# ASSESSMENT OF COMPUTER MODELING ACCURACY IN FLOODPLAIN HYDRAULICS

# Motivation for this Study

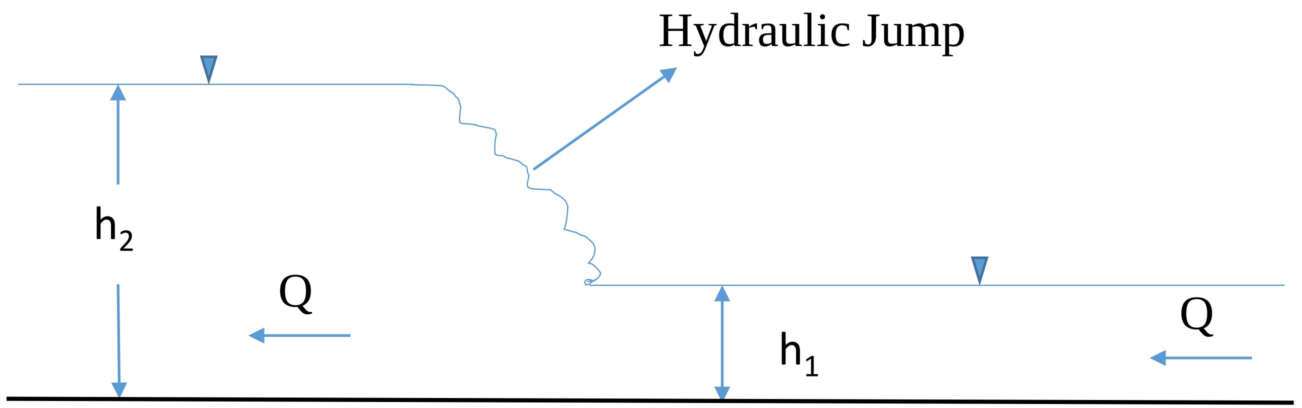
- Computer Modeling is a powerful tool for simulating complex flows
- In Modeling, the mathematical equations that describe the flow physics are solved by numerical techniques
- All COMPUTATIONAL MODELS are based on some assumptions, that the end users might not be aware of
- Testing the performance of existing models to experimental data will provide better insights into the models strengths and limitations

# Motivation for this Study

- In Computational Hydraulics, modeling a ‘*Hydraulic Jump*’, where the flow transits from supercritical to subcritical is accepted as a critical benchmark test

- In this work, the performance of multiple models, was tested by comparing their predicted hydraulic jump results with experimental data

