EXPERIMENTAL INVESTIGATION AND NUMERICAL MODELLING OF EMBANKMENT FAILURE BY OVERTOPPING

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MOTIVATION

Levee failure by Hurricane Katrina, August 2005

Ka Loko Dam Breach (Hawaii), 2006

- Dikes and dams are essential infrastructures for water resources management and also for flood control
- Inundation by dam and dikes breaches results in loss of lives and severe property and environmental damage
- Embankment dams and dikes often fail by overtopping
- Reliable simulation tools are needed for land-use management and for civil protection safety plans
- Breach formation mechanisms are not completely described

Recent studies: geotechnical failure occurs in discrete events but the breach discharge hydrograph is continuum

GOALS

1. **Development of a conceptual model for embankment breach, featuring both geotechnical and hydraulic phenomena**
2. **Implement the conceptual model in a existing existing shallow-water and morphological solver: STAV-2D**

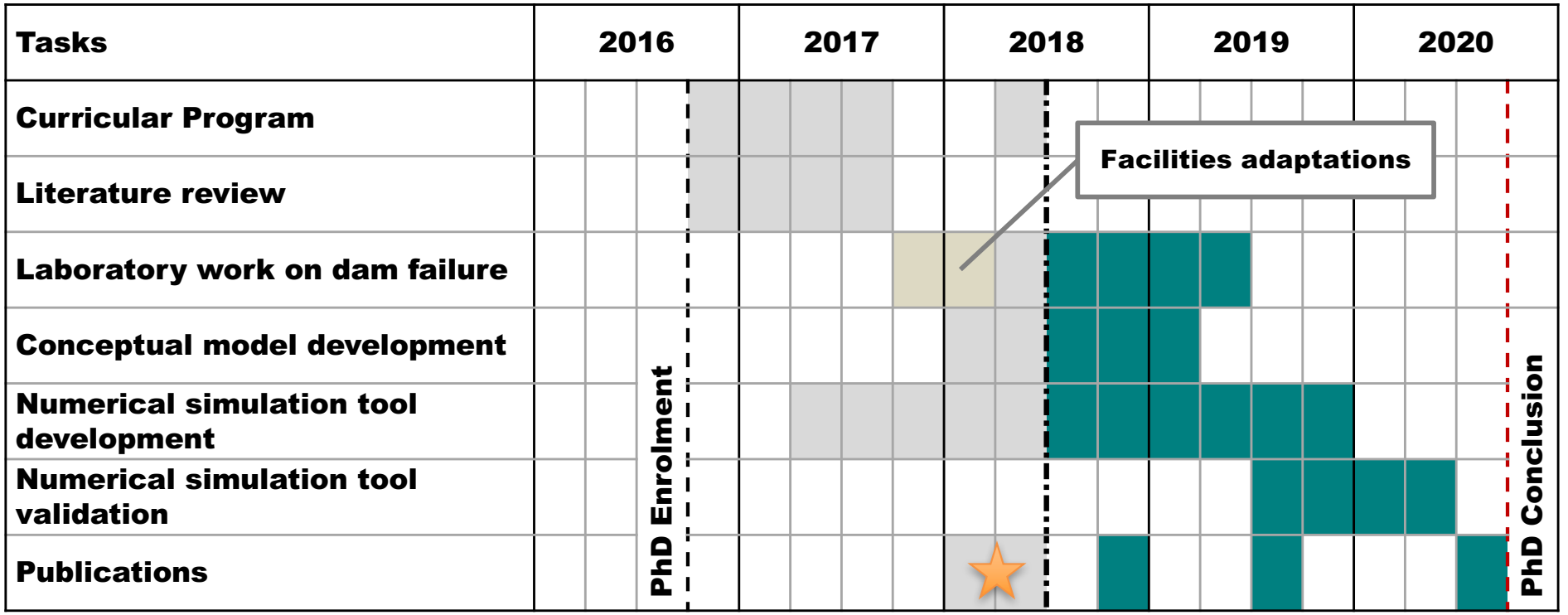
Main Challenges

- Physical processes
  Inclusion of mass detachments
- Geometry and materials
  Inclusion of more realistic embankment characterization (e.g. filters, zoned dams)

