# Hydraulic engineering solutions for withdrawal and permanent storage of solid carrying water from seasonal flash floods in semi-arid regions

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# Overview

- Introduction in rural and urban flash floods
- Methods for risk analysis
- Method application on semi-arid regions
  - Flood risk management
  - Storage of water
- Conclusion

# Rural and urban flash floods

- High intensity rain of short duration (e.g. >100 mm / 6 h)
- Multiple events in 2016, increasingly frequent
- Injuries (e. g. seven dead) & high level of damage


Source: Allianz

**Flash flood in June 2016, Germany/Simbach**


Source: Südwest Press


Source: deutsche-wirtschafts-nachrichten.de

# Rural and urban flash floods

- Risk analysis
- Preventive measures
  - public administration measures and communication
  - regional planning and area development planning
  - engineering flood prevention, facility protection

**Storage capacity of roads**


Source: DWA

**multi-functional use**


Source: DWA

**mobile flood barriers**


Source: Fa. Blobel

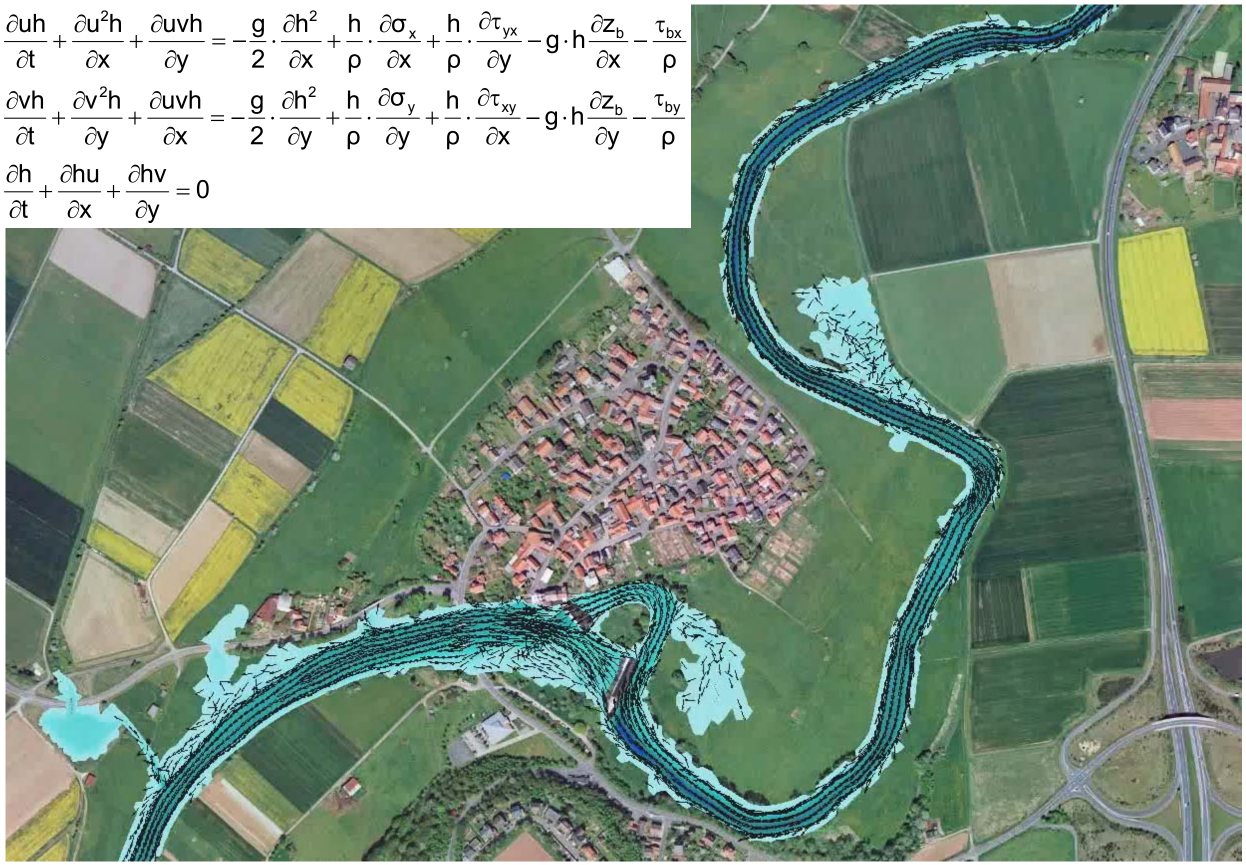
# Risk analysis - Method

- 2D-HN-Simulation (flow velocity, water depth)

$$\frac{\partial uh}{\partial t}+\frac{\partial u^2h}{\partial x}+\frac{\partial uvh}{\partial y}=-\frac{g}{2}\cdot\frac{\partial h^2}{\partial x}+\frac{h}{\rho}\cdot\frac{\partial \sigma_x}{\partial x}+\frac{h}{\rho}\cdot\frac{\partial \tau_{yx}}{\partial y}-g\cdot h\frac{\partial z_b}{\partial x}-\frac{\tau_{bx}}{\rho}$$

$$\frac{\partial vh}{\partial t}+\frac{\partial v^2h}{\partial y}+\frac{\partial uvh}{\partial x}=-\frac{g}{2}\cdot\frac{\partial h^2}{\partial y}+\frac{h}{\rho}\cdot\frac{\partial \sigma_y}{\partial y}+\frac{h}{\rho}\cdot\frac{\partial \tau_{xy}}{\partial x}-g\cdot h\frac{\partial z_b}{\partial y}-\frac{\tau_{by}}{\rho}$$

