Flood Inundation Modelling of Flash Floods in Steep River Basins and Catchments

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Flash Flood Inundation Modelling

- Determine what type of flood inundation models should be used for predicting flood depths, velocities and inundation extent for flash flood events

- Three different 2D model configurations:
  - a configuration that solved the full 2D shallow water equations (i.e. the MAC test case)
  - a configuration based on a simplified version of the 2D shallow water equations (i.e. the SI test case)
  - a configuration that included shock-capturing ability (i.e. the TVD test case)

Stability Issues

$$\frac{\partial \boldsymbol{X}}{\partial t} + \frac{\partial \boldsymbol{F}}{\partial x} + \frac{\partial \boldsymbol{G}}{\partial y} = \boldsymbol{S} + \boldsymbol{T}$$

$$\boldsymbol{X} = \begin{bmatrix} \eta \\ q_x \\ q_y \end{bmatrix}, \boldsymbol{F} = \begin{bmatrix} q_x \\ \frac{\beta q_x^2}{h+\eta} + \frac{g\eta^2}{2} + gh\eta \\ \frac{\beta q_x q_y}{h+\eta} \end{bmatrix}, \boldsymbol{G} = \begin{bmatrix} q_y \\ \frac{\beta q_x q_y}{h+\eta} \\ \frac{\beta q_y^2}{h+\eta} + \frac{g\eta^2}{2} + gh\eta \end{bmatrix}, \boldsymbol{S} = \begin{bmatrix} 0 \\ g\eta \frac{\partial h}{\partial x} - \frac{g q_x \sqrt{q_x^2 + q_y^2}}{(h+\eta)^2 C^2} \\ 0 \end{bmatrix}, \boldsymbol{T} = \begin{bmatrix} 0 \\ 0 \\ g\eta \frac{\partial h}{\partial y} - \frac{g q_y \sqrt{q_x^2 + q_y^2}}{(h+\eta)^2 C^2} \end{bmatrix}$$

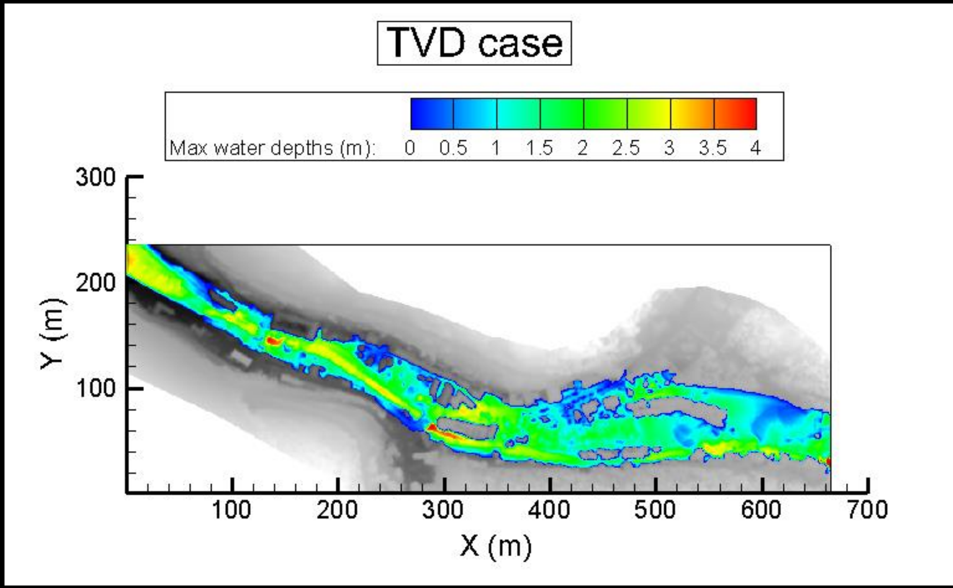
- Modification to stabilise the MAC solution method was based on the reduction of the value of the momentum correction factor β:
- The momentum correction factor β was reduced to:
  - 0.50 when 0.50 <= Fr <0.75
  - 0.25 when 0.75 <= Fr <1.0
  - 0 when 1.0 <=Fr
- Accuracy is expected to be compromised.