# Definition Sketch of a Hydraulic Jump




Subcritical flow
(high depth, low velocity)
$FR_2 < 1$

Supercritical flow
(low depth, high velocity)
$FR_1 > 1$

$$V_1 = \frac{Q}{A_1}$$

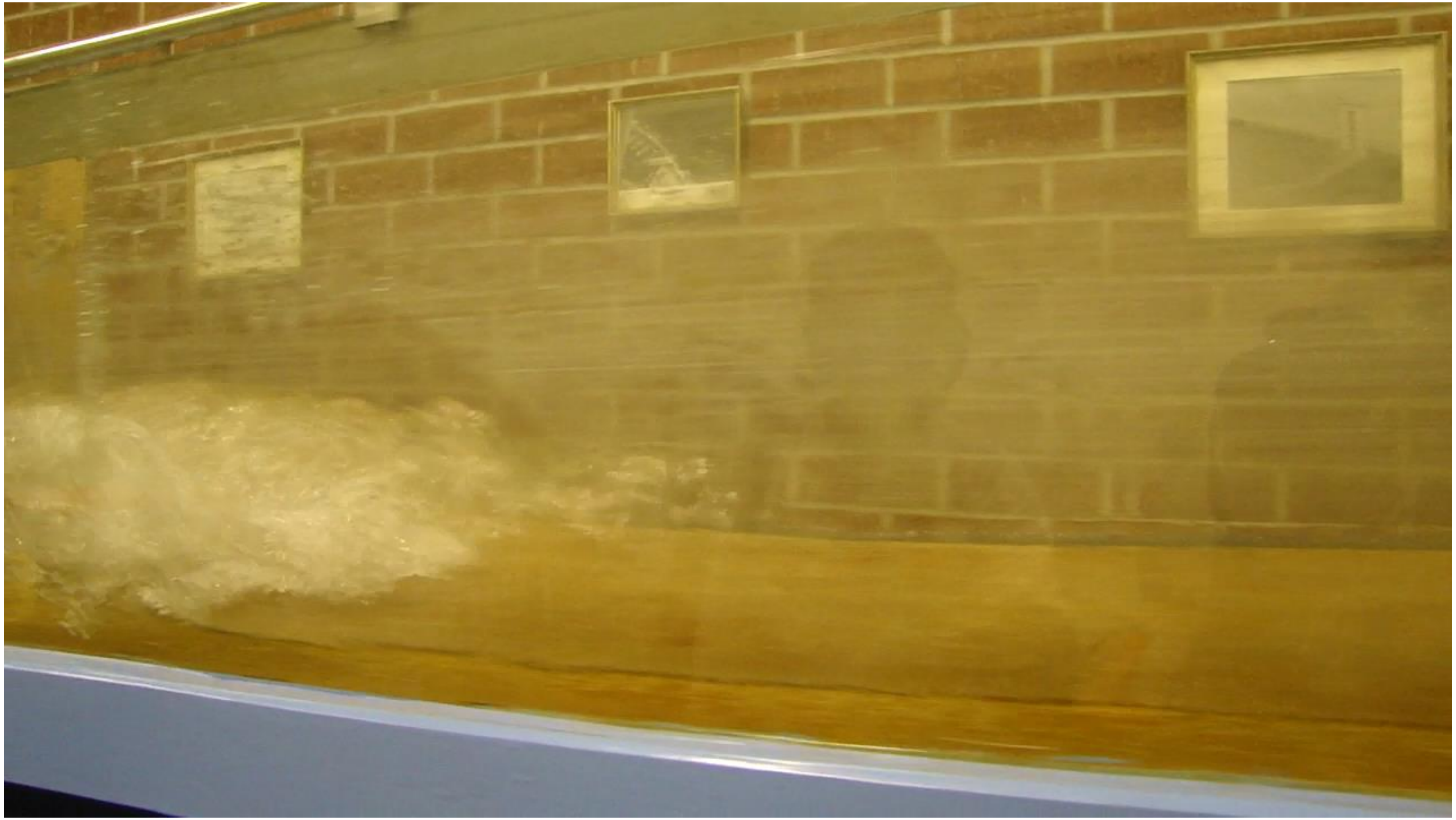
$$V_2 = \frac{Q}{A_2}$$

FR = Froude Number

$$FR_1 = \frac{V_1}{\sqrt{gh_1}}$$

$$FR_2 = \frac{V_2}{\sqrt{gh_2}}$$

# Video of Hydraulic Jump in Rectangular Channel



Source: Hydraulics Laboratory, California State University, Fullerton

# Hydraulic Jump Flow Equations

The flow continuity and momentum equation for one dimensional flow, in a rectangular channel, can be written as*