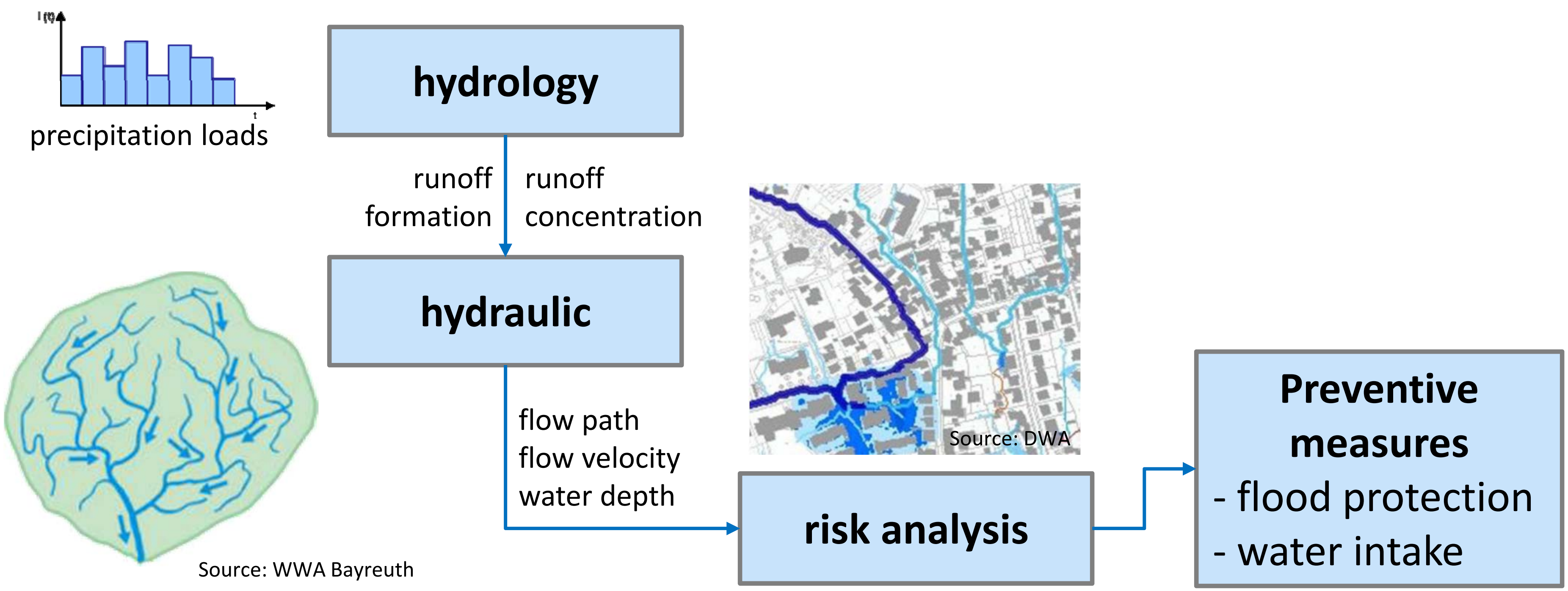
$$\frac{\partial h}{\partial t}+\frac{\partial hu}{\partial x}+\frac{\partial hv}{\partial y}=0$$



**Flood 1984, Lahn river, Germany/Roth**

# Risk analysis - Method

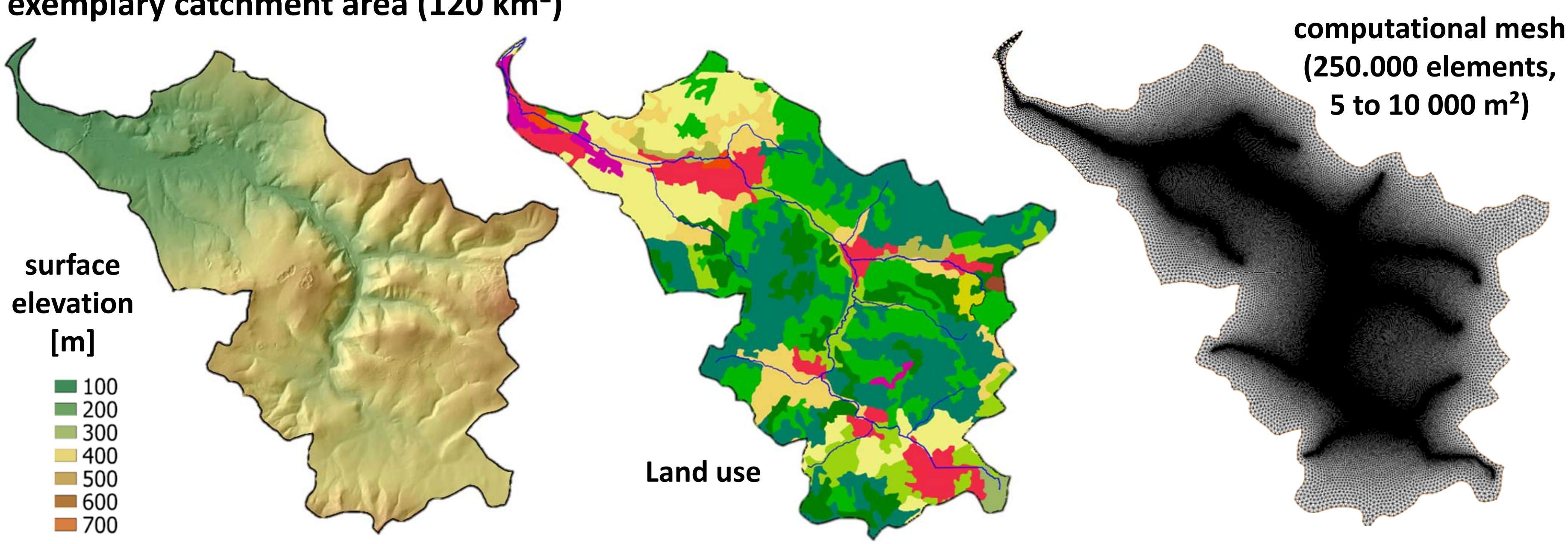
- Coupling the hydrologic and hydraulic process
- Large scale 2D-HN-model to simulate the surface runoff (not only streams, entire catchment area)



