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Session D7: Is CFD an Efficient Tool to Develop Pool Type Fishways?

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Is CFD an efficient tool to develop pool type fishways?

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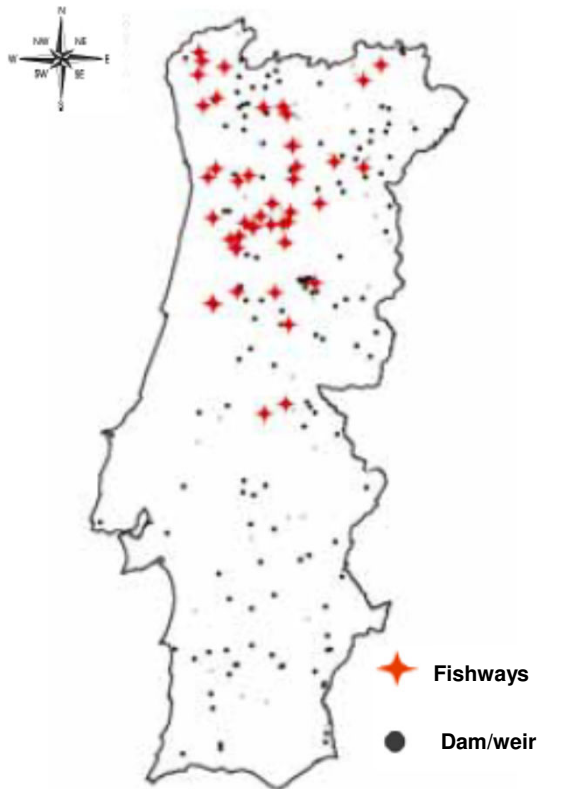


CERIS

CIVIL ENGINEERING RESEARCH AND
INNOVATION FOR SUSTAINABILITY

TÉCNICO LISBOA

Introduction



Fishways in Portugal (Santo , 2005)

- More than **150 large dams** and **3 000 small weirs**
- Only around **40 fishways** **37** of which **pool-type fishways**



Pool-type fishway with cross-walls equipped with notches and bottom orifices in Nunes mini-hydroelectric plant

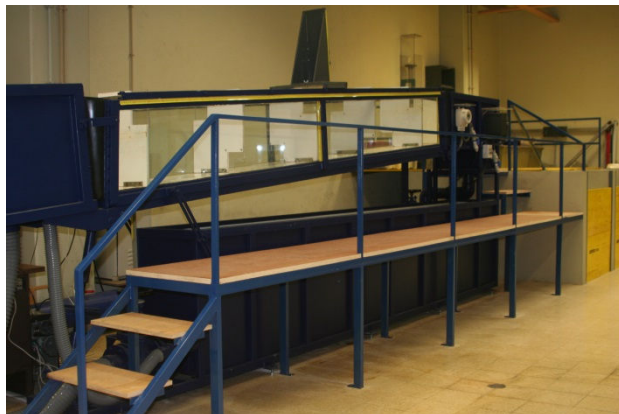


Framework

- Indoor **full scale pool-type fishway** located in LNEC (Laboratório Nacional de Engenharia Civil)
 - 10 m long, 1 m wide and 1.2 m high



LNEC's prototype pool-type fishway flume



IST's 1:2.5 scaled pool-type fishway flume

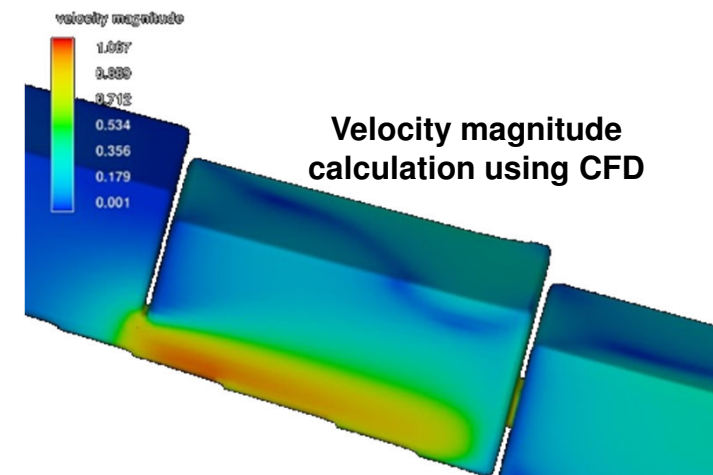
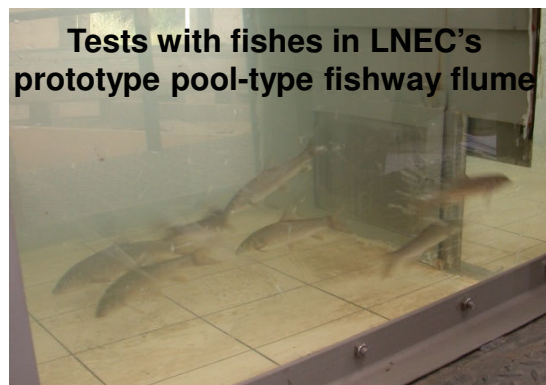
- A **1:2.5 scaled fishway** was built at IST (Instituto Superior Técnico)

