Wetropolis: models for education & water-management of floods and droughts

Onno Bokhove[1], Tom Kent[1], Henk de Poot[2] and Wout Zweers[3]

[1]School of Mathematics, University of Leeds, Leeds, UK; [2]Nobis & [3]Wowlab, Enschede, The Netherlands
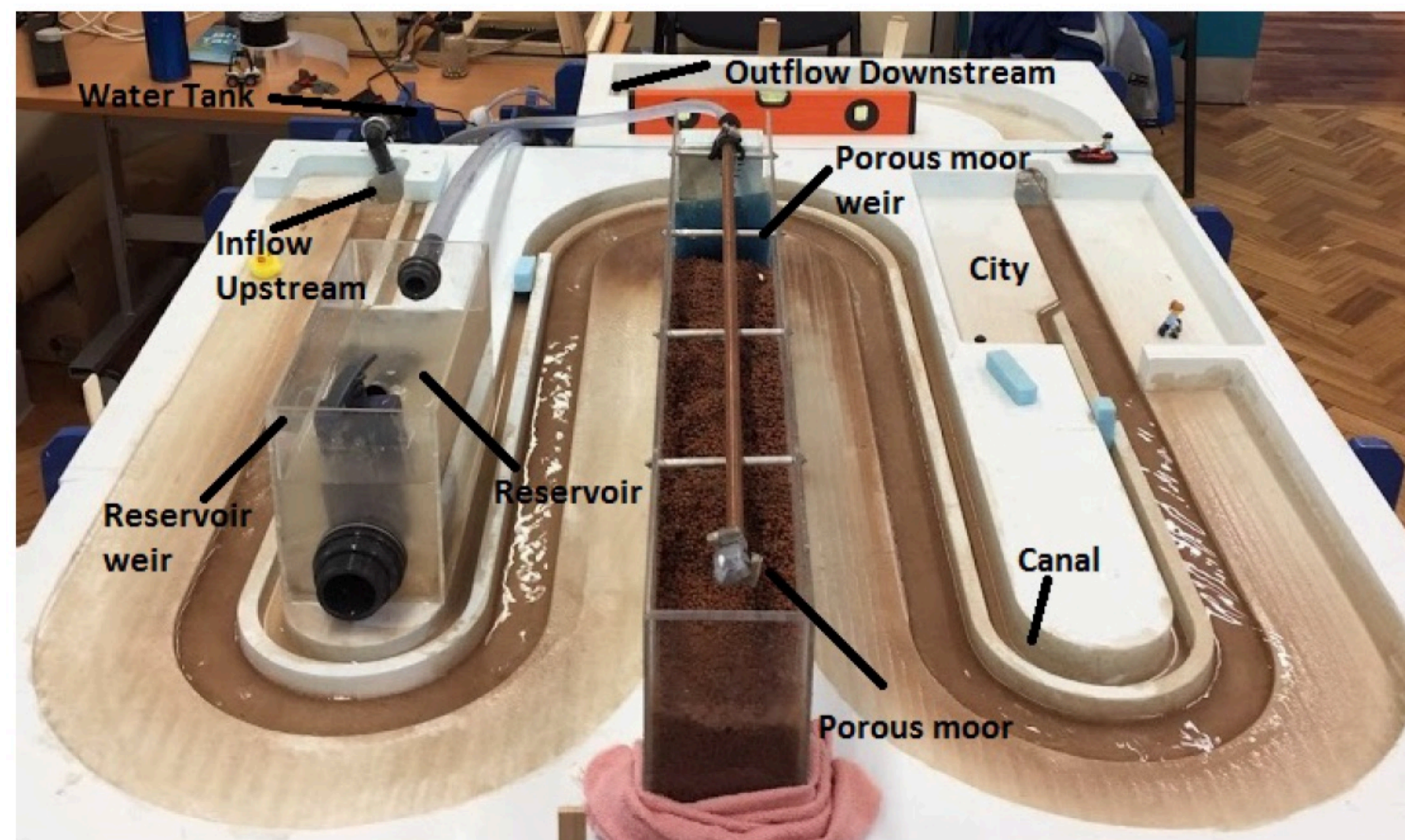
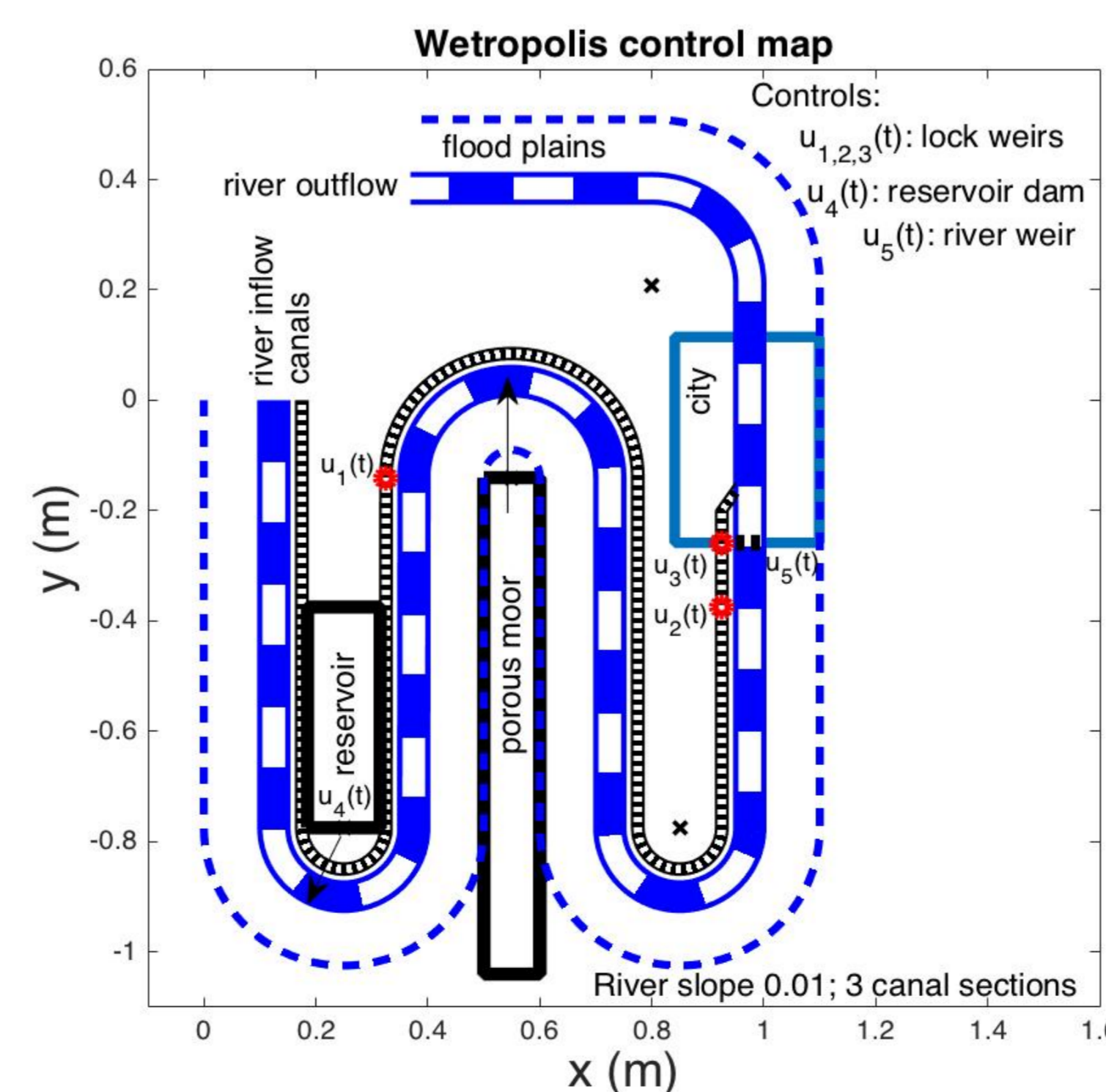## Mathematics of extreme rainfall/flood demonstrator