# Large scale 2D-HN-modelling - Data

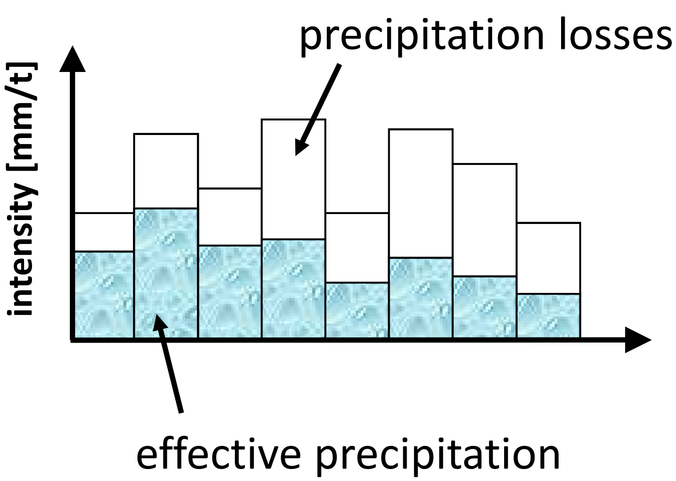
- Surface elevation (DEM) and stream bathymetry
- Land use, soil parameter (roughness, infiltration, evaporation)

