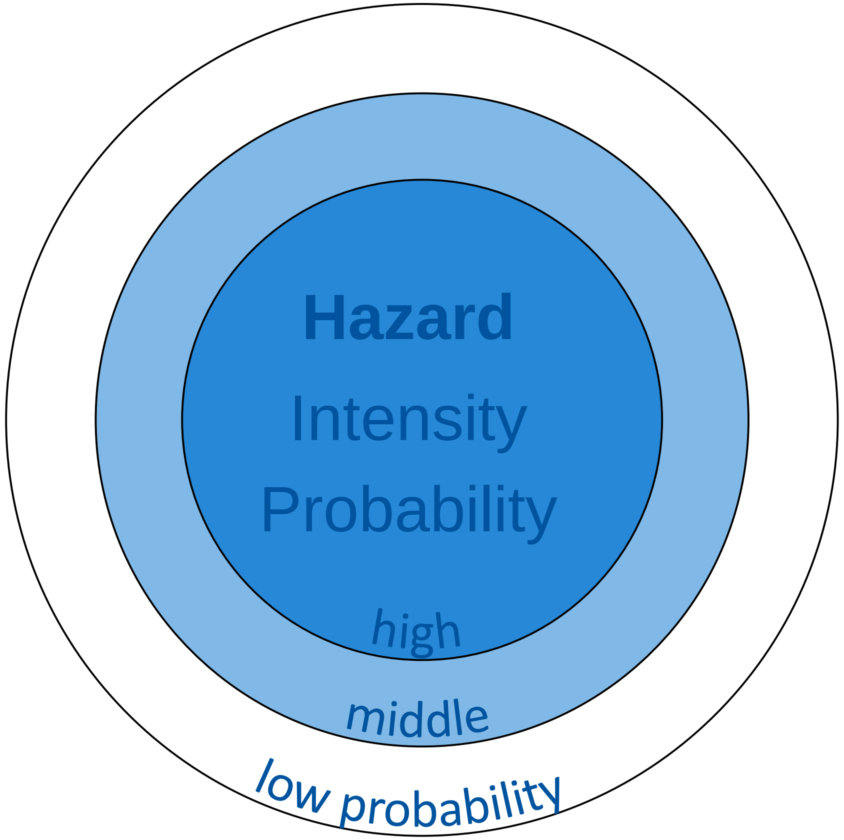
Flood Risk – Definition and General Concepts

Rural Measures

Urban Measures

Protection Strategies

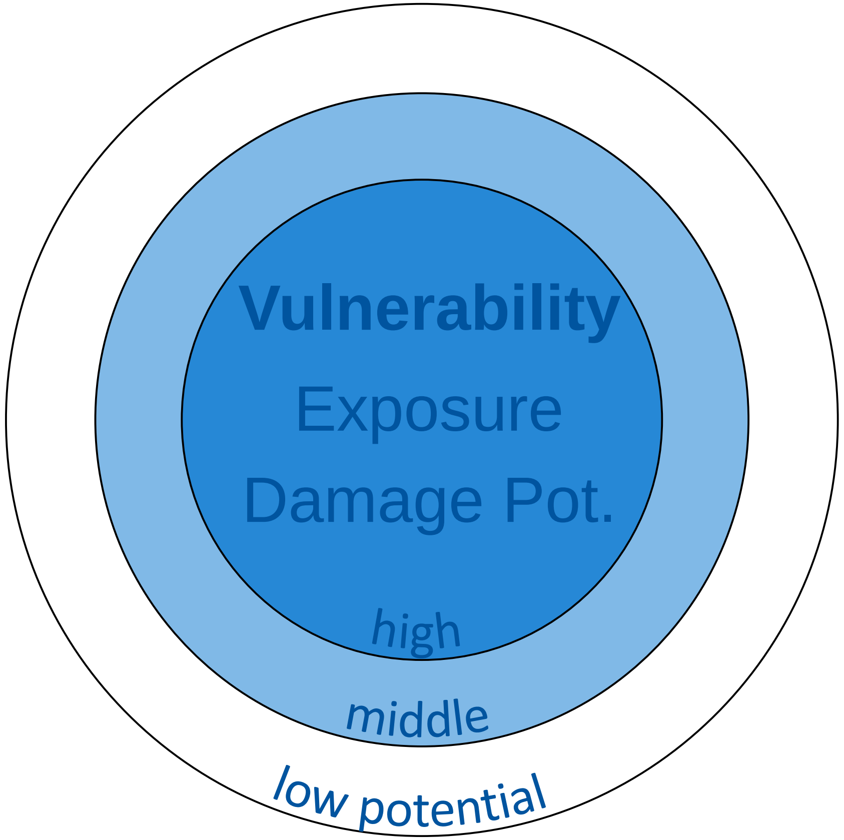
Definition of Flood Hazard



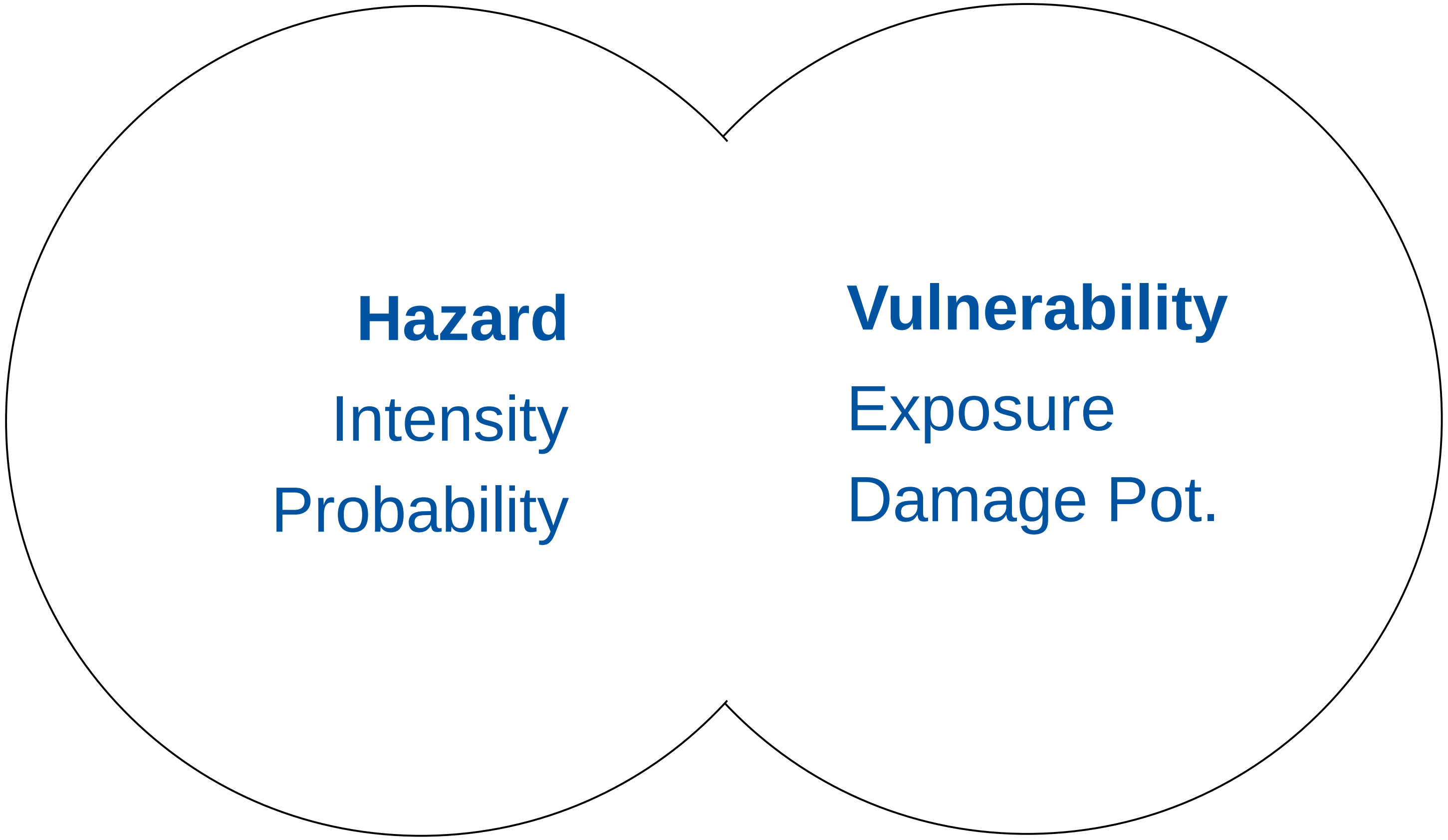
StMUV (2014)

Definition of Vulnerability

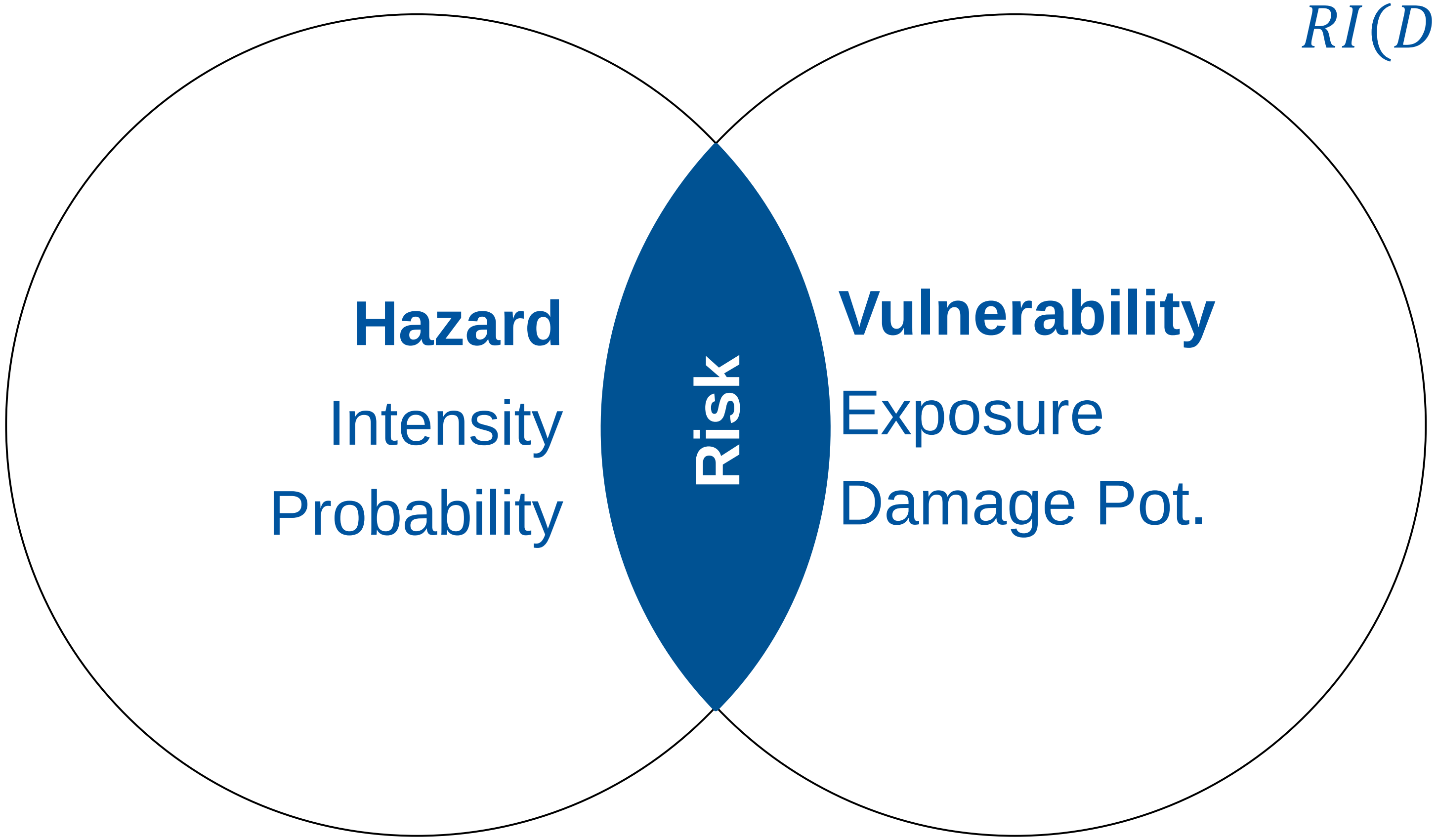
(Wolfgang Rattay/Reuters)



Definition of Flood Risk



Definition of Flood Risk



$$RI(\vec{D}) = \sum_{j} n_j * k_j * \int_0^\infty \varphi_j(u) * f_u(u) * du$$

D = measure (scenario)
n = number of elements at risk
k = maximum damage due to event u
$\varphi_j(u)$= relative vulnerability
$f_u(u)$= probability densitity function of event u
j = category index

$$RI(\vec{D}) = \sum_{(u)} Pr(u) * C(u)$$

Pr = exceedance probability
C = consequence (cost)

Assessment with flood hazard and flood risk maps

Structural and non-structural flood protection

Flood Management Measures

All planned actions or structures

- Aim to reduce the effect of floods
- Preventive and protective measures
- Take into account contingencies: failure of system components

Structural (traditional)

Flood pathway control

Separate river and population

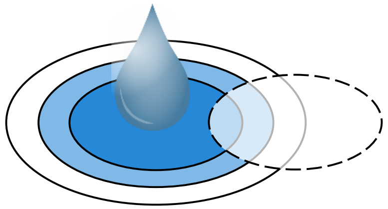
dams, dykes, retention basins, channelization, …