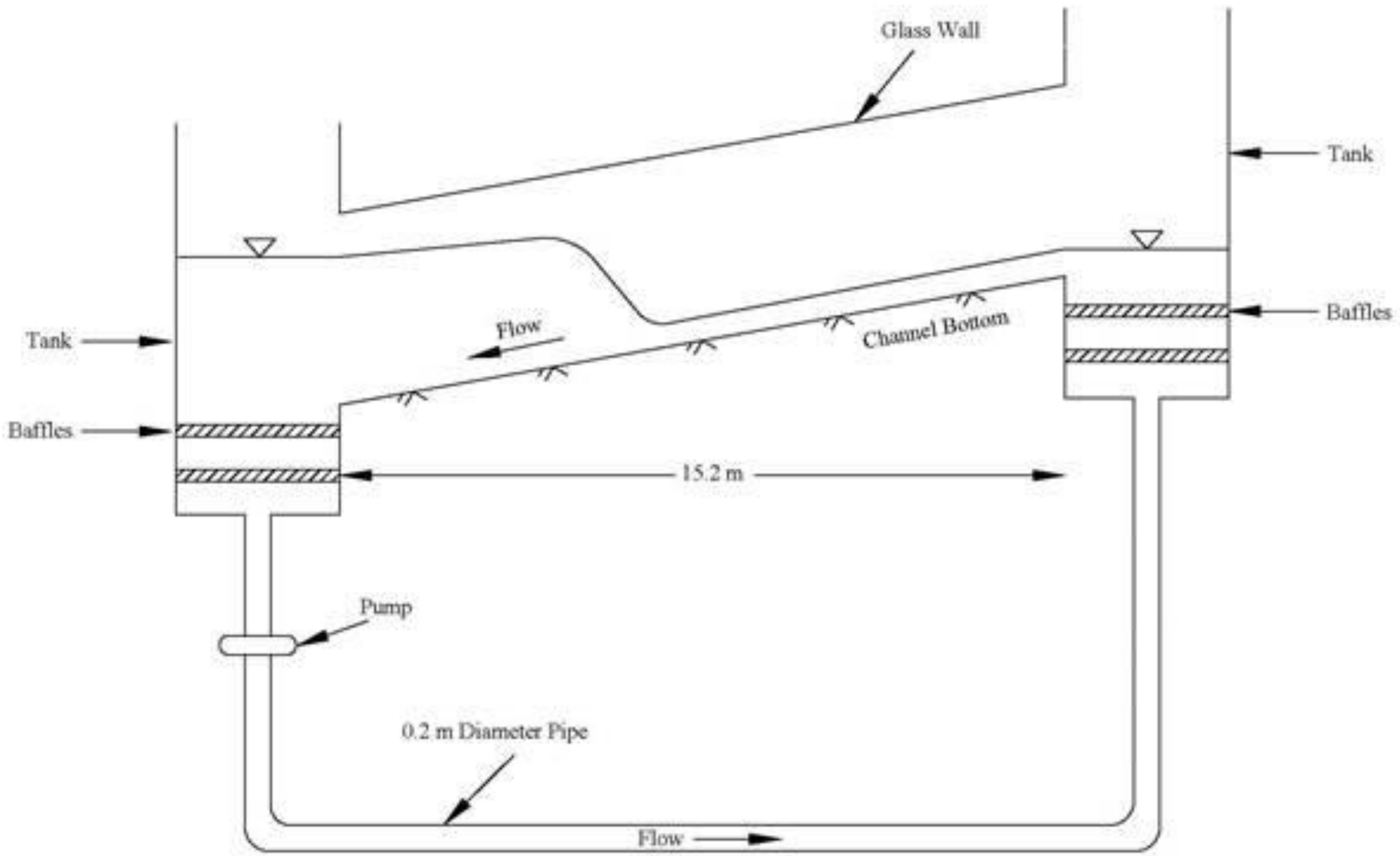
- $\frac{\partial h}{\partial t} + \frac{\partial (uh)}{\partial x} = 0$

- $\frac{\partial (uh)}{\partial x} + \frac{\partial}{\partial x}\left(u^2h + \frac{gh^2}{2}\right) = gh(s_o - sf)$

h = flow depth
U = flow velocity
$s_o$= channel bed slope
$s_f$ = channel friction slope
g = gravitational constant