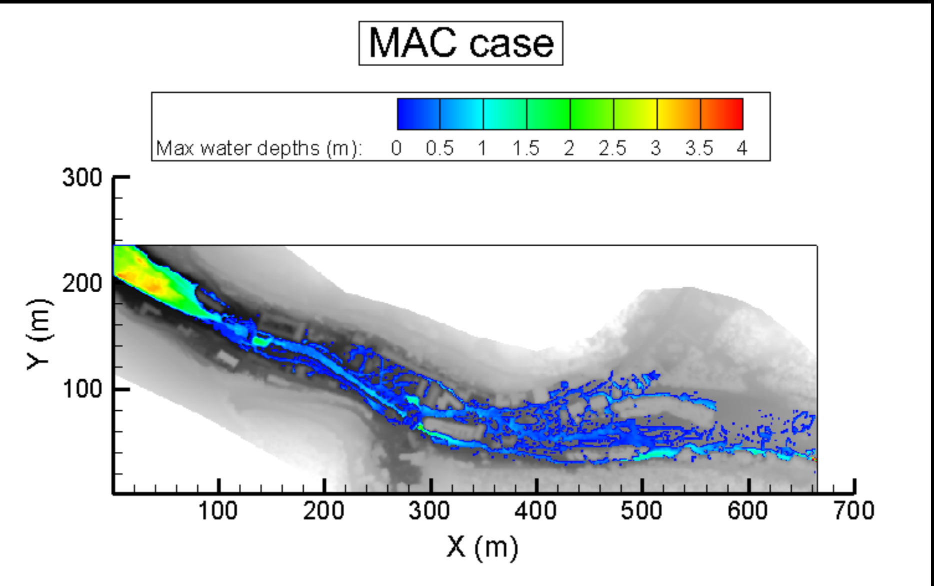
Boscastle

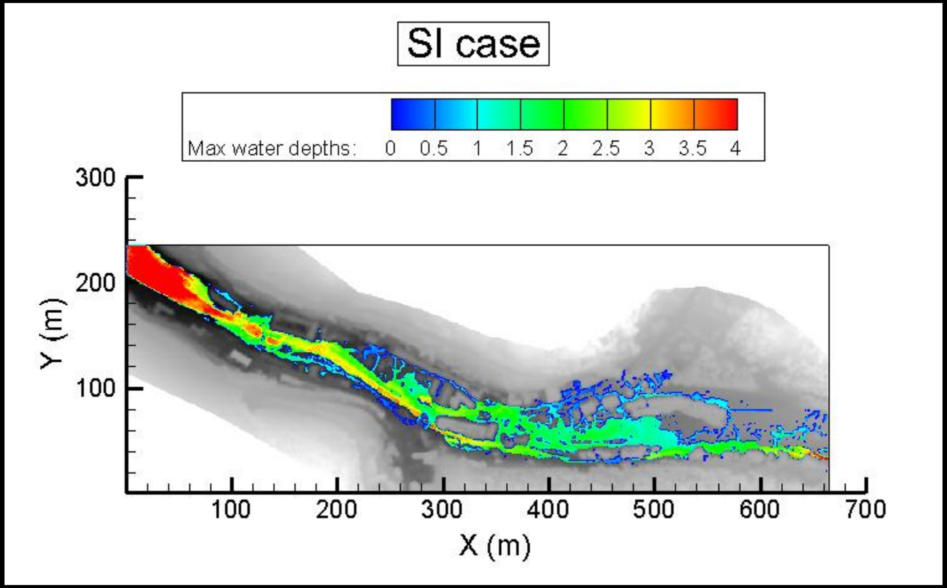
Boscastle 2004 Flash Flood

Boscastle: Case Study Domain

Boscastle: Model Predictions

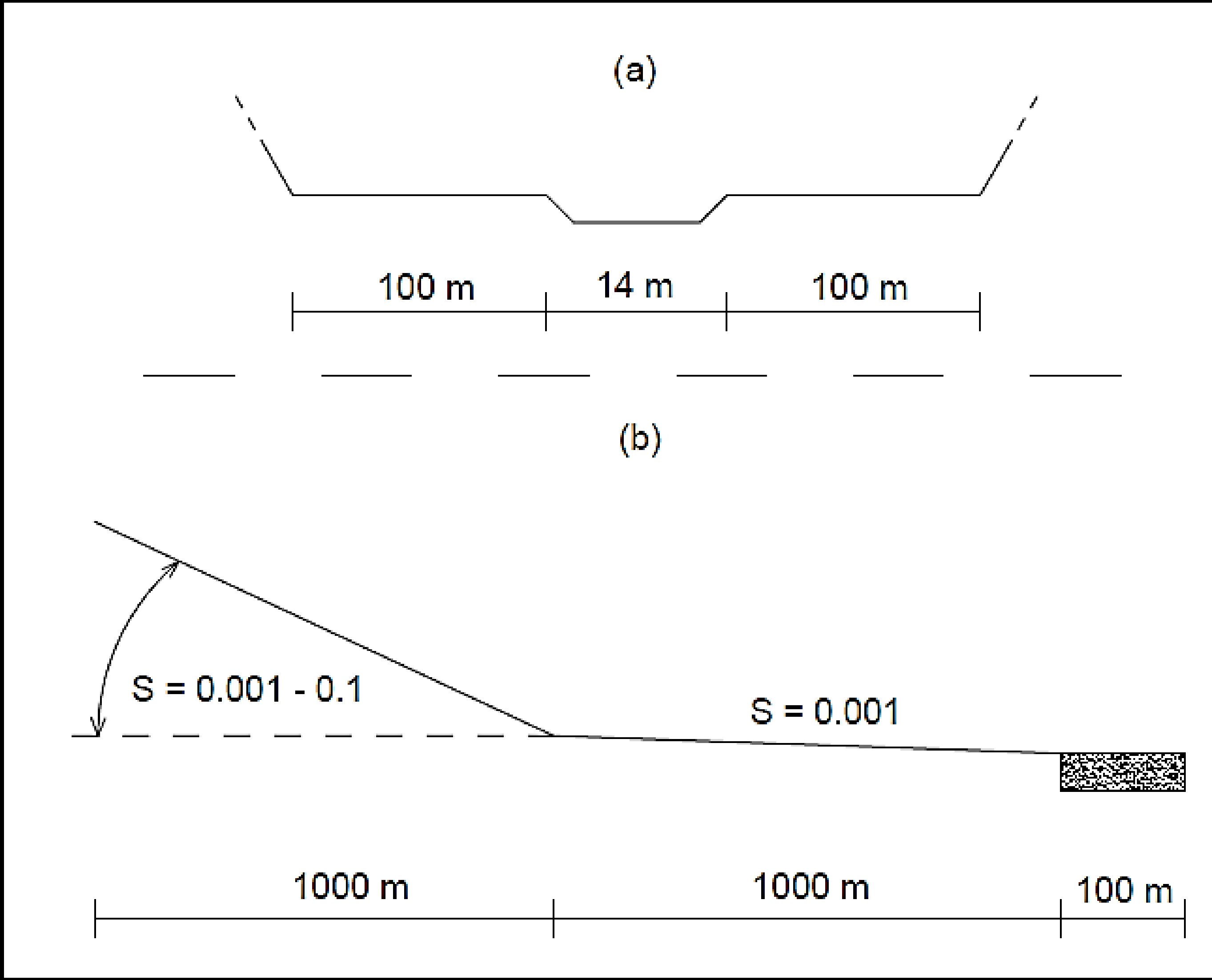




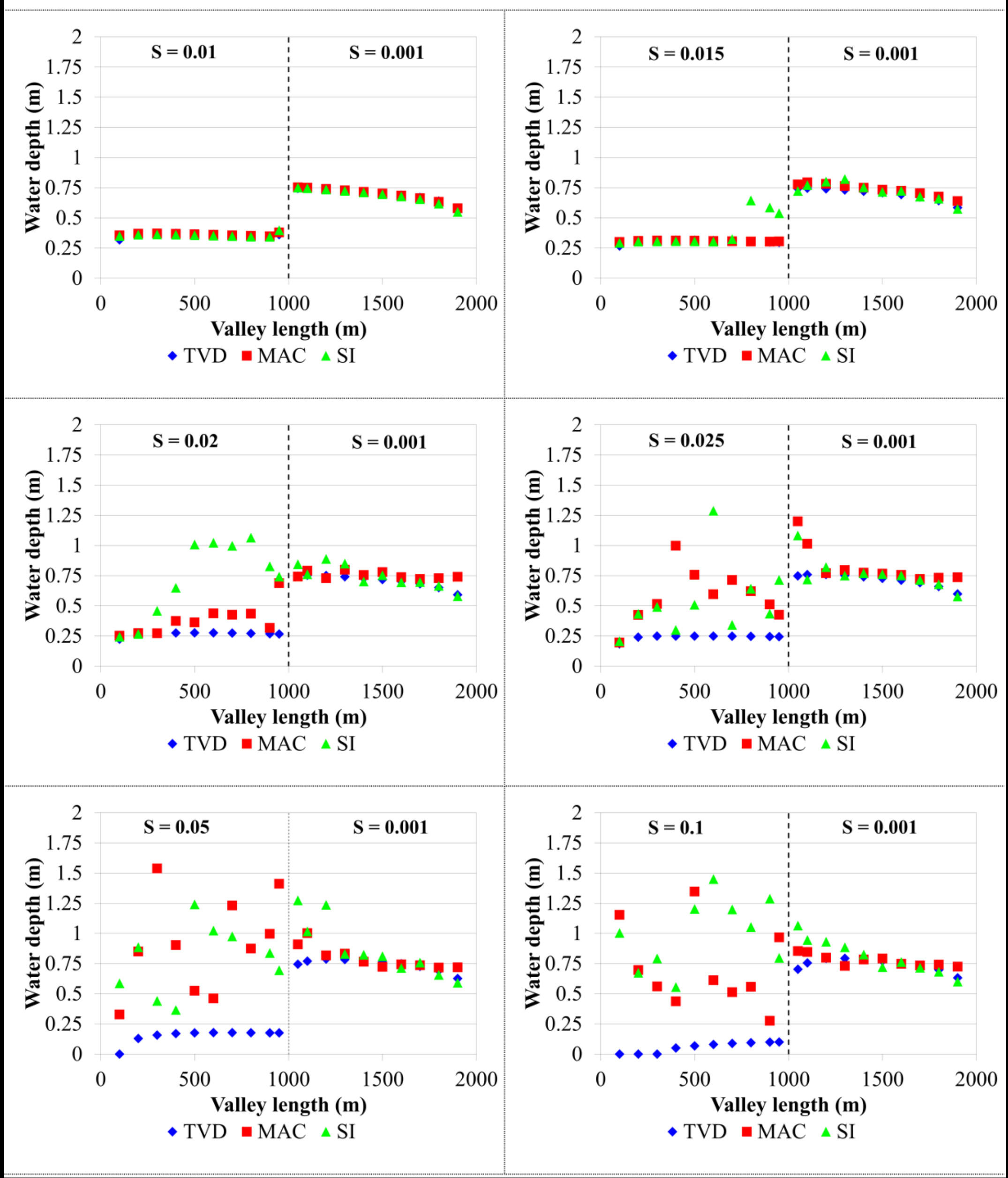


Model configuration	Nash – Sutcliff model efficiency