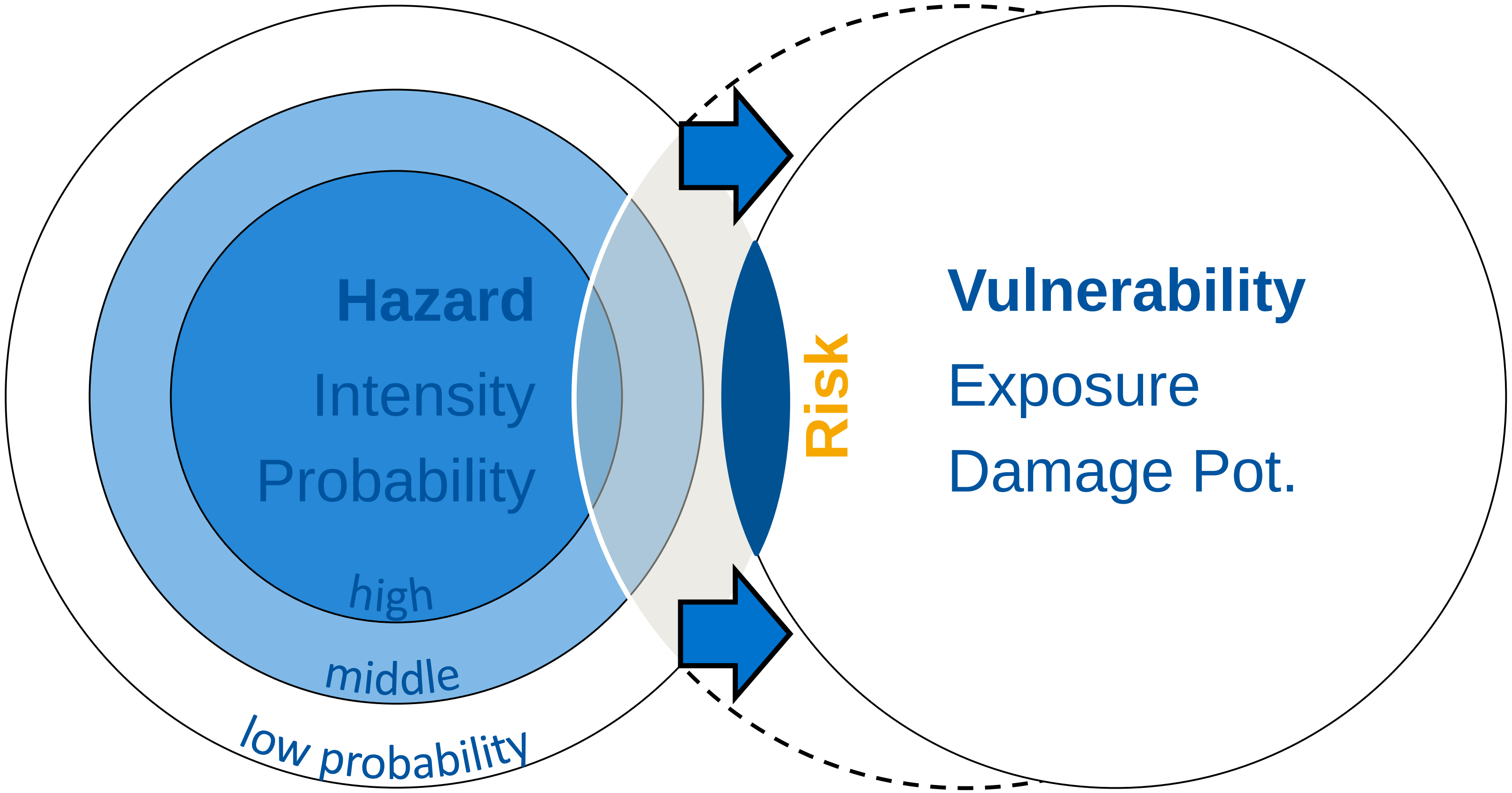
Non-Structural (modern)

Learning to live with rivers

information, spatial planning, building regulations, strengthen retention capacity (river basin), …