Objectives



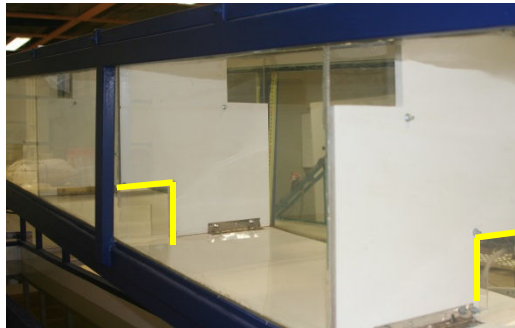
- Our **goal** is to use 3D CFD models to **develop innovative design solutions** of pool-type fishways adequate to cyprinid species with emphasis on the geometry of the cross-walls openings, namely **slots and double slots**

- Hydraulics measurements at IST's facility are used to **calibrate numerical simulations**



- Developed configurations will be tested with fish at LNEC's flume to verify their efficiency.

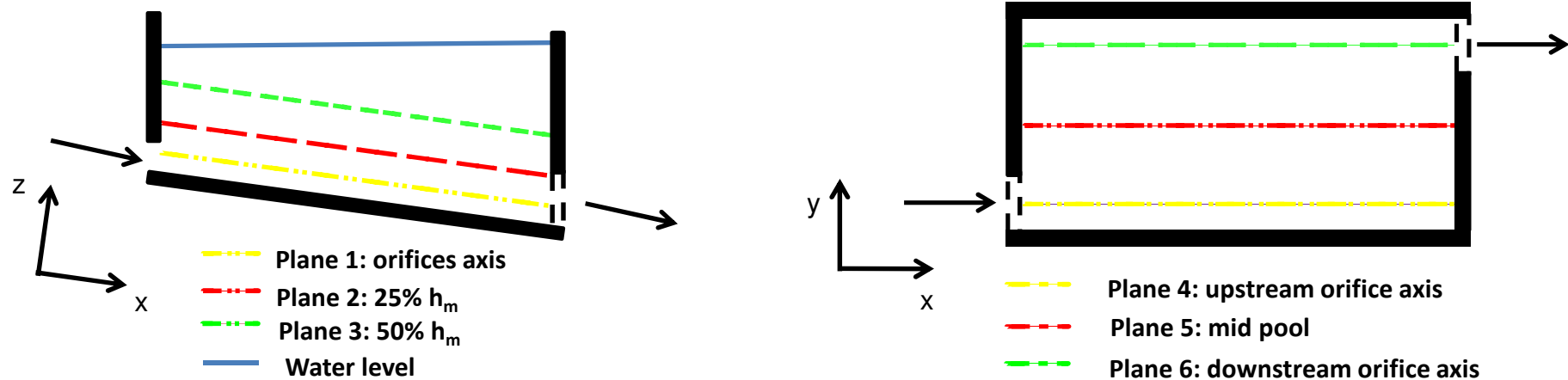
Experimental Setup



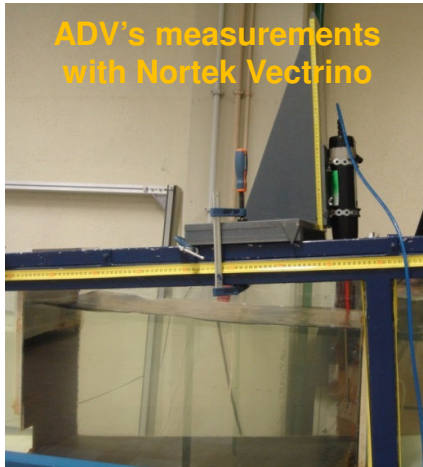
Cross-walls detail: consecutive orifices positioned in opposite sides of the cross-walls

- 4 pools, each 0.76 m long x 0.40 m wide x 0.50 m high
- cross-walls equipped with **bottom orifices** (0.08 x 0.08 m)
 - $s = 8.5\%$; $Q = 4.4 \text{ L/s}$; $\Delta h = 6.4 \text{ cm}$; $h_m = 35.2 \text{ cm}$
- Velocity measurements in the third pool in 6 planes:
 - 3 parallel to the flume bottom and 3 parallel to the sidewalls