TVD case	0.9863
MAC case	0.8530
SI case	0.8684

Idealised Valley Test: Set Up



Idealised Valley Test: Results



Borth

Borth: Study Domain

Picture courtesy of Google Earth

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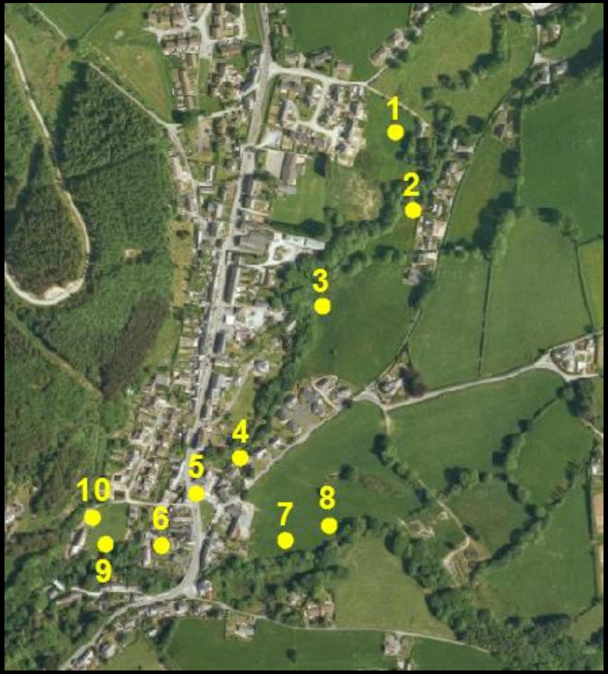
2012 River Leri Flash Flooding

