

#### **CFD Modelling for Spillways**

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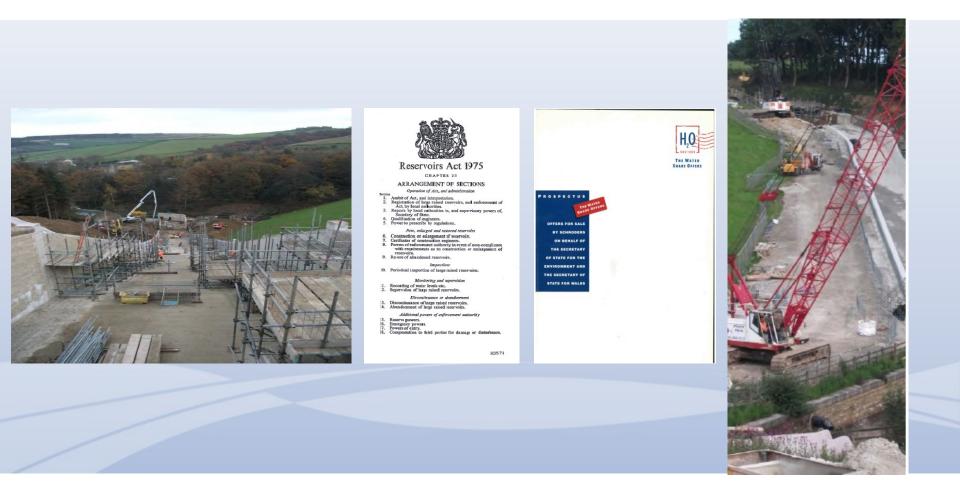
#### Outline

- Introduction Andrew
- The challenge in Yorkshire Andrew
- CFD for Spillways John
- Results from Strines and Stubden John
- Comparison with physical models David
- Outcomes for Strines and Stubden Jon
- Other applications & future research Jon

















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After 25 years of major projects.., water companies have reached a position where they have most of their major assets in place. AMP6 is, therefore, about optimisation



We need to achieve efficiencies right across the project life cycle

The better we make our technology.. that allows us to present the results in a medium people understand











- A company skill set? •
- A passing interest? •









- The Yorkshire Water Asset Management Purpose
  - Provide and manage a safe, reliable and affordable asset base that is optimised for operational risk and delivers long term outcomes for our customers









• How can we change?











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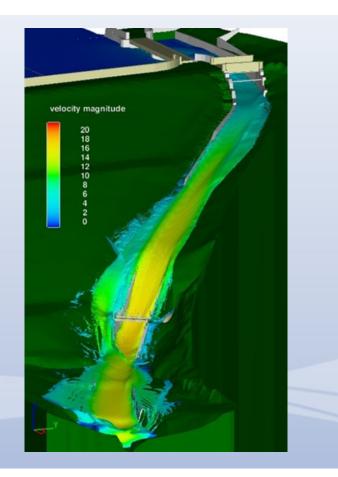




#### What do we expect from CFD?

- Early Inspections
- Contract process

#### Working together









#### What is CFD?

#### "Computational Fluid Dynamics"

The use of numerical methods and algorithms to solve and analyse problems that involve fluid flows (today typically refers to 3D applications)



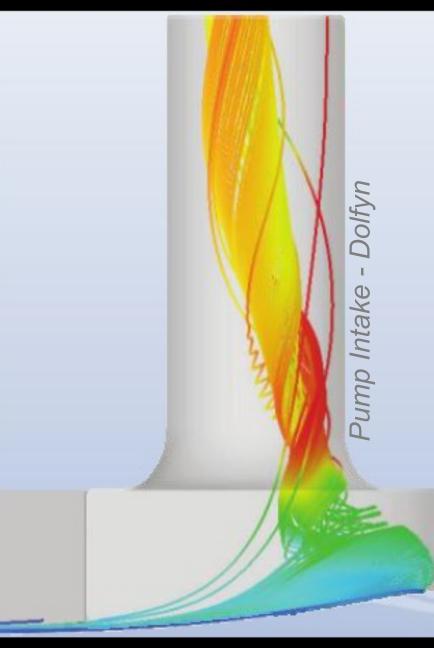






## **CFD** Development

- 1940s through to present day
- Early applications included m surface ships, submarines, ai automobiles
- Use of CFD today is widespread
  - Any discipline involving fluids (a
  - Today CFD is often paired with numerical models such as Finite models of structures









### CFD for spillways

- Spillways have been physically modelled for over 100 years
- The use of CFD for spillways has been under development since the 1970s
- Initially used as a research tool before gradually being accepted by the dam engineering community
- Currently used on most major new builds

Stilling Basin – Flow3D

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### Software and Methodology

- Flow 3D, OpenFOAM, Ansys CFX & Fluent, Dolfyn, STAR-CCM+, NUMECA...
- Both commercial and opensource
- Differentiated by differences in;
  - Discretisation, volume and surface tracking
  - turbulence models
  - multiphase modelling, bubble and air entrainment physics and cavitation modelling
  - and sediment modelling
  - (to name a few)







### Software and Methodology

- Methodology
  - Pre-Processing
  - Simulation
  - Post-Processing
  - Interpretation



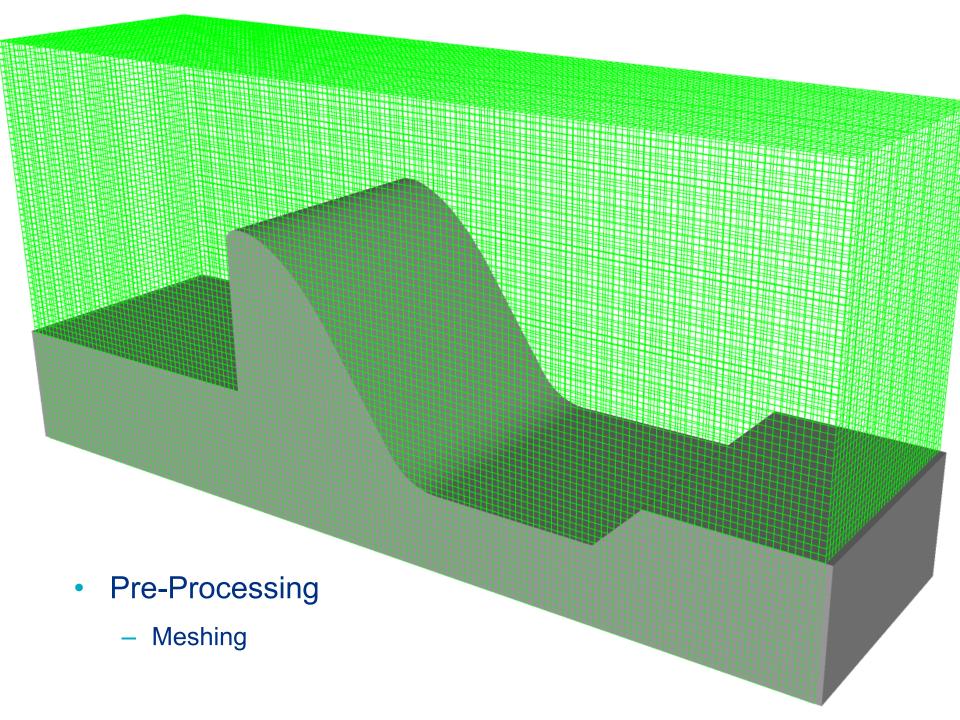






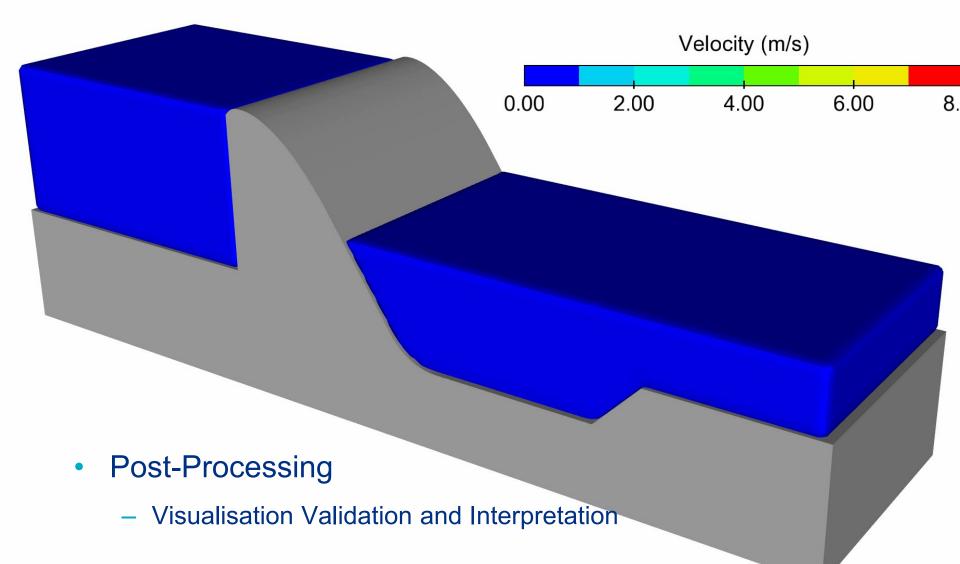
- Pre-Processing
  - Geometry

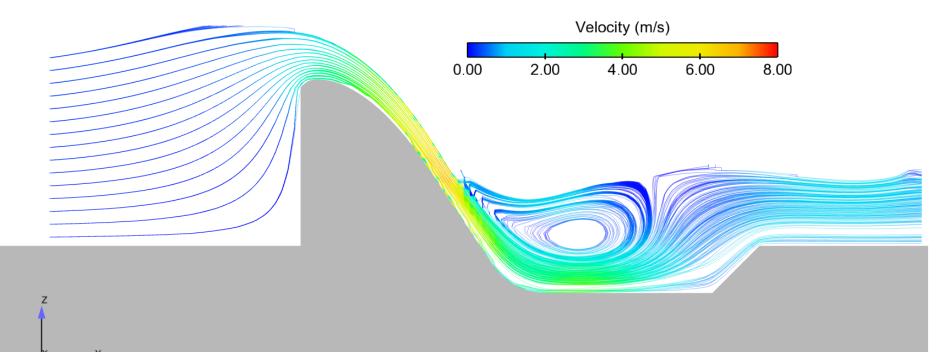
- Pre-Processing
  - Meshing



- Pre-Processing
  - Initial Conditions and Physics

- Simulation
  - Sensitivity, calibration and final runs





- Post-Processing
  - Visualisation Validation and Interpretation







#### Considerations...

- Models are never 100% reliable
  - Input data may require assumptions
  - Mathematical models may be inadequate
  - Accuracy limited by available computing power
  - Interpretation and skill of the modeller and engineer