Need for experimental characterization

Breach morphology, discharges and hydrodynamic variables

WORK PLAN



Papers in conference proceedings

Alvarez; T., Conde, D., Amaral, S., Viseu, T., Ferreira, R.M.L. (2018). 2D numerical modelling of fluvial dike breach by overtopping. *5th IAHR Europe Congress - New challenges in hydraulic research and engineering*, Trento, 12-14 June

Amaral, S., **Alvarez; T.,** Viseu, T., Ferreira, R.M.L. (2018). Image analysis detection applied to dam breach experiments. *5th IAHR Europe Congress - New challenges in hydraulic research and engineering*, Trento, 12-14 June

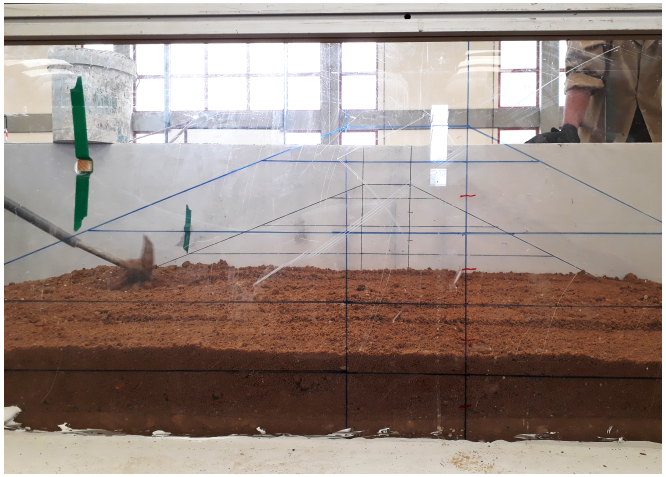
Amaral, S., **Alvarez, T.,** Viseu, T., Ferreira, R. (2018). Modelação Física da rotura de barragens de terra. Instrumentação e métodos de monitorização. *14º Congresso da Água*, Évora, 7-9 March

