A paradigm shift in the design of fluvial futures

Situation: Adapting a densely populated delta to the combined impacts of climate change and socioeconomic developments presents a major challenge for the sustaining multiple functions throughout the 21st century. The ecological function requires a divers natural wetland with suitable habitat for all taxonomic groups of species that are characteristic of the fluvial area, which contrasts with the agricultural function that thrives by dry meadows and agricultural fields. The European Water Framework Directive (WFD; 2000/60/EC) aims at a good ecological and chemical status for surface water, which should be based on a river basin approach. The flood conveyance functions of deltaic rivers requires interventions to convey higher discharges from upstream, while taking the rising sea level into account that determines the downstream boundary condition. The EU Flood Directive (FD; 2007/60/EC) requires all member states to “to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk.” Lastly, navigation requires harbours and deep channels, while housing and industries also need additional space. In the Netherlands, interventions in the river area must comply with the Dutch water law, and the hydrodynamic effects of the intervention should be limited to the constraints set by the hydraulic evaluation framework: less than 2 mm water setup, less than 5 m^3/s difference in the distribution of water at the river bifurcations, negligible cross currents in the main channel to serve save navigation of barges, and only very small changes to the morphological development are allowed. The interventions to reach the often conflicting goals of the WFD, FD and hydraulic evaluation framework include side channels, longitudinal training dams, embankment setback, removal of obstructions, and natural vegetation succession.

Current paradigm: Within the current paradigm, the typical workflow to design the river interventions comprises a geodatabase with spatial information that is converted to input data for a hydrodynamic model. Experts, together with stakeholders, choose what measure will be implemented, and manual adjustments are made to the geodatabase and the derived hydrodynamic model. Expert judgment drives this process, which is limited by the amount of manual work required to update the hydrodynamic model with a realistic bathymetry and land cover at the spatial extent of the measure. These processes can take years for simple measures, and more than a decade for complicated projects due to the complex and iterative nature of joint decision making. Decision support systems (DSS) for these long term planning projects in the preparedness phase are scarce, contrary to DSSs for operational flood management. Decisions on the interventions require an overview of cost and benefits immediately after the implementation of the intervention and a solid understanding of the temporal development regarding morphology, vegetation succession, biodiversity, and costs.

Ongoing research: Current research on intervention planning and evaluation has provided the tools to create an extensive overview of interventions and their development over time. The intervention planning and evaluation has been automated to create an overview of costs and benefits of common landscaping measures within the context of increasing discharge and sea level rise (Straatsma et al. 2018). The positioning and parameterization of the intervention was based on an adaptive set of user-specified rules. For example the cross sectional shape of a side channel was based on settings and the suitability of a floodplain area for a side channel was based on land cover and proximity to the main channel and the embankment. Seven intervention types were evaluated on their efficiency in flood hazard reduction, potential biodiversity, number of stakeholders as a proxy to governance complexity, and measure implementation cost. Clear trade-offs were revealed between evaluation parameters, but no single measure represented the optimal combination on all aspects (Straatsma et al. 2019).

Paradigm shift: The coupling of AI with hydromorphological, ecological, and economic models will create a shift in the design process of the fluvial future. It enables the co-creation of adaptation paths between computer-generated designs and input and evaluation from river managers and stakeholders. The future of the river area can be explored extensively by the coupled AI-river model with a very large set of interventions. The output can be presented using strong visual representations of the land cover immediately after the implementation of the measure as well as its ecomorphological development over the next 50 years. Subsequently the design options can be evaluated by river managers, from which the coupled model learns for the next iteration in the design cycle. The solution space should be fully interactive to give the managers the ability to explore the source data and the proposed intervention at the required level of detail.

WFD: https://ec.europa.eu/environment/water/water-framework/index_en.html

FD: https://ec.europa.eu/environment/water/flood_risk/

Hydraulic evaluation framework: https://www.helpdeskwater.nl/onderwerpen/wetgeving-beleid/waterwet/@178387/rivierkundig/

Straatsma et al. 2019: https://www.nat-hazards-earth-syst-sci.net/19/1167/2019/

Straatsma et al. 2018: https://www.sciencedirect.com/science/article/pii/S1364815217307272