# "The purpose of computing is insight, not numbers"

Richard Hamming, Numerical Methods for Scientists and Engineers (1962)







### **Strines Spillway Blocks**



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# Strines Spillway Blocks

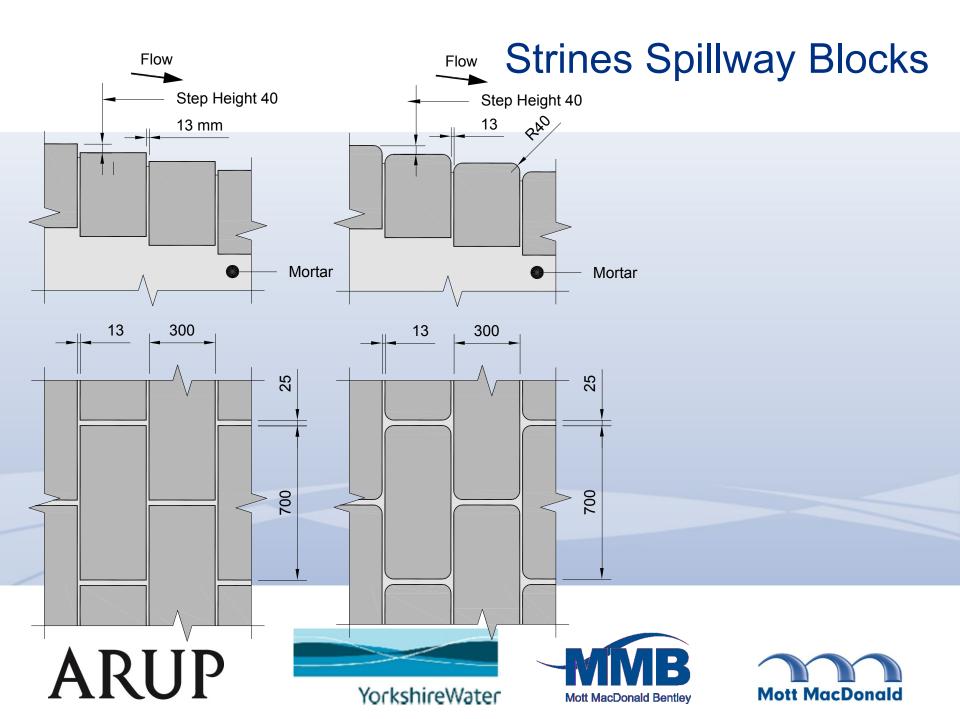


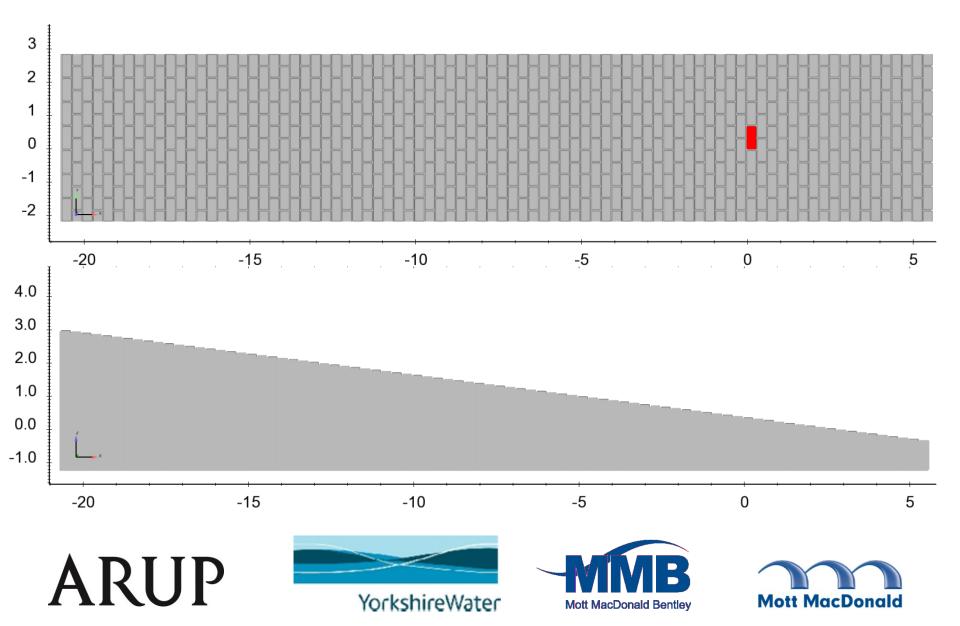
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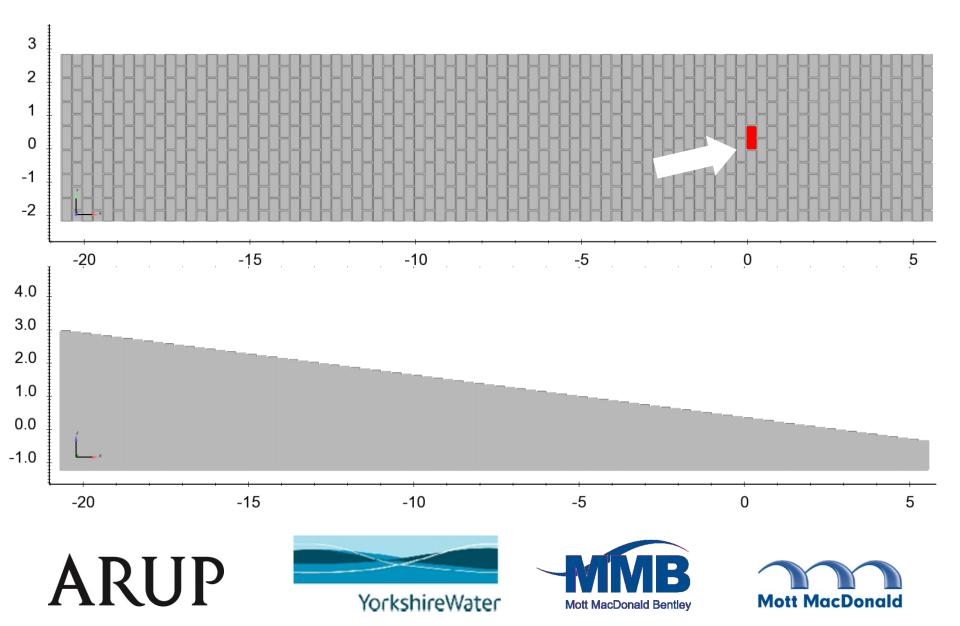