Wetropolis interactive flood demonstrator is based on a mathematical design and visualises how extreme rainfall events can cause extreme river-flood events in a dynamic, conceptual and scaled table-top set-up. Galton boards are used to model different rainfall scenarios over the course of a Wetropolis day (wd=10 seconds) and extreme flooding in a city by rainfall on the current and previous days, as in the real world [1].

Overview, modelled after Leeds' Boxing Day flood 2015 (1:300yr return-period event):
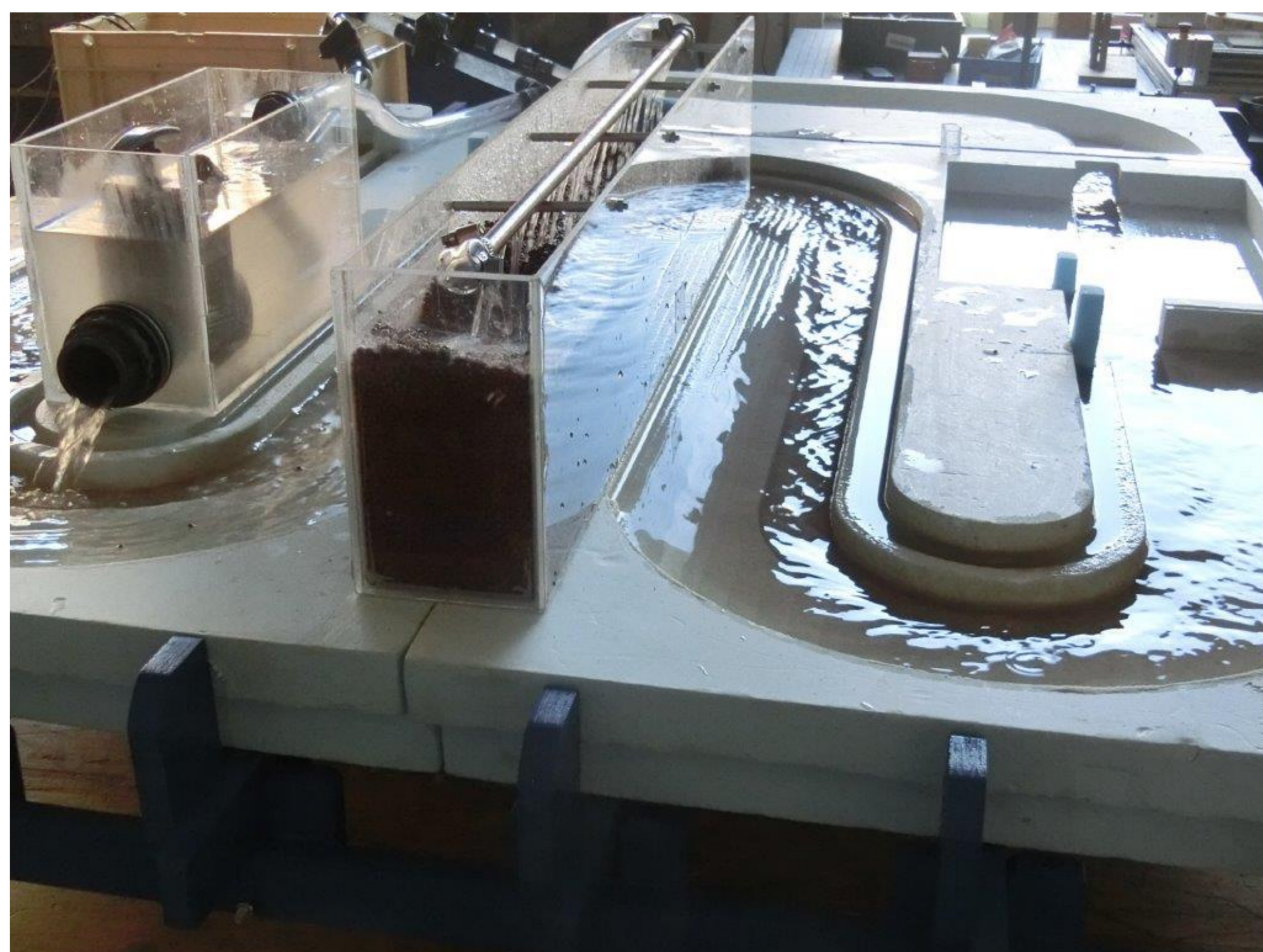- 1:100 sloped river bed; Wetropolis day 10s; upstream inflow; with canal, reservoir/lake & porous groundwater moor draining into river;
- chance of rare flood event in city after 90% rainfall (9s/wd) is (1/16)x(7/16)=7/256 with a *(256/7)x10s=6:06min return period*.

Galton boards: steel balls travel down and land in 1 of 4 columns with at each junction a 50% chance of ball going left or right. Galton boards randomly determine: (i) rainfall amount (columns: 1s, 2s, 4s, or 9s) and (ii) rainfall location (columns: lake/reservoir, moor & reservoir, moor, or no rainfall). Probability asymmetric Galton board: (3,7,5,1)/16. *Plan view*:

Wetropolis is designed to *flood* (right) under extreme rainfall (9s/wd) in moor & reservoir; two consecutive wd's of extreme rainfall lead to a chance of (7/256)² <1%; cf. Boxing-Day flood 2015, see; https://youtube.com/watch?v=N4Sp5gHXcz4
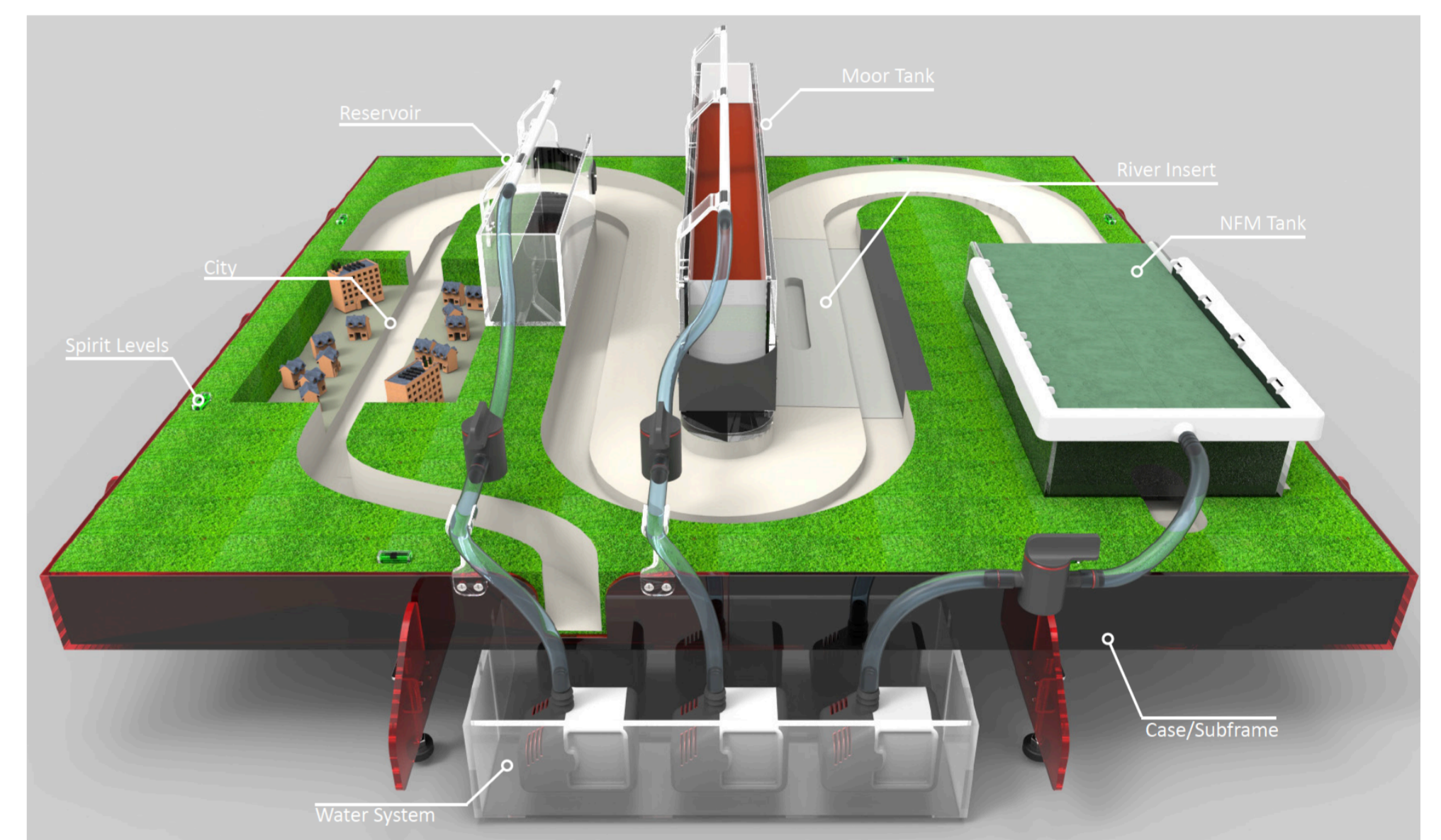

Education & water-management

Droughts: to visualise drought for the 1/16th route of a dry day, we use the outcome of the first Galton board (not used without rainfall) after 2 pins with (3,1)/4 probability. For the 1/4-case, we enforce drought for 4 days, visualised by a drinkwater pipe from the moor falling dry: *no water supply!* New probabilities then adjust to: (12,28,20,3,4)/67 for rainfall in reservoir, moor & reservoir, moor, no rain on single day & no rain for 4 days. *Drought return period: 67x10s=11:10min. New flooding return period: (16x67/28)x10s=6:23min.*