Measurement Planes

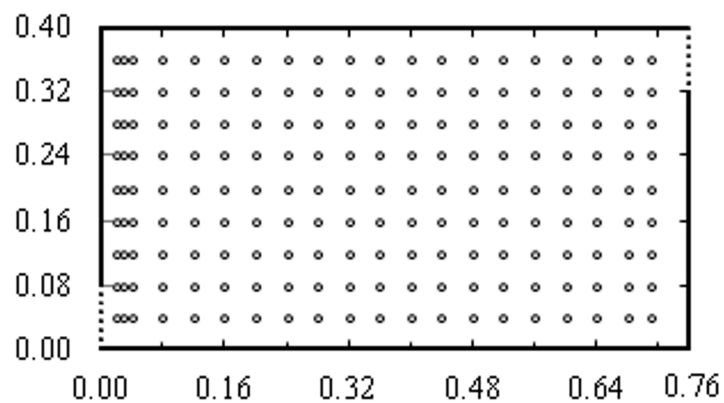


Instrumentation and post-processing procedure

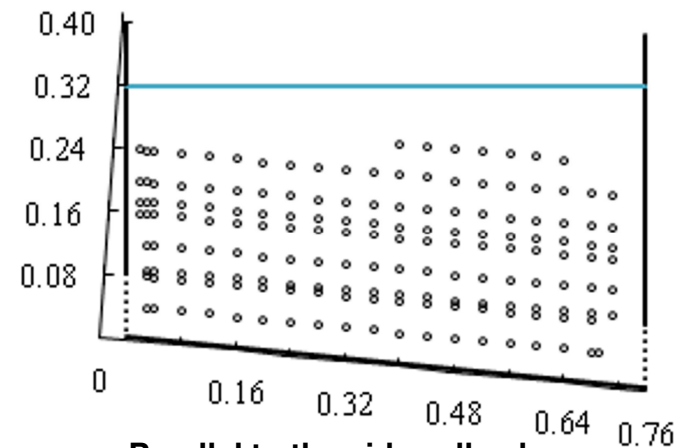


- 3D velocity components (u , v , w) obtained using an ADV
- 840 points measured with a maximum spacing of 0.04 m
- Data was post-processed using phase-space threshold despiking method (Goring and Nikora 2002) and Hurther and Lemmin (2001) noise reduction method

Measurement grid

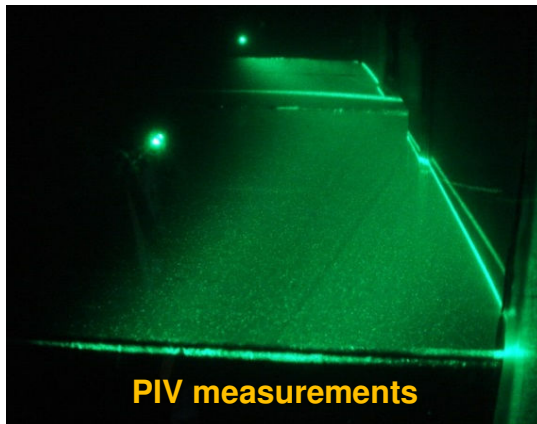


Parallel to the flume bottom planes



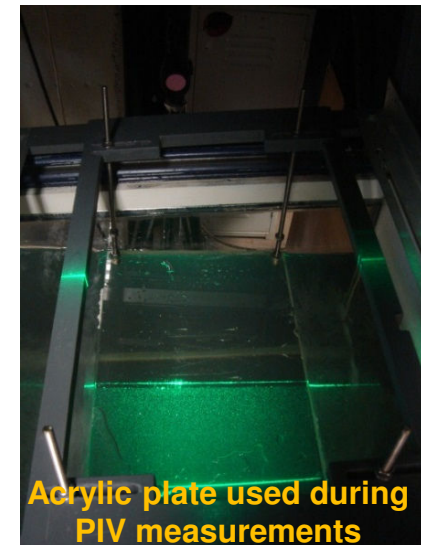
Parallel to the sidewalls planes

Instrumentation and post-processing procedure



- Instantaneous velocity maps were acquired with a 2D PIV system
- Parallel to the flume bottom planes divided into 21 parts
- Parallel to the sidewalls planes divided into 13 parts
- spatial resolution yielded interrogation volumes of $0.0017 \times 0.0017 \times 0.002 \text{ m}^3$