BORTH: MONITORING POINTS

Tal-y-bont



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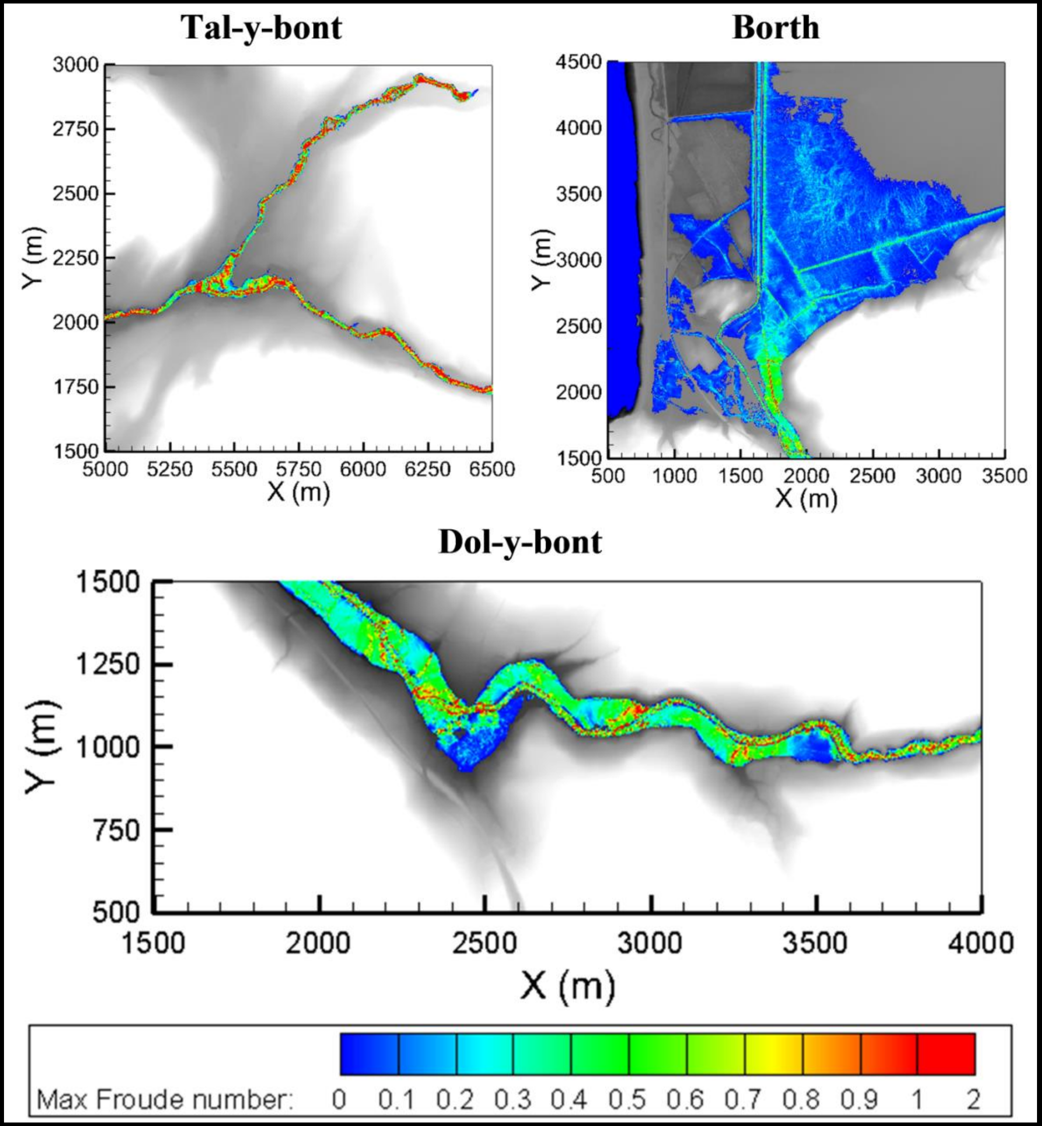
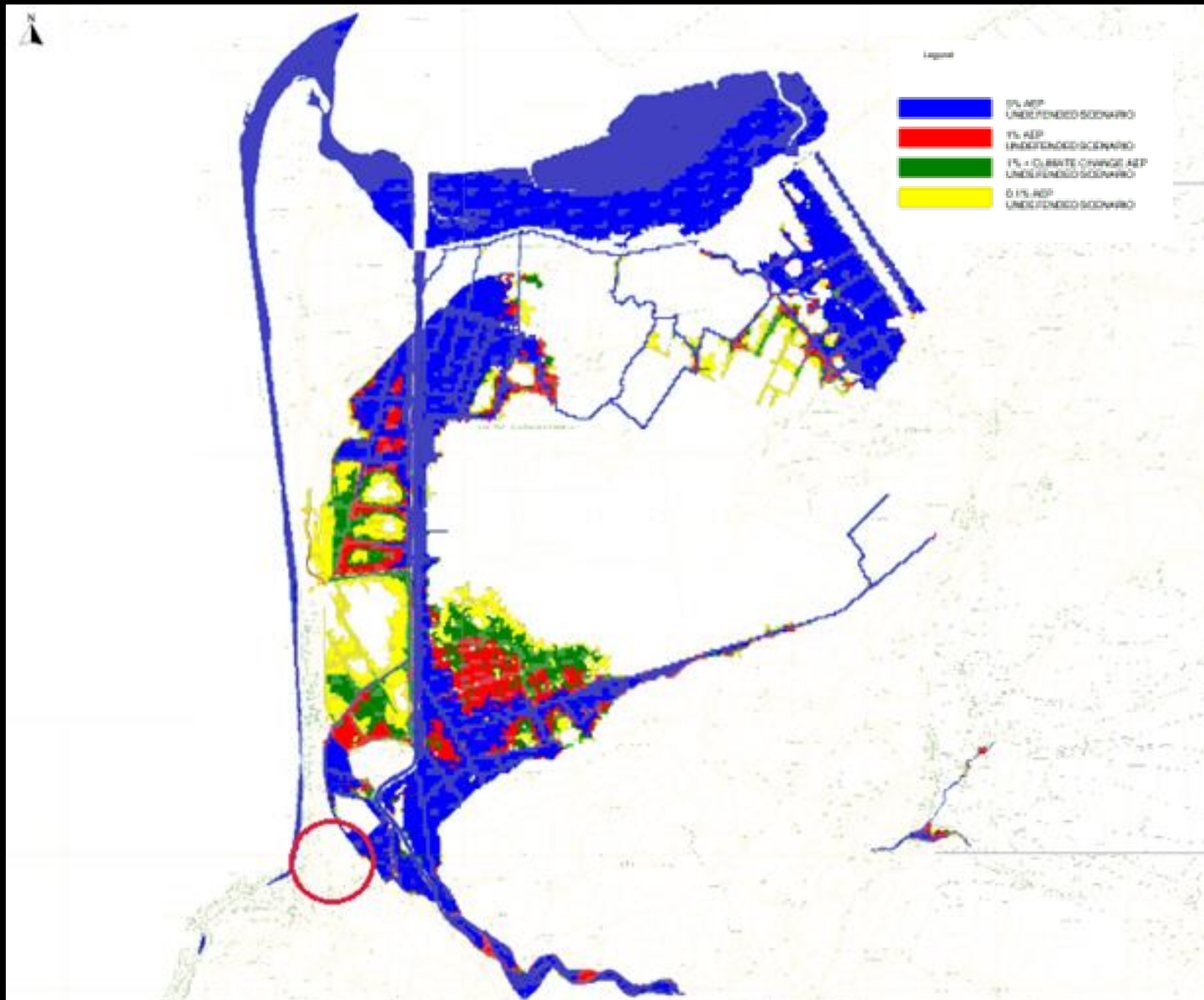
Dol-y-bont

