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Quantifying System Limits: Flood Oriented Operational Stress Testing under Intensified Precipitation Regimes in Central Europe

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Scenario-based stress testing (FLOOD-ST)

Urban flood risk is often assessed using design events, hazard maps, or single-model scenarios. However, recent flood events have shown that critical impacts frequently emerge when hydraulic loading, infrastructure constraints and operational response limits interact. Bridges, culverts, retention basins, pumping stations, underpasses and access routes may become decisive system elements, even when they are not the primary focus of conventional flood modelling.

This Technical Note introduces **Flood-Oriented Operational Stress Testing (FLOOD-ST)** as a structured approach for identifying functional system limits under plausible but challenging flood scenarios. The method combines scenario-based hydrological loading, hydrodynamic simulation, infrastructure-oriented diagnostics and operational interpretation. Instead of asking only where flooding occurs, FLOOD-ST asks **which system functions fail, under which stressors, and which barriers can prevent or mitigate consequences**.

Methodologically, the approach links catchment-specific stressor selection, hydraulic model diagnostics, and further risk-structuring methods. This supports translating model results into decision-relevant information for flood risk management, emergency planning, and stakeholder communication.

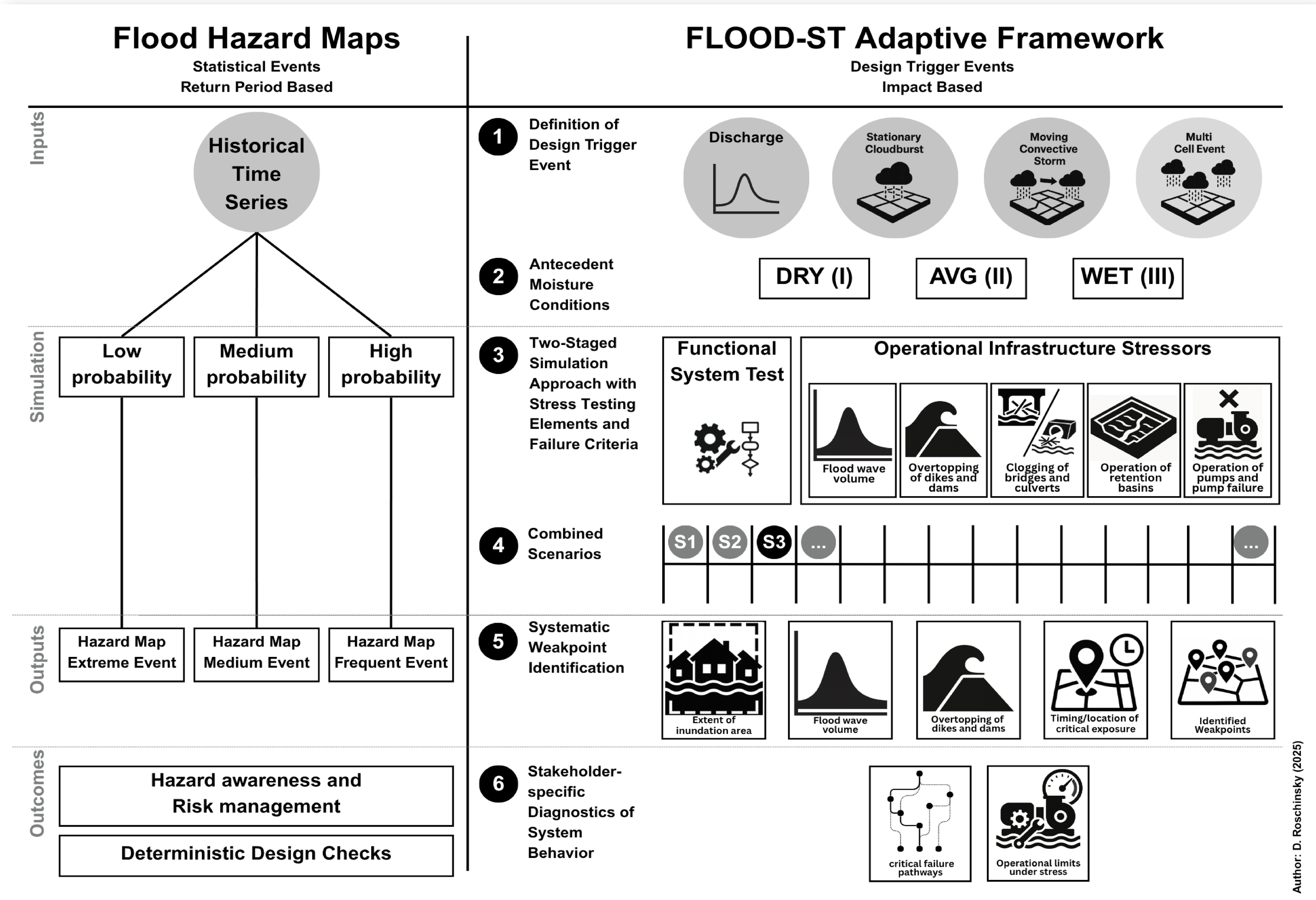

Figure 1: Conceptual workflow of FLOOD-ST. The approach starts with catchment-specific stressors and scenario archetypes, translates them into hydrological and hydraulic model inputs, evaluates exceedance of functional system limits, and links the diagnostic results to preventive and mitigative measures.

1. Definition of design triggers
The framework starts by defining flood-relevant design triggers, such as rainfall characteristics, discharge conditions, or infrastructure-related stressors, that are relevant to the investigated catchment and decision context.

2. Representation of antecedent moisture conditions
Catchment state is explicitly accounted for by distinguishing among dry, average, and wet initial conditions. This step acknowledges that flood response is not determined solely by rainfall intensity.

3. Two-staged assessment of flood-system performance
FLOOD-ST combines a **functional system test** with an **operational infrastructure stressor assessment**. This allows the analysis to move beyond inundation patterns towards diagnosing performance limits in urban flood-risk systems.

4. Development of combined scenarios
Stressors are systematically combined to generate plausible yet challenging flood scenarios. These may include intensified precipitation regimes, altered catchment states and infrastructure-related constraints.

5. Identification of functional system limits
Hydrodynamic model outputs are evaluated with respect to critical thresholds, such as exceeding conveyance capacity, local surcharge, flow path relocation, ponding at low points, or loss of drainage performance.

6. Stakeholder-oriented diagnosis of vulnerabilities and barriers
The final step links modelling results to practical flood-risk management by identifying vulnerable system elements, relevant preventive and mitigative barriers, and priorities for planning, maintenance and emergency response.

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