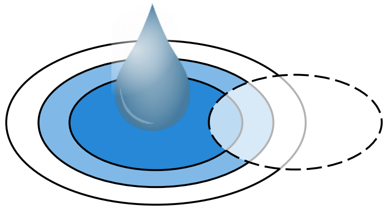
Avoidance

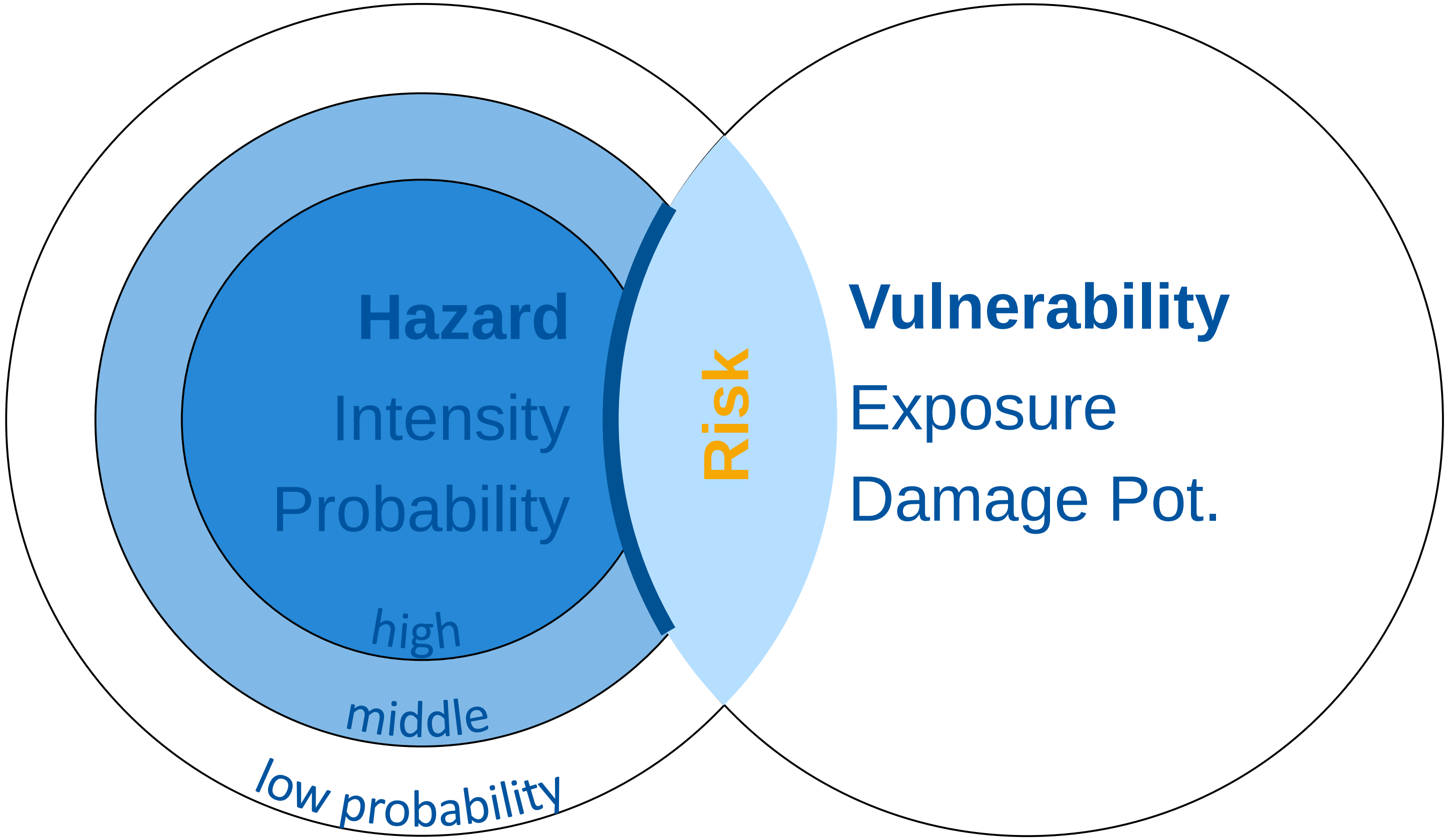




Removal of vulnerable objects out of the risk zone

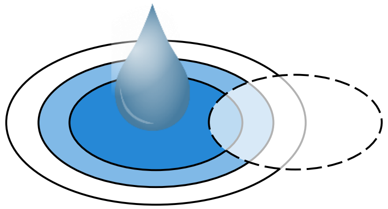
Resistance

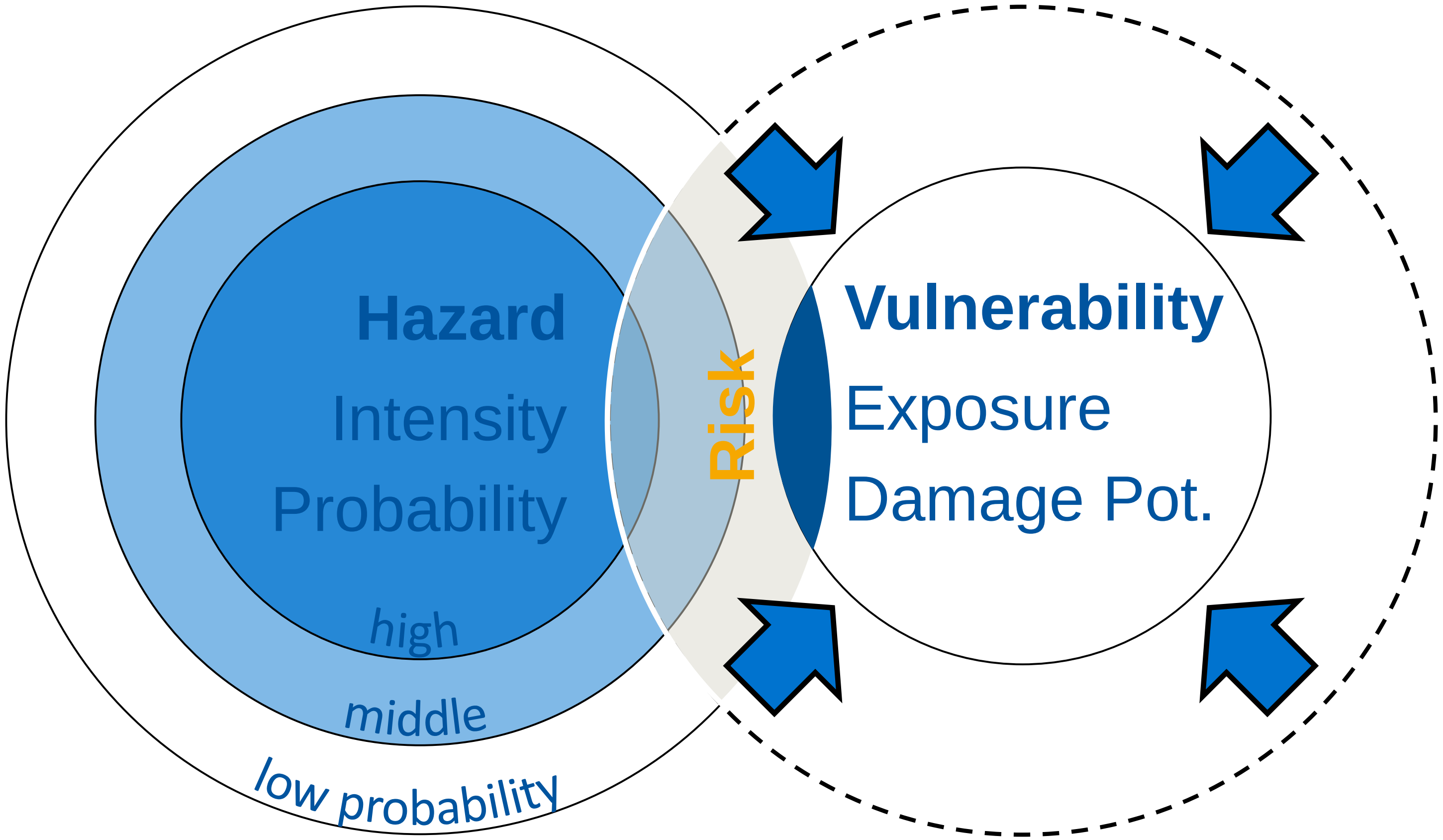




Flood protection by technical measures for a defined exceedance probability

Alleviation





Reduced vulnerability through resilient design

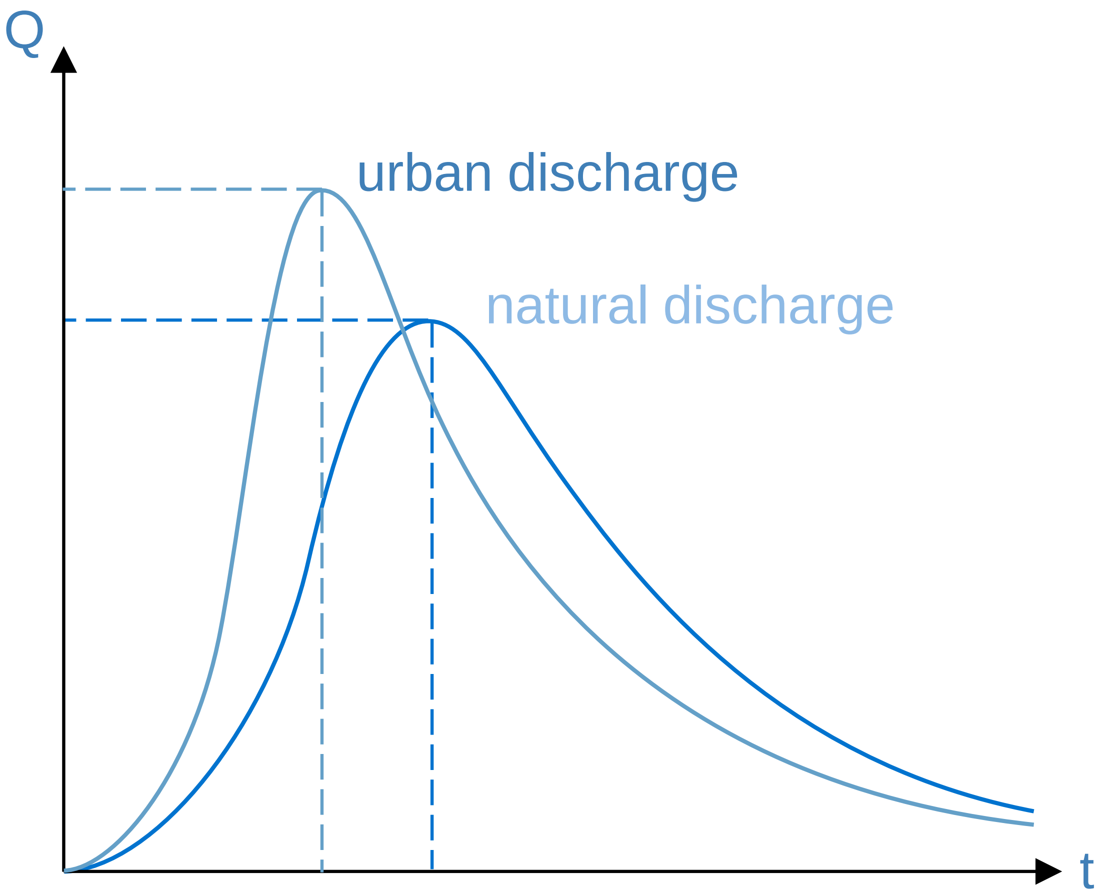
Increasing Flood Risk in Urban Areas

Climate Change

- more frequent and intensive heavy precipitation events
- rise of sea level

Urbanization

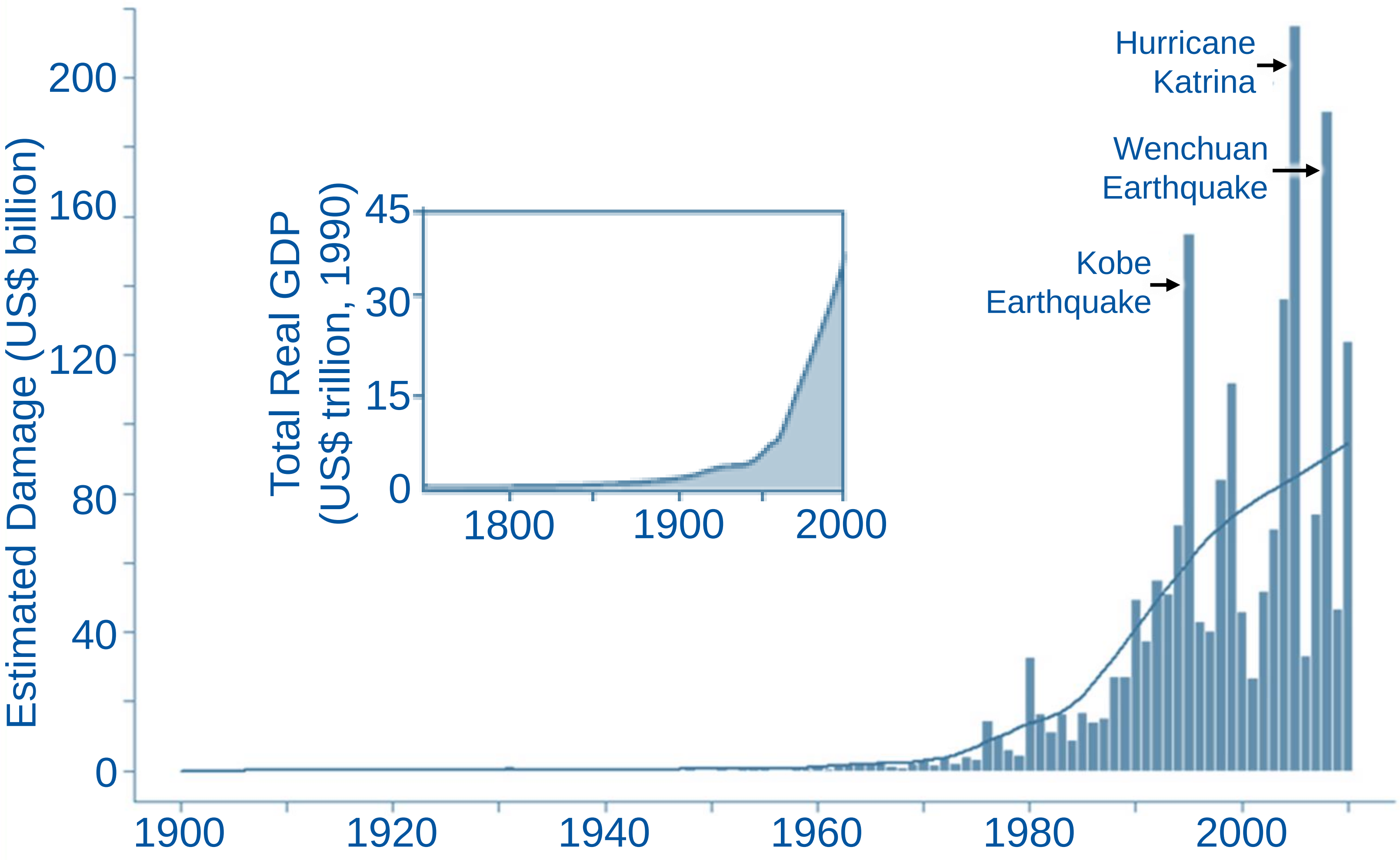
- increased impervious areas in cities
- more assets in flood prone areas
- higher vulnerability



Jha et al. (2012)

More GDP – More Natural Disasters

Estimated Damage (US$ billion) caused by Natural Disasters 1900 - 2010

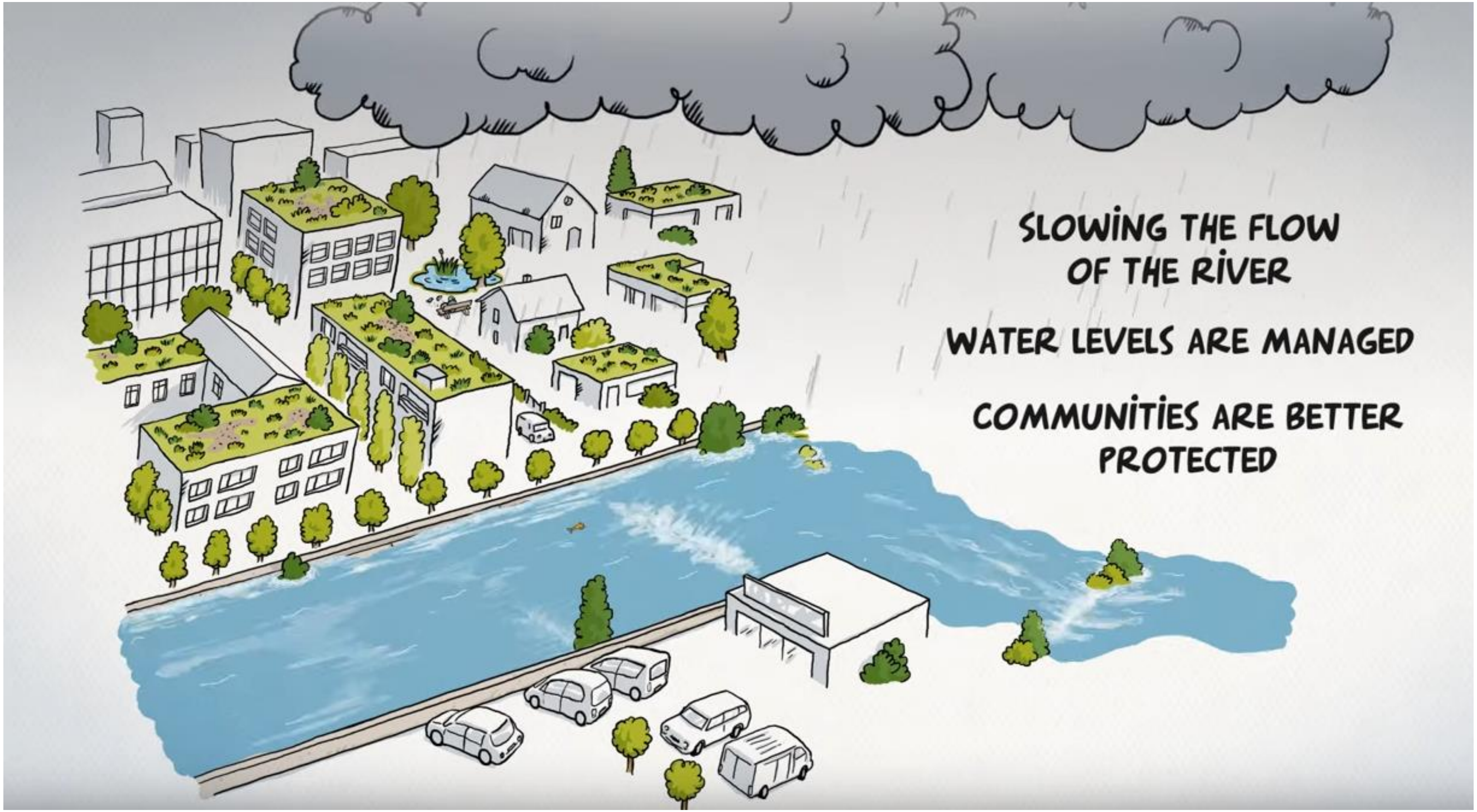


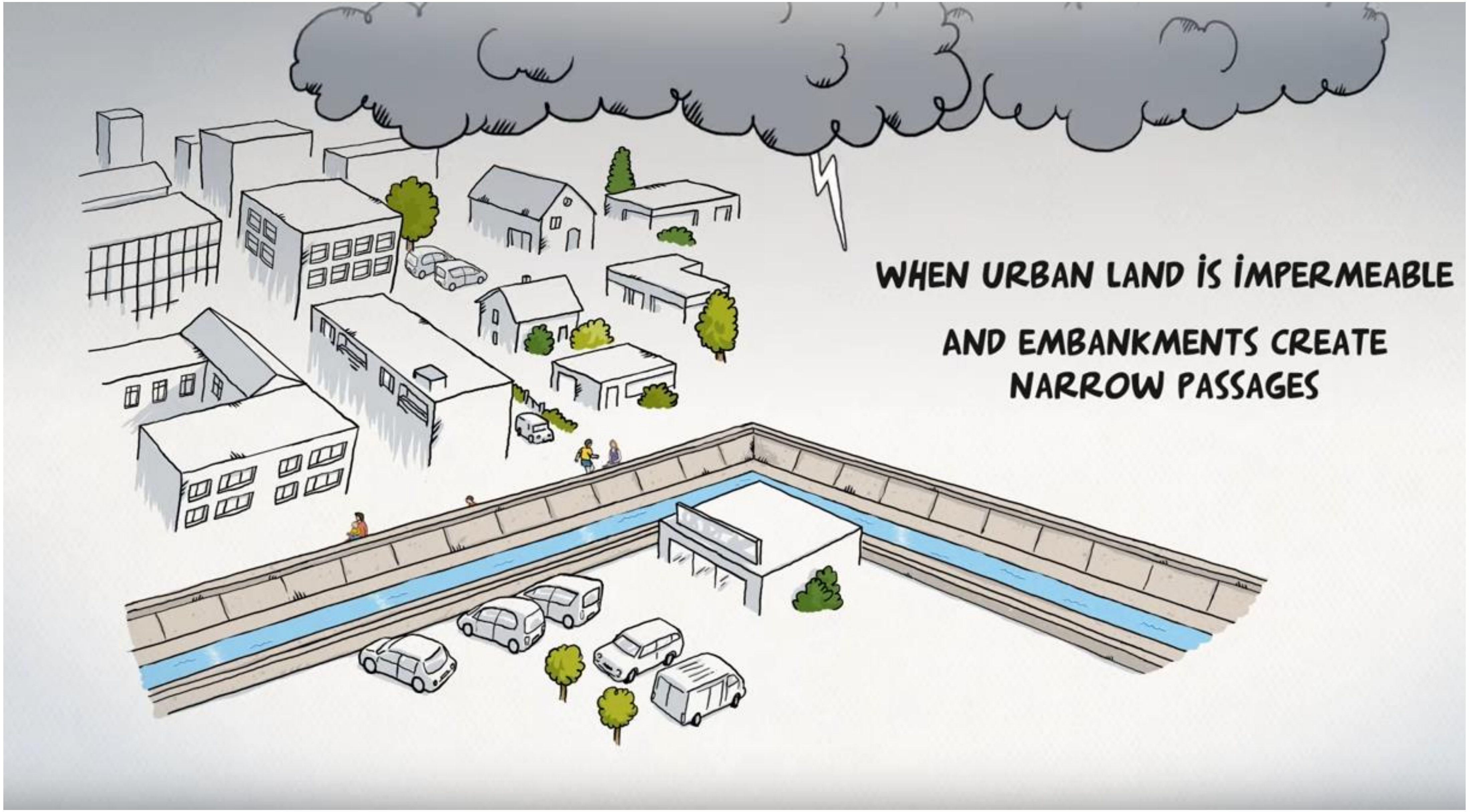
Steffen et al. (2004)
Guha-Sapir, D., Below, R., Hoyois, Ph. (2016)