Max Froude Number



Max Flood extent for a 1:1000 year flood



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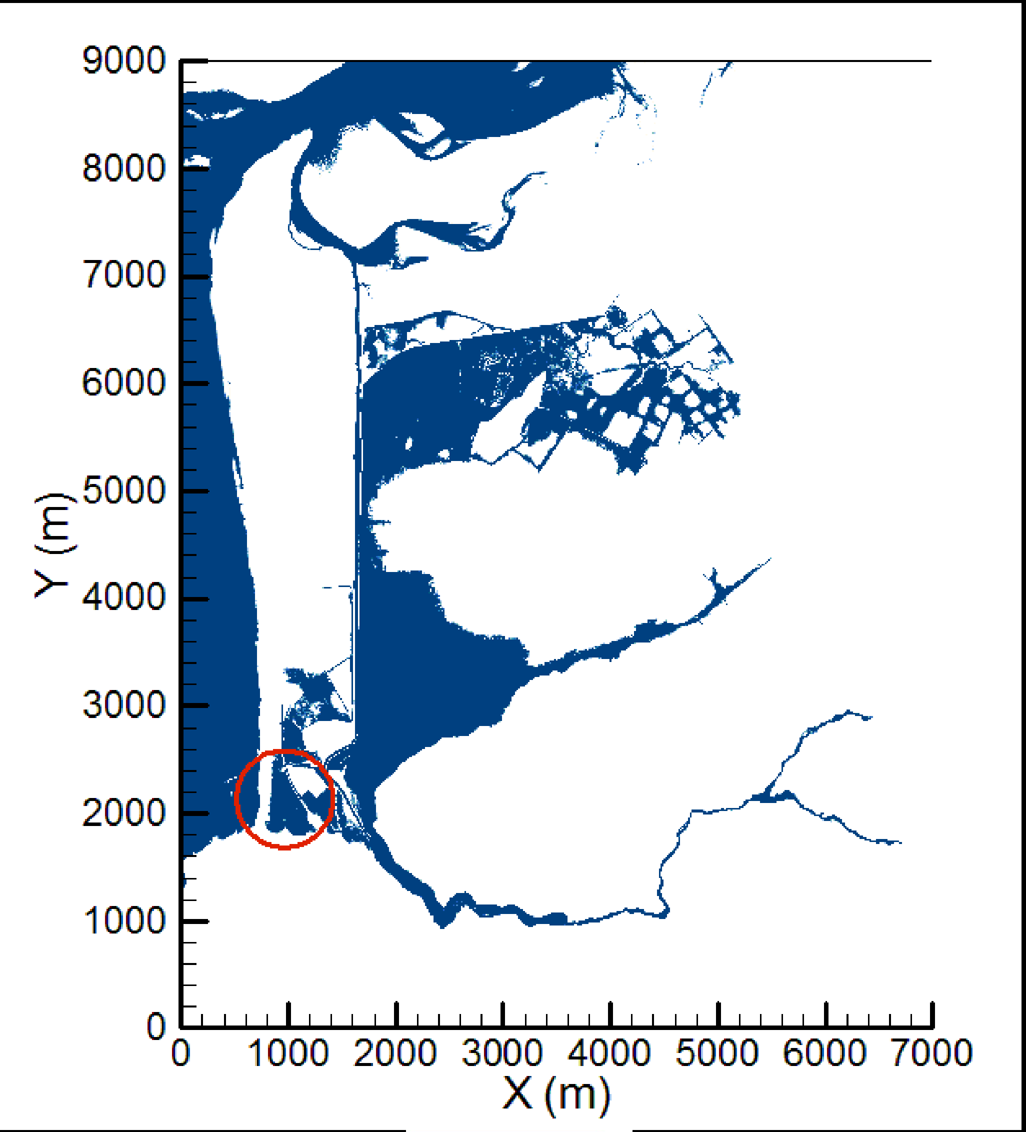

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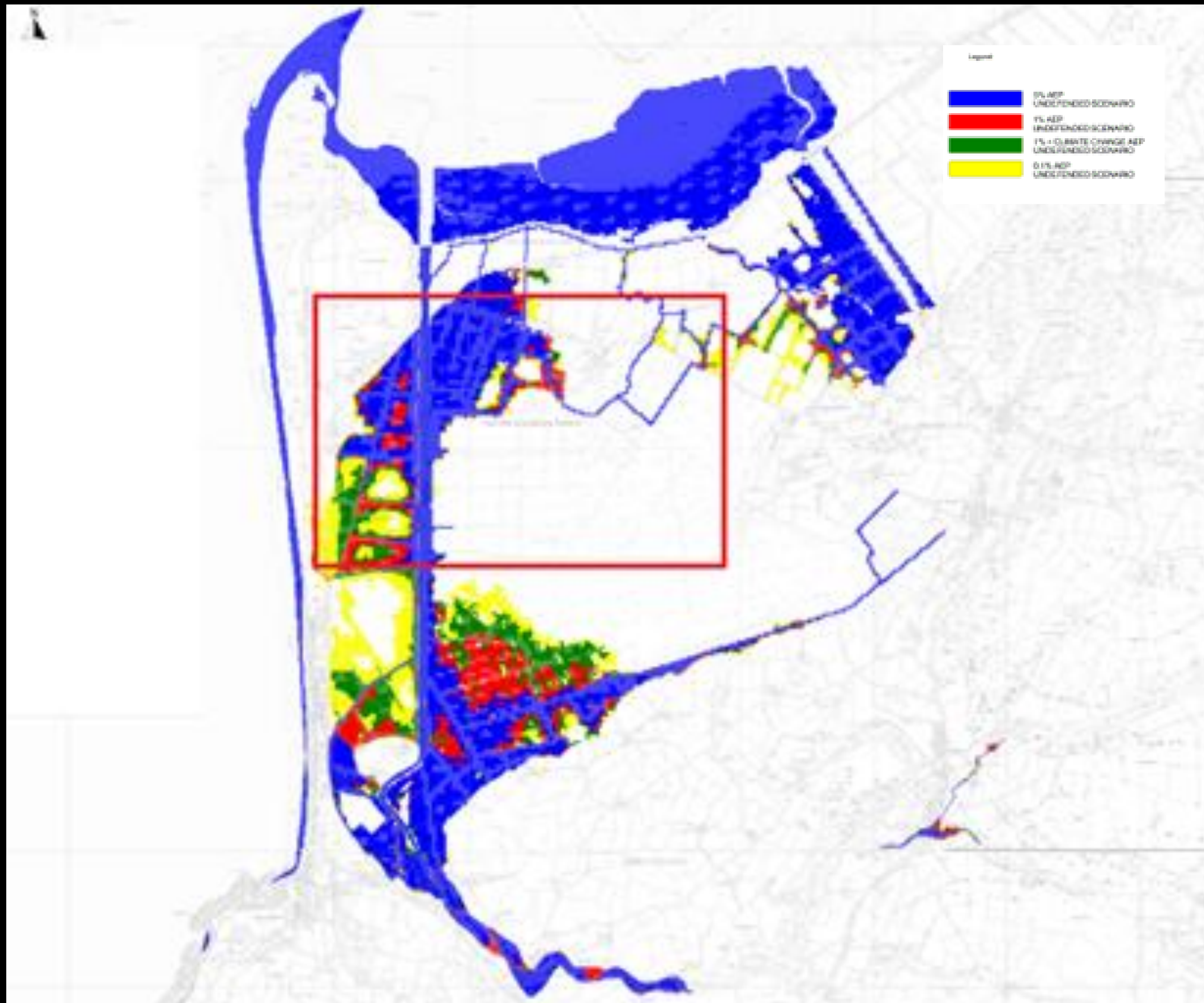