EXPERIMENTAL INVESTIGATION

EXPERIMENTAL FACILITY

EMBANKMENT CONSTRUCTION

Soil homogenization and humidification



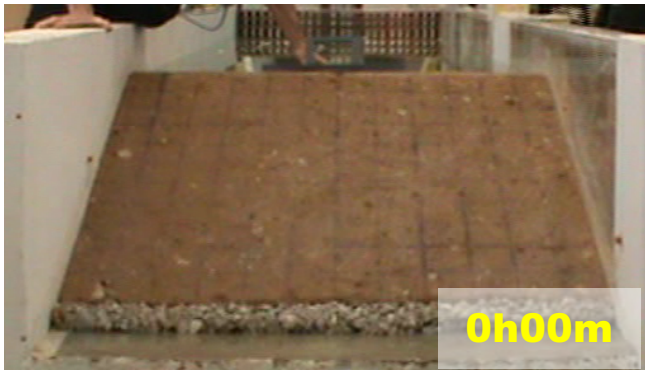
Embankment compaction

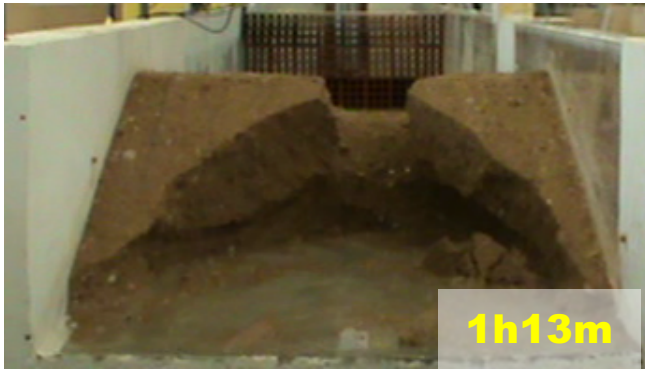
Sand replacement test

Embankment final cut

Toe drain

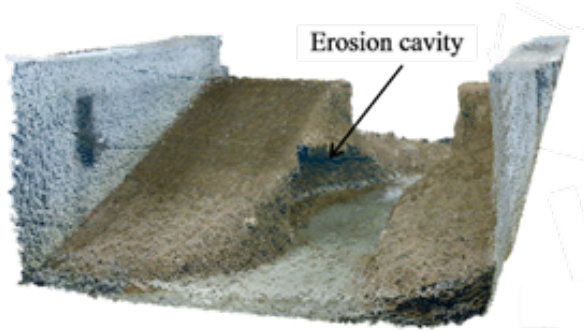
First Results





Pilot channel depth x height: 2 x 2.5 cm

Pilot channel depth x height: 10 x 13 cm



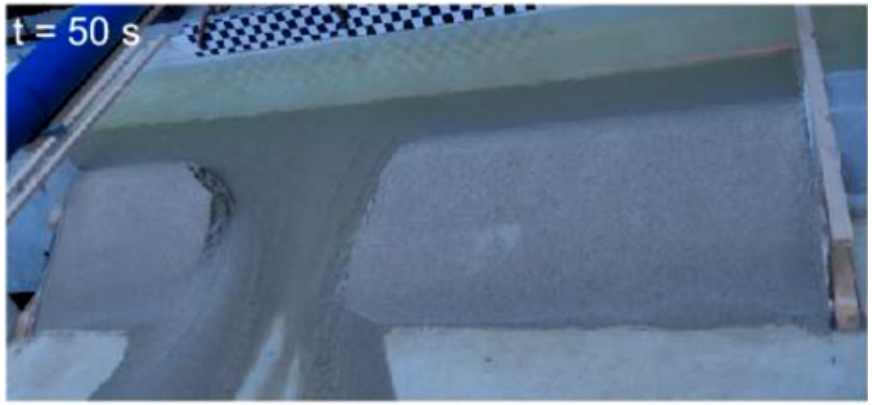
3D reconstruction surface of the failed dam

NUMERICAL MODELLING

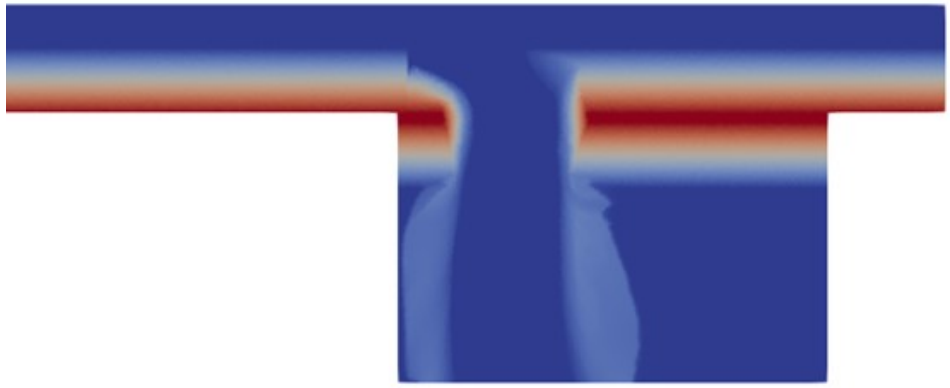
Objective and Approach

Validate STAV-2D for fluvial dike breach, *i.e.* with longitudinal flow, due to overtopping with a simplified geotechnical model

For this purpose experimental data from Rifai (2017) were used (breach of a homogeneous, noncohesive fluvial dike)