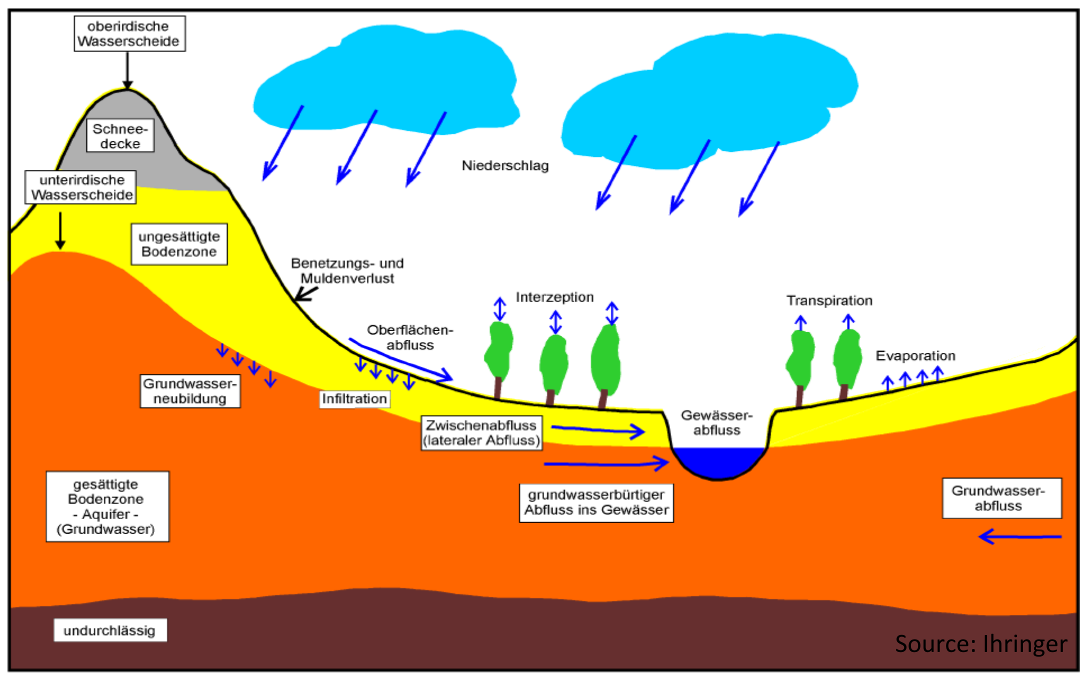
**exemplary catchment area (120 km²)**



# Simulation Tool - Input

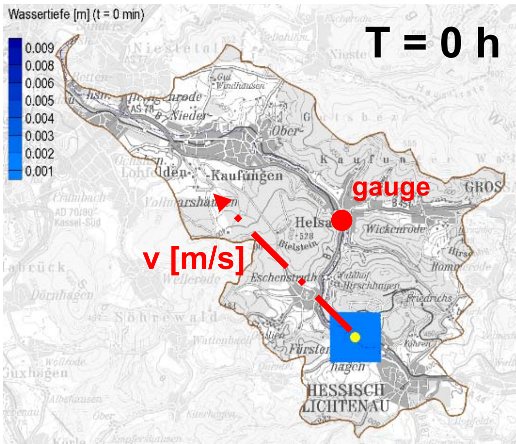
- Spatial precipitation loads
  - Duration, distribution, compass direction and velocity
- Time and soil variable runoff coefficient

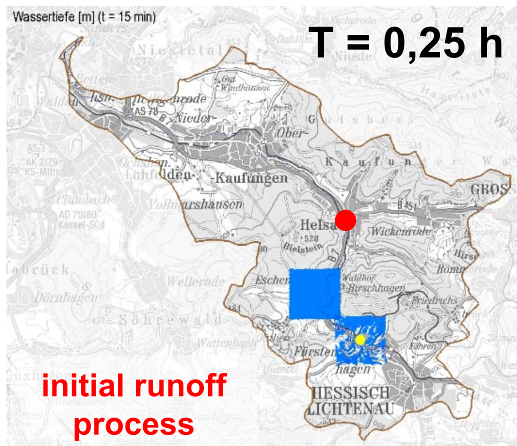


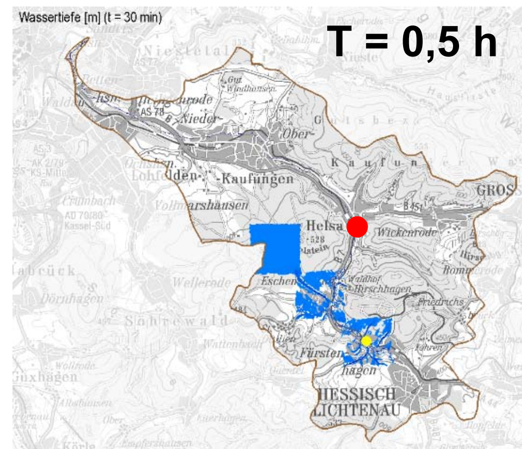



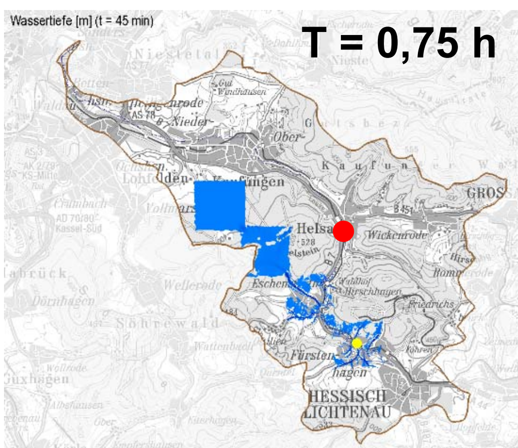
# Simulation Tool - Input

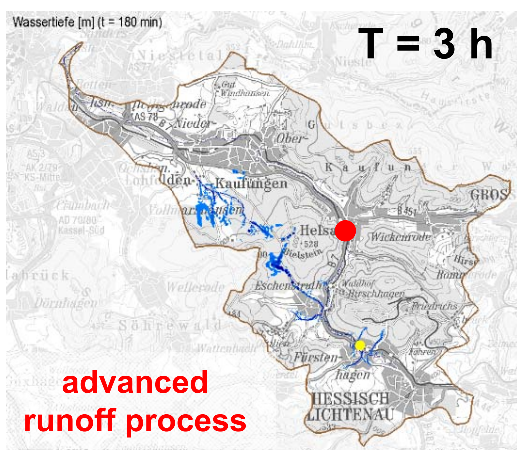
- Movable precipitation load and runoff process