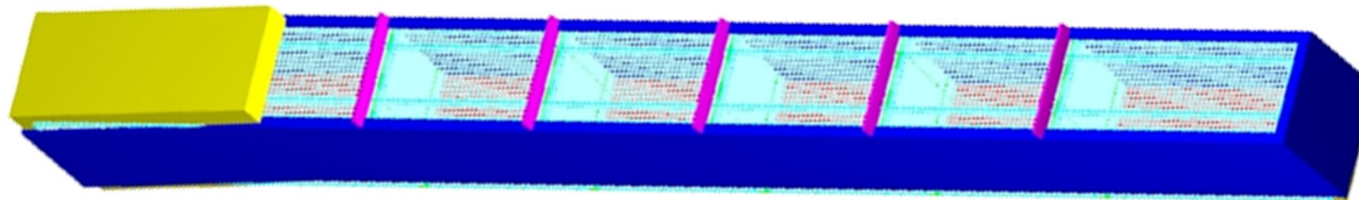
- An acrylic plate was placed on the water surface to eliminate oscillations of the water surface that would diffract the vertically incident light sheet
- The normalized median test (Westerweel and Scarano, 2005) was used for spurious vector detection





Numerical Model

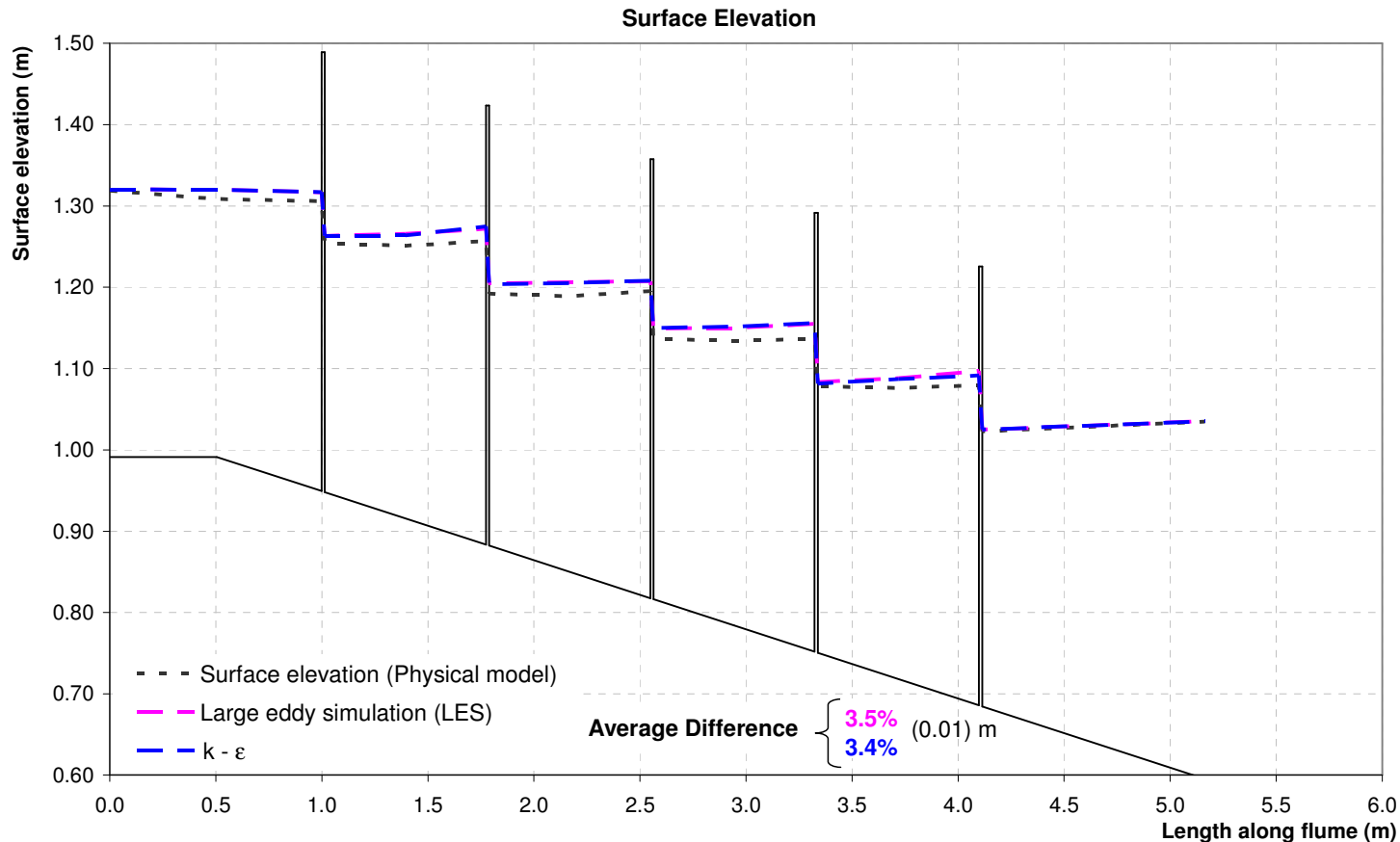
- A commercial CFD software, FLOW-3D, was used to simulate the flow
- Calibration was made by comparing the numerical model results with the measured discharge flow rate and flow depths
- Meshing: 2 cm mesh for the entire channel and a 1 cm mesh for the cross-walls and the 3rd pool
- Turbulence models used: $k-\varepsilon$, Large eddy simulation (LES)