Max Flood extent for a 1:1000 year flood

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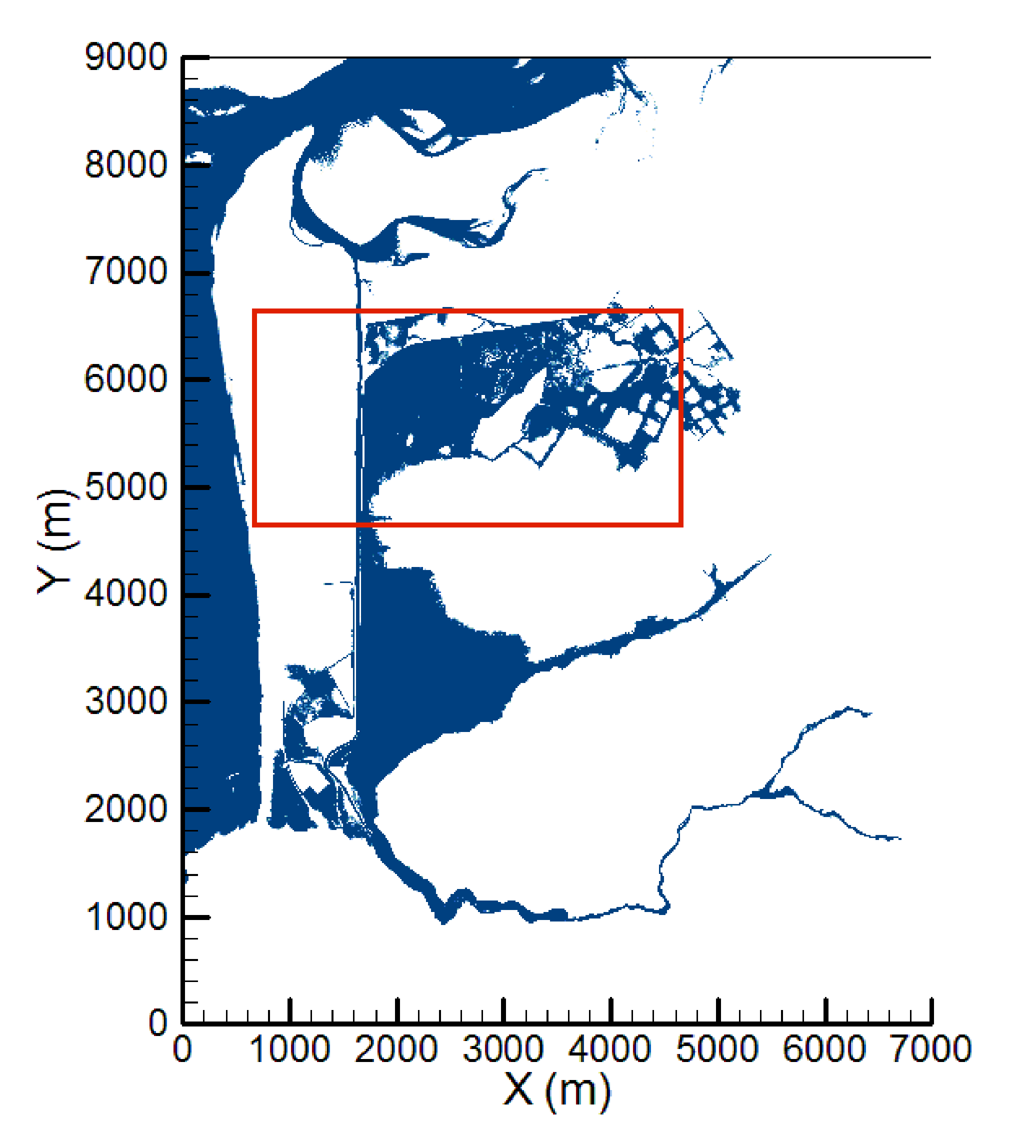

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Monitoring Point Observations

Monitoring point	Observed/estimated depth	Source
5	0.5 m	Picture (BBC, 2012b, WalesOnline, 2014)
12	1.2 m	Eye-witness account (BBC, 2012b)
17	1.2 m	Eye-witness account (BBC, 2012a)
18	0.3 m	Picture (Retrieved from http://www.alananna.co.uk)
19	0.3 m	Picture (Retrieved from http://www.alananna.co.uk)
20	0.3 m	Picture (Retrieved from http://www.alananna.co.uk)
24	0.5 m	Picture (ITV, 2012)
25	0.5 m	Picture (WalesOnline, 2012)
27	0.3 m	Picture (Retrieved from http://www.alananna.co.uk)