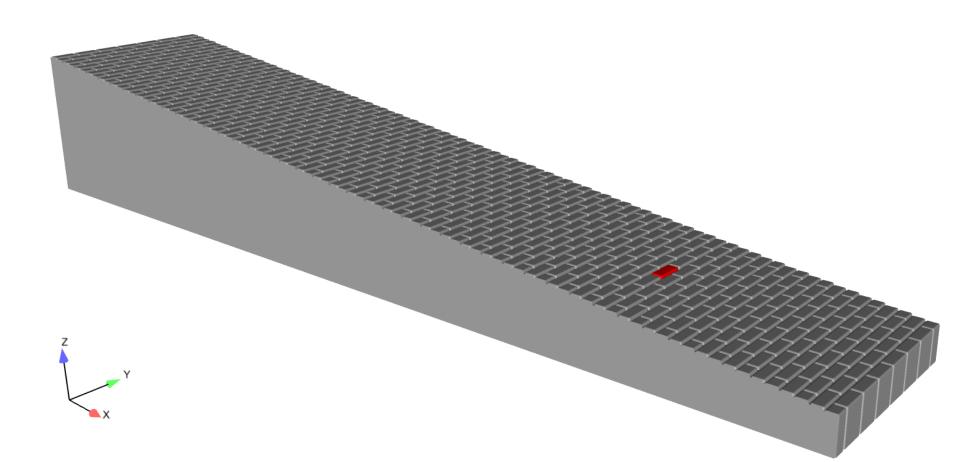




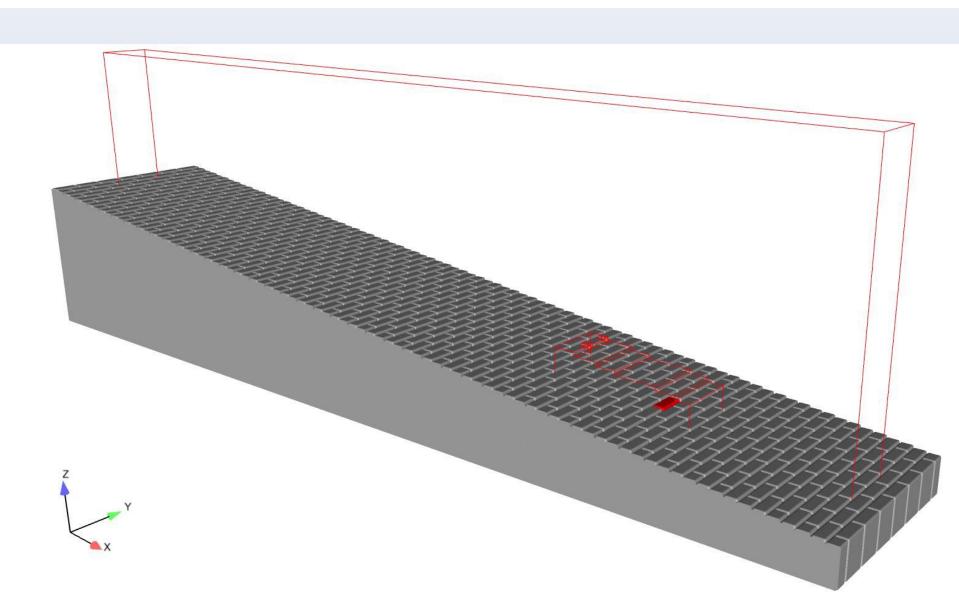




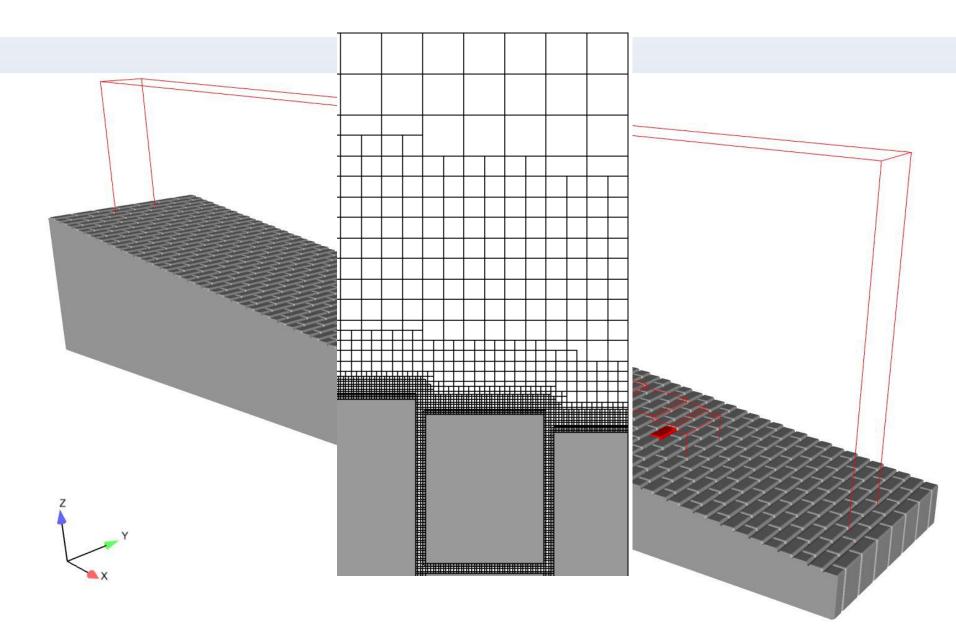
## Pre-processing | Geometry

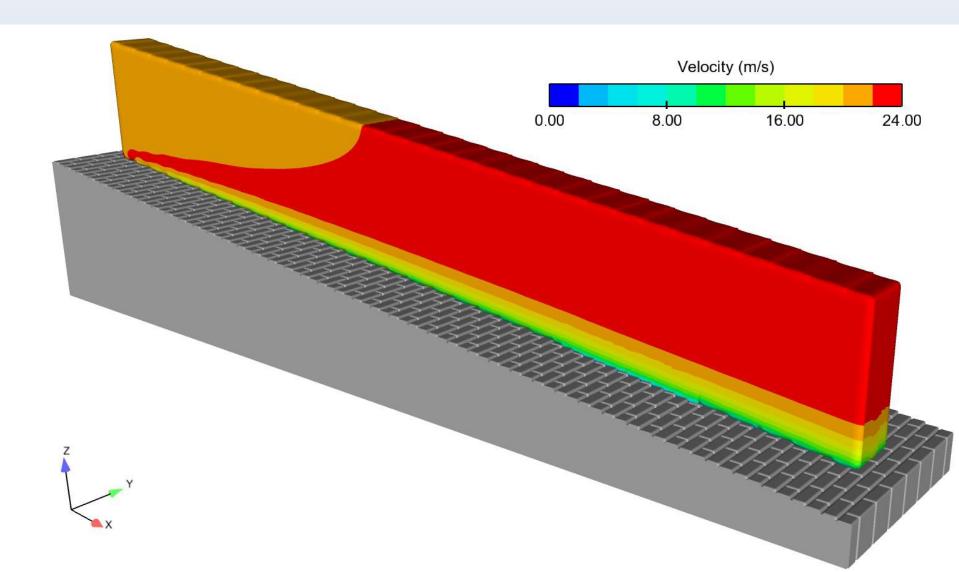


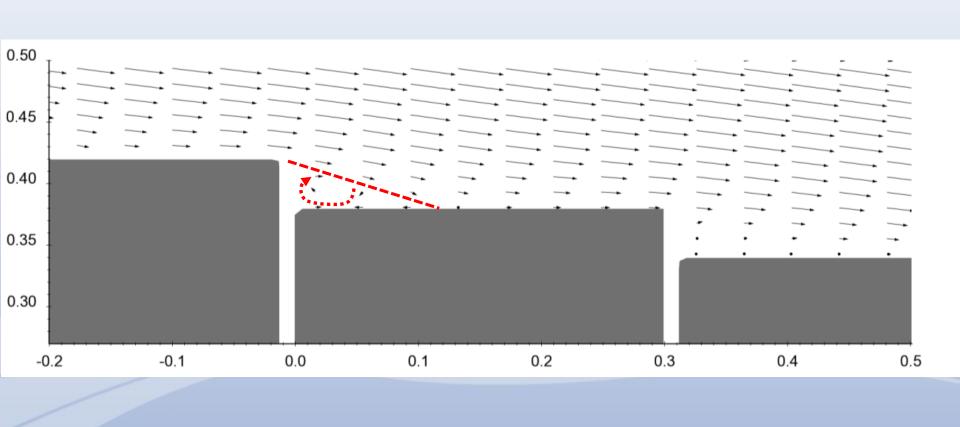
# Pre-processing | Geometry



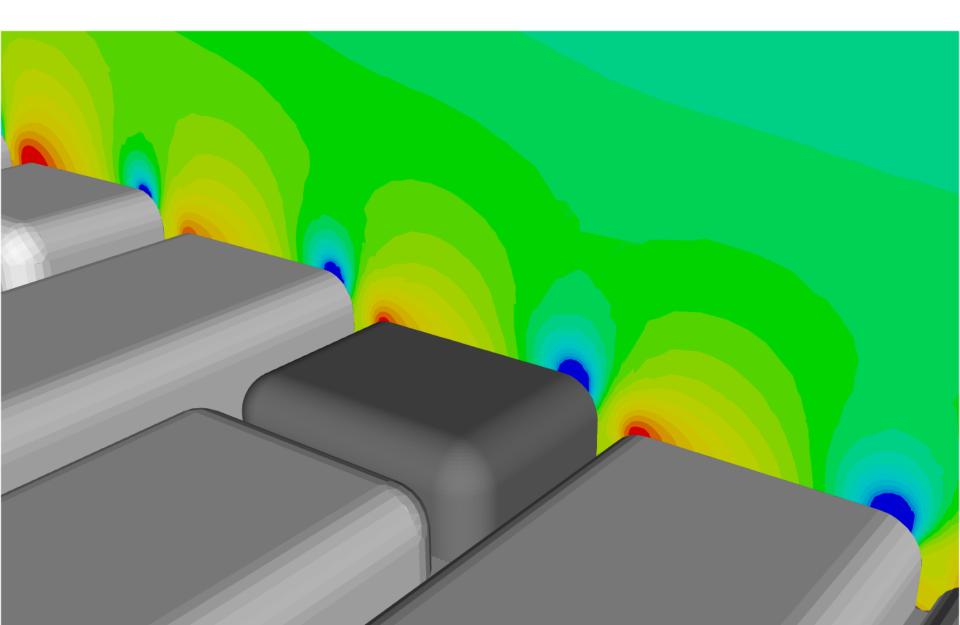
# Pre-processing | Mesh

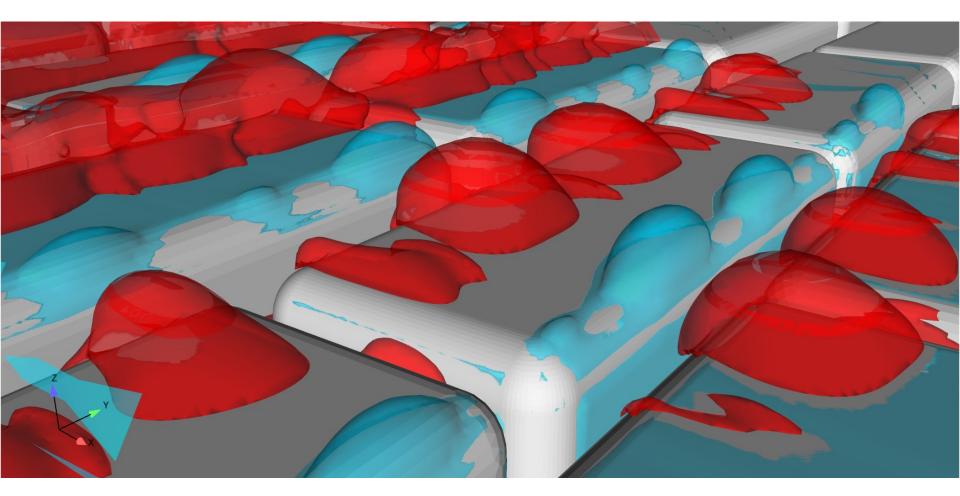












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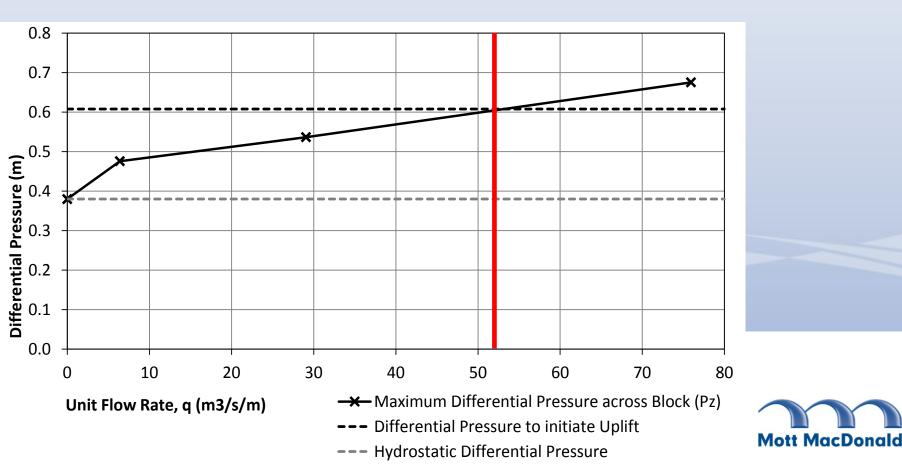






