Conceptual approach for a holistic low-flow risk analysis

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FONA Forschung für Nachhaltigkeit

WaX Wasser-Extremereignisse

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Introduction

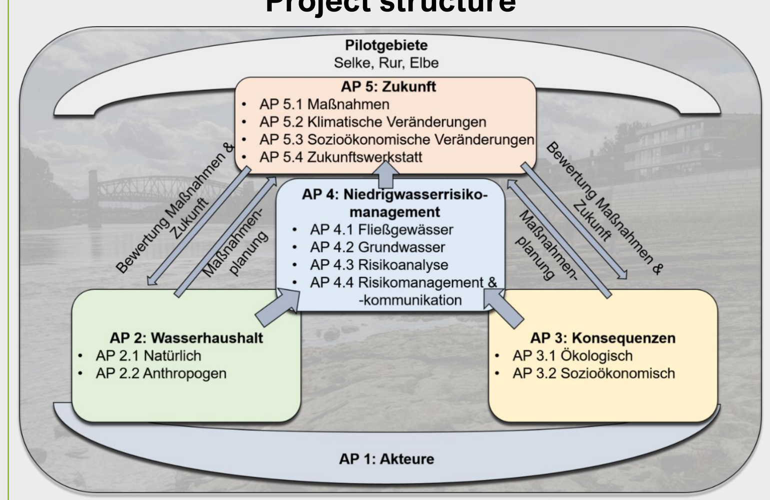
Why do we need low-flow risk management?

- Drought events in recent years lead to massive consequences
- Nuclear power plants in France needed special permits, because of high water temperature (2022)
- Shipping on the river Rhine was disturbed for weeks, leading to disrupted supply chains and higher freight costs (2018, 2022)

Transparent and fair distribution strategy through low-flow risk management

Low-flow risk analysis as basis for low-flow risk management

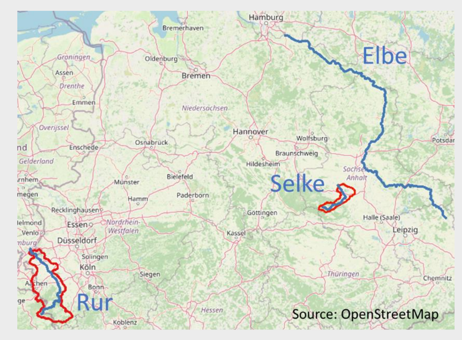
DRYRIVERS



Development of a tool for low-flow risk management

DryRivers-Project

- Part of the research framework WaX (Wasser-Extremereignisse)
- Funded by the Federal Ministry of Education and Research of Germany
- Project duration: 2022 – 2025



Partner

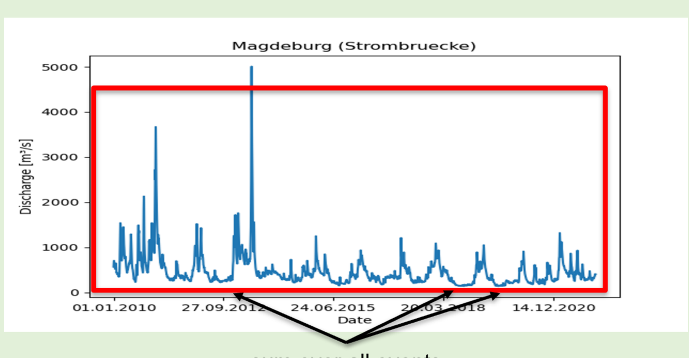
- University of Applied Sciences Magdeburg-Stendal
- RWTH Aachen University
- umweltbüro Essen
- LimnoPlan