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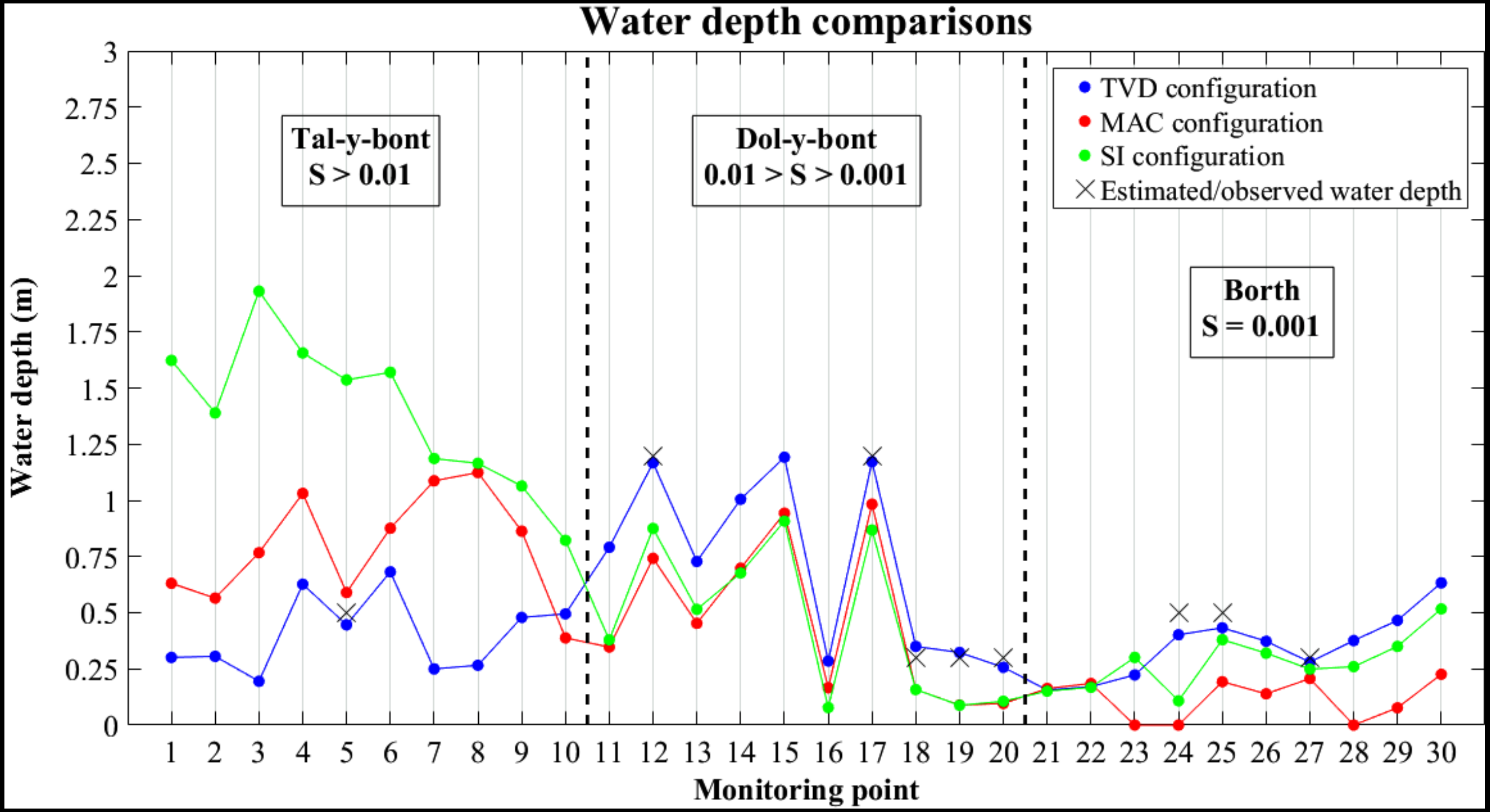
BORTH: WATER DEPTH COMPARISONS



	Average difference in water depth prediction	
Bed slope	**MAC vs TVD**	**SI vs TVD**
S > 0.01	40.9 cm	99.0 cm
0.01 > S > 0.001	25.9 cm	26.2 cm
S ≈ 0.001	20.8 cm	6.6 cm

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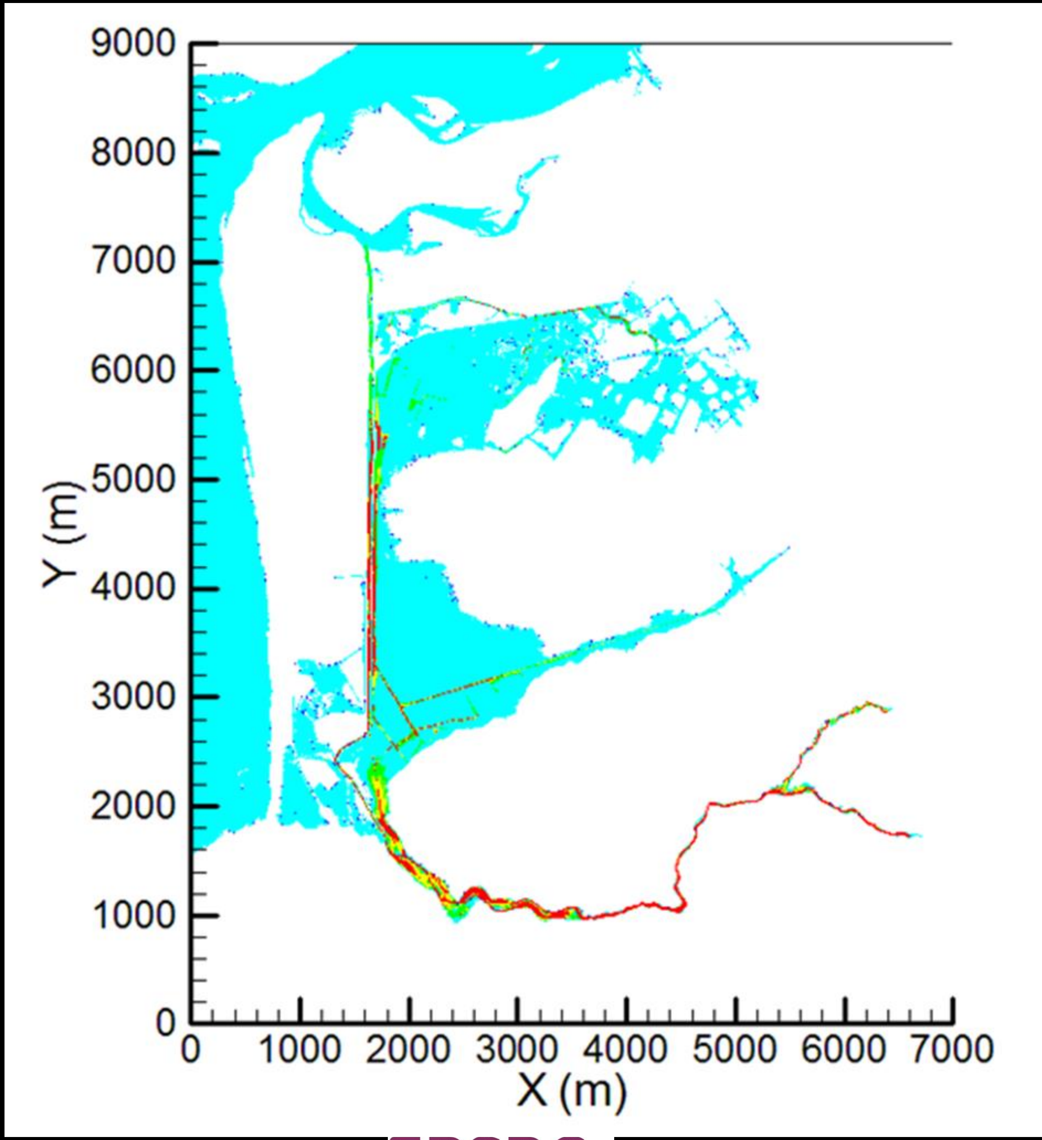
HRC Flood Hazard for a 1:1000 year flood