#### Interpretation | Visualisation

- Confirmed square stepped blocks inherent stability
- Sensitive to block shape and condition of mortar



# Stubden Spillway

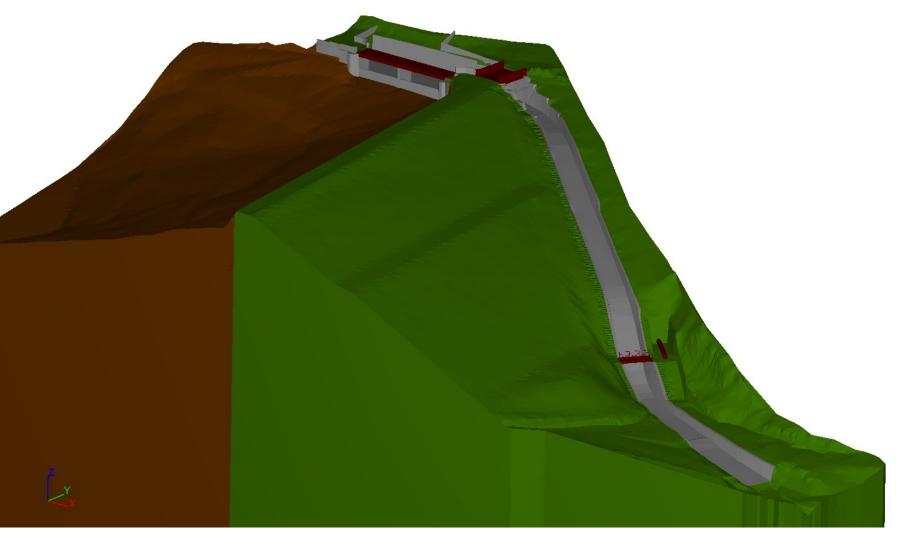


#### **Spillway Chute**





#### **Pre-Processing - Geometry**









#### **Pre-Processing - Geometry**



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#### **Pre-Processing – Fluid Region**



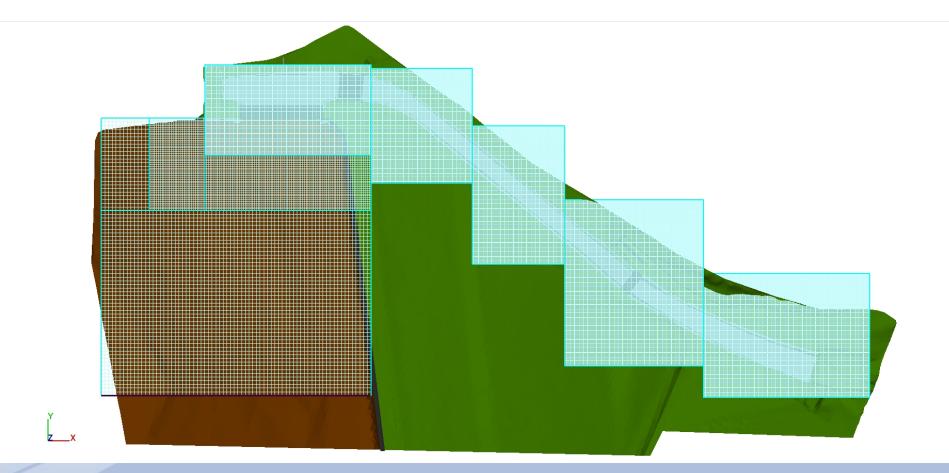
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#### **Pre-Processing - Meshing**



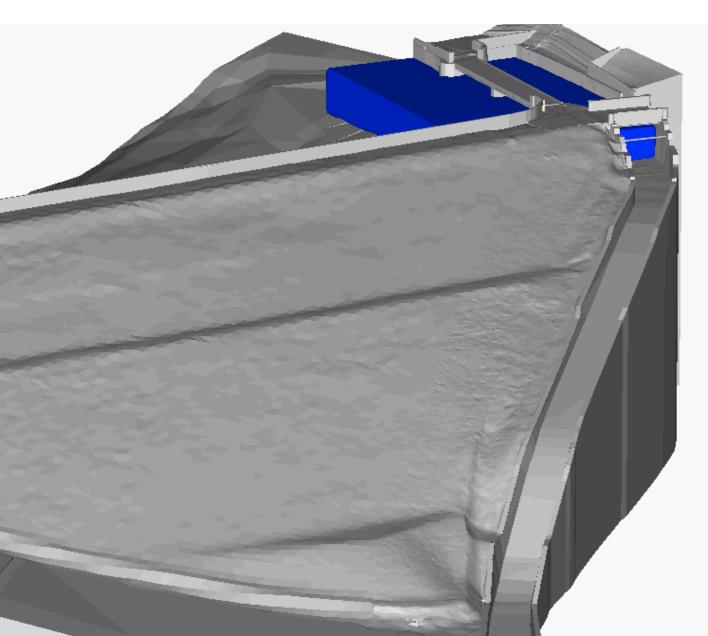
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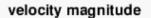


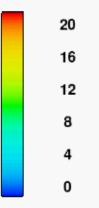




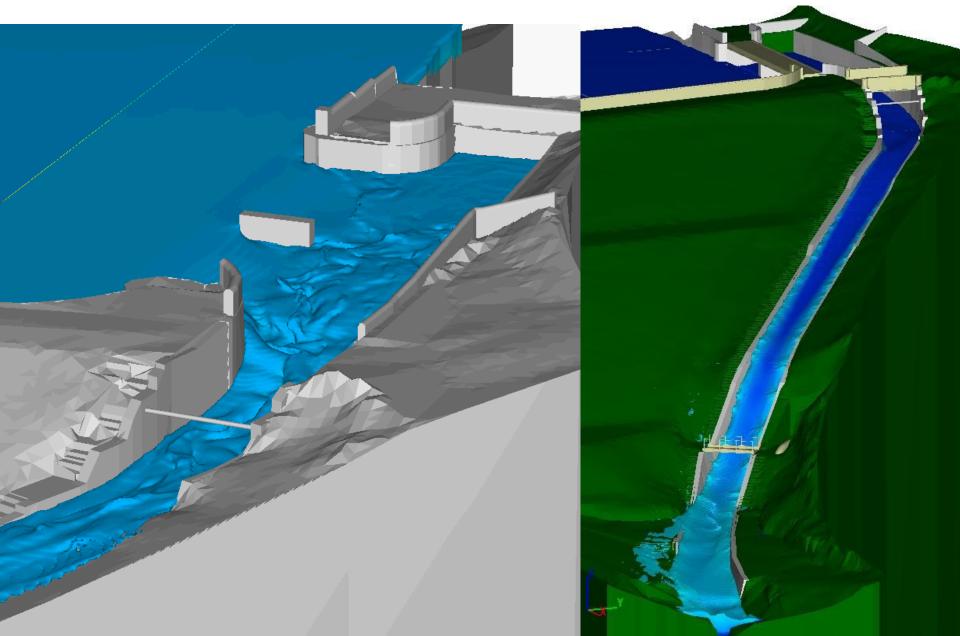
### Simulation | Sensitivity Testing



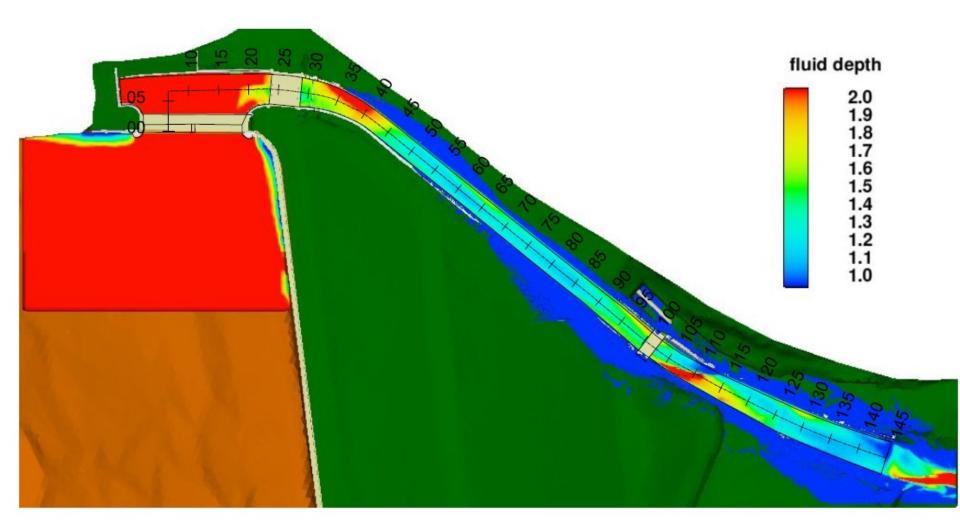




### Post-Processing | Visualisation



#### Post-Processing | Visualisation

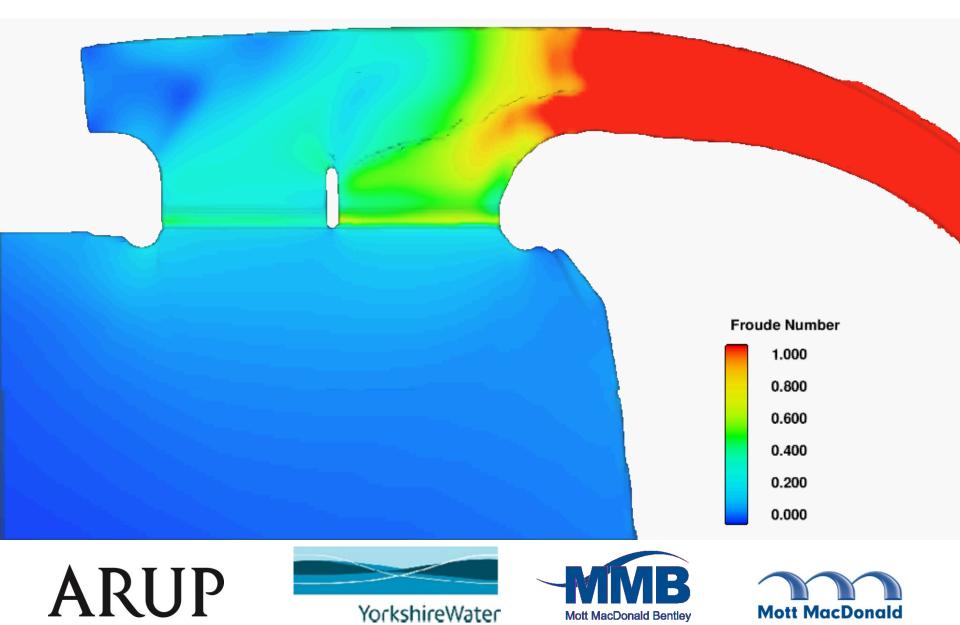








#### Interpretation



#### **Model Comparison**









### Model Comparison

### **3 Independent Models**

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#### CFD 1:1 OpenFOAM

Flow3D

#### **Physical 1:20 Gravity**

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CFD





#### Flow Depth & Velocity

### All Models run at:

1:1000

1:10000

PMF PMF + 10% 12m<sup>3</sup>/s 19m<sup>3</sup>/s 38.7m<sup>3</sup>/s 42.6m<sup>3</sup>/s