Mesh block detail



Numerical Model - Calibration



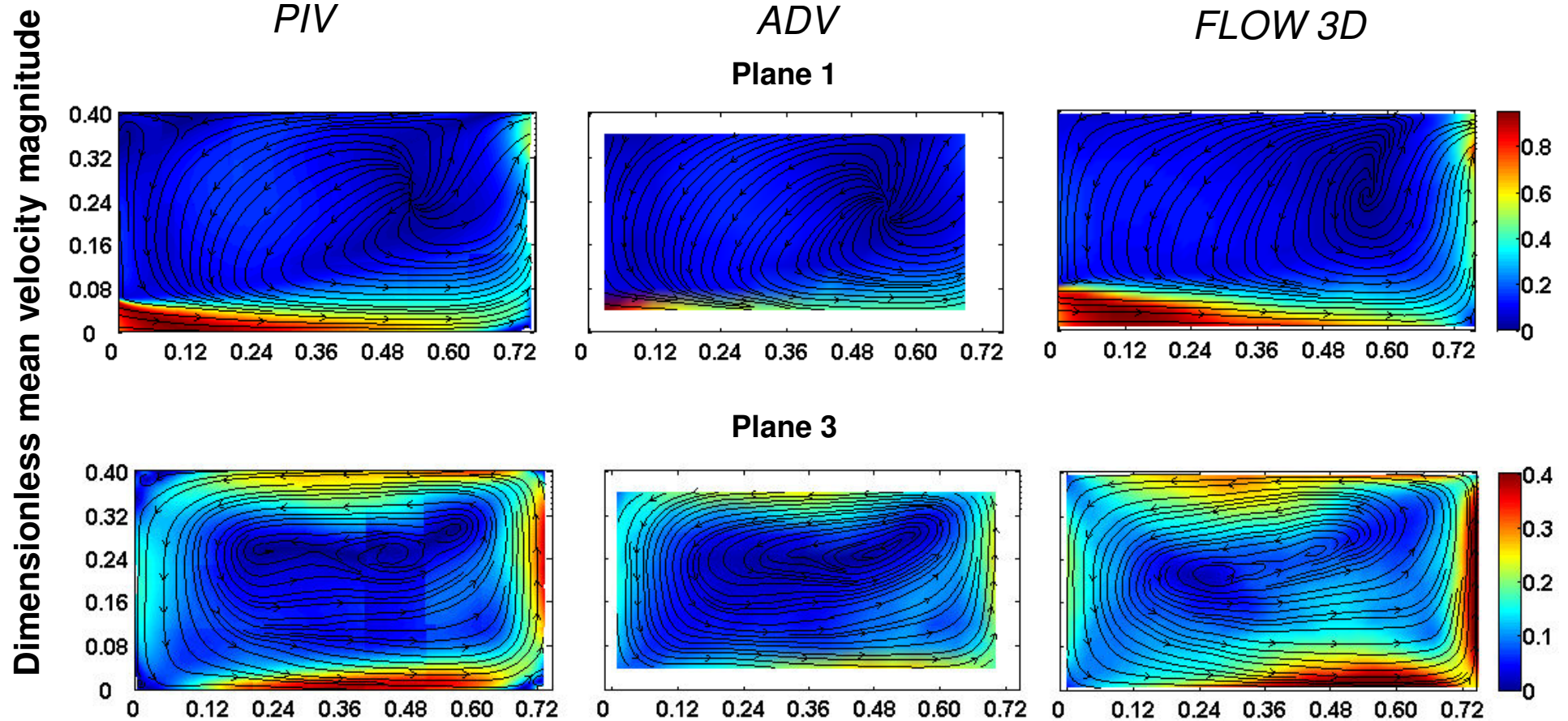
Flowrate Q – Physical Model Average Q = 4.5 l/s

Numerical Model Average Q = 4.7 l/s

} Difference = 4.7% (0.2 l/s)



