



FROM TRADITION TO INNOVATION: THE REVOLUTION OF PHYSICAL AND CFD MODELLING IN HYDRAULIC ENGINEERING

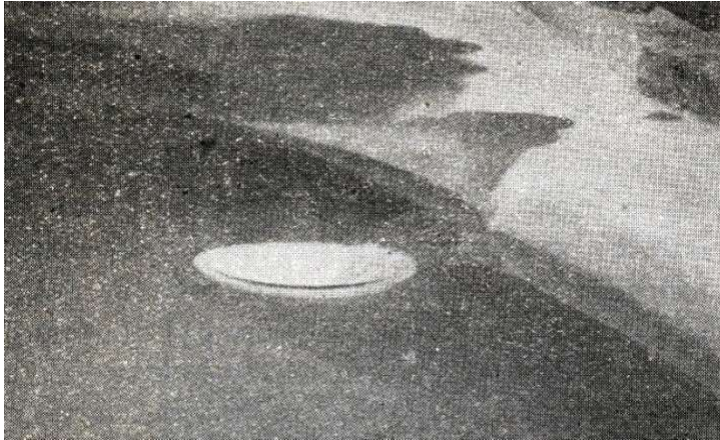


LABORATÓRIO NACIONAL
DE ENGENHARIA CIVIL

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Teresa VISEU

1951: first physical models

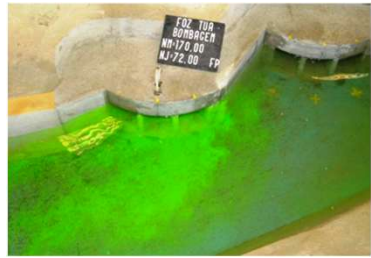
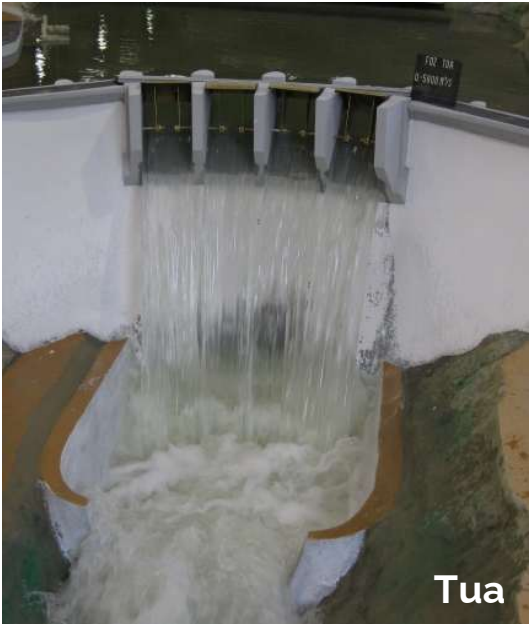
Campilhas (1952)



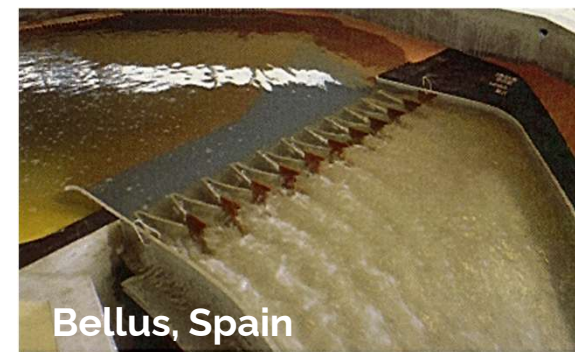
Salto de Funil, Brazil (1952)



National physical models



International physical models



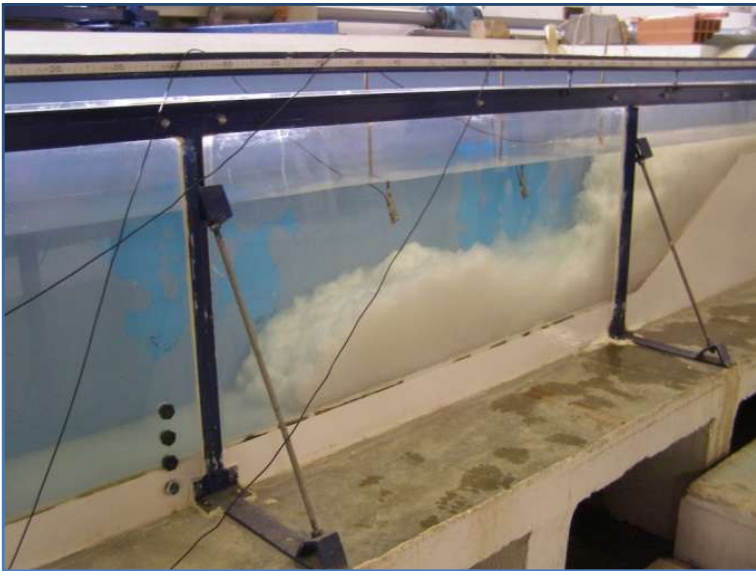
74 years of physical modelling:

142 models

98% dams

70% national, **30%** international

Permanent facilities



sedimentation channel



compound channel



fishway



spillwa



dam & dike erosion



jet pool



variable slope channel

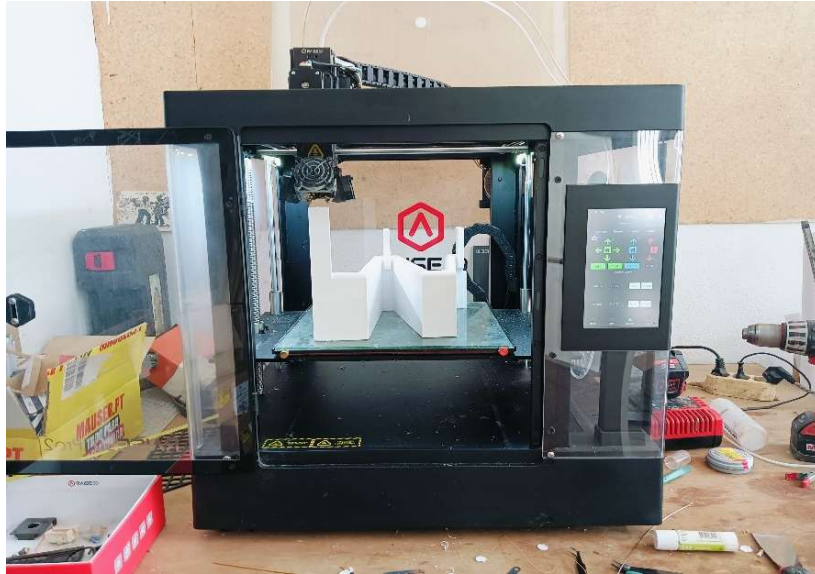


Traditional construction methods



bricks
cement
sand
steel
plaster
gravel