#### **Comparison tonight on PMF**







#### Weir & Tumblebay Arrangement

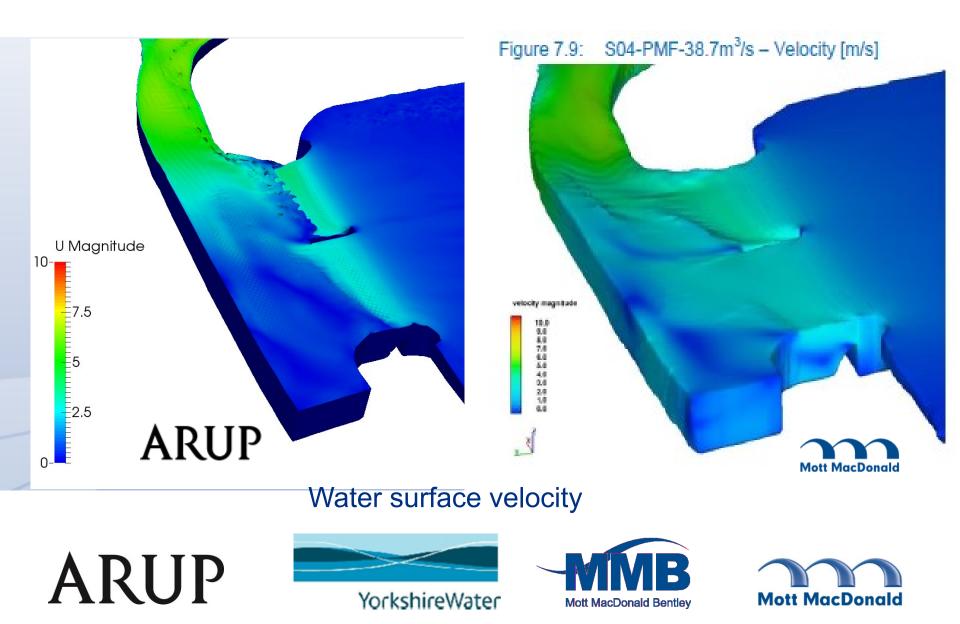




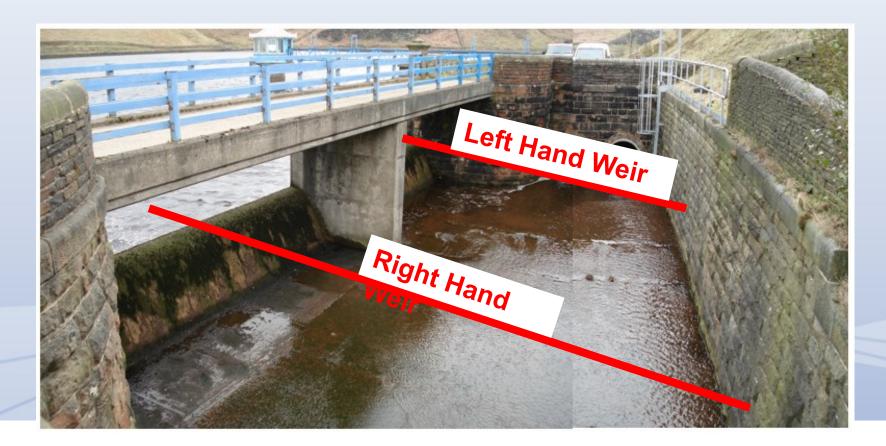




#### Weir and Tumblebay Flow Regime



#### Weir and Tumblebay Flow Regime



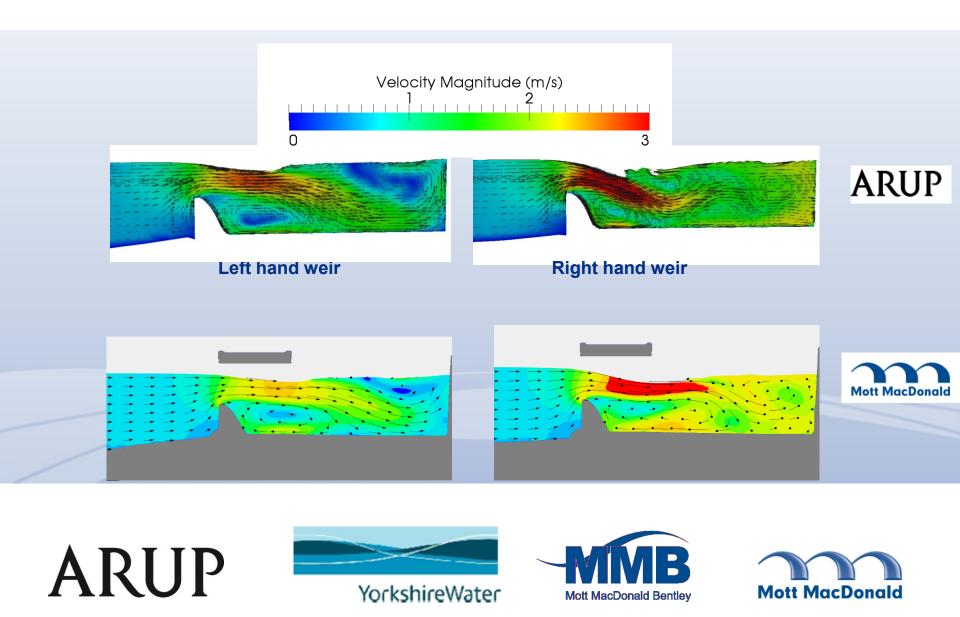
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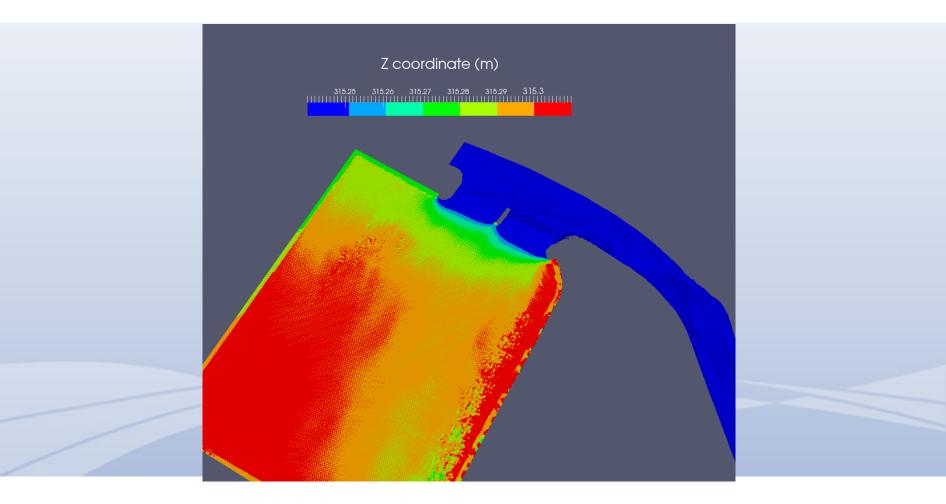


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#### Weir and Tumblebay Flow Regime





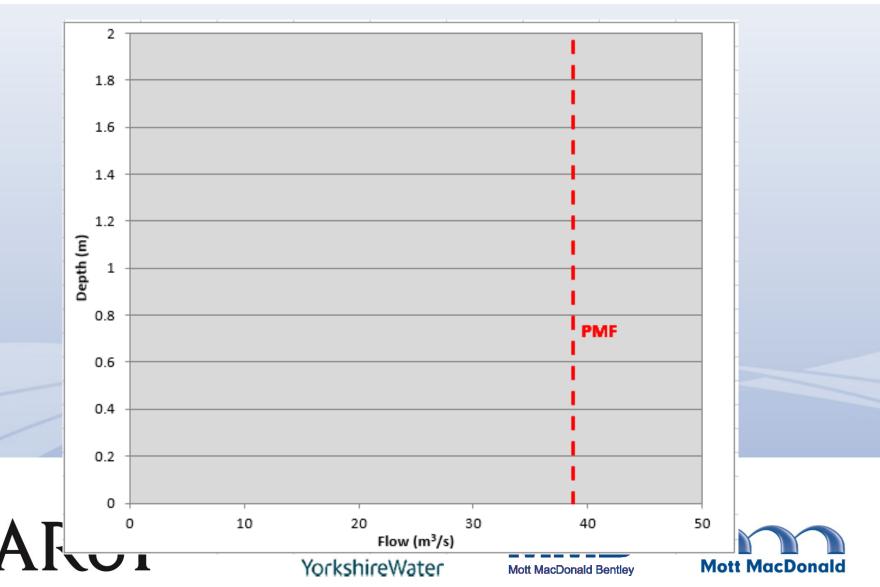
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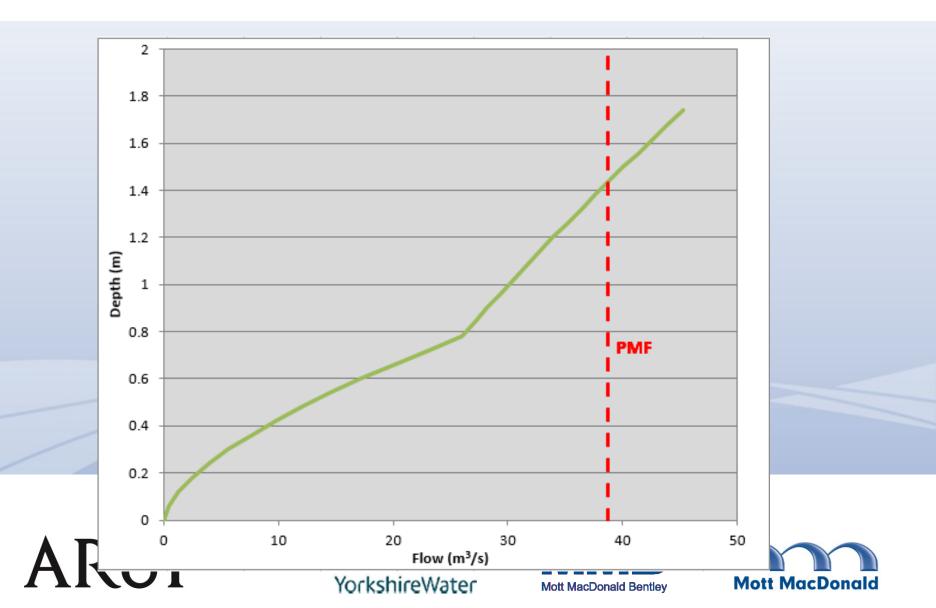