Long-term series approach

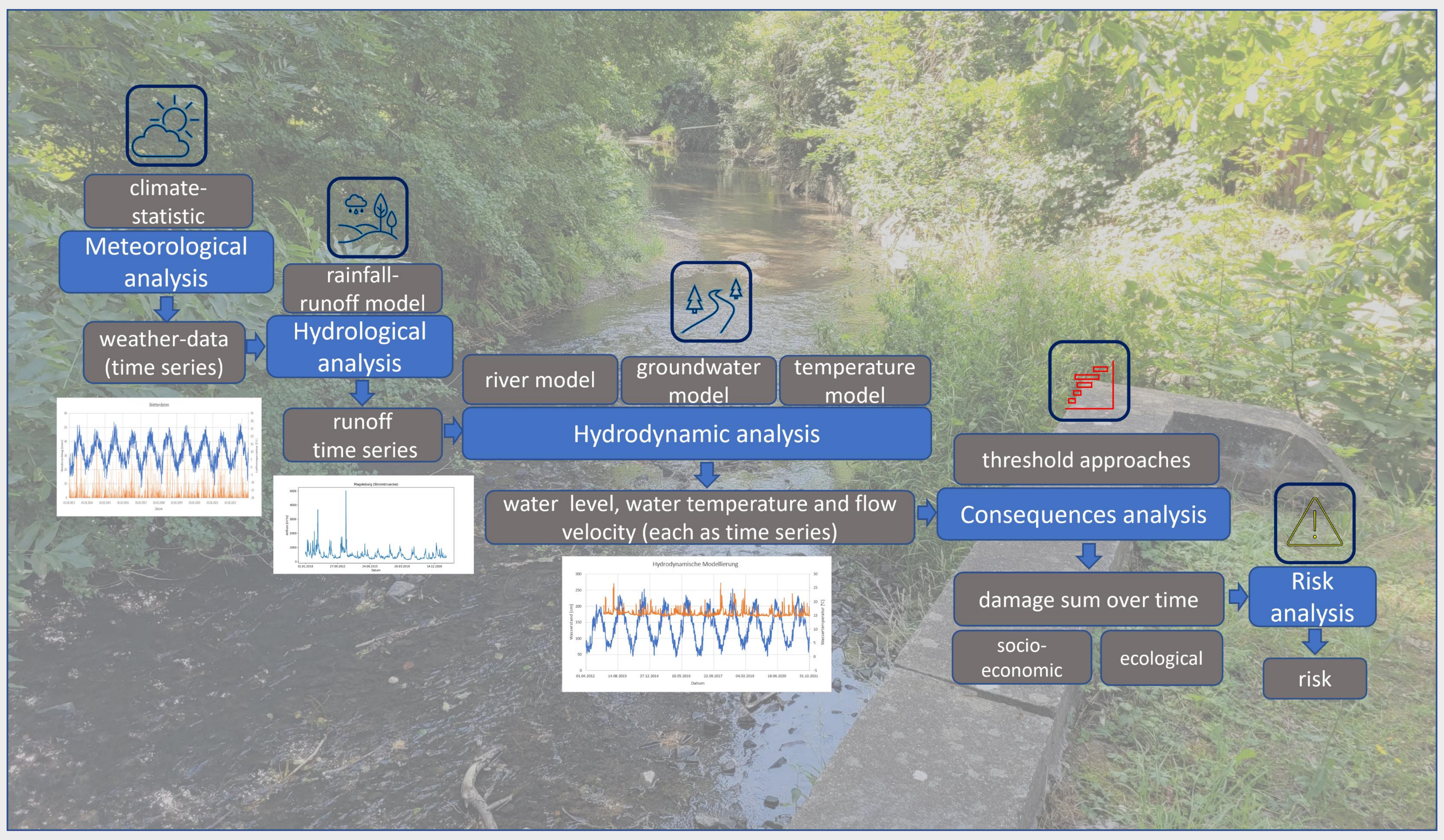
- Flood risk analysis: **Scenario-based approach**
  - Scenario-based calculations (e.g., HQ_{100})
  - Duration of flood event short: few days till few weeks

→Low-flow: How to define a scenario?
- Low-flow risk approach: **continuous approach**
  - Duration of a low-flow event over month and years
  - Hydrological conditions from previous years are essential