Results

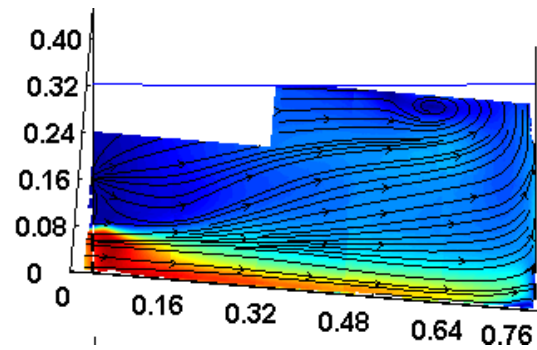




Results

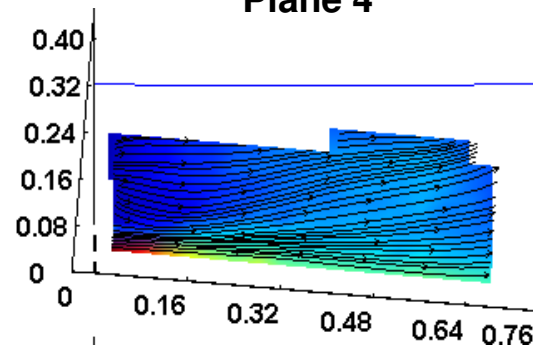
Dimensionless mean velocity magnitude

PIV

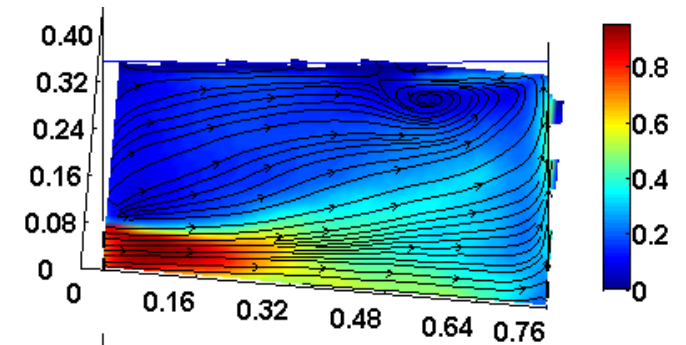


ADV

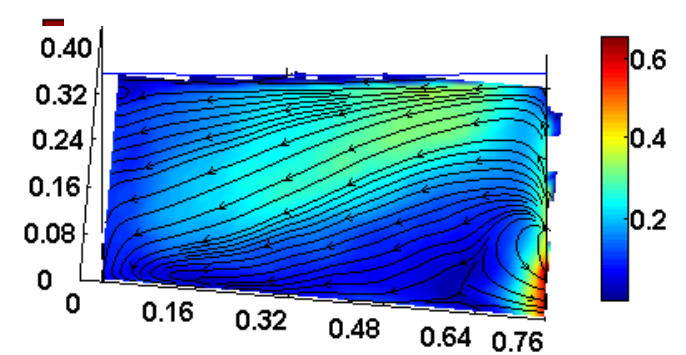
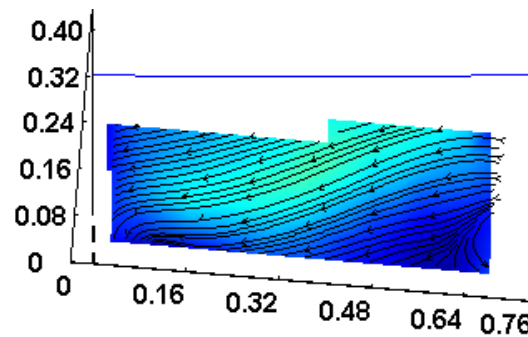
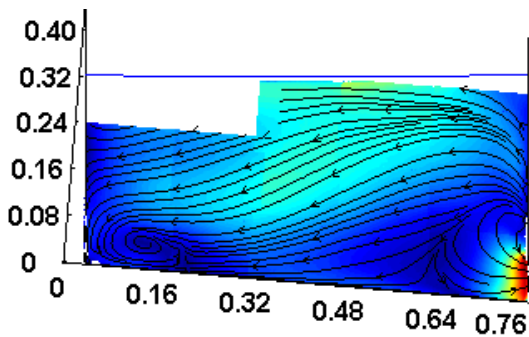
Plane 4