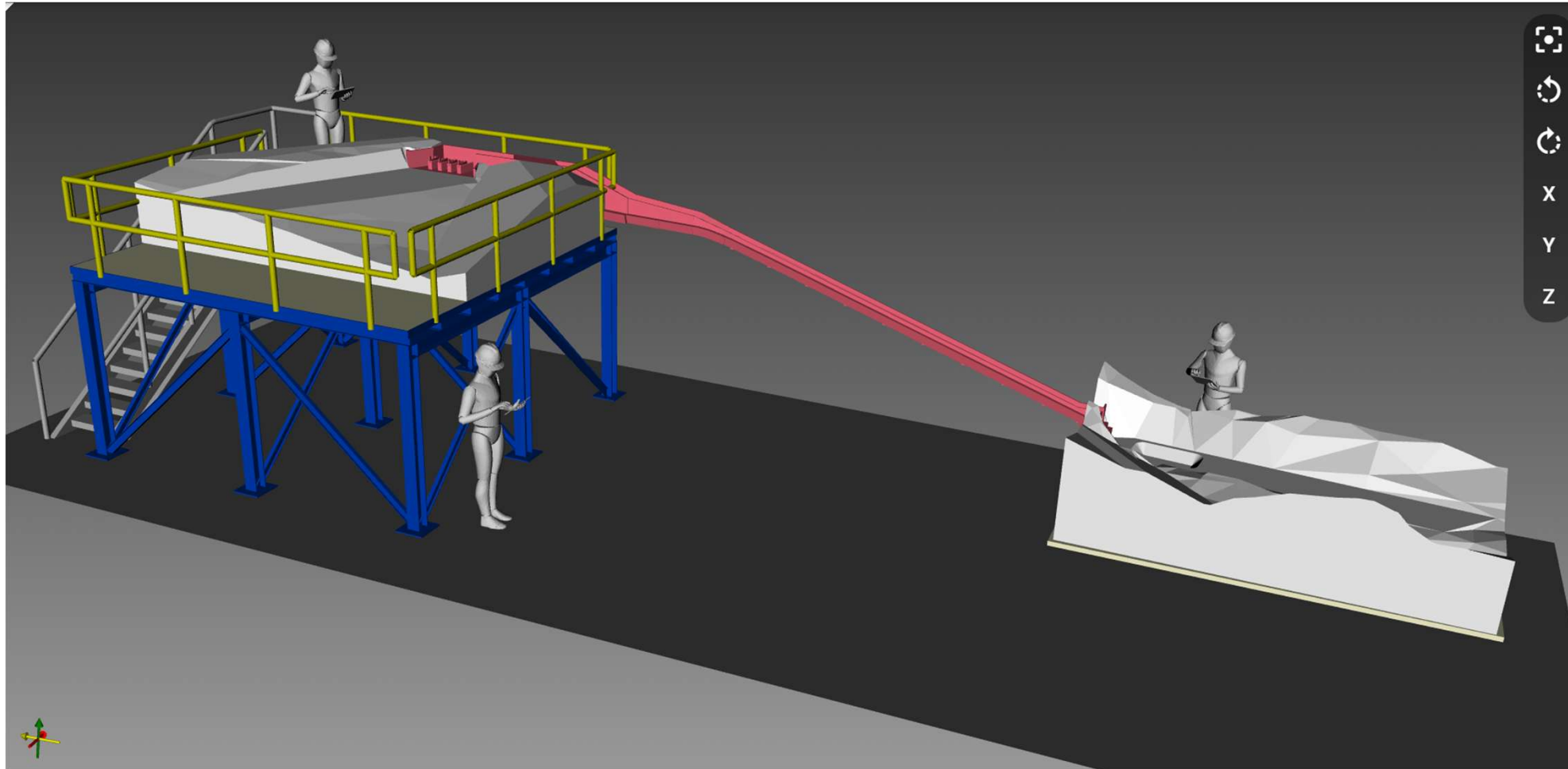
2017: new construction methods



2017: new construction methods



2025: construction method

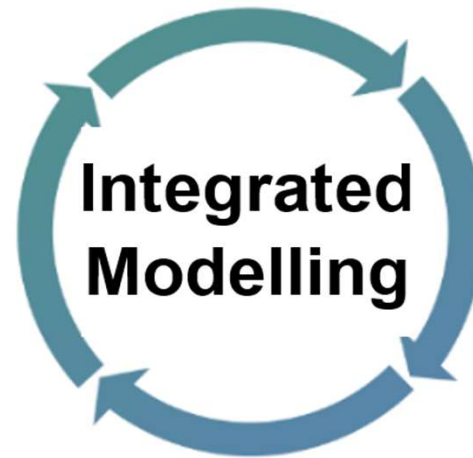


2010: LNEC goal of 3D numerical modelling

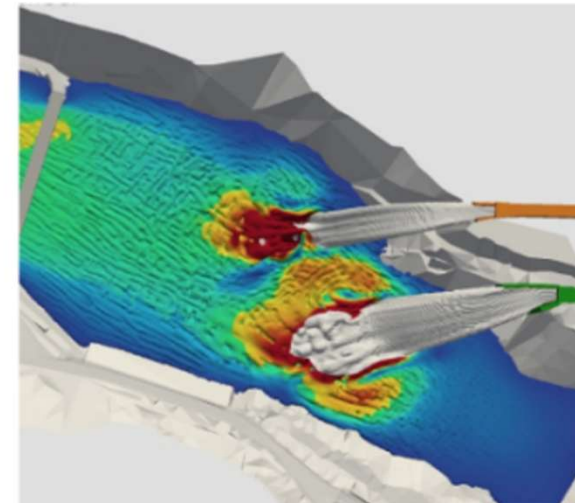
Physical Modelling



- reliability
- scale-effects
- time-consuming
- costly