* Open Channel Flow, M.H.Chaudhry, Prentice Hall, pp.205

# Experimental Setup



# Experimental Setup

The channel cross section is rectangular

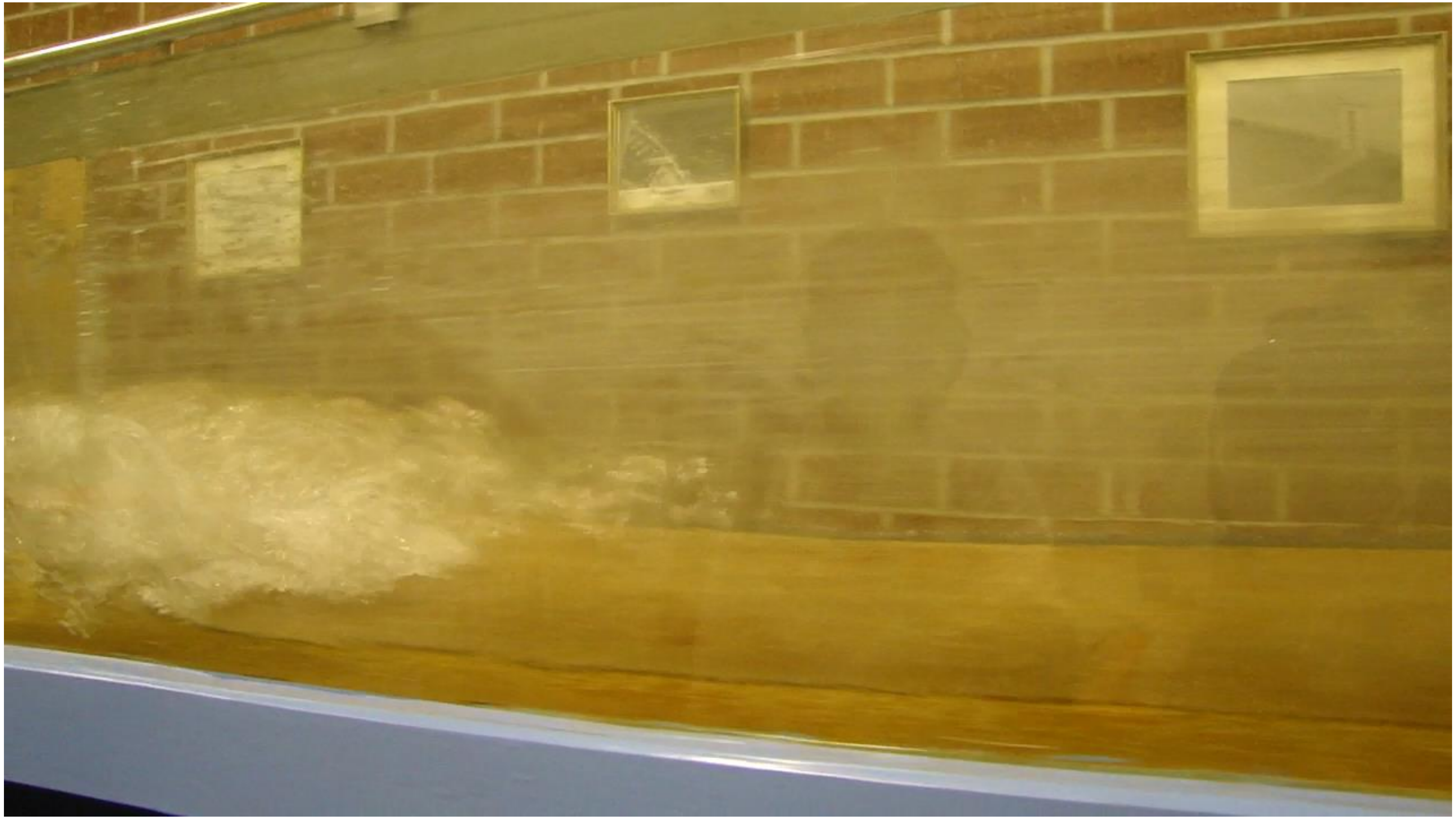
Channel width = 1.5 ft. = 0.46 m

Channel length = 50 ft. = 15.24 m

Source: Hydraulics Laboratory, California State University, Fullerton

# Experimental Setup

# Experimental Setup



Source: Hydraulics Laboratory, California State University, Fullerton