→Long-term series to capture all aspects



Concept low-flow risk analysis

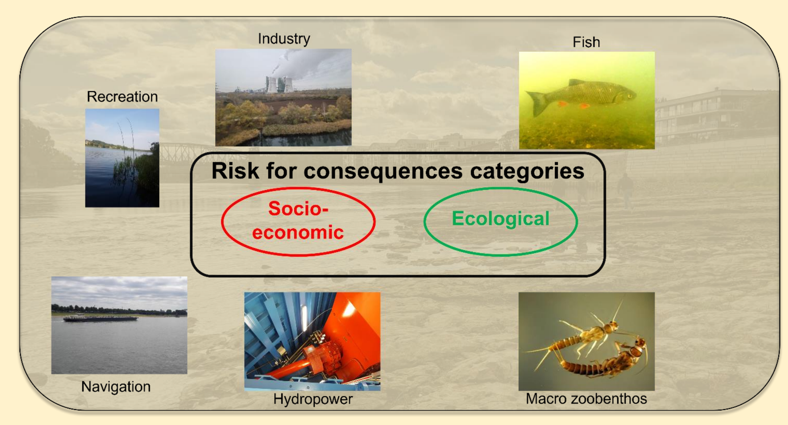


Risk analysis

Risk for consequences categories

- risk analysis over **long-term series of the consequences** for different categories
- long-term damage sum of the respective consequence category $K_{i,j}$ are divided by the number of simulated years n to calculate the risk R_i

$$R_i = \frac{\sum_{j=0}^{n} K_{i,j}}{n}$$



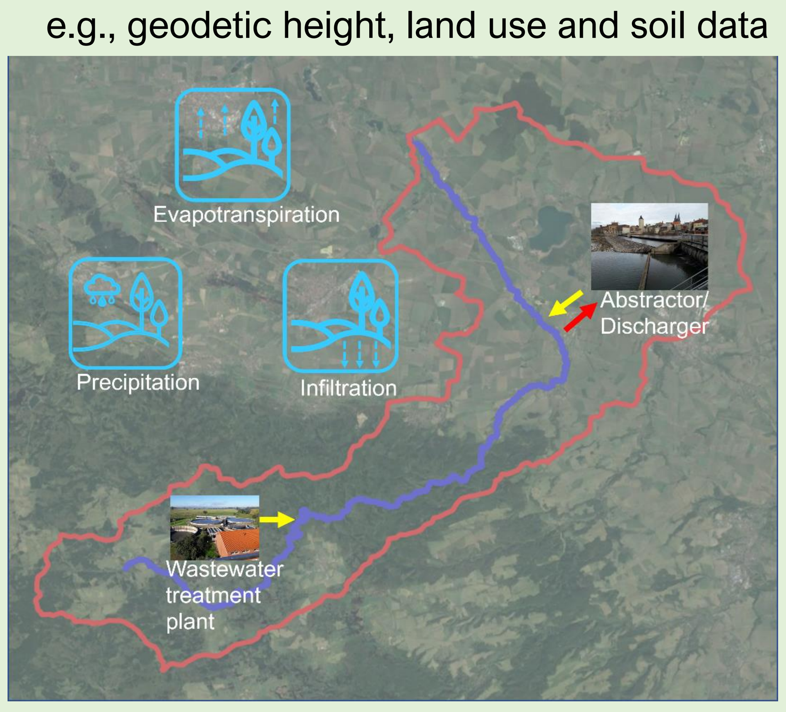
Meteorological-Hydrological analysis

Meteorological analysis

- Based on a statistical description of the current (or future) climate
- Synthetic **long-term weather data time series** are generated
- Represents the selected climate state over a period of several hundred years
- Tool: e.g., a stochastic weather-generator

Hydrological analysis

- **Weather data time series** from meteorological analysis are transformed into **runoff time series**
- Tool: e.g., rainfall-runoff modeling
- Consideration of catchment characteristics e.g., geodetic height, land use and soil data