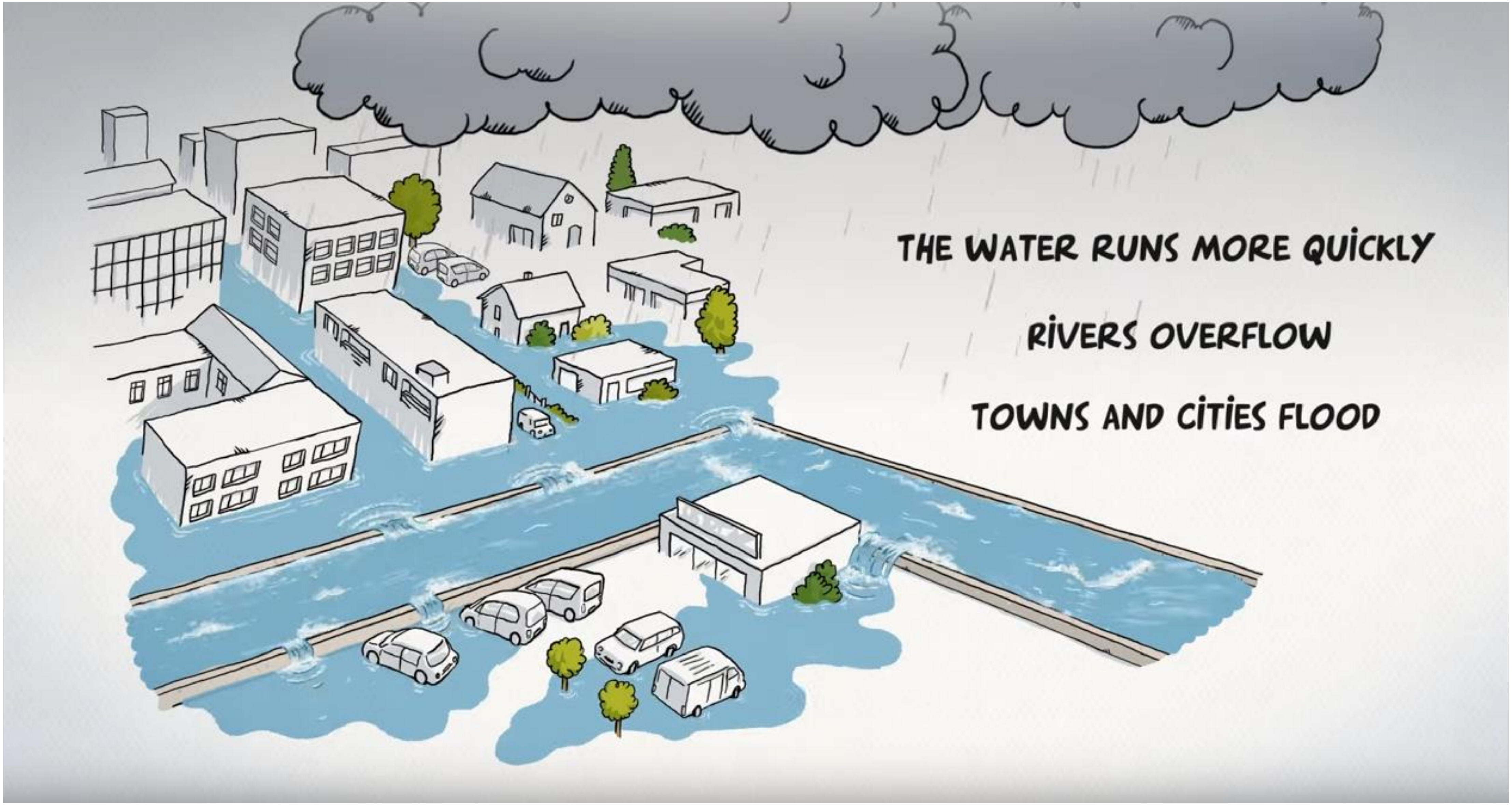
Examples


IN TOWNS AND CITIES,
PUSHING BACK THE EMBANKMENTS
WIDENS THE RIVER CORRIDOR

AND MAKES IT MORE
ATTRACTIVE AND ACCESSIBLE
TO LOCAL COMMUNITIES


SLOWING THE FLOW
OF THE RIVER
WATER LEVELS ARE MANAGED
COMMUNITIES ARE BETTER
PROTECTED


WHEN URBAN LAND IS IMPERMEABLE
AND EMBANKMENTS CREATE
NARROW PASSAGES

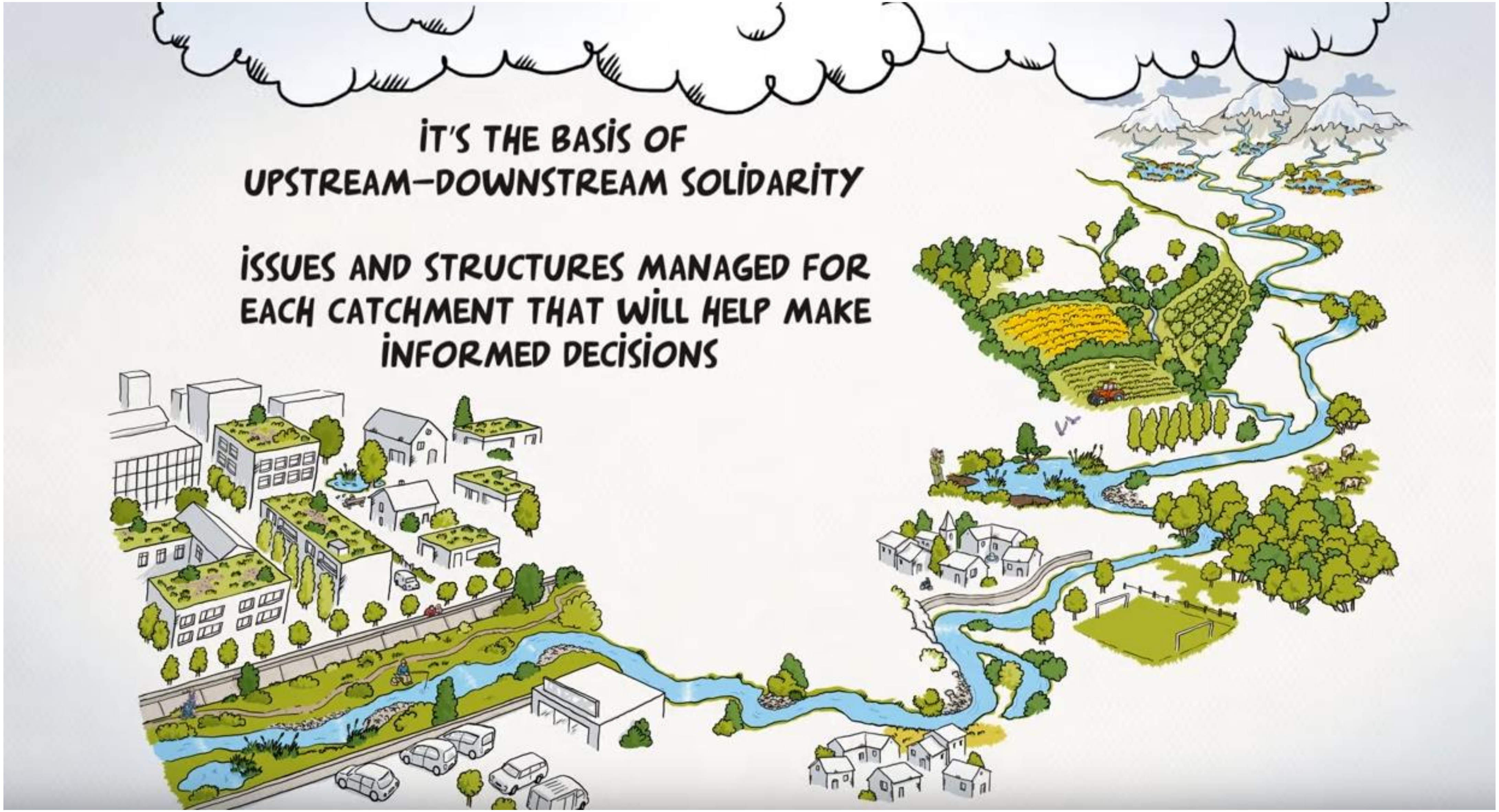

THE WATER RUNS MORE QUICKLY
RIVERS OVERFLOW
TOWNS AND CITIES FLOOD


THE RIVER RECONNECTS WITH ITS FLOODPLAINS
IT HELPS PROTECT VULNERABLE COMMUNITIES AND AREAS


A RIVER THAT NATURALLY MEANDERS...
IMPROVES WATER QUALITY
ENRICHES BIODIVERSITY
CAN REDUCE FLOOD RISK
HAS BETTER EXCHANGE WITH GROUND WATER


FLOOD FLOWS ARE SLOWED
FLOOD PEAKS ARE DELAYED WHICH GIVES MORE TIME TO PREPARE


THE RIGHT DECISIONS CAN ONLY BE MADE TOGETHER
AND ON A WHOLE CATCHMENT SCALE


IT'S THE BASIS OF
UPSTREAM–DOWNSTREAM SOLIDARITY
ISSUES AND STRUCTURES MANAGED FOR
EACH CATCHMENT THAT WILL HELP MAKE
INFORMED DECISIONS

LfU project ProNaHo

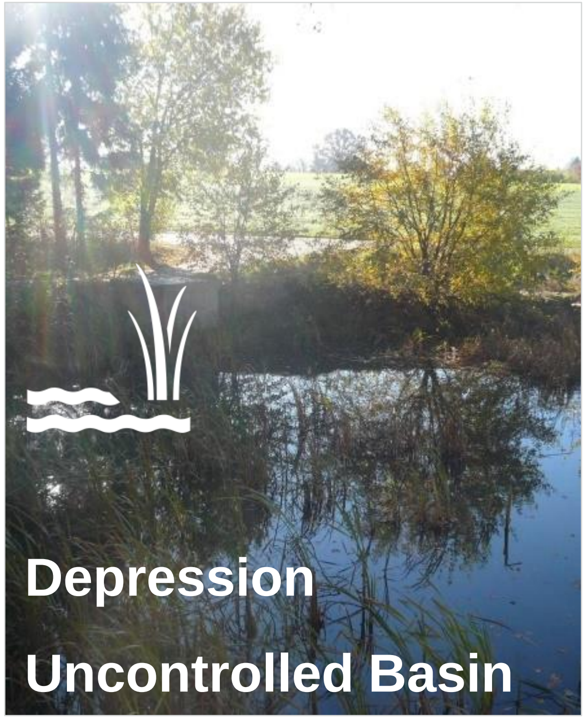
Runoff Generation | Runoff Concentration | Routing

Agriculture

Forestry

areal distributed

Retention

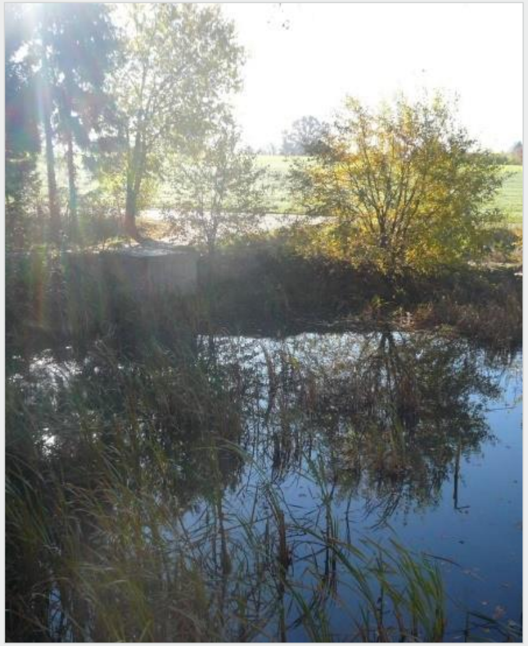


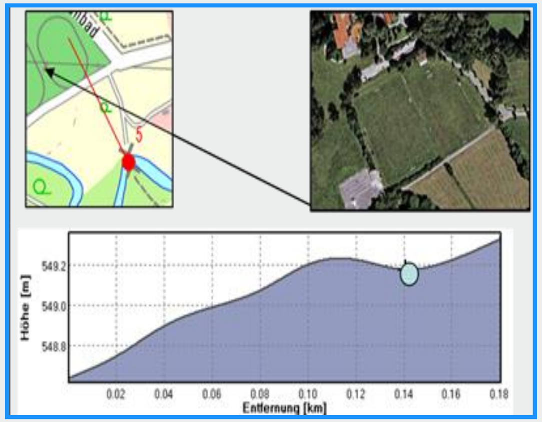
Ecol. River Rest.