# Channel and flow conditions for the two laboratory tests

| | **TEST CLUSTER 1** (CSU, Fullerton) | **TEST CLUSTER 2** (Univ. of Queensland) |
|---|---|---|
| Width (m) | 0.46 | 0.5 |
| Length (m) | 15.24 | 12 |
| Q ($m^3/s$) | 0.036 | 0.035 |
| Upstream depth (m) | 0.04 | 0.062 |
| Downstream depth (m) | 0.24 | 0.235 |
| Channel Slope | 0.012 | 0.028 |
| Roughness Factor (Manning's) | 0.01 | 0.007 |

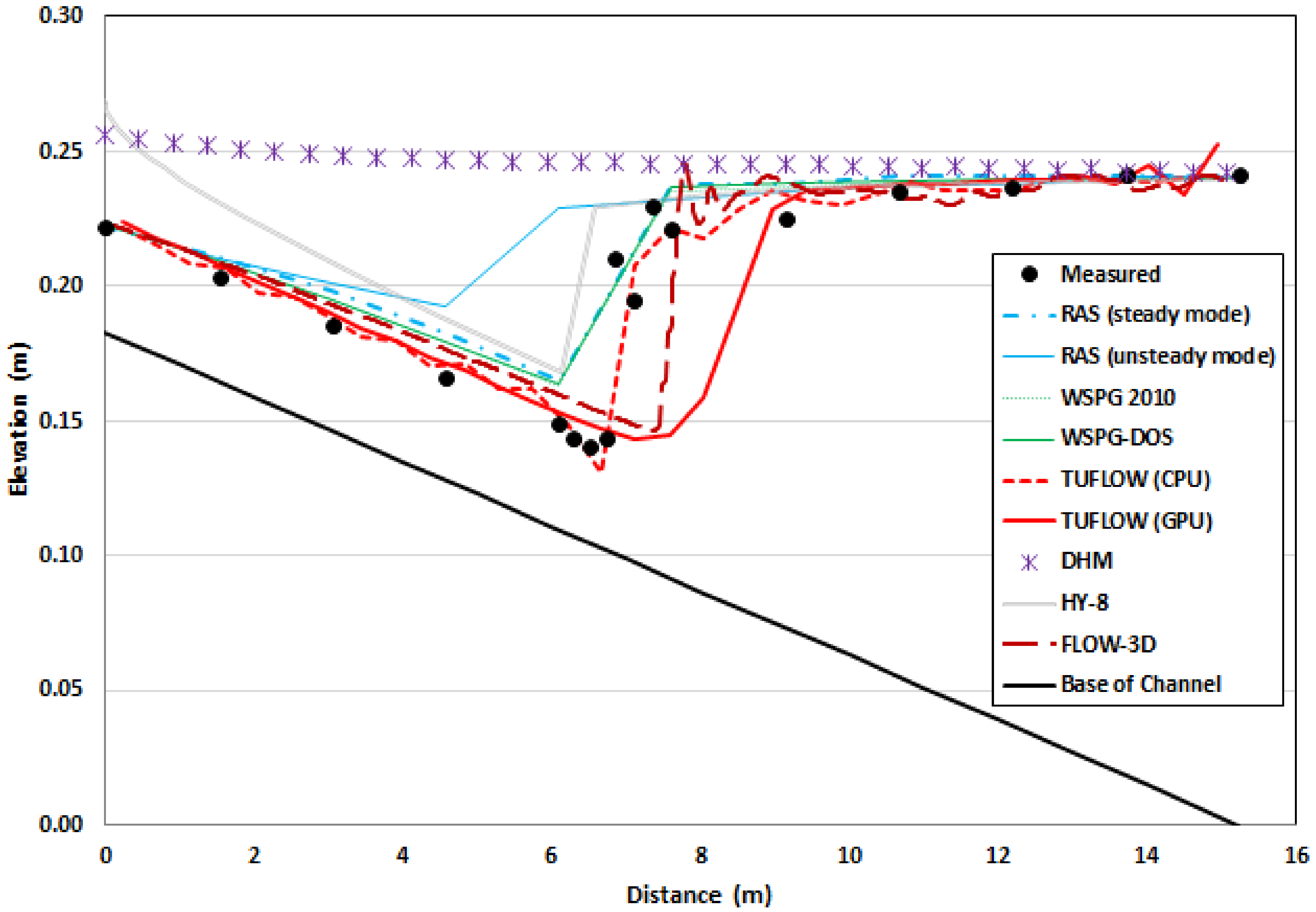
# Summary details of the tested software