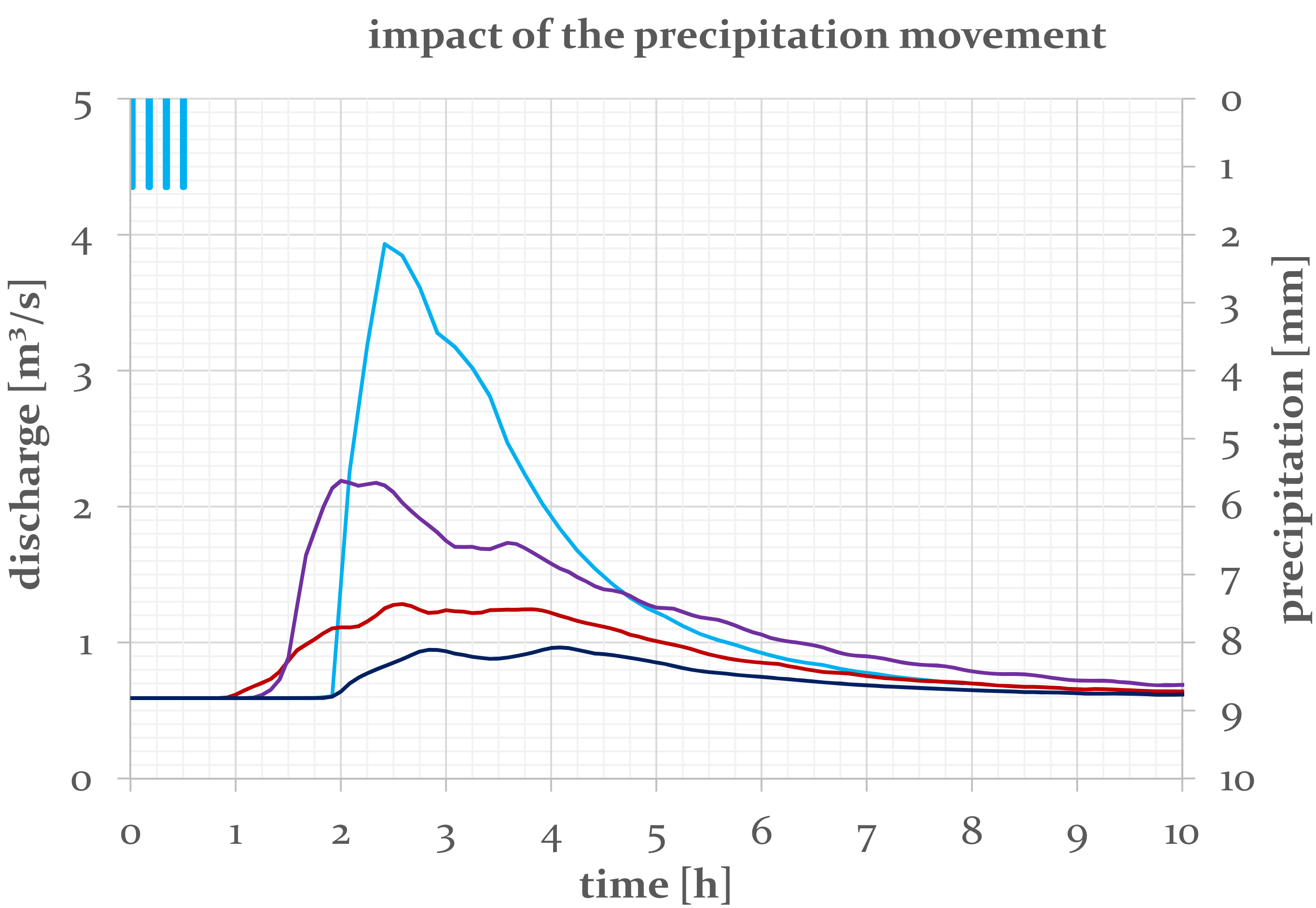



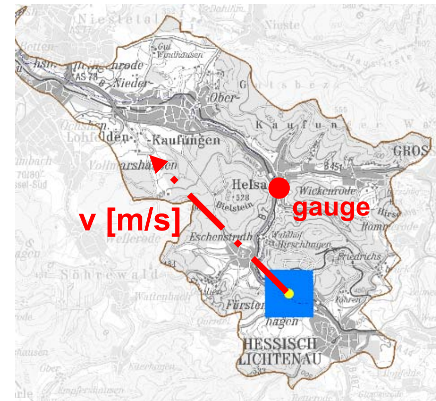

Spatial distribution
$A_N$ = 4 km²

Precipitation load
$h_N$ = 20 mm, ψ = 0.25, $t_N$ = 1 h

speed of precipitation movement
v = 1 m/s

# Simulation Tool - Results



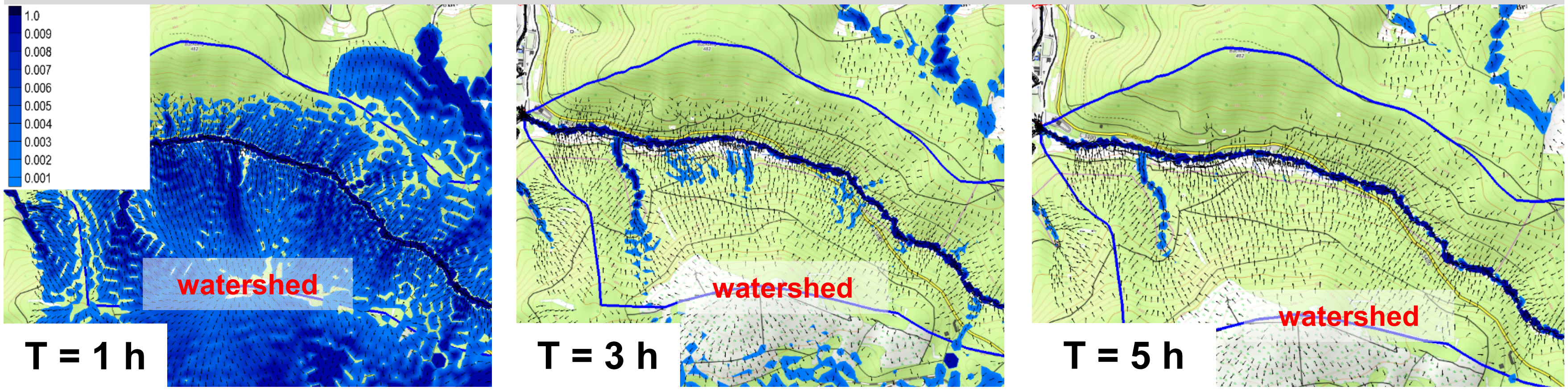




Different scenarios of precipitation movement

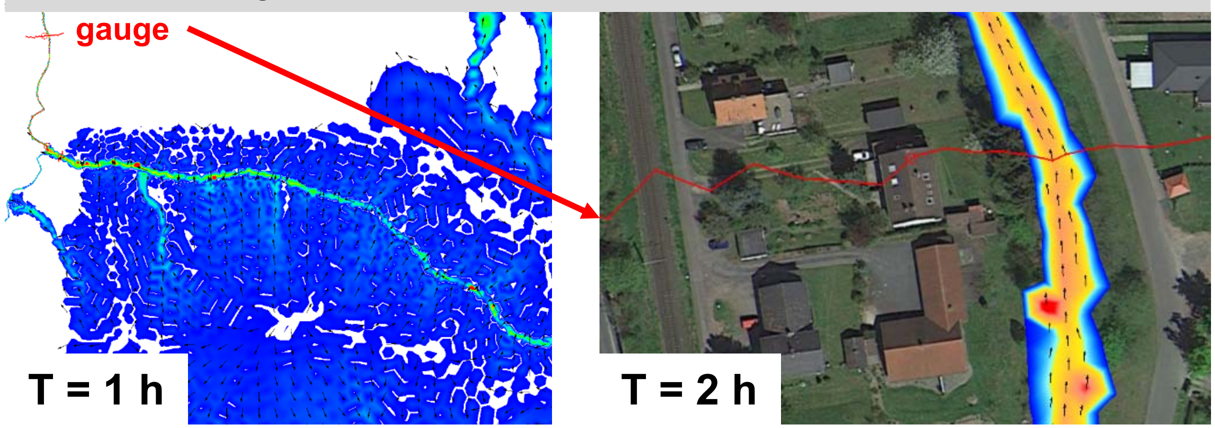
- steady
- v = 1 m/s
- v = 2 m/s
- v = 4.5 m/s

# Simulation Tool - Results

**surface runoff, flow path, water depth**




**flow velocity**



# Simulation Tool - Output

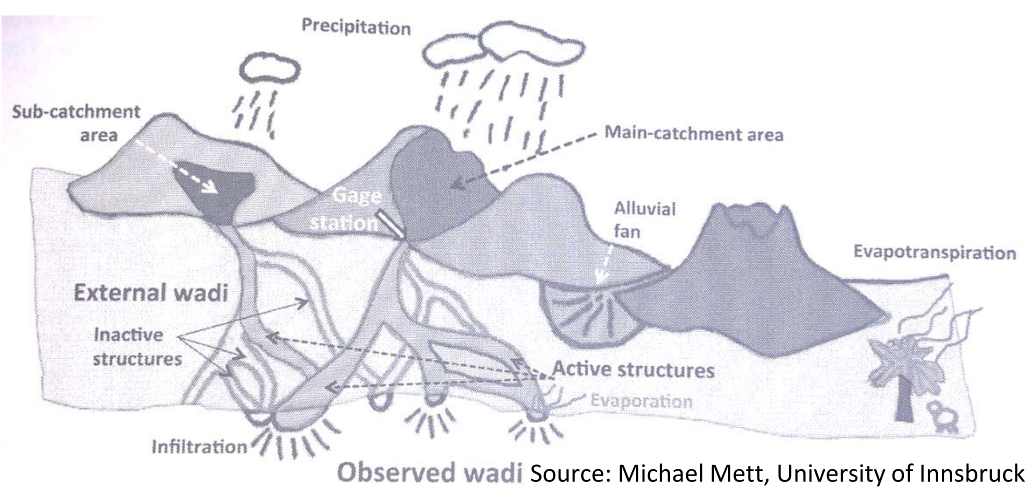
- Basin reaction (runoff formation and concentration)
- Travel times of flash floods and catchment outlet
- Surface runoff (flow velocity and water depth)

Risk analysis and planning preventive measures

Planning water intake structure

# Application on semi-arid regions

- Seasonal and short-term precipitation of high intensity
- Exploitation of flash flood runoff (Rainwater harvesting)
- Identify the watershed area and flow paths
- Find sites for flood protection measures and decentralized water withdrawal structures



Source: Michael Mett, University of Innsbruck

Source: Google earth

# Reservoir - Problems

- Sedimentation (& salinization)

Source: Tewedros Fikre Zenebe, Delft

# Storage of water

- Separate water flow from solids
- Rainwater harvesting (reservoirs, underground storage, infiltration)
- Identify flow zones prone to special phenomena of sediment transport and fluvial morphology
  - Design and operation of hydraulic structures used for water abstraction and infiltration
  - Consider the effects of suddenness, sediment transport and clogging