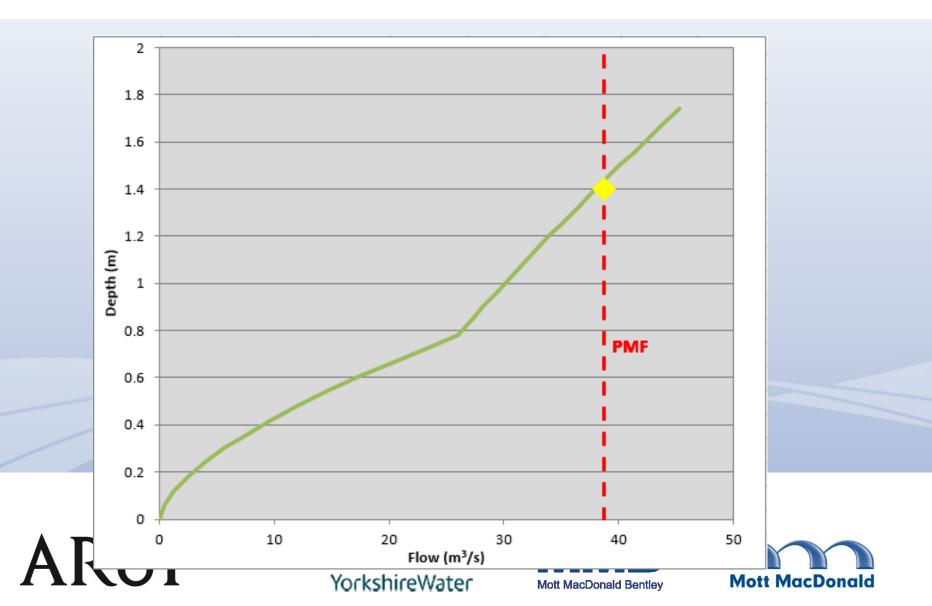


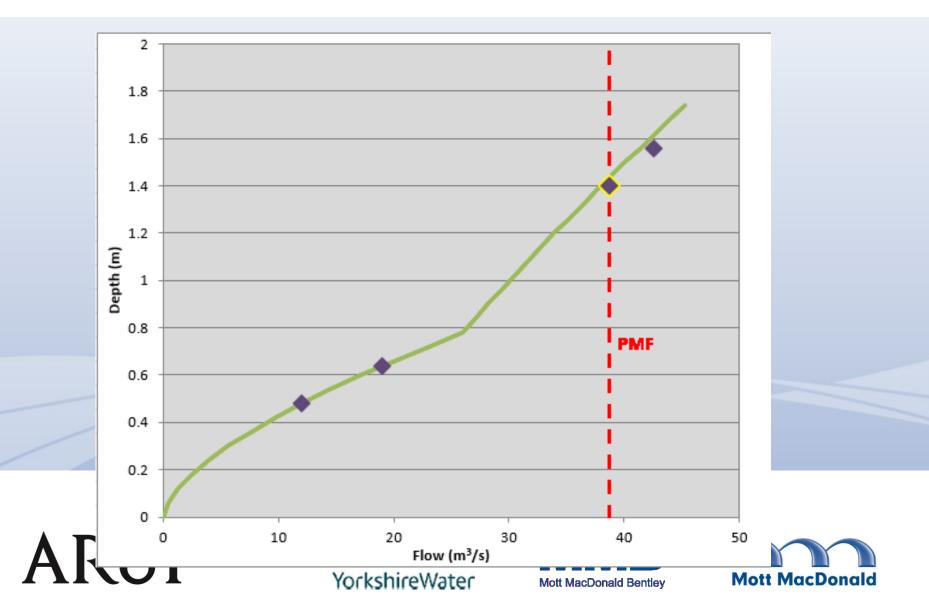


#### **Probable Maximum Flood**

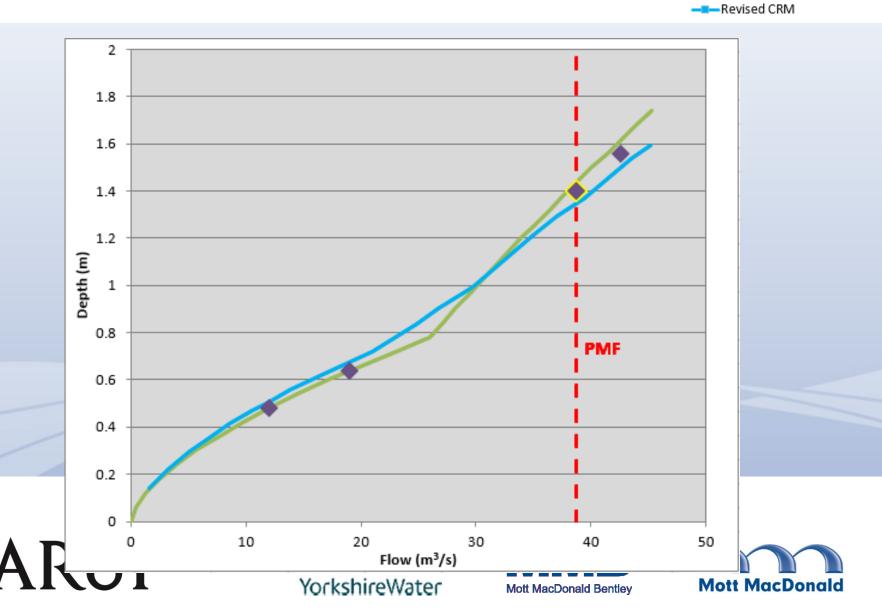




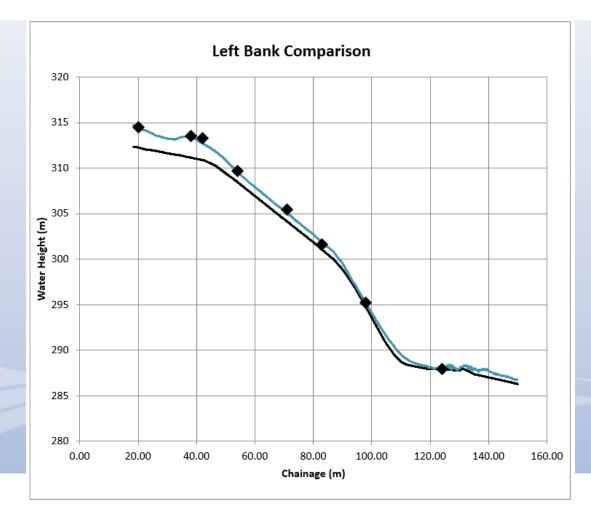








#### **PMF Flow Depth**



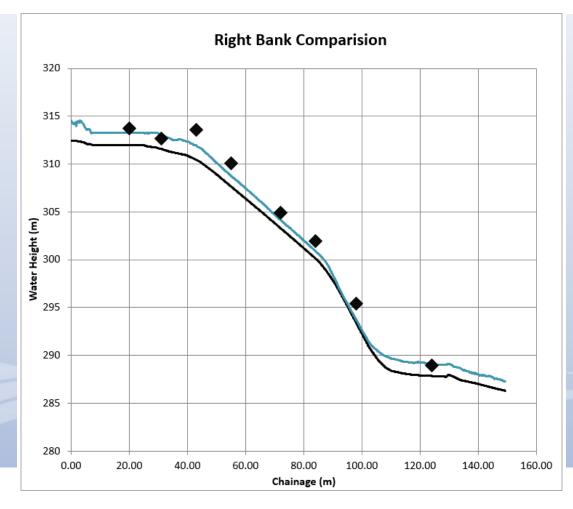
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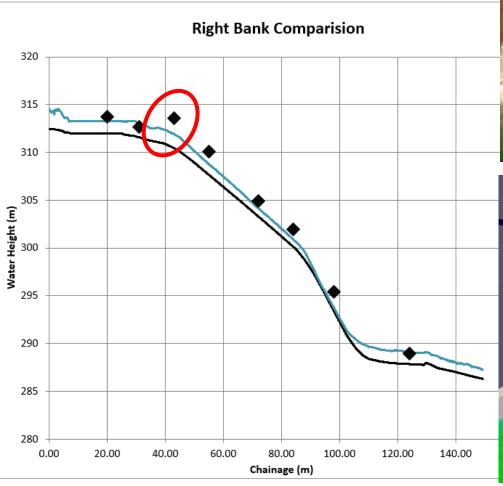
#### **PMF Flow Depth**