| Software | Vendor | Version | Flow equations | Ability | Cost |
|---|---|---|---|---|---|
| **DHM** | USGS | | 2-D | Steady,Unsteady | Free |
| **HEC-RAS** | U.S. Army Corps of Engineers | 4.1.0 | 1-D | Steady,Unsteady | Free |
| **WSPG** | Civil Design | 14.07 | 1-D | Unsteady | $ |
| **WSPG 2010** | XP-Solutions | 14.05 | 1-D | Unsteady | Free |
| **TUFLOW** | BMT WBM | 2013 | 2-D | Unsteady | $ |
| **MIKE 11** | DHI | 2008 | 1-D | Unsteady | $ |
| **MIKE 21** | DHI | 2008 | 2-D | Unsteady | $ |
| **FLOW-3D** | Flow Science Inc. | 9.2.1 | 3-D | Unsteady | $ |
| **FLO-2D** | FLO-2D Software Inc. | Pro | 2-D | Unsteady | $ |
| **HY-8** | U.S. Federal Highway Administration | 7.30 | 1-D | Steady | Free |

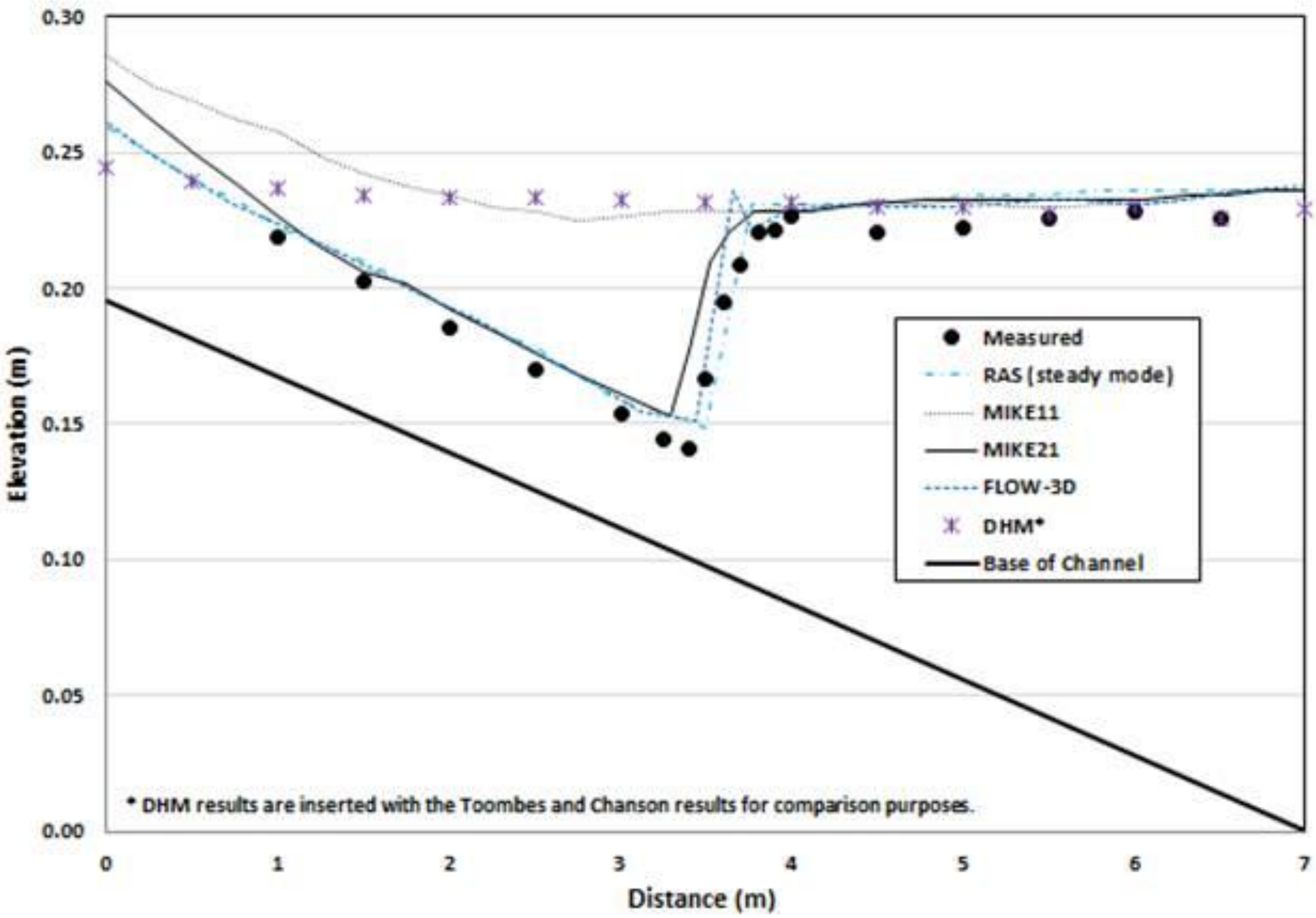
# Comparison of model results for Test Cluster 1 data