FLOW 3D



Plane 6





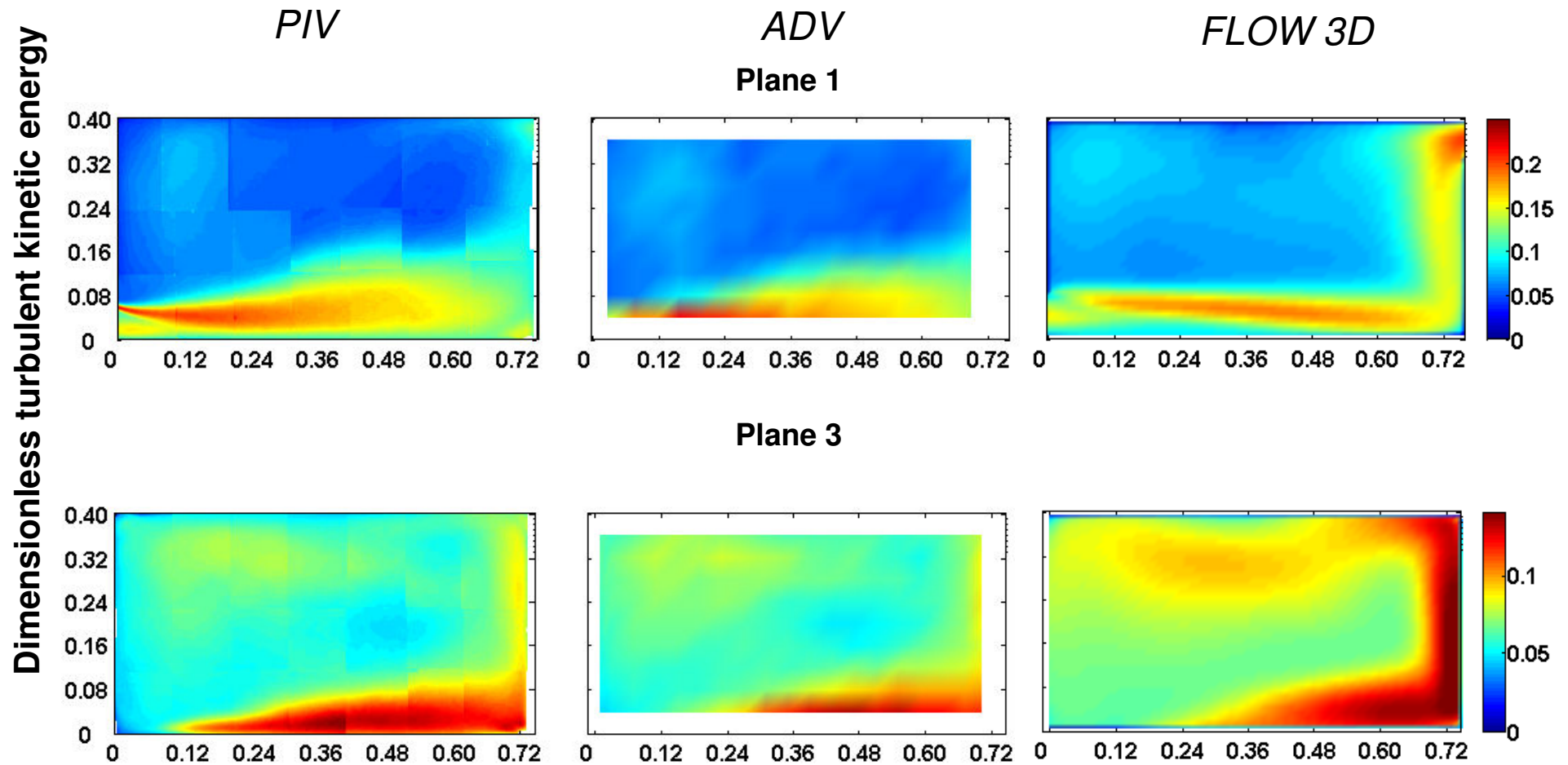
Results

		ADV	Flow 3D
Mean velocity magnitude	U		
	μ (m/s)	0.18	0.19
	σ (m/s)	0.12	0.15
	Maximum (m/s)	1.08	1.04
	Minimum (m/s)	0.02	0.01
	NMBD (%)		-1.0
	NMAD (%)		3.8
	NRMSD (%)		0.4
	Coefficient of determination (r^2)		0.83
Refined index of agreement (d_r)		0.75	

NMBD - Normalized mean bias difference
 NMAD - Normalized mean absolute difference
 NRMSD - Normalized root-mean-squared difference