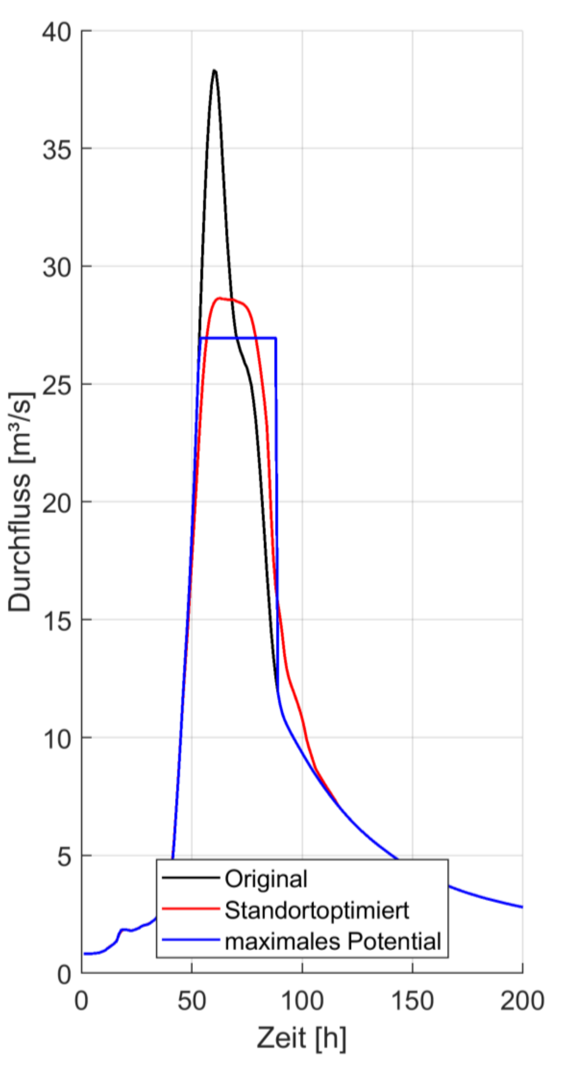
point and linear measures

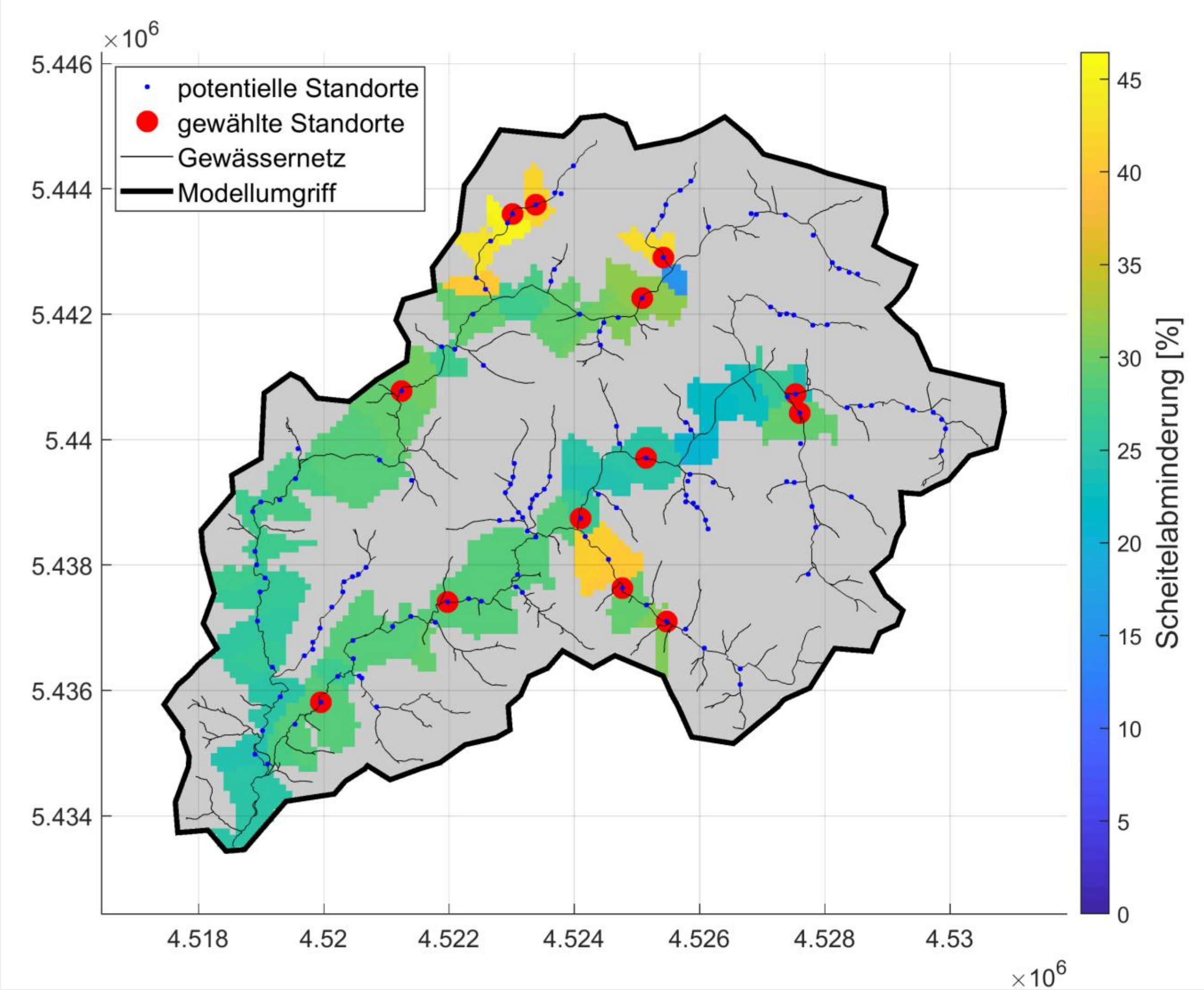
LfU project ProNaHo – Example Otterbach

Optimization of the location of small retention basins





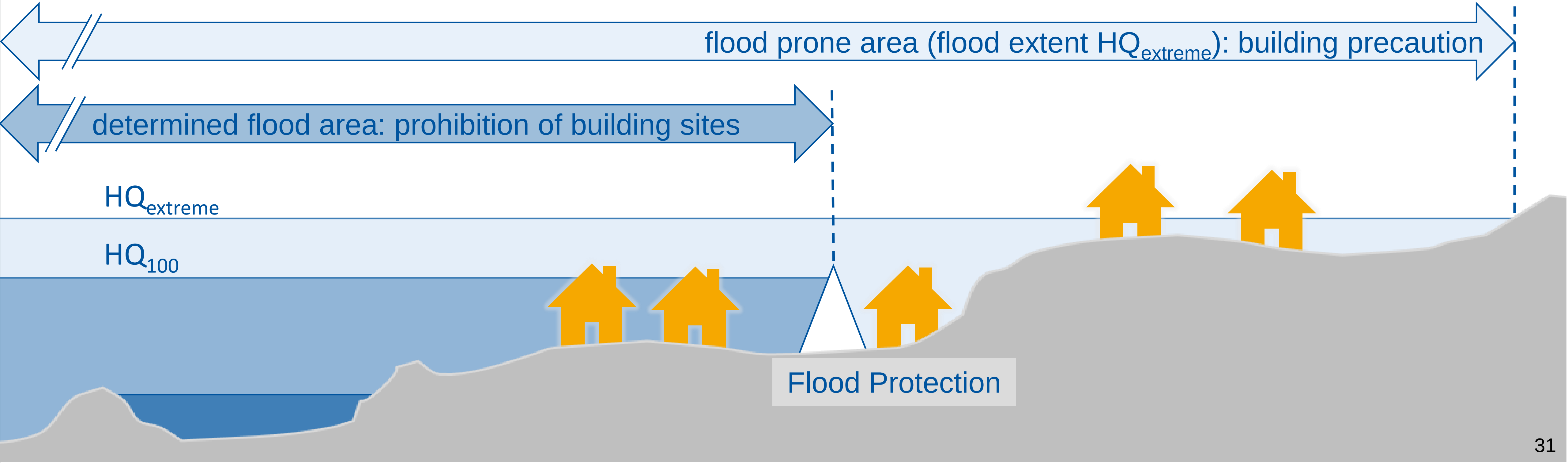




Otterbach, HQ100 (adv), sV = 4,3 mm

Adapted Land Zoning

Keeping flood-prone areas free and determine the way of land use.
Implementation in urban land-use planning by the government.



Emergency Management

Right behavior before, during and after a flood event, e.g.:

- Preparedness
- Evacuation plans
- Emergency Planning and Coordination
- Timely implementation of temporary flood protection measures

Technical Measures – Barriers

Stationary Measures

- Don’t require any lead time or preparation
- Change appearance of landscape
- Need space

BMUB (2015)

Temporary Measures

- Require lead time and preparation
- Often foundation needed (type dependent)
- Space can be shared

BMUB (2015)

Retention Areas

1. Infiltration

Desealing
- Improves permeability
- Increases Evapotranspiration
- Purification

2. Retention

Green Roofs
- Decentralized retention
- Increases evapotranspiration
- Improves insulation

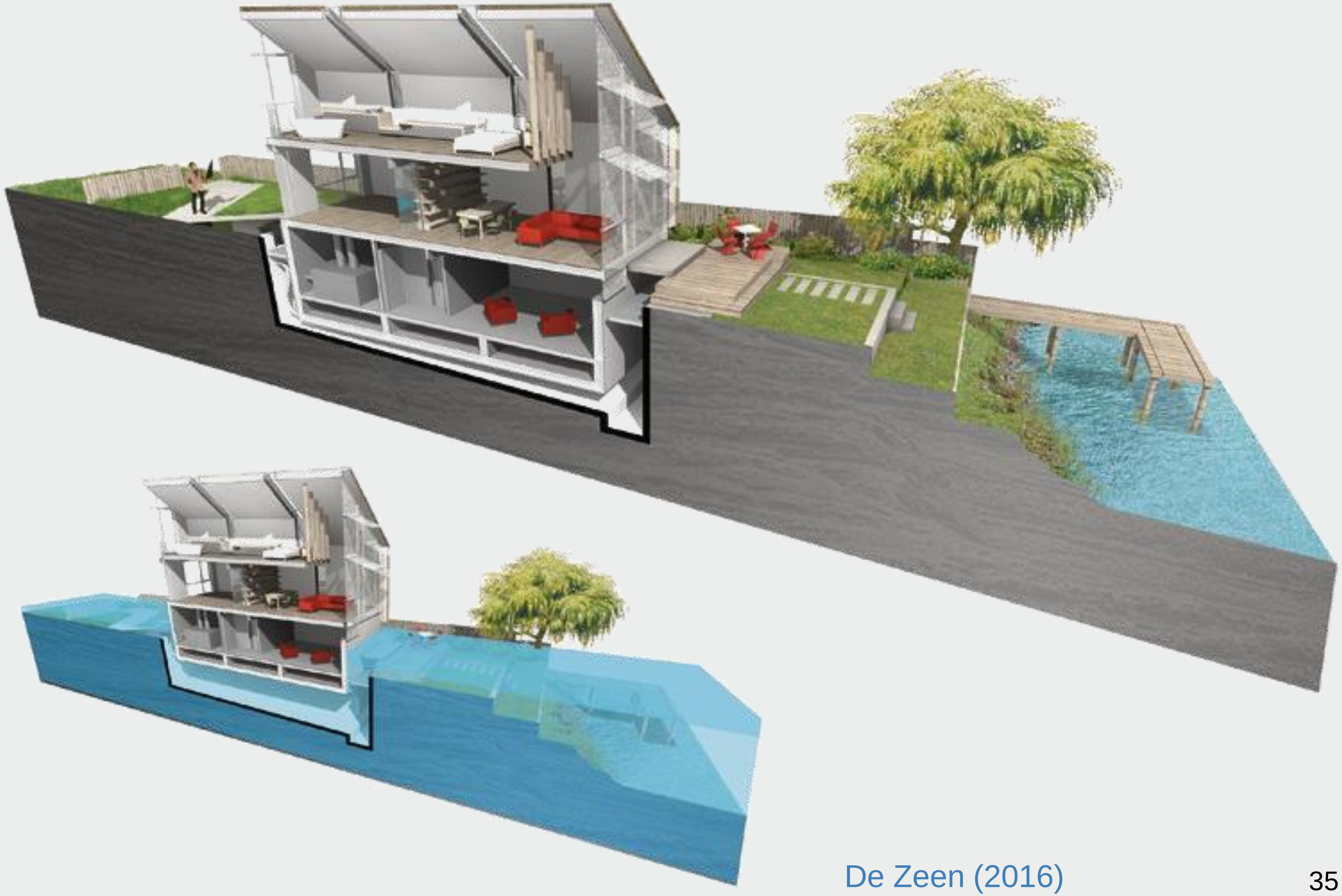
3. Retarded Runoff

Sewerage Storage
- Centralized retention
- No spilling of untreated water

Hamburg (2016), München (2015)

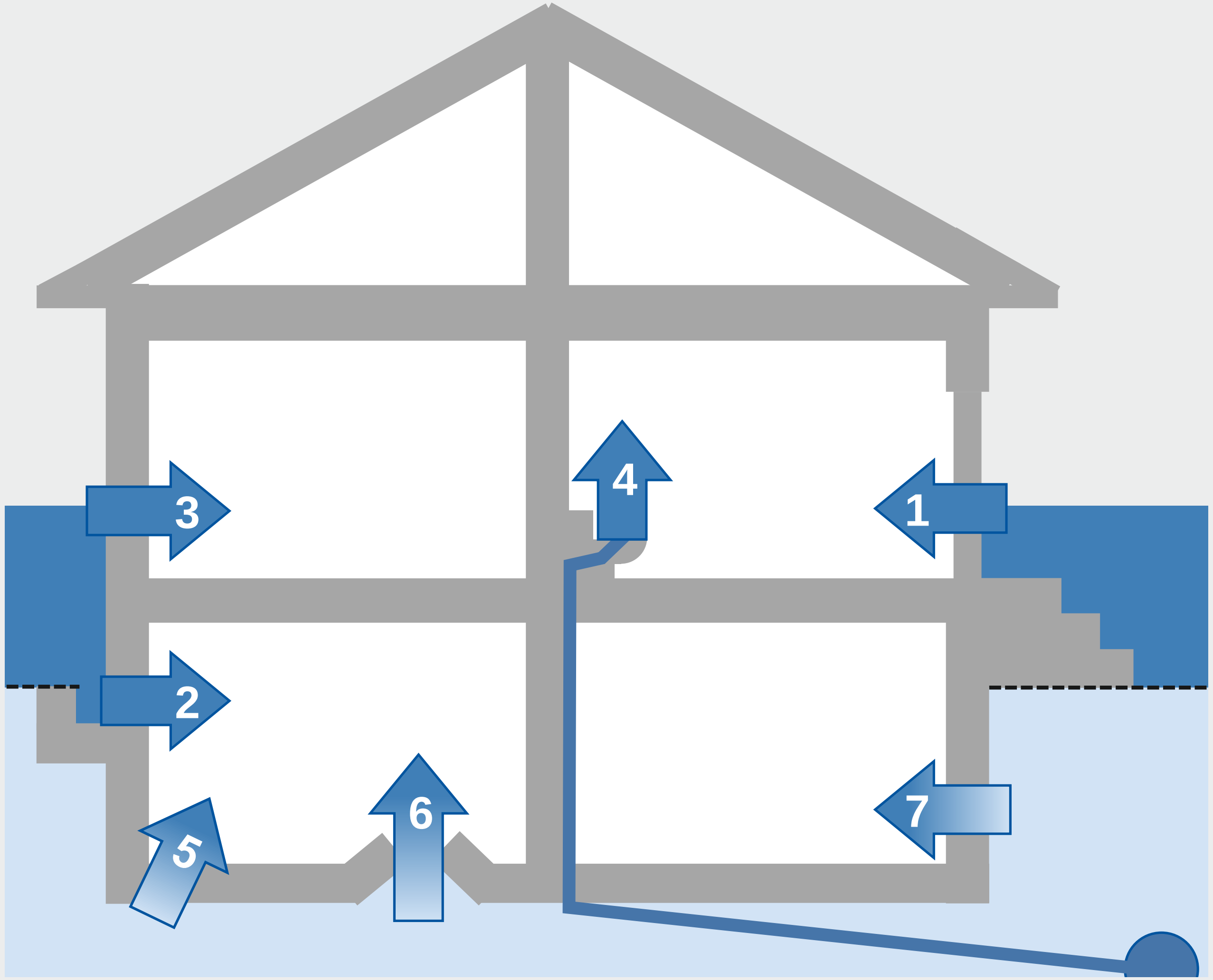
Building Codes – Avoidance

- Construction outside of the flooding zone
- Building without basement
- Building on stilts or piles
- “Swimming houses“



De Zeen (2016)

Building Codes – Resistance



BMUB (2015)

Resistance: Shielding against Floods

Surface Water Invasion:

1. through doors and windows
2. from light wells and cellar wells
3. through permeability in walls

Sewage Water Invasion:

4. backwater

Ground Water Invasion:

5. by sealing measures
6. undercurrents of groundwater flows
7. water penetration through walls

Building Codes – Alleviation

General:

- Relocation of sensitive furniture and applications to the upper floors
- Water resistant building materials

Measures for Buildings:

- Brick & Mortar Sealing
- Power Socket Height
- Drainage Points
- Outer layer with waterproof building materials
- Ventilated facade to support drying of isolation

increasing water resistance ↓

Anhydrite and Gypsum
Isolating Materials (Glass wool, etc.)
Wood
Cement-bound Building Materials
Homogeneous Building Materials
Metal, Glass and New Bricks