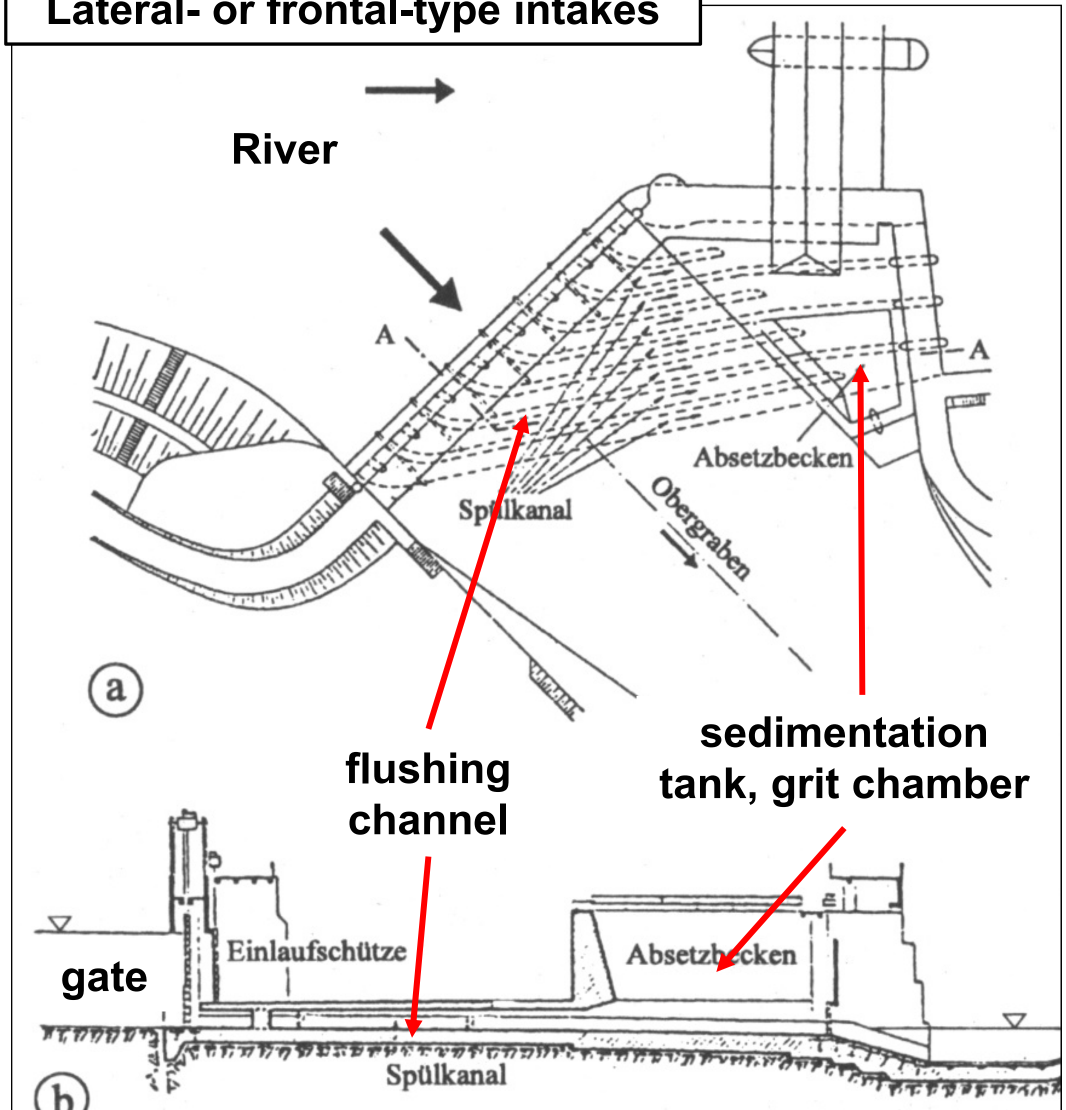

Source: zek 2017


Source: KKL-JNF

# Water intake

- Separate solids (sediments and debris) from water flow
- Minimize sediment input into the reservoir
- Reservoir desedimentation is increasingly important