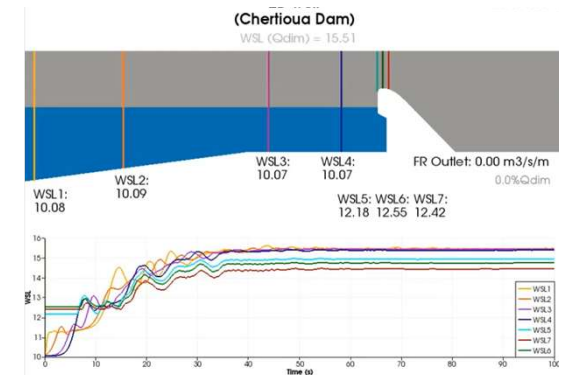
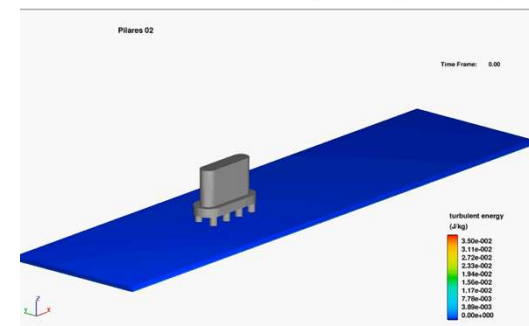
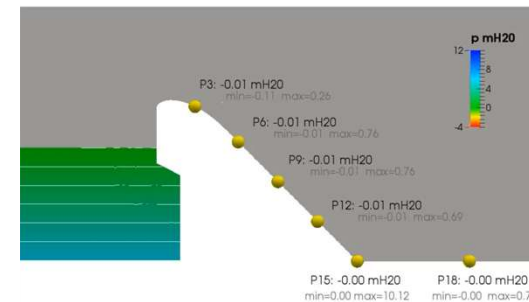
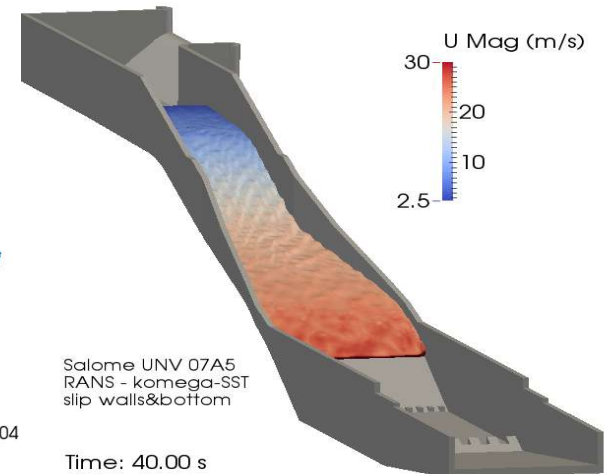
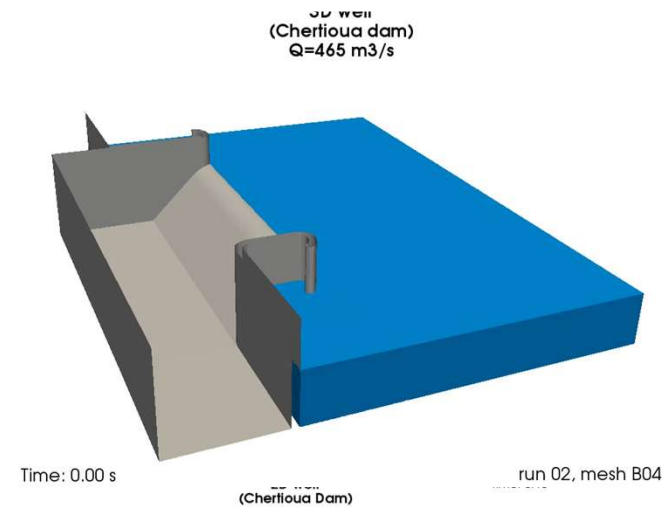
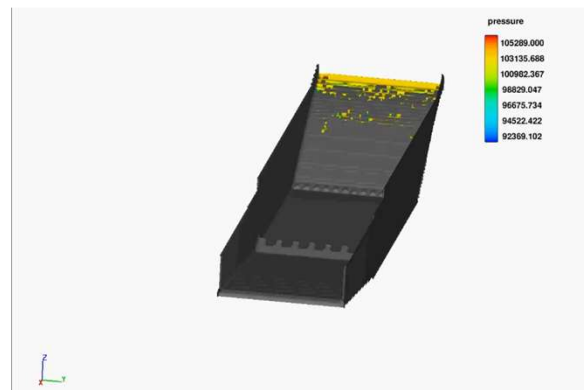
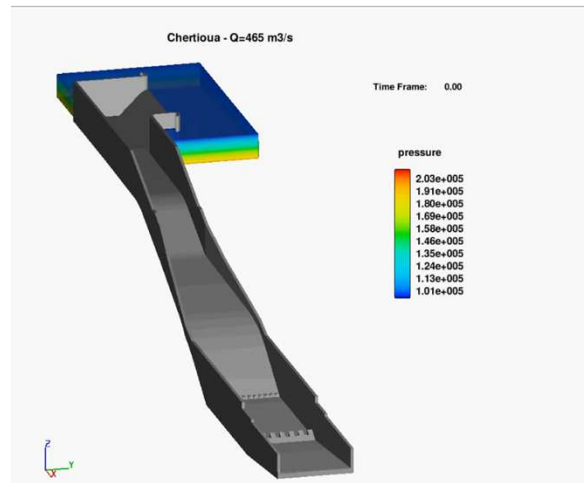
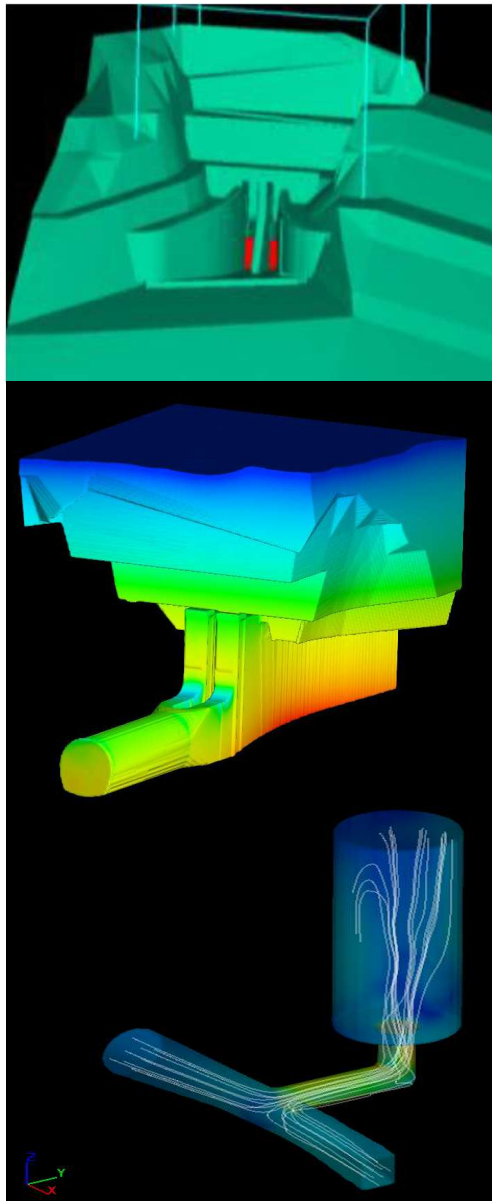
Numerical Modelling