The ability of the ten computational models to simulate the steady state location of the jump was tested

# Comparison of model results for Test Cluster 1 data



# Comparison of model results for Test Cluster 2 data



# IMPLICATIONS OF COMPUTATIONAL MODELING RESULTS VERSUS MEASURED WATER SURFACE ELEVATIONS

- Can computational models be relied upon for engineering design and planning purposes?

- Should computational modeling results be validated?

# IMPLICATIONS OF COMPUTATIONAL MODELING RESULTS VERSUS MEASURED WATER SURFACE ELEVATIONS

- For engineering design and planning, Is it reasonable to directly use computational modeling results from highly complex models and applications?

- Especially, if the computational results deem plausible and are well visualized with abundant use of color and graphical detail?

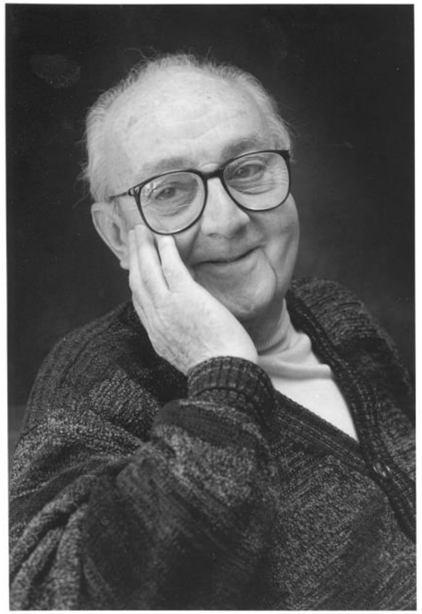
# IMPLICATIONS OF COMPUTATIONAL MODELING RESULTS

Phil Roe, Professor of Aerospace Engineering at the University of Michigan published his video lecture on Feb. 19, 2014 entitled, "Colorful Fluid Dynamics", dealing with topics of modern Computational Fluid Dynamics ("CFD"), and mentions, *"It's full of noise, it's full of color, it's spectacular, it's intended to blow your mind away, it's intended to disarm criticism."  Roe then discusses some issues with CFD and the dangers of "colorful fluid dynamics“*