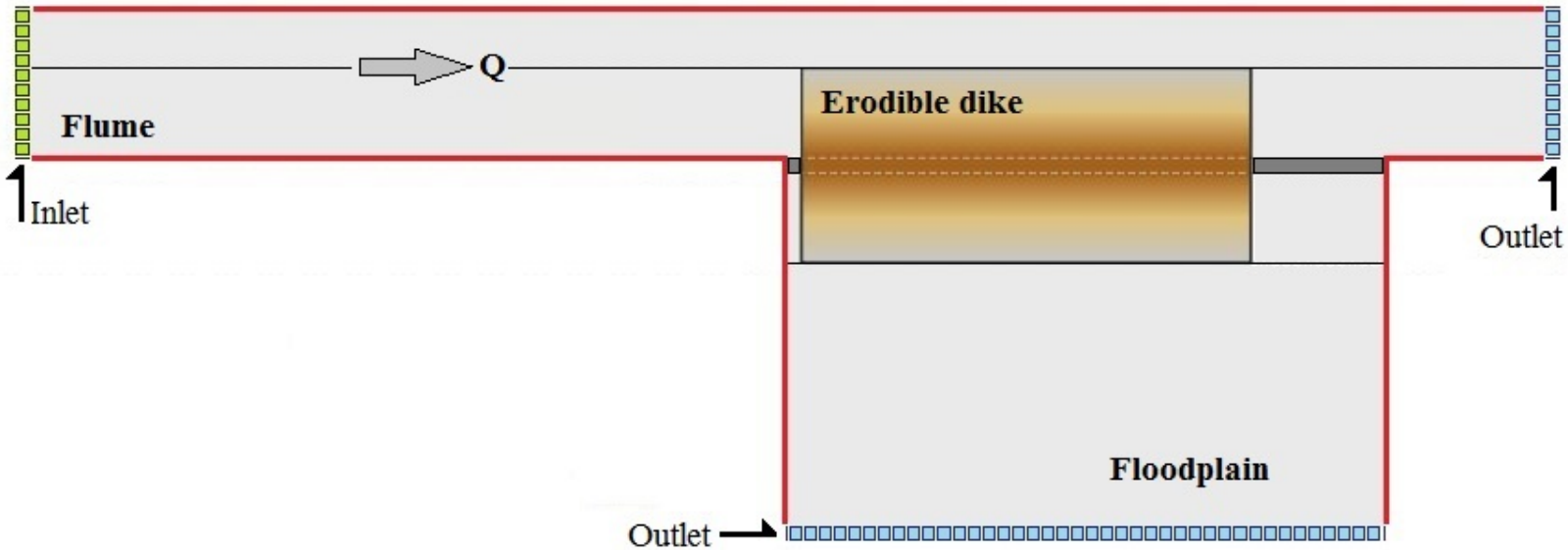
Physical model of Rifai (2017)



Numerical model results

Rifai, I., Erpicum, S., Archambeau, P., Violeau, D., Pirotton, M., Abderrezzak, K. E. K., & Dewals, B. (2017). Overtopping induced failure of noncohesive, homogeneous fluvial dikes. *Water Resources Research*, *53*, 3373–3386.

FLUVIAL DIKE BREACH: EXPERIMENTAL DATA FROM RIFAI (2017)



Flume

- 10.3 m long
- 1.0 m wide
- lateral floodplain

Dike

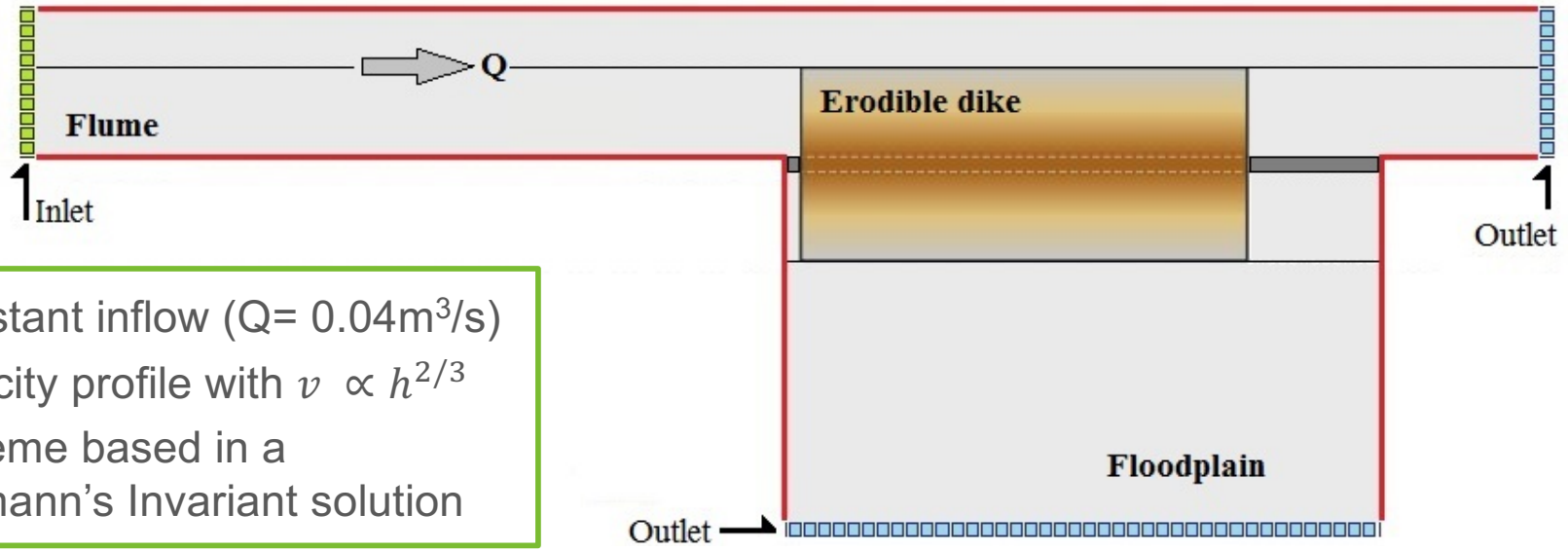
- 3 m long
- 0.3 m height
- trapezoidal shape with slopes 1V:2H
- small pilot channel (10 x 2 cm)