- complexity
- calibration and validation
- air-water mixture
- time and cost-saving

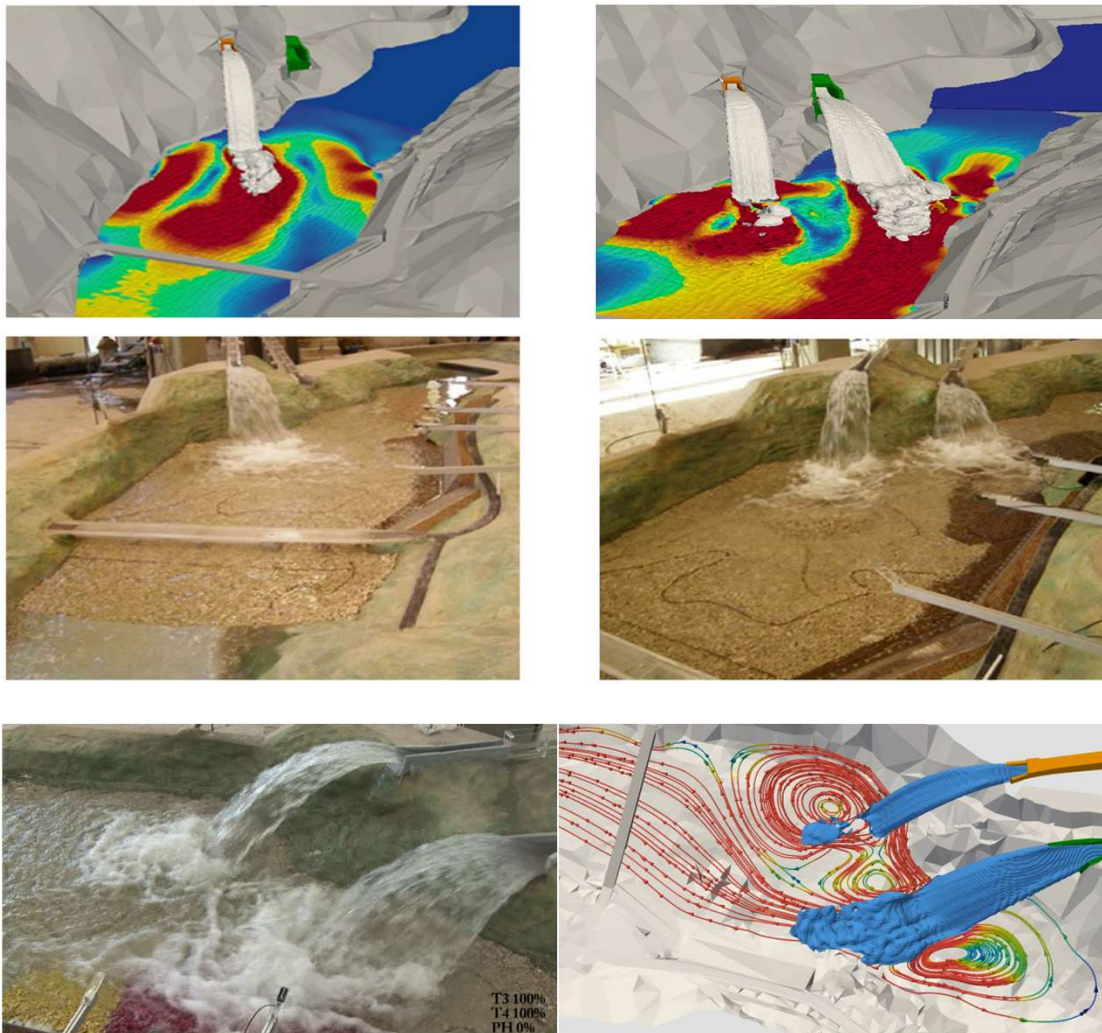
2014: 3D numerical modelling first applications