BWB (2016)

Flood Protection Strategies

Concepts:

- Green City Concept
- Blue City Concept
- Blue-Green City Concept

City of Rotterdam (2012)

The Green City

Local Conditions:

- Permeable, not-contaminated soil
- Space available
- Groundwater level far from surface

Strategy:

- New green areas for infiltration
- Decrease of impermeable areas
- Green Roofs
- Green Streets

Examples: Portland, New York, Chicago, London, Melbourne, Sydney

The Blue City

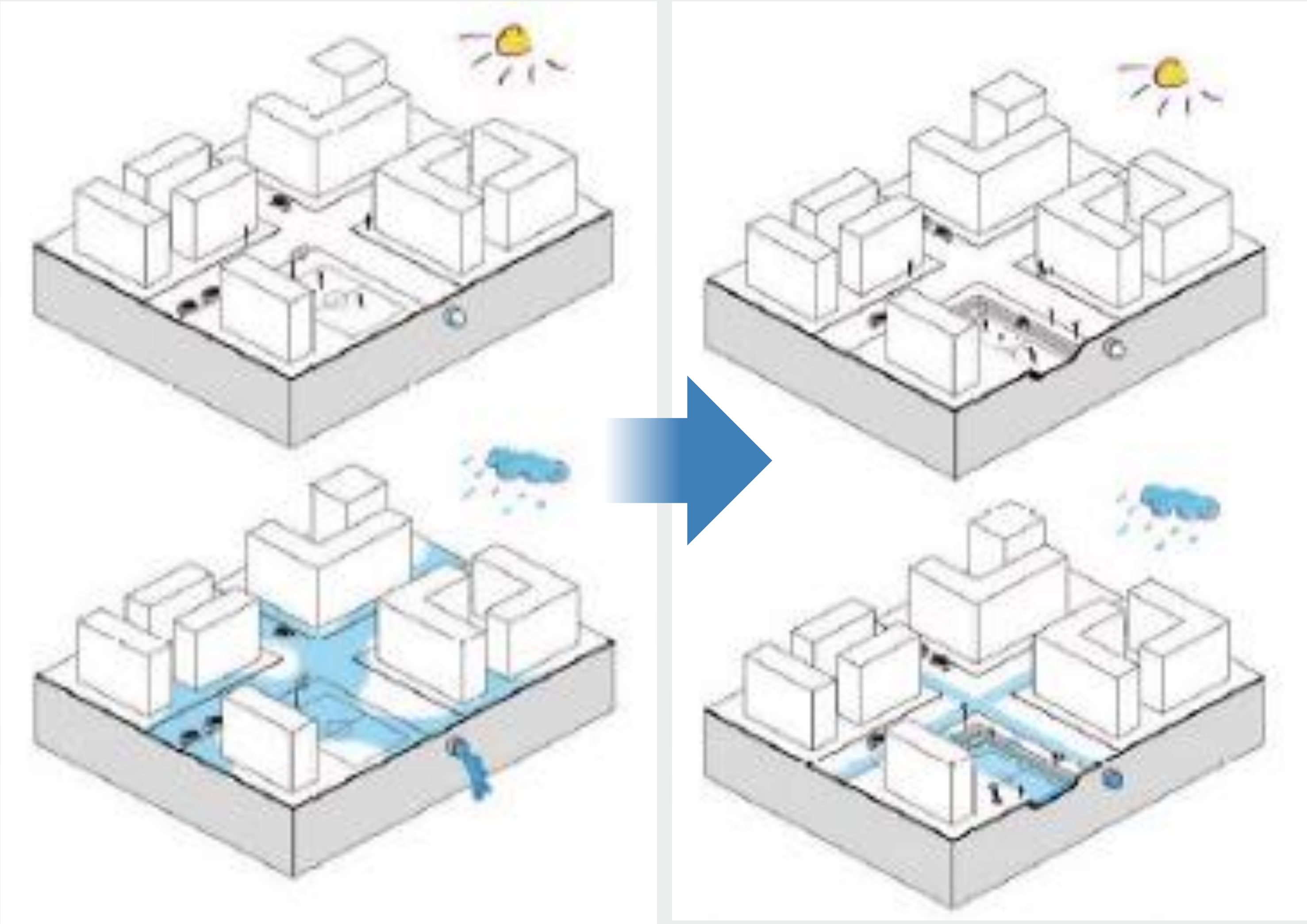
Local Conditions:

- Low permeability of soil
- Lack of space
- High groundwater level

Strategy:

- Integration of water into the city
- Multifunctional usage of areas
- Green and Blue Roofs

Examples: Rotterdam, Amsterdam, Copenhagen



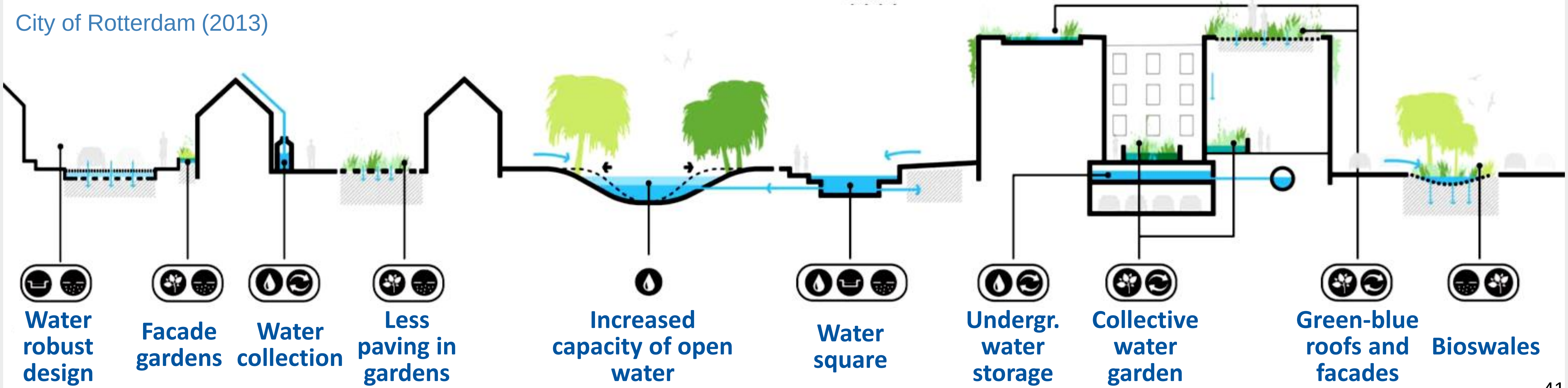
Kruse (2015)

The Blue City – Example: Rotterdam

A City Adapting to Climate Change

- Increased water retention
- Delayed infiltration to open and ground water
- Enhanced recycling of water / flood harvesting
- Temporary and permanent water storages

City of Rotterdam (2013)



The Blue-Green City

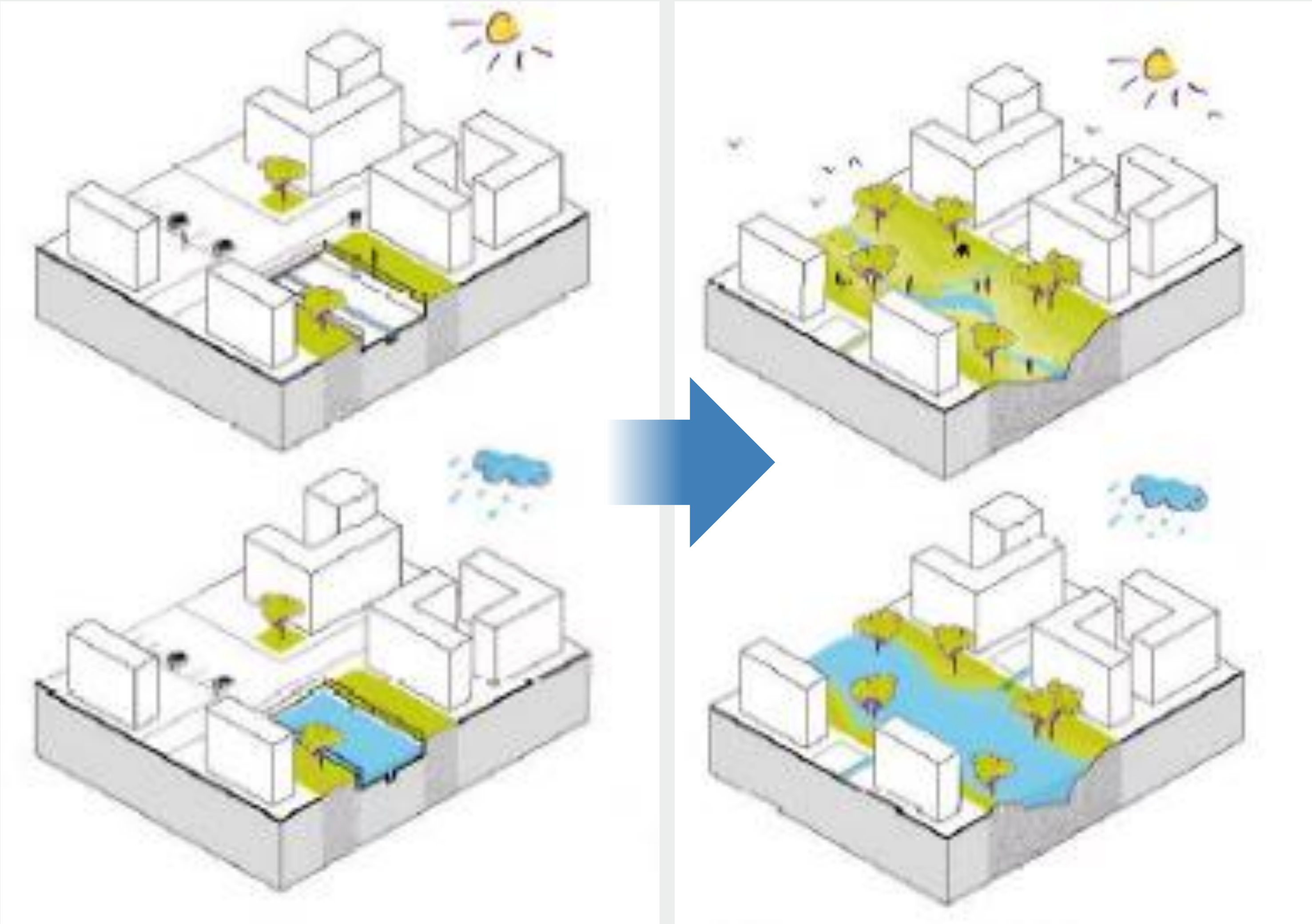
Local Conditions:

- Affected by river floods
- Space availability along the river
- Low permeability of the soil

Strategy:

- Integration of river sections into parks
- Ecological restoration of canalized river section
- Reservoirs, ponds, wetlands

Examples: Singapore, Houston, Malmö, Seoul, Glasgow, Munich



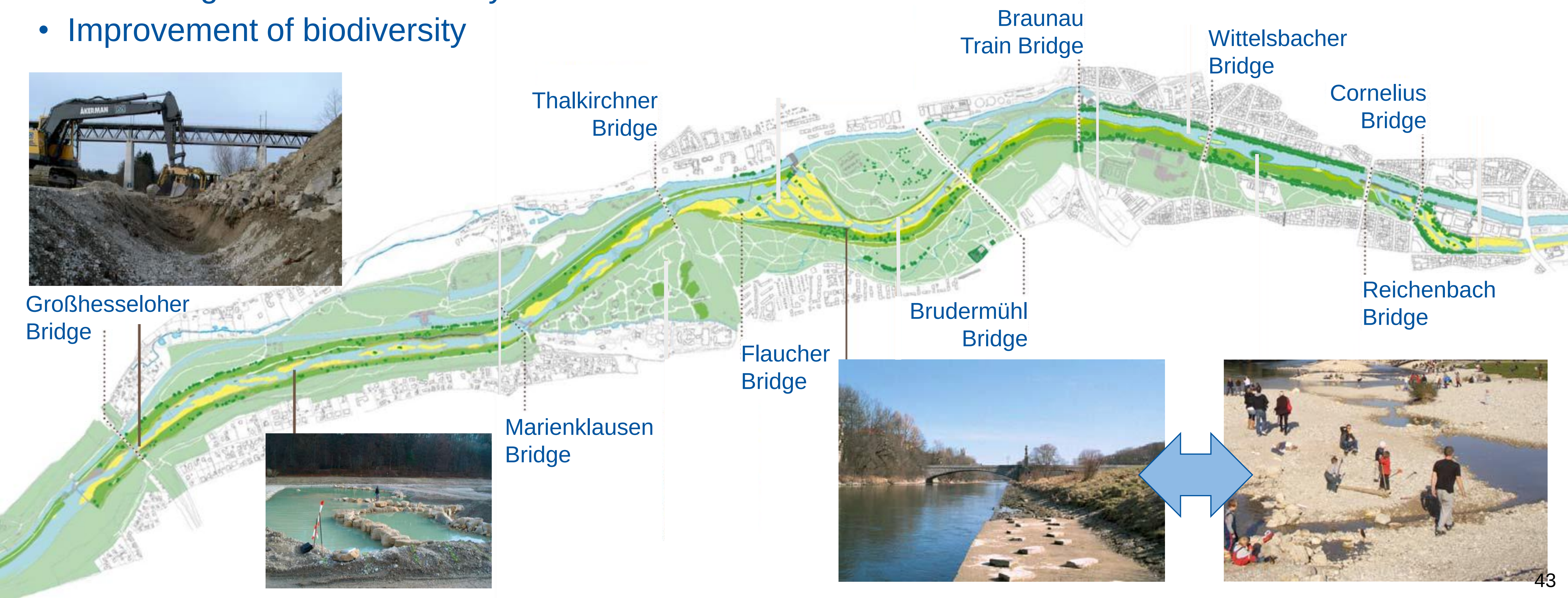
Kruse (2015)

The Blue-Green City – Example: Munich

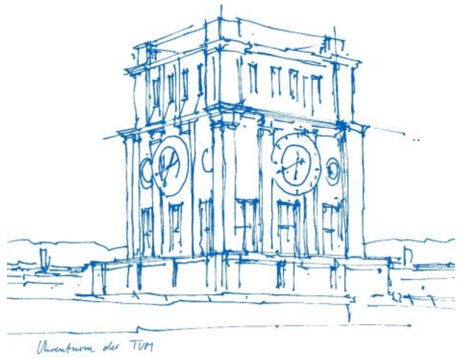
City of Munich (2011)