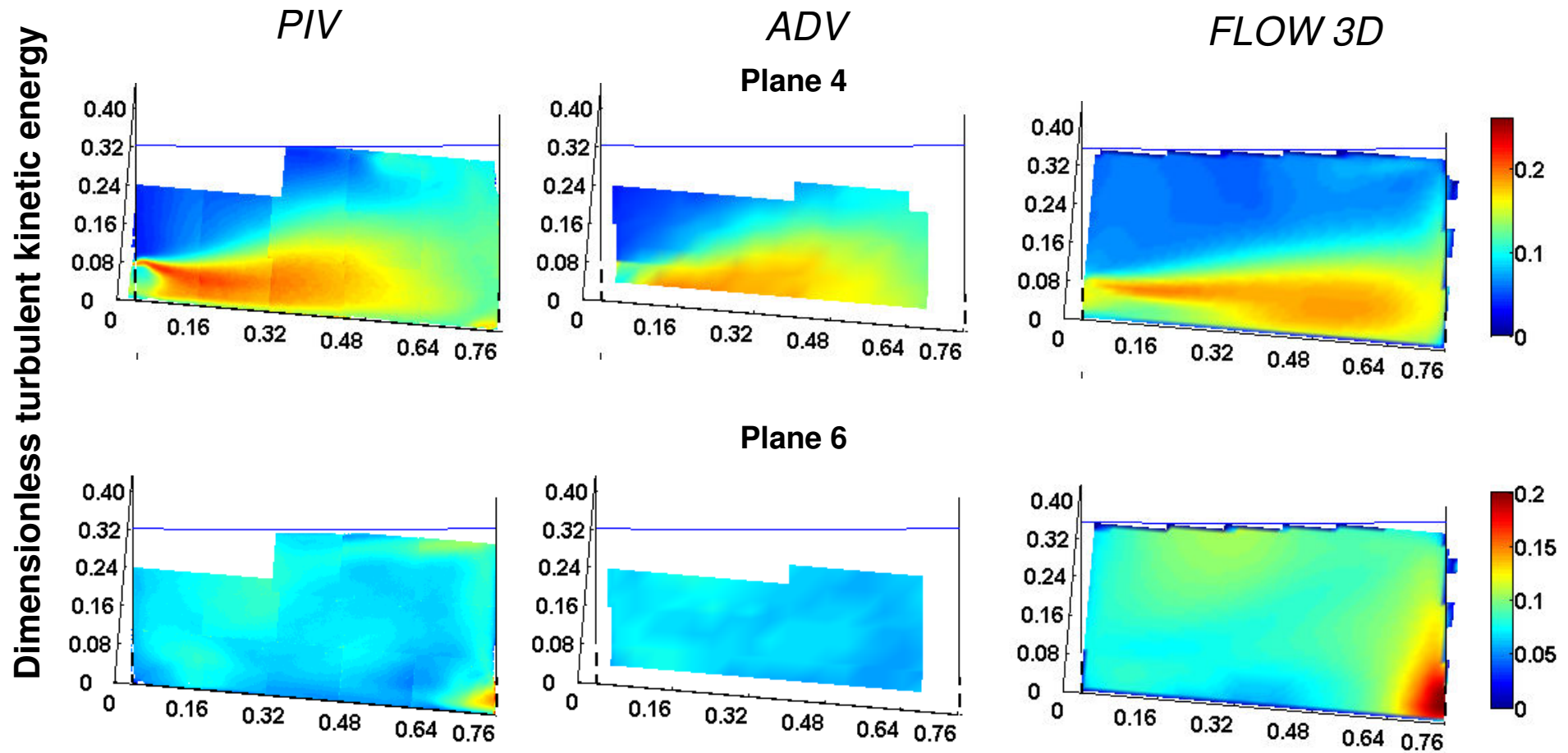


Results





Results





Results

Turbulent kinetic energy

		ADV	F3D
κ	μ (J/Kg)	0.012	0.012
	σ (J/Kg)	0.012	0.010
	Maximum (J/Kg)	0.073	0.045
	Minimum (J/Kg)	0.003	0.004
	NMBD (%)		0.2
	NMAD (%)		5.7
	NRMSD (%)		0.1
	Coefficient of determination (r^2)		0.65
	Refined index of agreement (d_r)		0.76

NMBD - Normalized mean bias difference

NMAD - Normalized mean absolute difference

NRMSD - Normalized root-mean-squared difference



Conclusions

- *The numerical model accurately reproduced the experimental flow characteristics for the considered conditions*
- *Although further experiments and numerical simulations have to be carried out, we consider that the numerical model is capable of representing the fishway flow for the considered conditions*
- *CFD can be an efficient and quicker tool to develop new designs to be tested with fish to verify efficiency*



References

Goring, D.G., Nikora, V.I. (2002). Despiking acoustic Doppler velocimeter data. *J. Hydraulic Eng.* 128(1), 117–126

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Questions? Comments?

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