OpenFOAM, Flow 3D, HPC



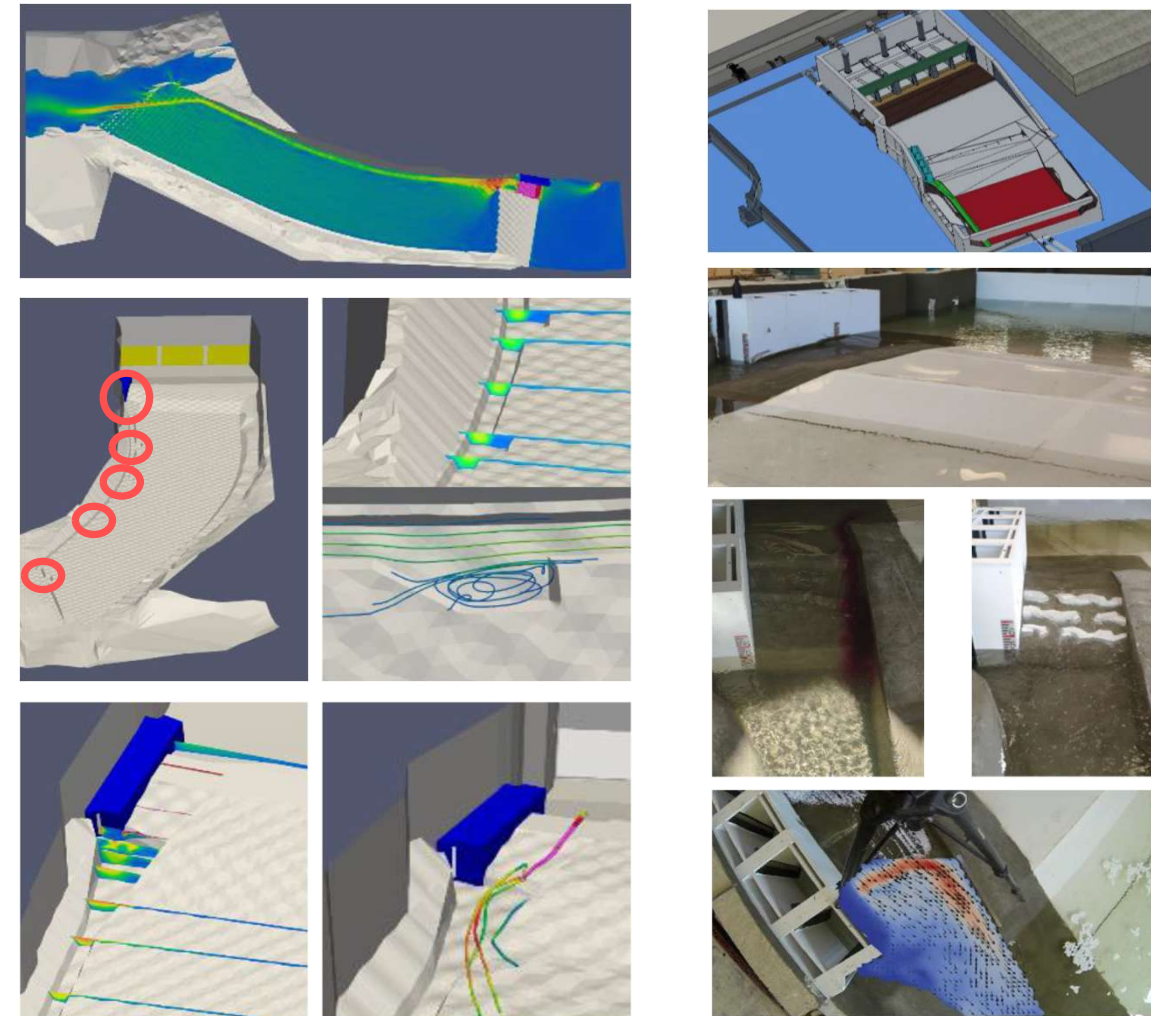
2016: integrating numerical and physical

Fierza, Albania for KESH



2022

Fratel, Portugal for EDP



METHODOLOGY

1. Preliminary numerical

- a. general understanding
 - flow, potential design issues
 - optimize before physical modelling
- b. information for conception of the physical model
- c. efficient placement of sensors

2. Preliminary physical

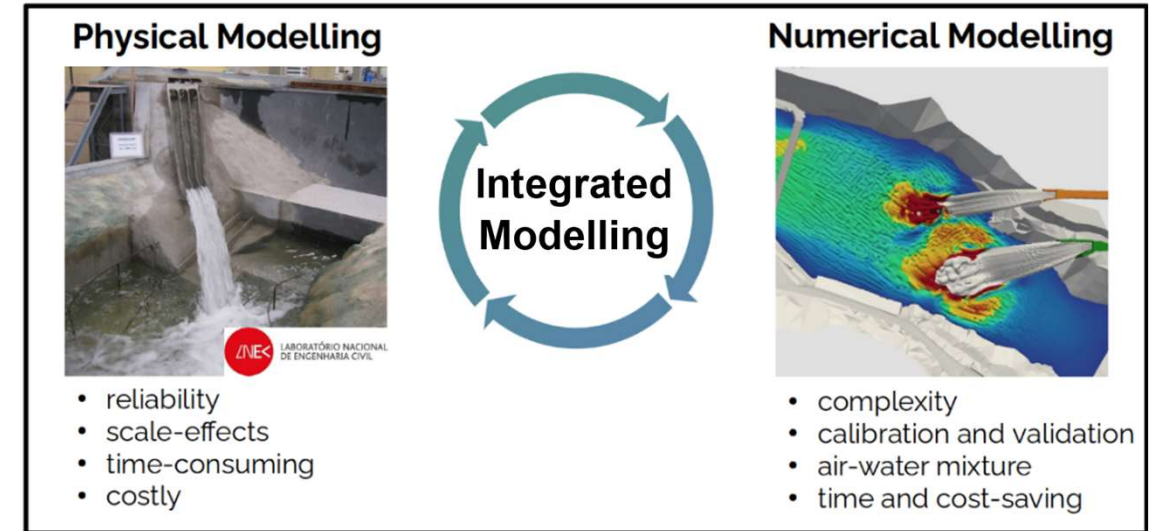
- a. initial design
- b. data to calibrate the numerical