# IMPLICATIONS OF COMPUTATIONAL MODELING RESULTS

**Doug McLean** (video lecture "Common Misconceptions in Aerodynamics", Oct 21, 2013, Boeing Technical Fellow): "*These days it is common to see a complicated flow field, predicted with all the right general features and displayed in glorious detail that looks like the real thing. Results viewed in this way take on an air of authority out of proportion to their accuracy...*"

# IMPLICATIONS OF COMPUTATIONAL MODELING RESULTS



George Box, *"All models are wrong but some are useful..."* Box, G. E. P. (1979), "Robustness in the strategy of scientific model building", in Launer, R. L.; Wilkinson, G. N., Robustness in Statistics, Academic Press, pp. 201–236.

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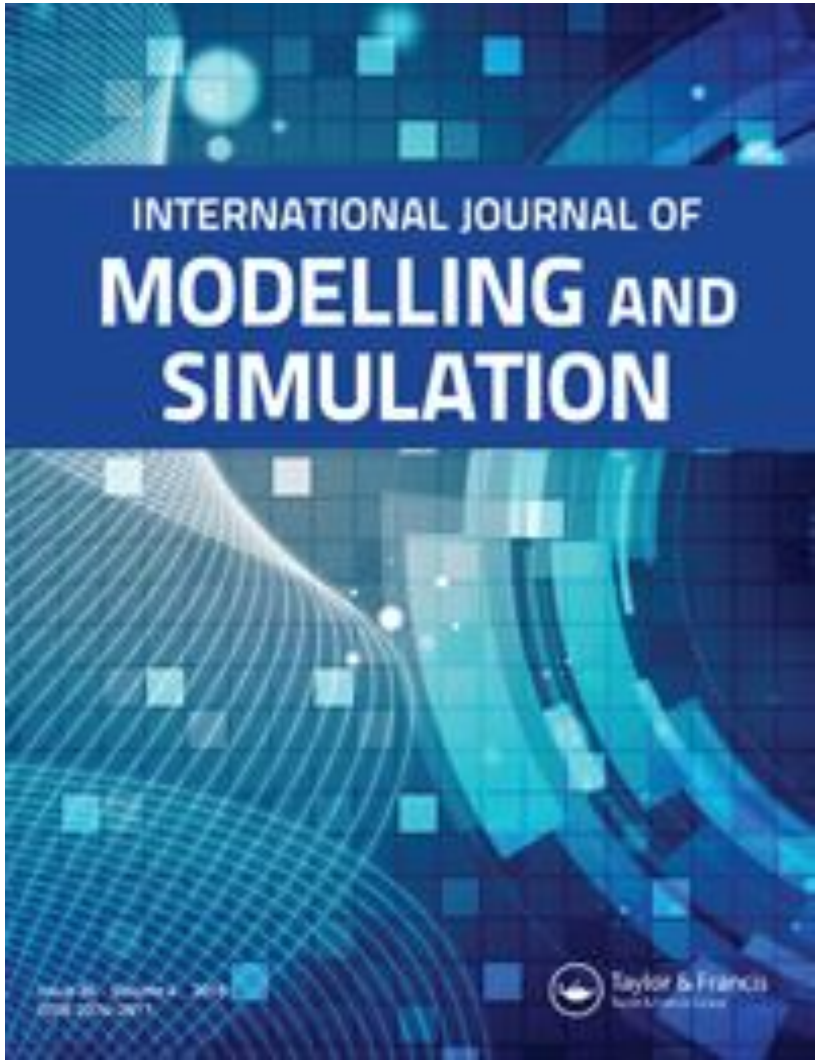


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# References

Toombes L. and Chanson H., 2011. Numerical Limitations of Hydraulic Models, The 34th International Association for Hydraulic Research (IAHR) World Congress, Brisbane, Australia. pp. 2322-2329.