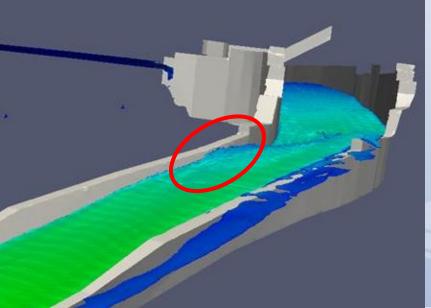












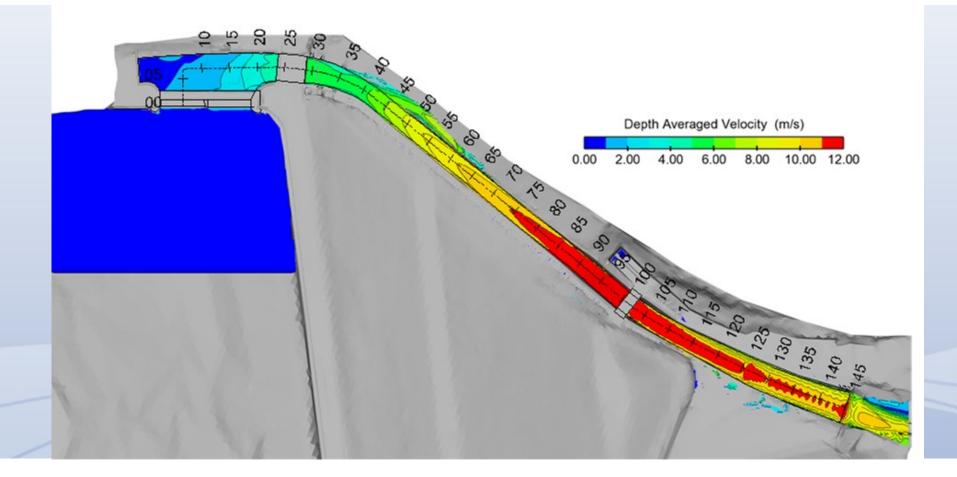
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#### **PMF** Velocities

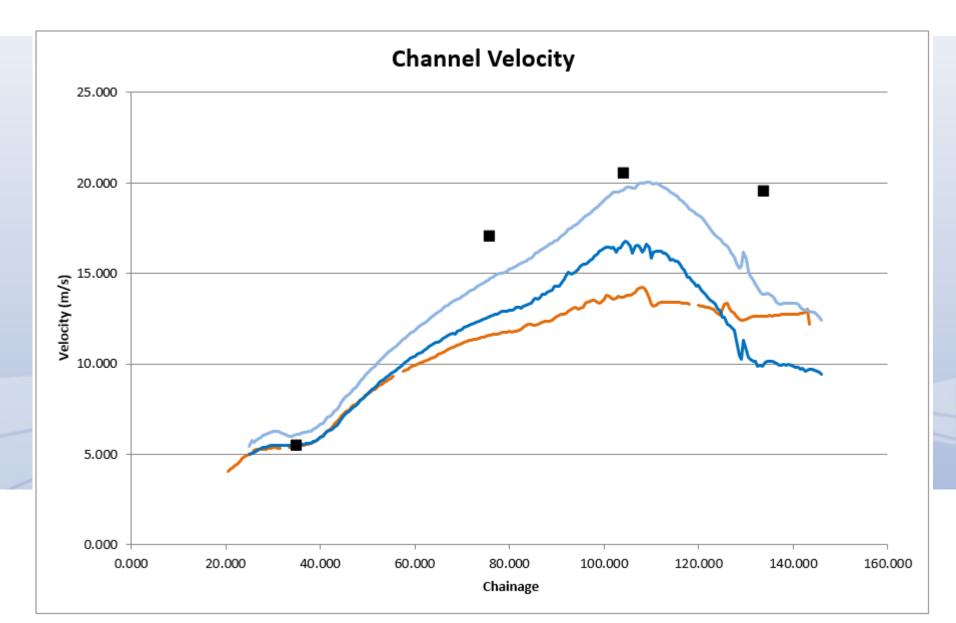




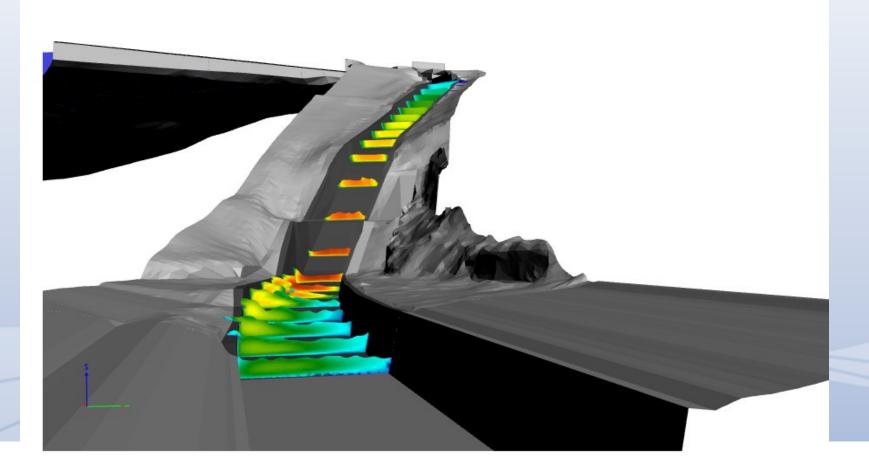




#### **PMF Velocities**



#### **Velocity Sections**



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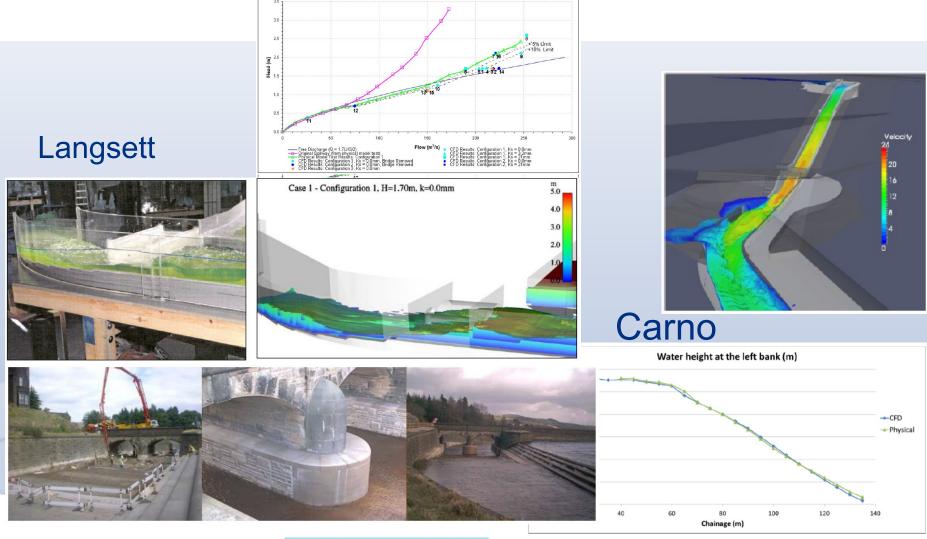
#### **PMF** Overtopping





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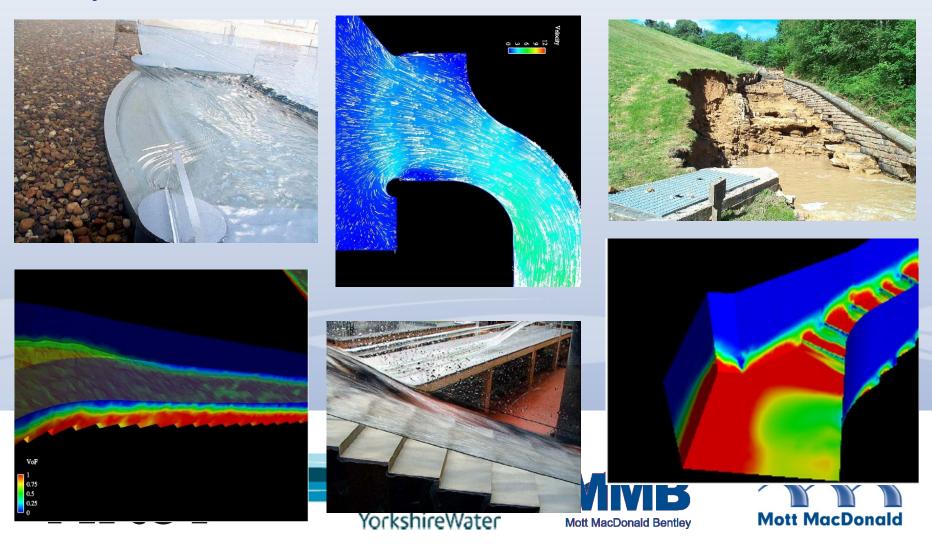


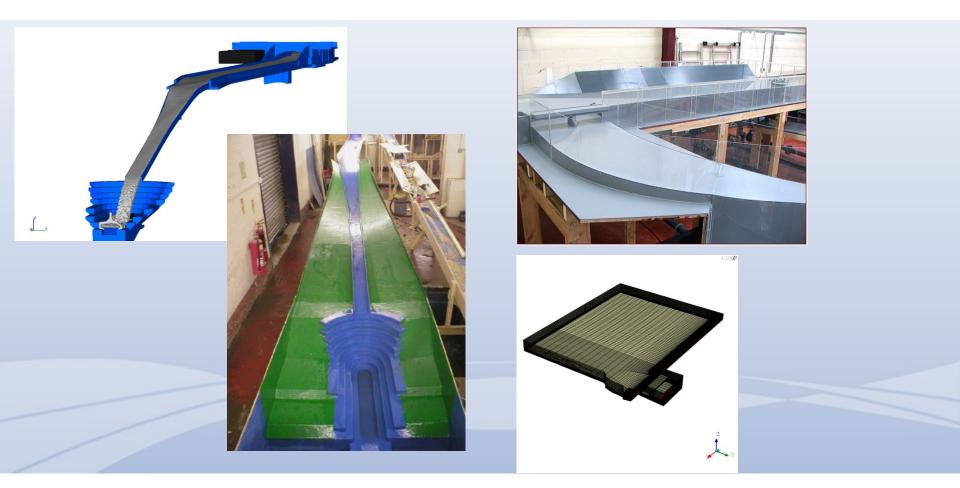






#### Boltby





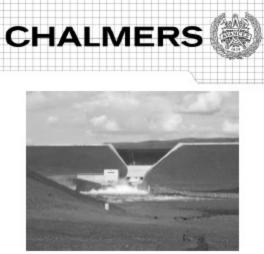
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Computational Modeling of Flow over a Spillway In Vaturafellsstifla Dam in Iceland Master of Science Thesis

#### BJÖRN MARGEIRSSON

Department of Applied Mechanics Distation of Fhatd Dynamics CHALMÜRS UNIVERSITY OF TECHNOLOGY Octhersburg, Sweden, 2007 Matter's Thesis 2007:29