3. Numerical -> validation and calibration

4. Numerical tests of enhanced designs

5. Physical of final design

6. Numerical of high-resolution of final design



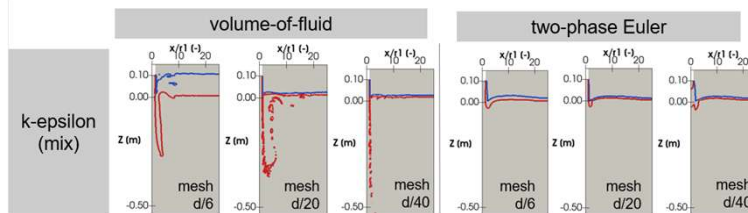
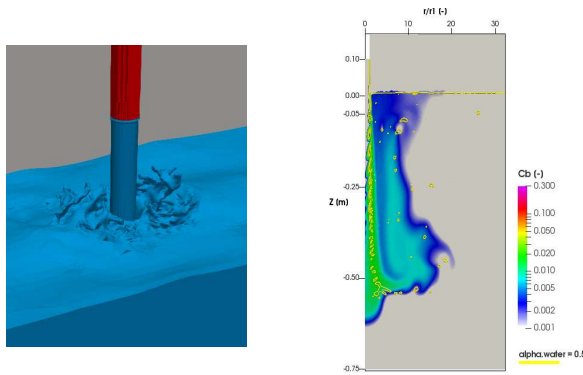
Methodology implementation:

time/resources **vs** accuracy

research **vs** consultancy

experience **vs** efficiency

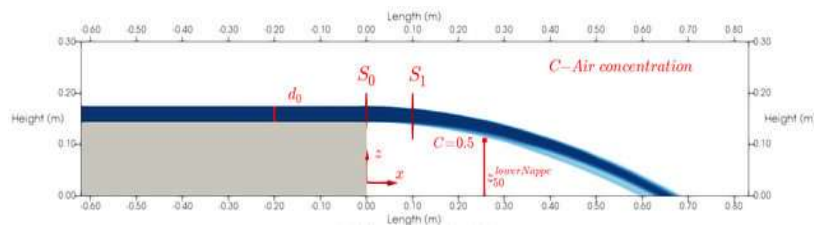
2017: numerical modelling research



(f) TPVoF, $k-\omega$ SST; $R_m = 20$



(h) CTPE, $k-\omega$ SST Sato; $R_m = 20$



2 PhD thesis, 4 papers

VOF

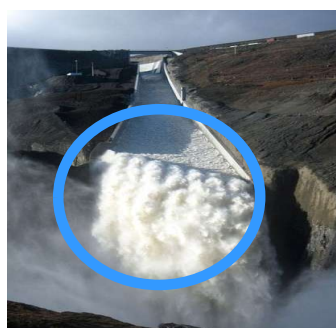
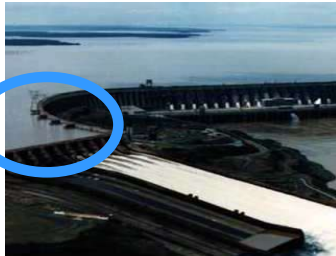
- no aeration
- physical model

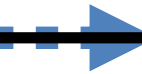
VOF + SGBP

- low air concentration
- self-aeration in channels

Complete 2-phase Euler

- Med to high air concentrations
- Jets, long and steep chutes, aerators, dissipation basins.





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geo_00and10.vtkjs	alteracao_projeito		Uploader	02/04/2025	View Download Edit Delete
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Numerical Model Report

The following 3D visualization showcases the numerical modeling for the project, highlighting key calculations and simulations used in the process.