Ecological Restoration – Giving Rivers Space

- Increasing habitat connectivity
- Improvement of biodiversity



Introduction to Resilience



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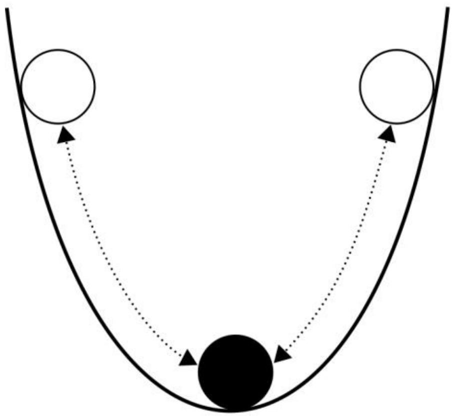
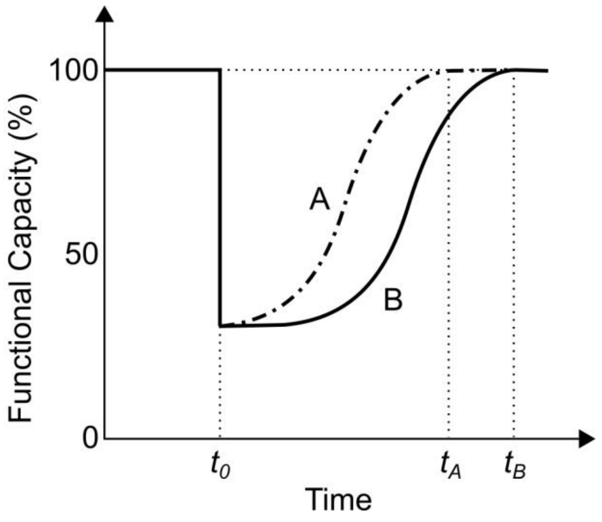
Conceptualizing Resilience

Engineering Resilience

- Target = remain at ideal state by resisting change
- "Bouncing back"
- Best for individual measures
    - dikes, dams, etc.



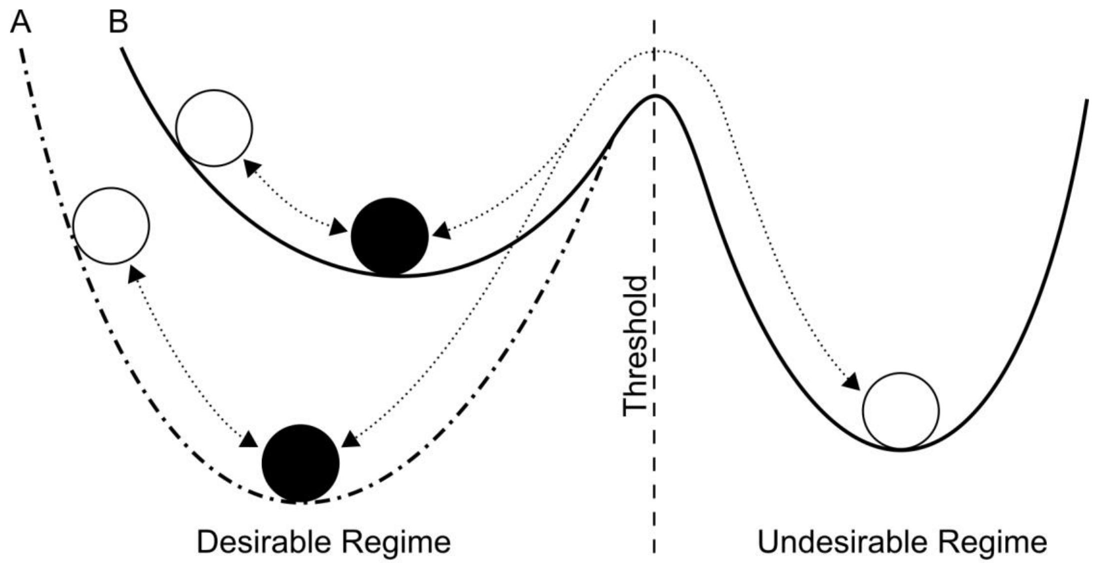


Exploring the relation between flood risk management and flood resilience, M Disse, TG Johnson, J Leandro, T Hartmann, Water Security 9, 100059

Conceptualizing Resilience

Social-Ecological Resilience

- Target = continue functioning after disturbance by changing equilibrium state
- “Absorbing shocks”
- Key aspect = adaptation
- Best for complicated systems
    - changing relationships of sytem elements
    - interventions can be reversed/restored



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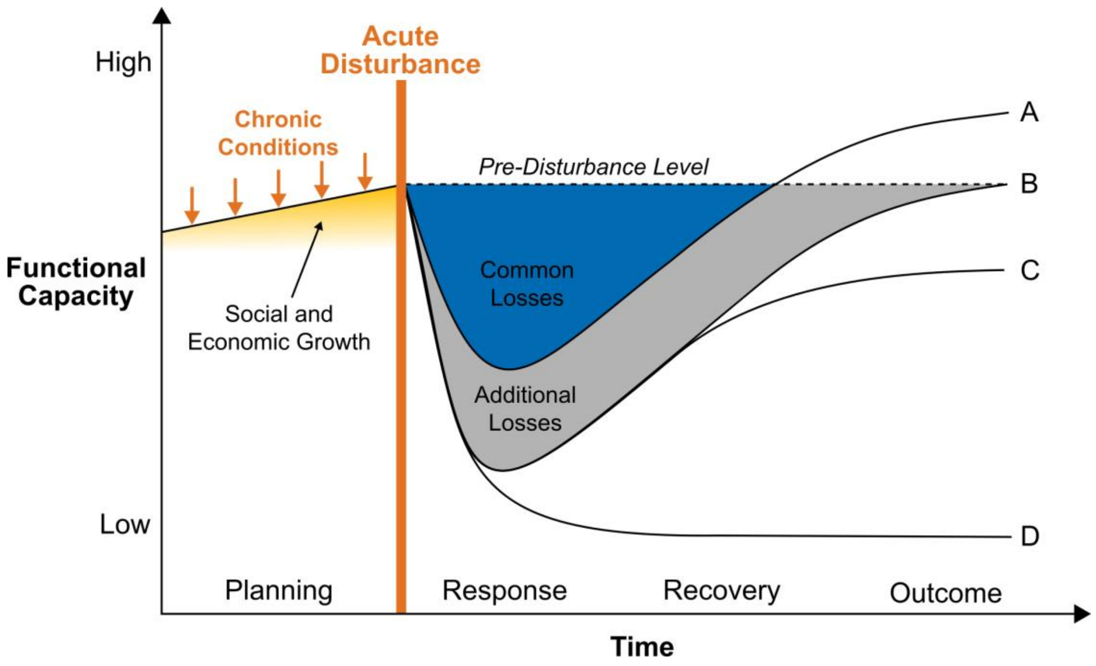
Conceptualizing Resilience

Conceptual Model

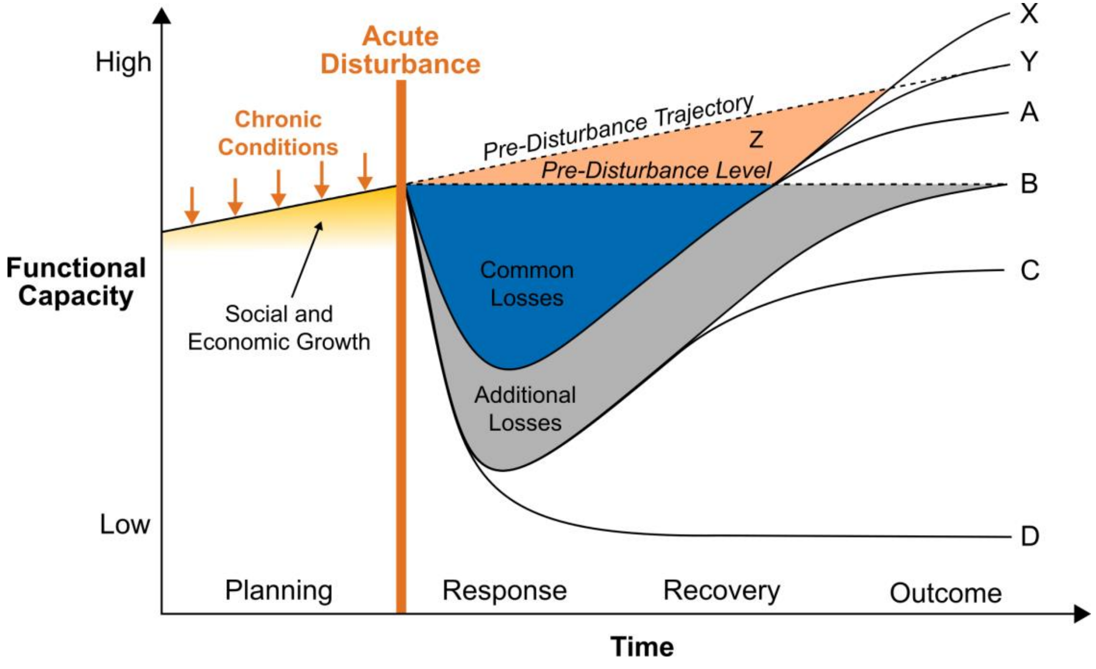


- A helpful tool for communication (CARRI 2017)
- Components
  - unbound axis
  - social & economic growth
  - multiple outcomes
  - resilience losses

Exploring the relation between flood risk management and flood resilience, M Disse, TG Johnson, J Leandro, T Hartmann, Water Security 9, 100059

Conceptualizing Resilience

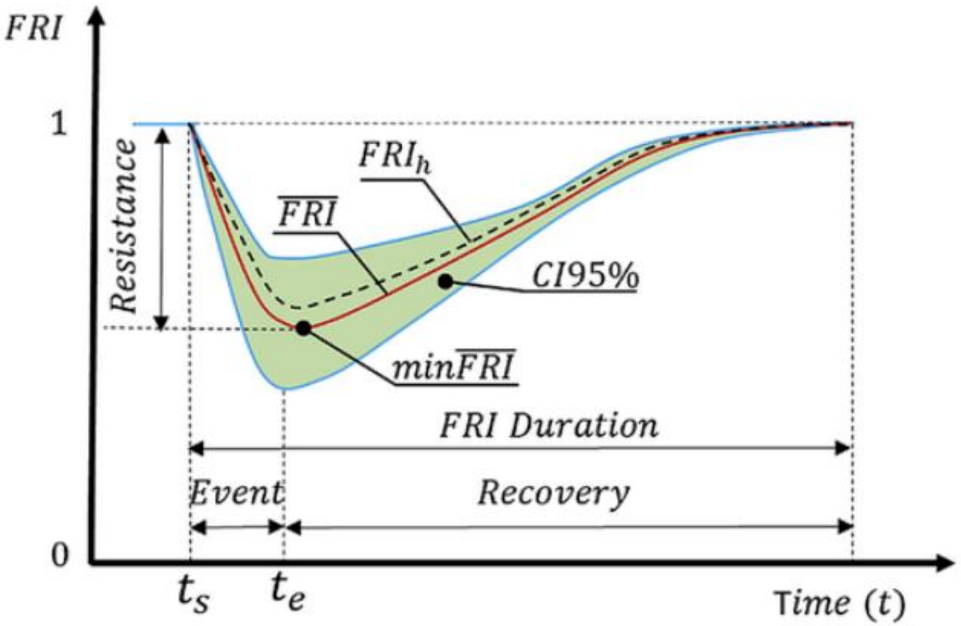
Conceptual Model



- A helpful tool for communication (CARRI 2017)
- Components
  - unbound axis
  - social & economic growth
  - multiple outcomes
  - resilience losses
- Issues
  - Pre-Disturbance or Trajectory?
  - Functional Capacity?

Met. 2: Flood resilience

“the **capacity** to withstand adverse effects following flooding events and its **ability** to quickly recover to a level of system performance not affected by flooding. (Kai-Feng Chen, and Ieandro 2019)”



water

MDPI

Article

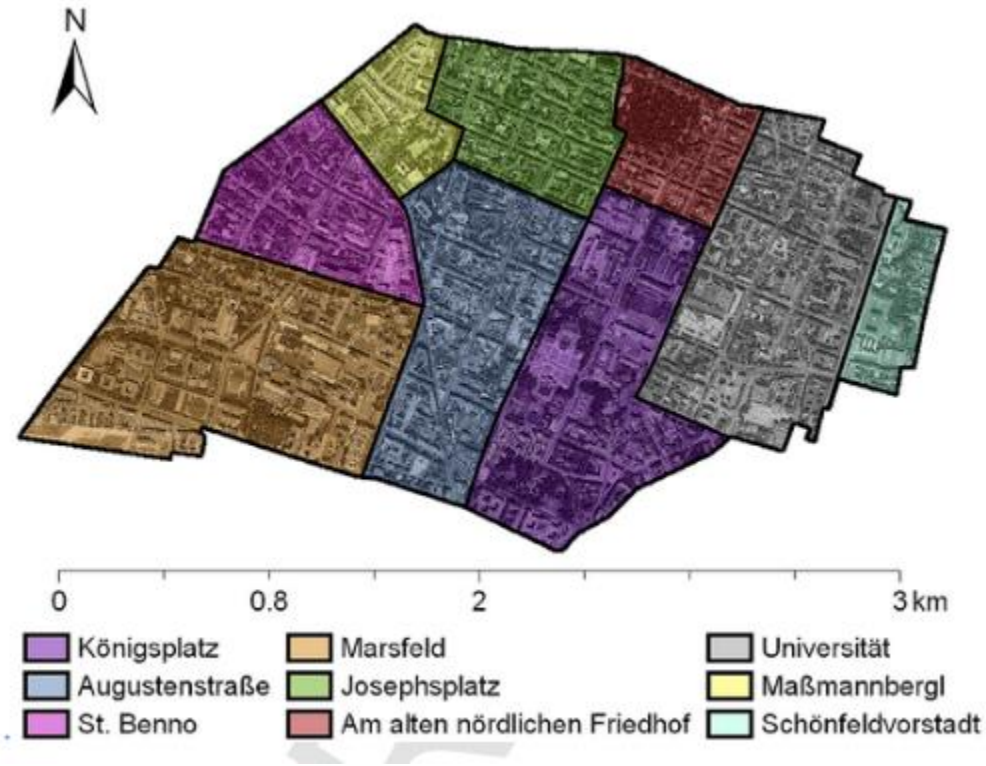
A Conceptual Time-Varying Flood Resilience Index for Urban Areas: Munich City