Dike material

- homogeneous, noncohesive sand
- mean diameter of 1 mm
- density of 2500 kg/m^3
- porosity of 36%

FLUVIAL DIKE BREACH: COMPUTATIONAL MODEL

Experimental ratting curve
Scheme based in Riemann's Invariant solution

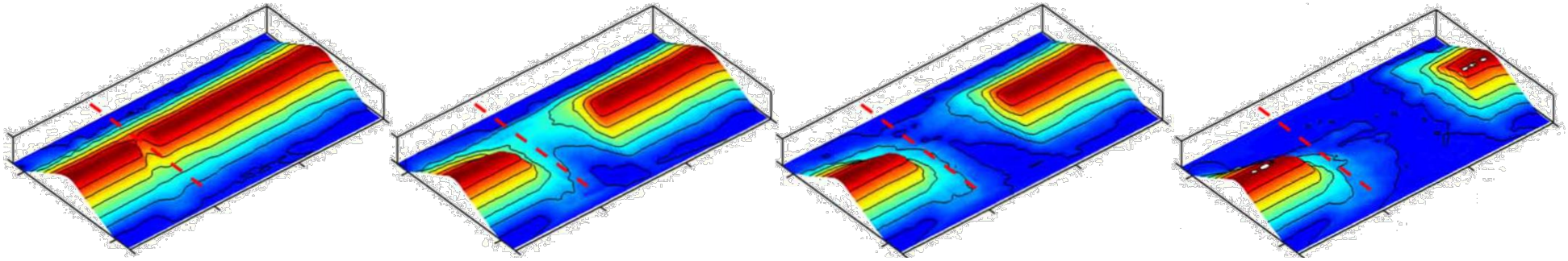


Constant inflow (Q= 0.04m^3/s)
Velocity profile with $v \propto h^{2/3}$
Scheme based in a Riemann's Invariant solution