dttoolslnec.github.io/glancewebapp/index.html

Glance

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OPEN SAVE STATE ABOUT

DATASETS

TOOLS

structure

guardrail

terrain

floorPRFV

workers

steps

spillway

ground

dttoolslnec.github.io/gaze/index.html

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GAZE

Display

background

autoRotate

wireframe

selection

post

screenSpacePlan

postColor

logColor

Lighting

Model Data

Environment Data

Measurements

Show Edge

Post Measure Tool

Clear Measurements

Close Controls

HPC expansion 10x

Efficiency

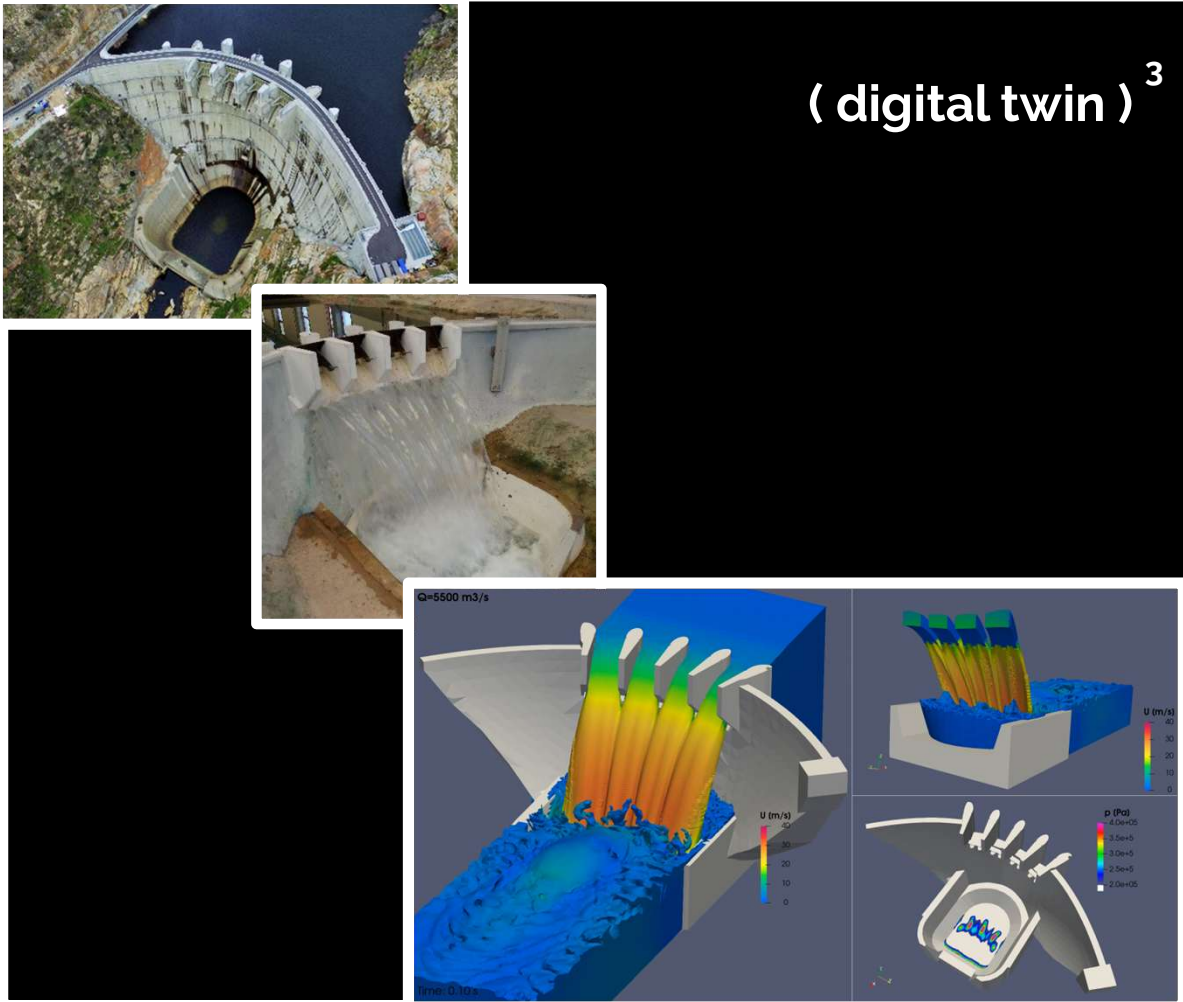
6-step methodology

Erosion - sediments, fractured rock-beds

Complete 2-phase euler in large cases

Communication + IT Tools

Digital twins



References

Melo JF, Kacurri E, Mendes LS, Topore A (2019) Modelling of Fierza Dam spillway operation and downstream effects on river bed and slopes, *Dam Engineering*, vol. 29, no. 2

Mendes LS (2022) Computational Fluid Dynamics of Aerated Flows in Spillways Chutes, PhD thesis, Universidad de Cantabria, <http://hdl.handle.net/10902/23909>

Mendes LS, Lara JL, Viseu MT (2021) Do the Volume-of-Fluid and the Two-Phase Euler Compete for Modeling a Spillway Aerator? 13, 21, <https://www.mdpi.com/2073-4441/13/21/3092>

Lourenço Sasseti Mendes, Javier L. Lara, and Maria Teresa Viseu. 'Is the Volume-of-Fluid Method Coupled with a Sub-Grid Bubble Equation Efficient for Simulating Local and Continuum Aeration?' In: *Water* 13.11 (2021), p. 1535. doi: 10.3390/w13111535

Muralha A., Melo JF, Ramos HM (2020) Assessment of CFD Solvers and Turbulent Models for Water Free Jets in Spillways, *Fluids*, 5, 3, <https://www.mdpi.com/2311-5521/5/3/104>

Muralha, A., Melo, JF., Ramos, HM. (2025). Validation of Computational Methods for Free-Water Jet Diffusion and Pressure Dynamics in a Plunge Pool. *Applied Sciences*, 15(4), 1963. <https://doi.org/10.3390/app15041963>