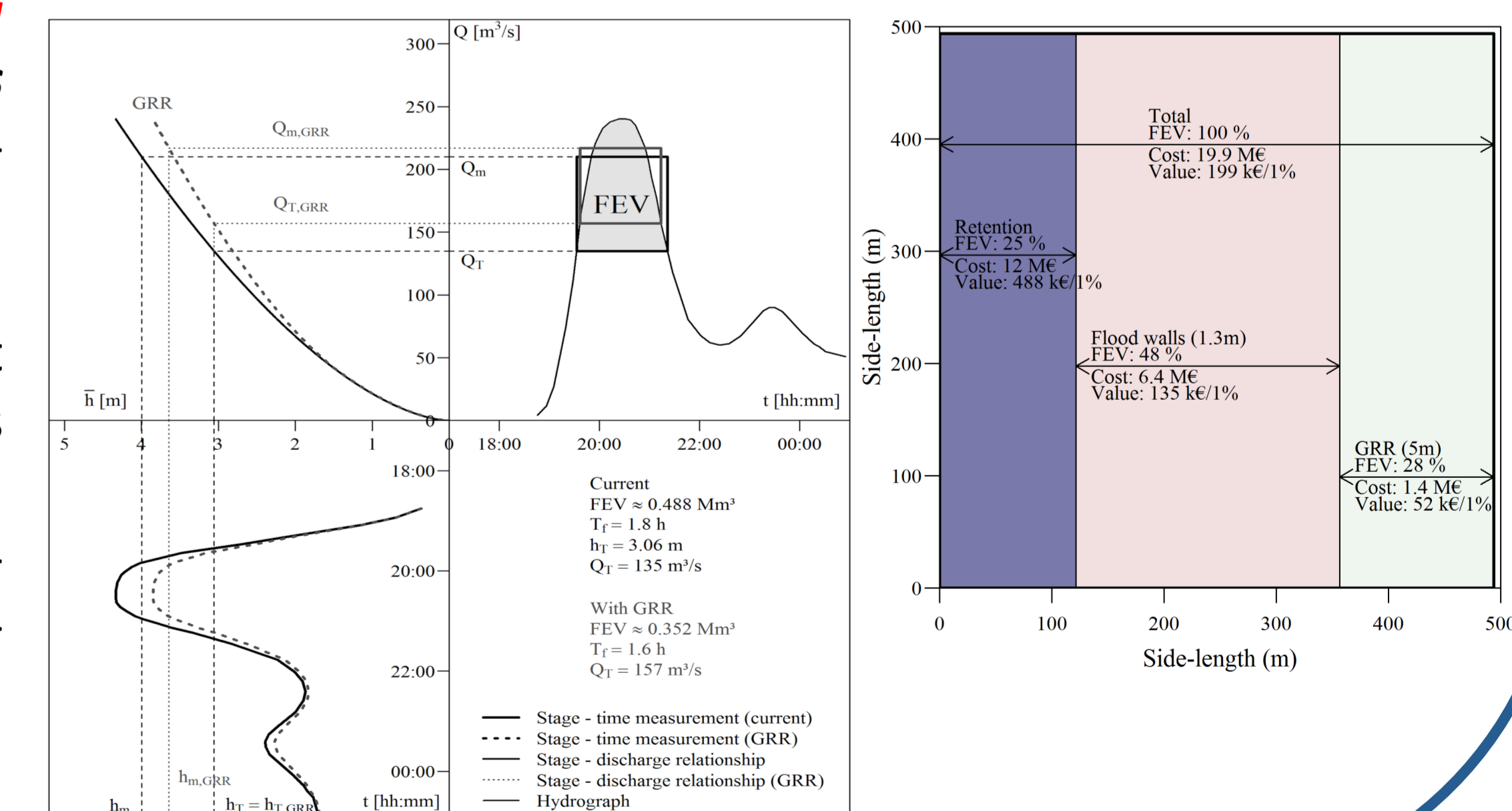*Modular design*: we are currently making a Wetropolis NFM demonstrator with
- participant-built *leaky dams* in oasis-landscape; and,
- river-bed inserts of different roughness ("trees, cement, gravel").
NFM = Natural Flood Management.

Design Changes & Improvements

Promote active thinking about different *scenarios* of flood/drought mitigation: Wetropolis is useful precursor in creation [2] of water-management solutions; also enhances citizens' participation. Wetropolis led to flood-excess-volume based cost-effectiveness analysis, e.g., River Brague flood 2015, France [3]:

References
[1] Bokhove et al 2019: Wetropolis paper & design. https://github.com/obokhove/wetropolis20162020
[2] Poot, de, et al 2019: Wetropolis EU project. https://www.wetropolis.nl/
[3] Bokhove , Kent, Kelmanson, Piton, Tacnet 2018: https://eartharxiv.org/87z6w/ (subm RRA);
    BKK: https://eartharxiv.org/stc7r/ & BKK: https://eartharxiv.org/w9evx/