Hydrodynamic analysis

River model

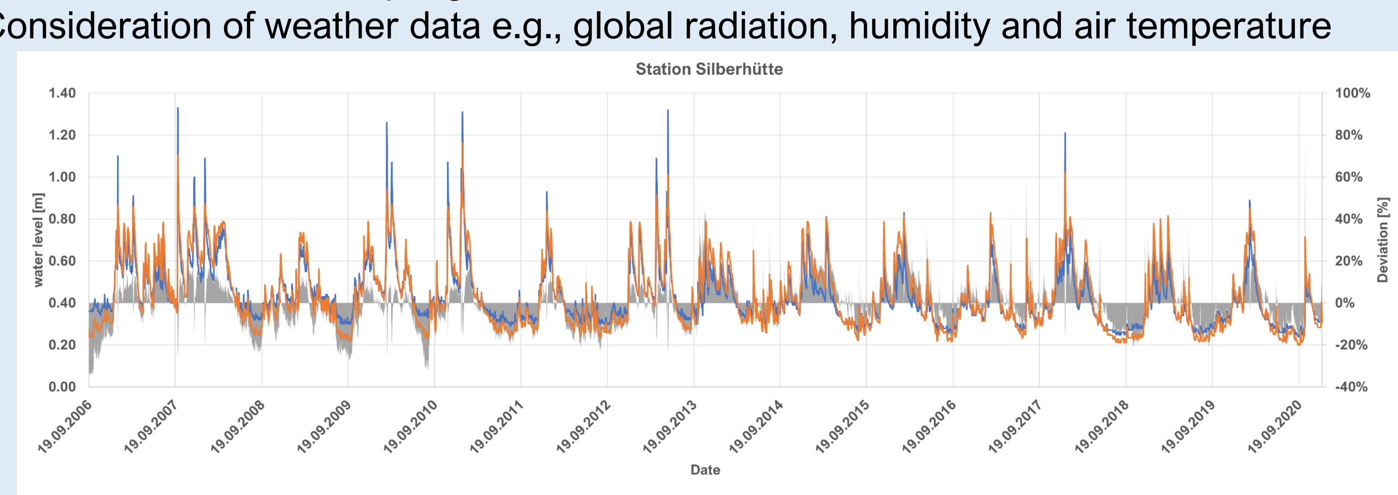
- **Runoff time series** derived from hydrological analysis are transformed into **time series of water levels and flow velocities** in the river
- Tool: e.g., hydro-numeric 1D-river model based on the diffusive wave approach (a simplification of the ST. VENANT-equations)
- Consideration of geometrical river characteristics by cross sections and roughness coefficients

Groundwater model

- Captures the interaction of the river with the near-surface groundwater close to the river
- Calculates the ex/infiltration between groundwater and river
- Tool: e.g., 2D-groundwater model with a bidirectional coupling to the 1D-river model
- Consideration of soil characteristic e.g., groundwater thickness and hydraulic conductivity

Temperature Model

- time series of water levels and flow velocities in the river are transformed into **time series of water temperature** in the river
- Tool: e.g.,1D-temperature transport model based on the advection-heat transfer equation with a unidirectional coupling to the 1D-river model
- Consideration of weather data e.g., global radiation, humidity and air temperature



Consequences analysis

Analysis of consequences

- Based on the **time series** resulting of the hydrodynamic analysis

Socio-economic consequences

- Diverse categories of consequence: navigation, hydropower, recreation, process water for industry, and more
- Tool: e.g., threshold approaches for quantification resulting in **long-term time series of economical consequences**
- For instance, navigation:
  low water level → reduced freight
  → higher freight costs
- Considering type specific economical characteristics e.g., tourism and navigation

Ecological consequences

- Based on impacts to fish and macro zoobenthos
- Tool: e.g., empirically based threshold approaches for quantification resulting in **long-term time series of ecological consequences**
- Considering river specific characteristics e.g., physical structure of the watercourse and biological data
- For instance, fish:
  Low water level + high water temperature
  →low oxygen level & high oxygen demand
  →population losses

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