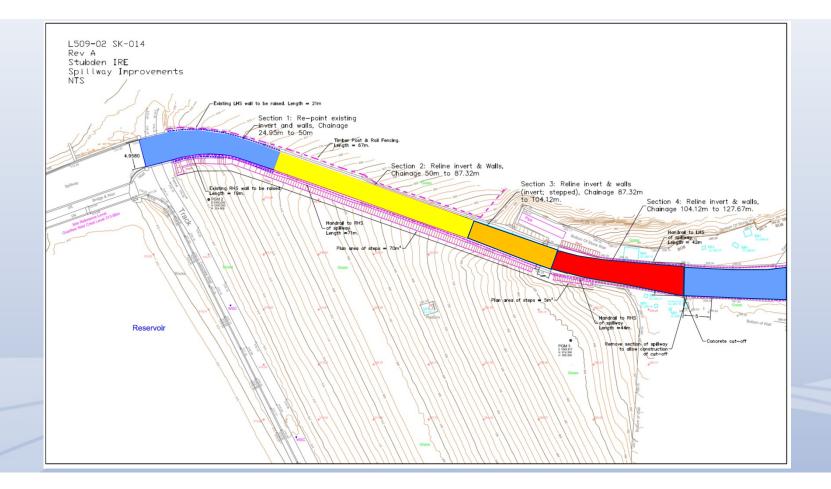
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#### **Outcome for Stubden**











#### **Outcome for Stubden**









#### **Outcome for Stubden**



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#### **Outcome for Strines**



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#### Pros and Cons of CFD

Aspect	CFD	Physical Model	
Scale effects			
Air entrainment			
Time-varying phenomena			
Model extent & flow			
Dimensional accuracy			
Speed of construction			
Ease of modification			
Measurement			
Future assessment			
Cost			







#### Associated Technology & Innovation

- Laser scanning:
  - condition surveying
  - confined spaces
  - for CFD
  - for BIM
- Photogrammetry using drones
- Virtual Reality







#### **Condition Surveys**



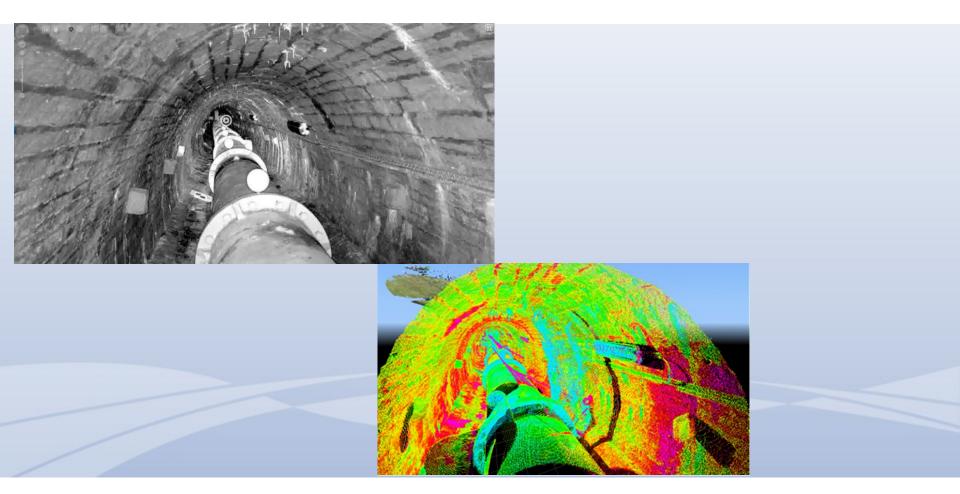








#### **Confined Spaces**



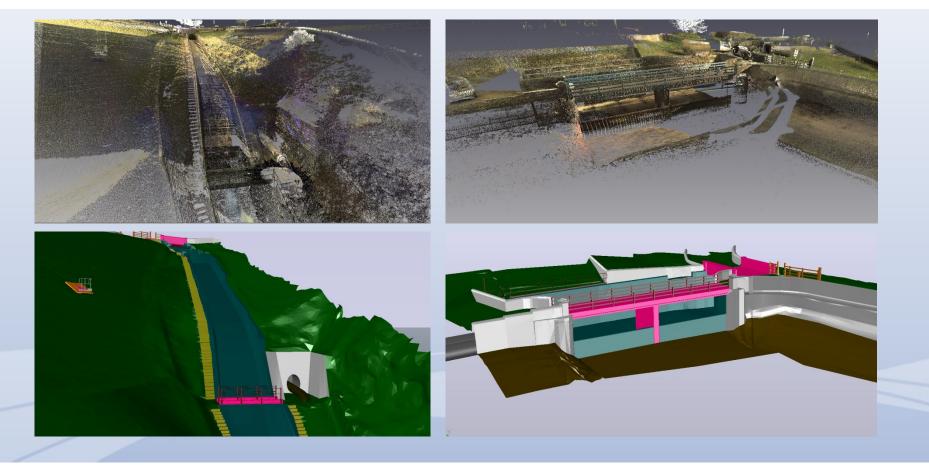
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#### For CFD software



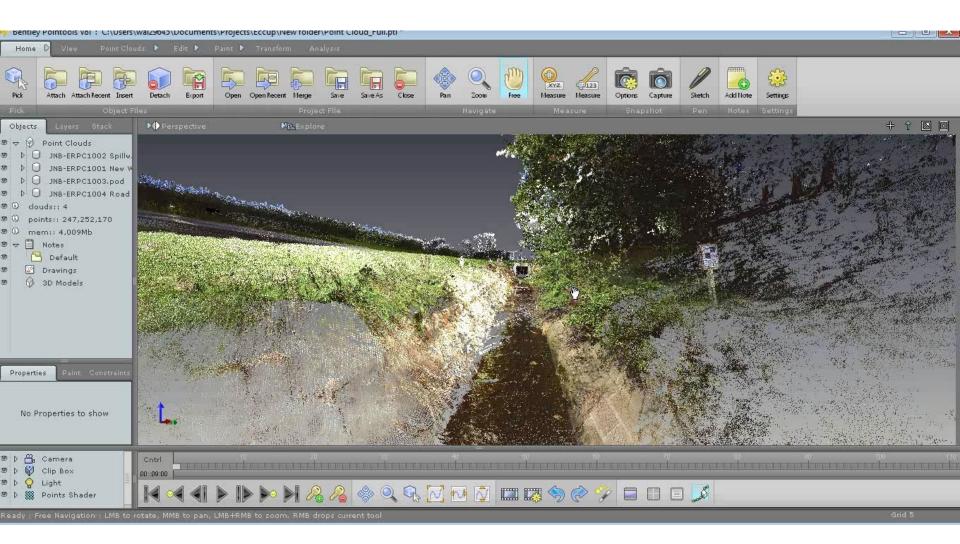
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#### For **BIM**



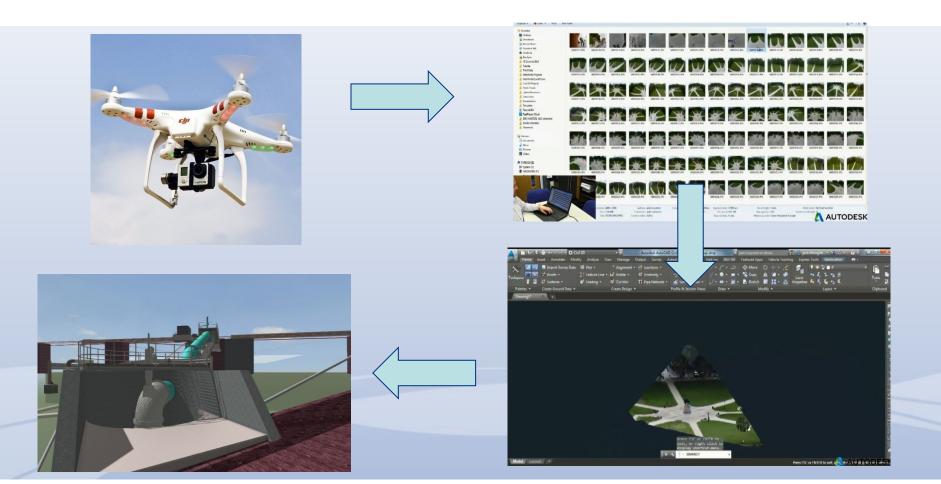
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#### Photogrammetry



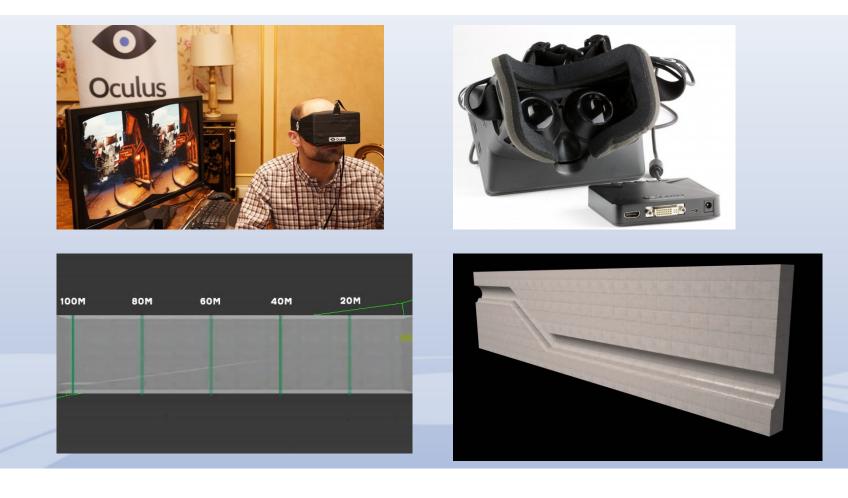
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#### **Virtual Reality**



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#### Summary

- Financial climate for water companies forces innovation
- Combined with environmental challenges = build less
- Carried out blind CFD studies and compared to physical model of a complex spillway
- Technology continues to develop
- CFD can now be accepted as another tool in the dam engineer's arsenal
- Further research and studies required









#### Further research

- Turbulence models
- Air entrainment
- Channel roughness and flow over masonry blocks
- Converting point clouds to 3D surfaces
- Real data









### **Questions?**

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