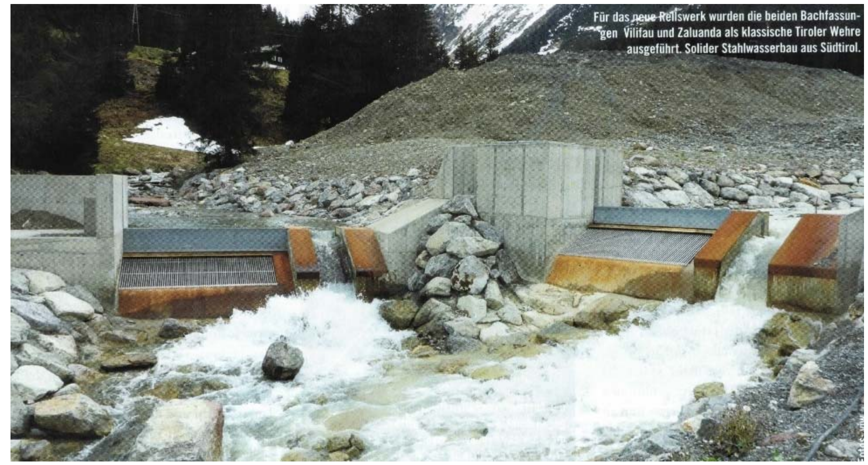
Lateral- or frontal-type intakes




Source: Giesecke, 2012

# Water intake

- Water intake structures in the Alpine region
- Reduced bedload transport

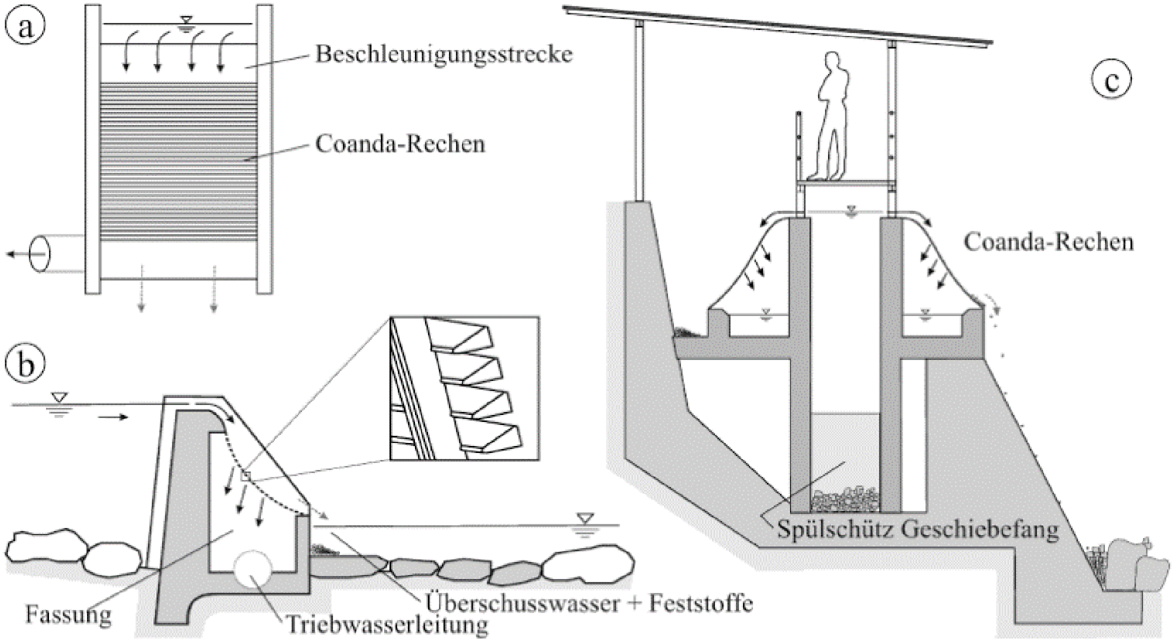




# Water intake

- Water abstraction from the river bed with coanda-screen and sand trap

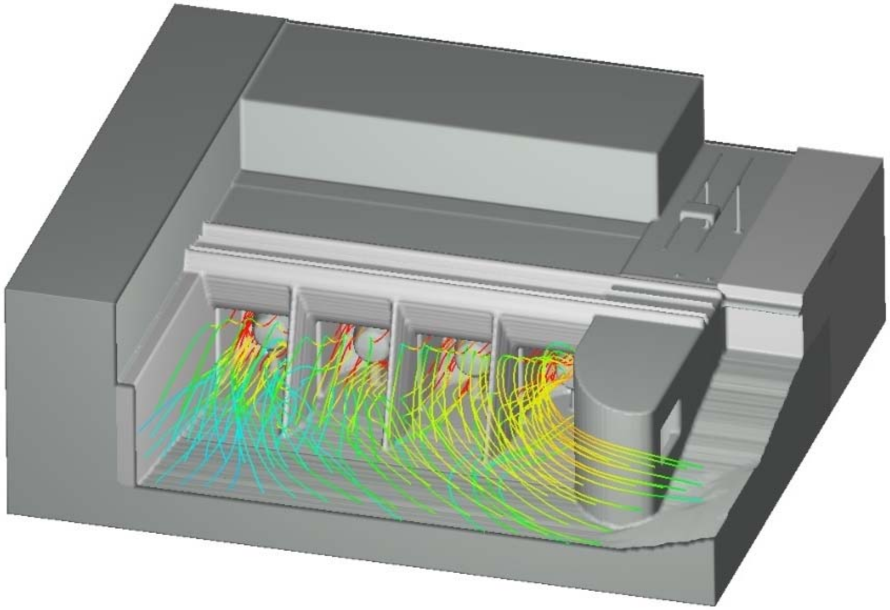
Source: Eberl, ZEK, 02/2017




Source: Giesecke, 2012

# 3D-HN-modelling / laboratory model

- Flow optimized design of hydraulic structures
- Simulation of erosion and sedimentation



# 3D-HN-modelling / laboratory model

- Morphologic investigations at the river Rhine on a hydraulic model with mobile bed

# Conclusion

- Models help to understand complex systems
- Proposed application of robust and efficient 2D-HN-modelling was experimentally applied on watersheds of several hundred km²
- Site identification for flood protection and water withdrawal
- Optimization of design of water abstraction
- Construction design and dimensioning
  - sand trap, screen / trash-rack, pipelines, reservoir

# Thank you for your attention

This wonderful *falaj* is in *Wadi bani Khalid, Al Sharqiyah* Region.