Kai-Feng Chen * and Jorge Leandro

Chair of Hydrology and River Basin Management, Department of Civil, Geo and Environmental Engineering, Technical University of Munich, Arcisstrasse 21, 80333 Munich, Germany; jorge.leandro@tum.de

* Correspondence: kaifeng.chen@tum.de; Tel.: +886 927-211-971

Case study: Maxvorstadt, München



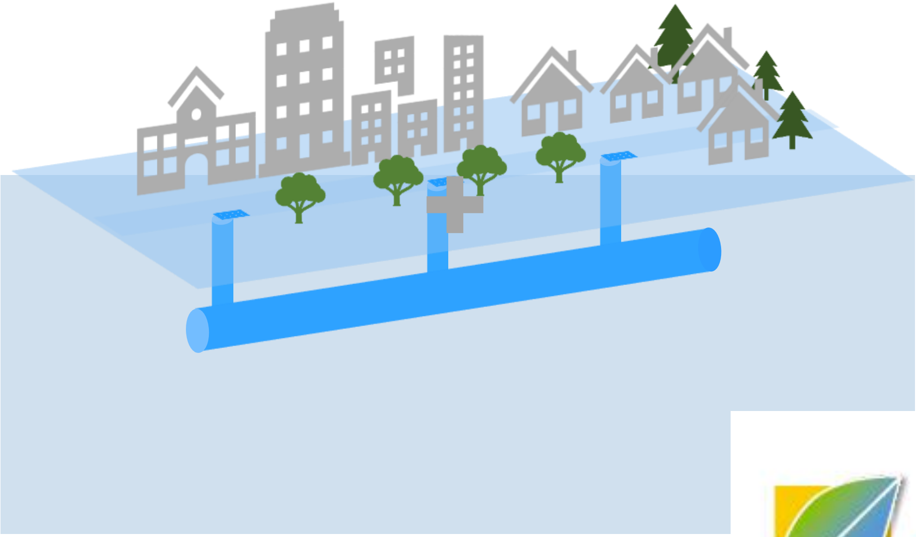
Catchment	141.2 ha
Pipeline	14.97km

Subcatchment	2927
Conduits	526
Junctions	493
Outfalls	11

1D-2D coupled model

- Input for Flood Resilience Assessment
- Urban flooding inundation with realistic manner

2D models



1D models

Urban flood waves
Advanced numerical solutions
Detailed urban geomorphology

Multiple adaptation strategies

Hydraulics in **drainage systems**

gefördert durch
Bayerisches Staatsministerium für
Umwelt und Verbraucherschutz

TUM LMU lrz

HiOS Hinweiskarte Oberflächenabfluss und Sturzflut

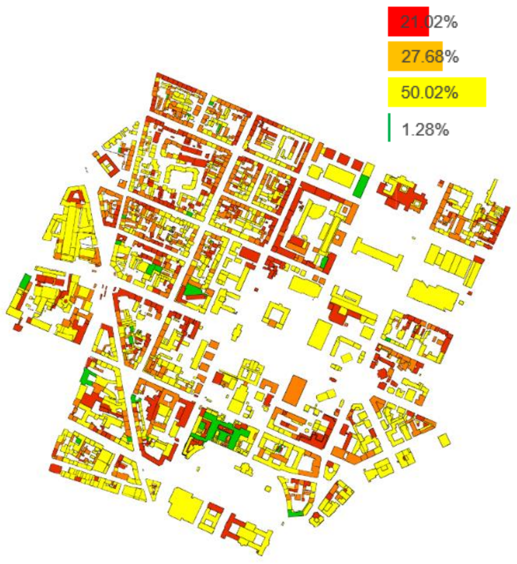
Impact of multi-strategies

Maximum indoor water depth in a 100-year event, 2070-2099

Building color

- >20 cm
- 10-20 cm
- 0-10 cm
- 0 cm

No measures



Impact of multi-strategies

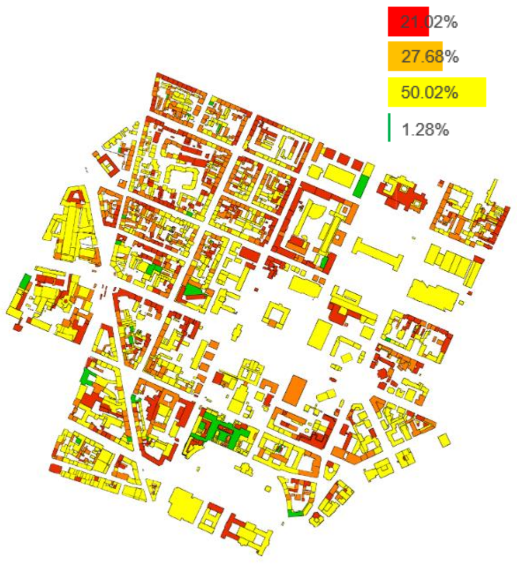
Maximum indoor water depth in a 100-year event,

2070-2099

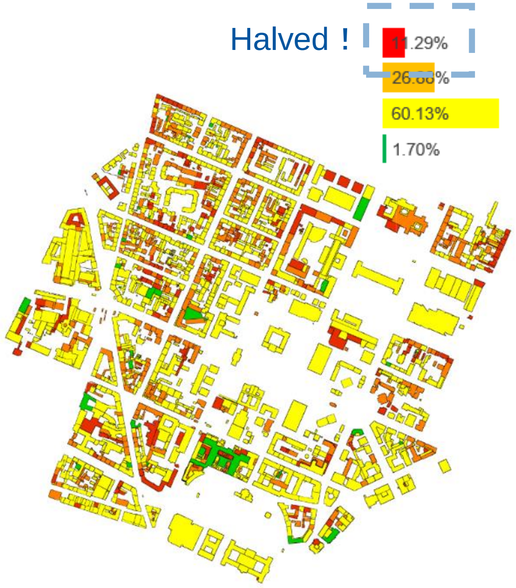
Building color

- >20 cm
- 10-20 cm
- 0-10 cm
- 0 cm

No measures	Grey



Halved !



- Areal measure
- Mitigating floods with high water levels

Impact of multi-strategies

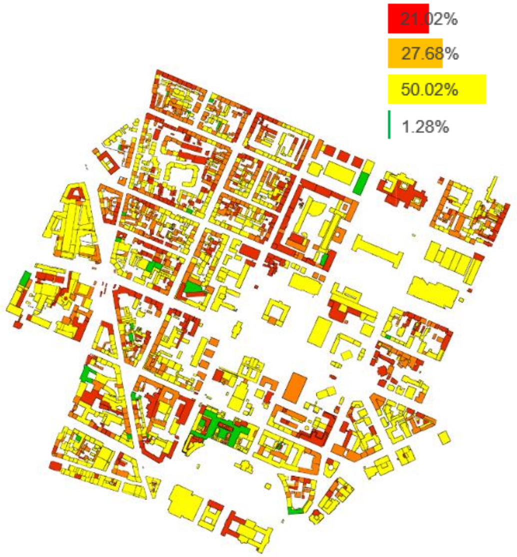
Maximum indoor water depth in a 100-year event,

2070-2099

Building color

- >20 cm
- 10-20 cm
- 0-10 cm
- 0 cm

No measures	Grey	Green Blue



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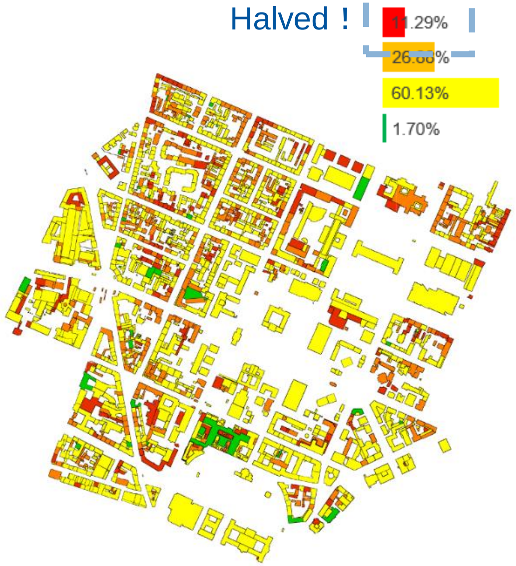
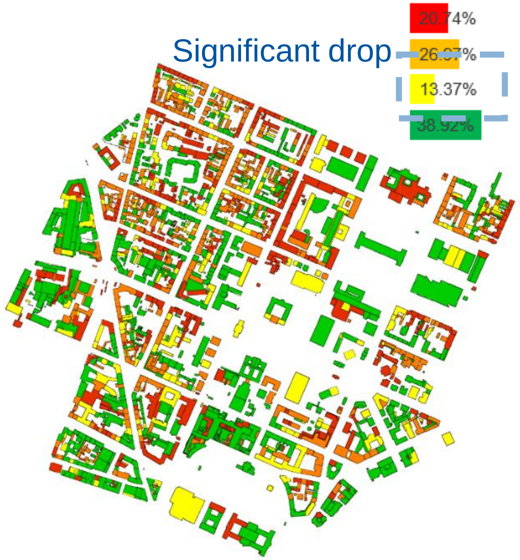


- Areal measure
- Mitigating floods with high water levels

Significant drop



- Point measures
- Mitigating minor floods

Impact of multi-strategies

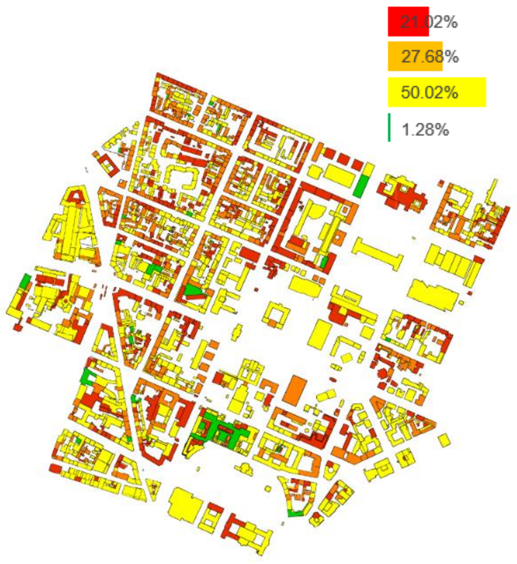
Maximum indoor water depth in a 100-year event,

2070-2099

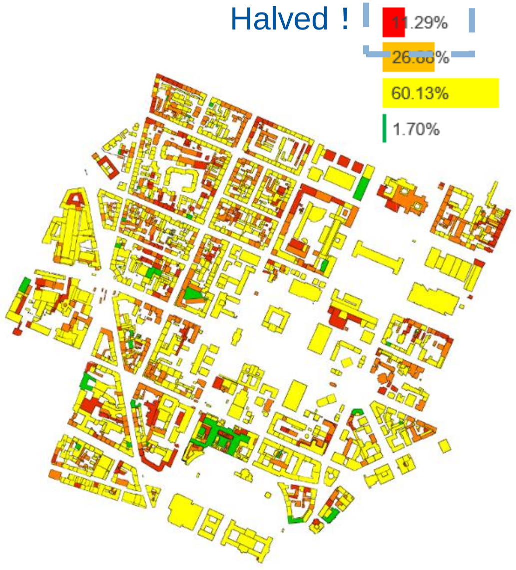
Building color

- >20 cm
- 10-20 cm
- 0-10 cm
- 0 cm

No measures	Grey	Green Blue	Hybrid

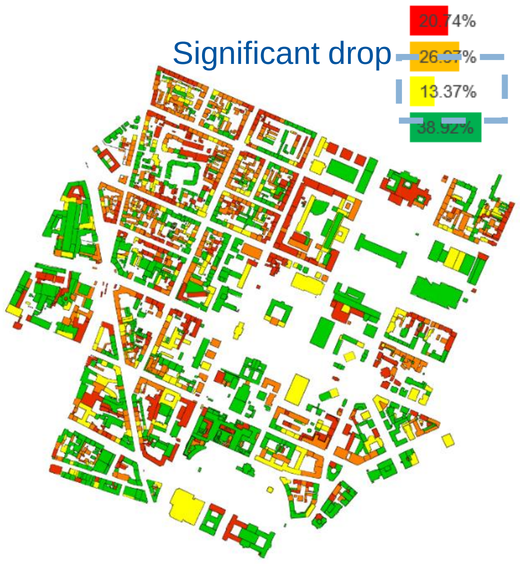


Halved !

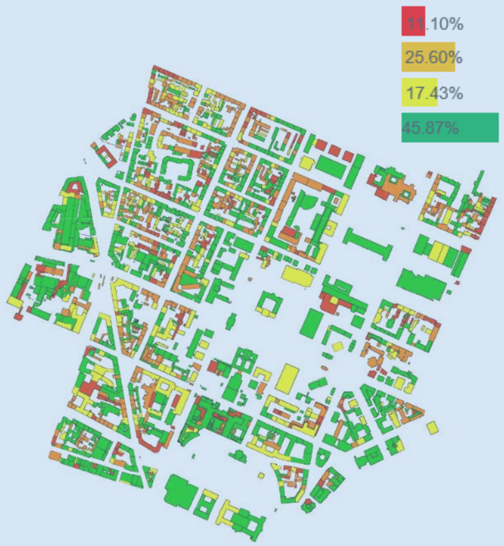


- Areal measure
- Mitigating floods with high water levels

Significant drop



- Point measures
- Mitigating minor floods



Collaborative effects

Conclusions

Adapting Flood Risk Management

- Build consensus
- Focus on recovery (not damage alone)

Exploring the relation between flood risk management and flood resilience, M

Thank you for your attention!

Finally, the following youtube video will give you a glimpse of our Danube Floodplain project. Feel free to ask me or Francesca Perosa for more information.

https://www.youtube.com/watch?v=pzgd-A9XqT8&t=6s

Thank you for your attention!

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