Open boundary
Scheme based in a zero gradient condition

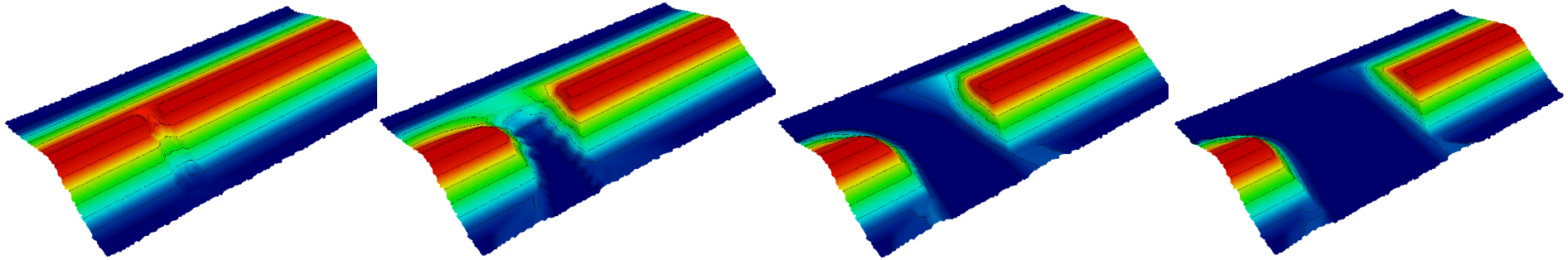
Fluvial Dike Breach: Main Results

Experimental



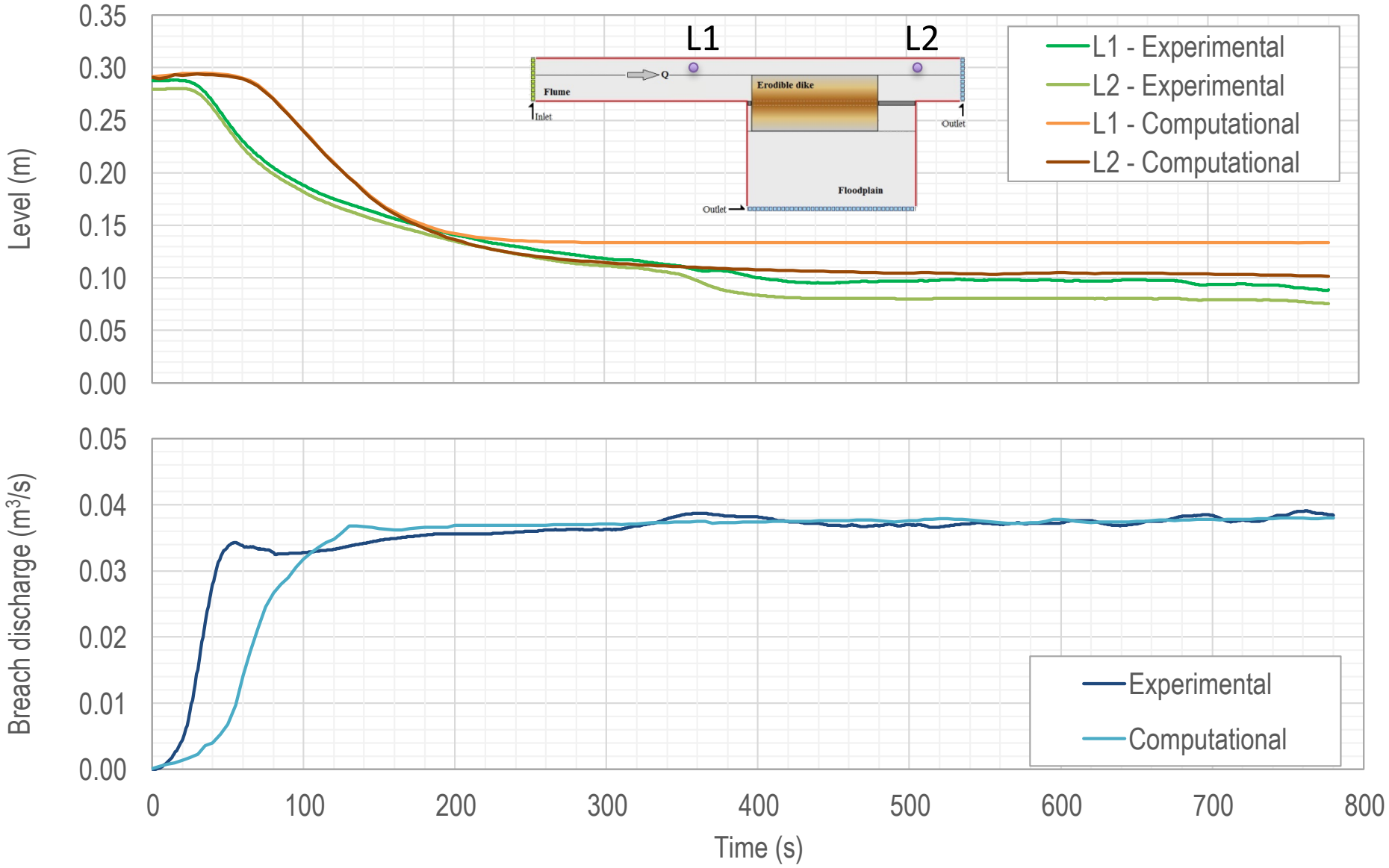
t = 19 s t = 90 s t = 210 s t = 600 s

Computational



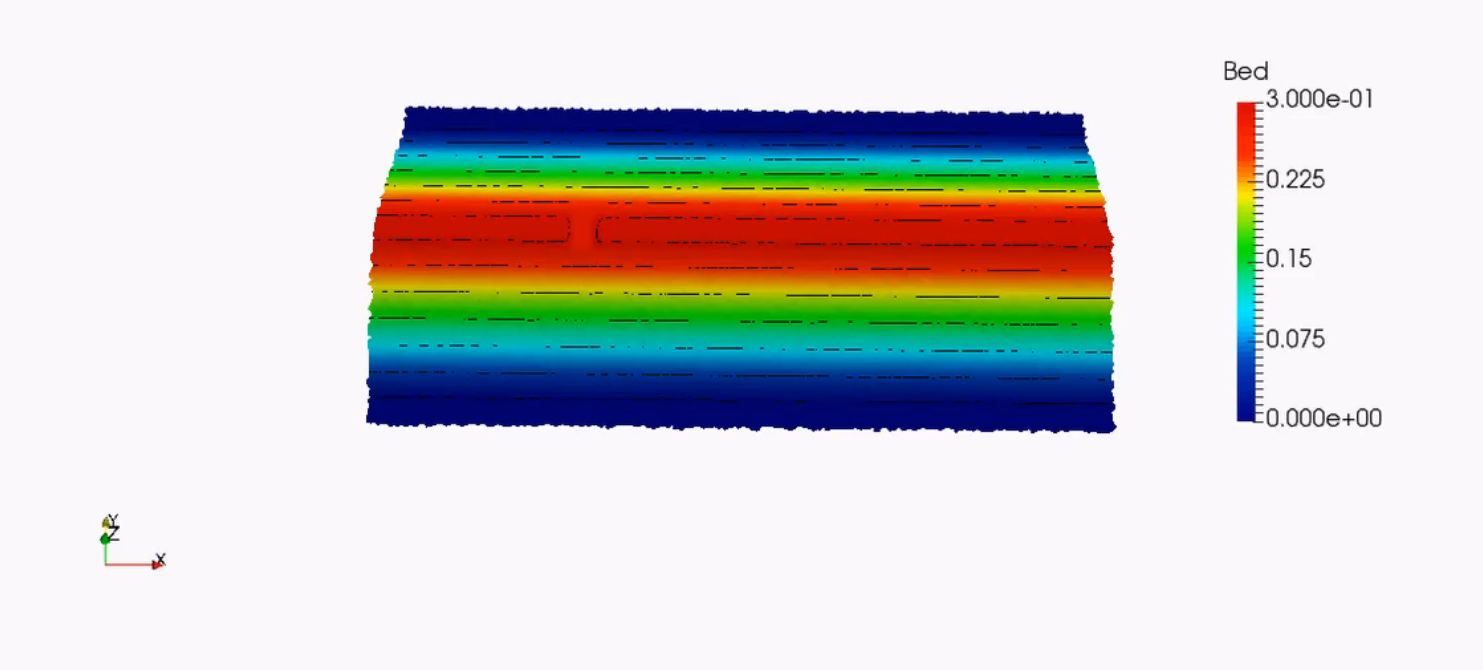
t = 20 s t = 90 s t = 210 s t = 600 s

FLUVIAL DIKE BREACH: MAIN RESULTS



FLUVIAL DIKE BREACH: DISCUSSION

- Stav-2d can roughly to reproduce the two stages of the breach development
- This validation exercise highlighted the needs for improving:
  - The evolution of the erosion in the left bank is not well represented because undercutting is not implemented
  - The mild slope on the right bank is not adequately represented and using a different value for the submerged repose angle does not help
- Improvement will be in the form of a novel geothecnical solver – in development



THANK YOU!