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1D/2D Linked Models Domain and Monitoring Points

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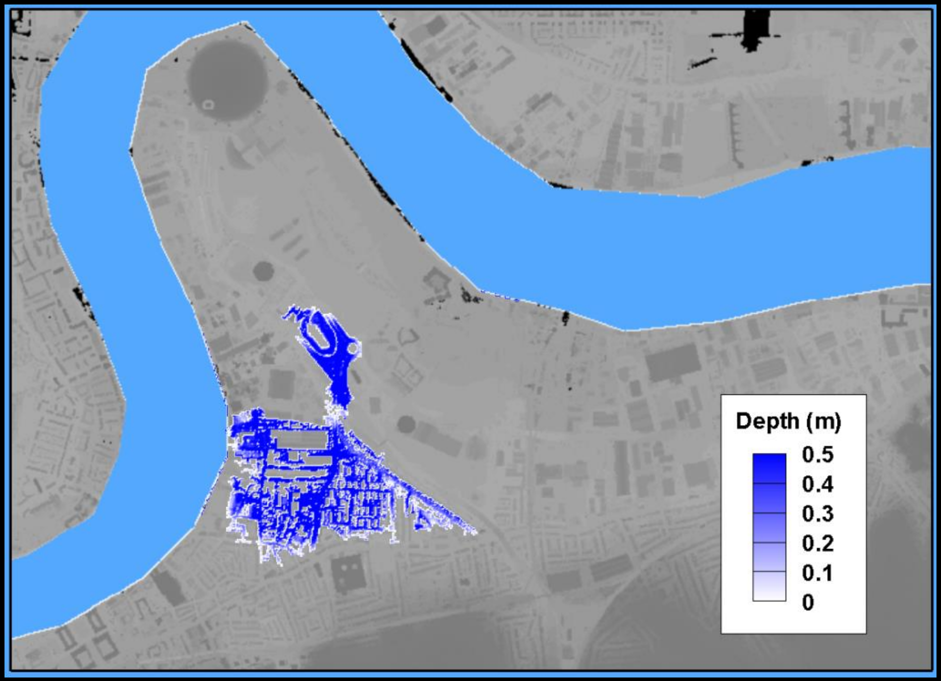
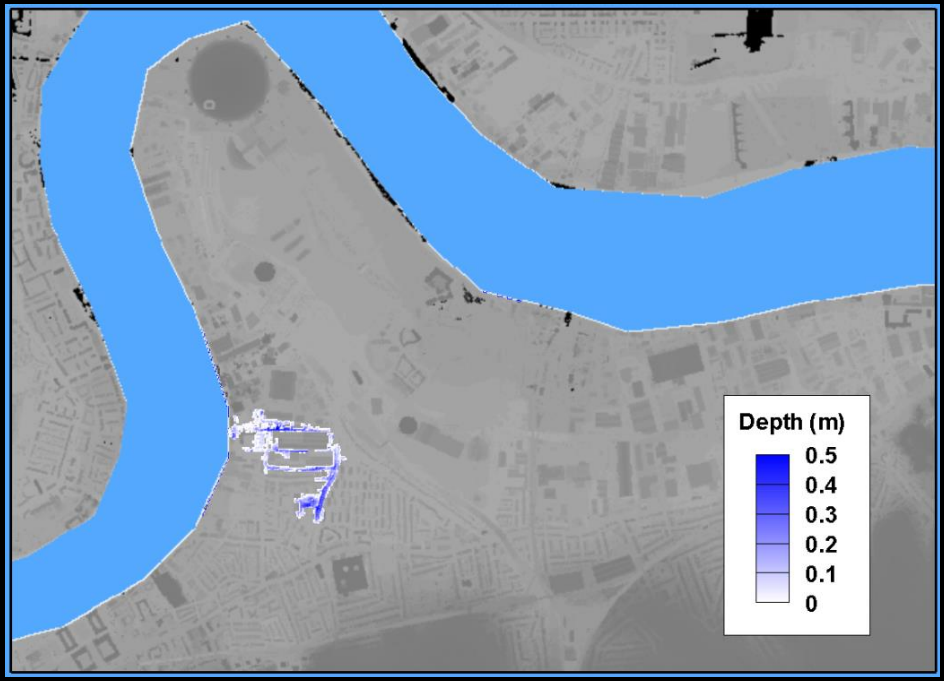
Differences in inundation extent of 1D/2D Linked Models



TVD



ADI

Dynamically linked model using water level links

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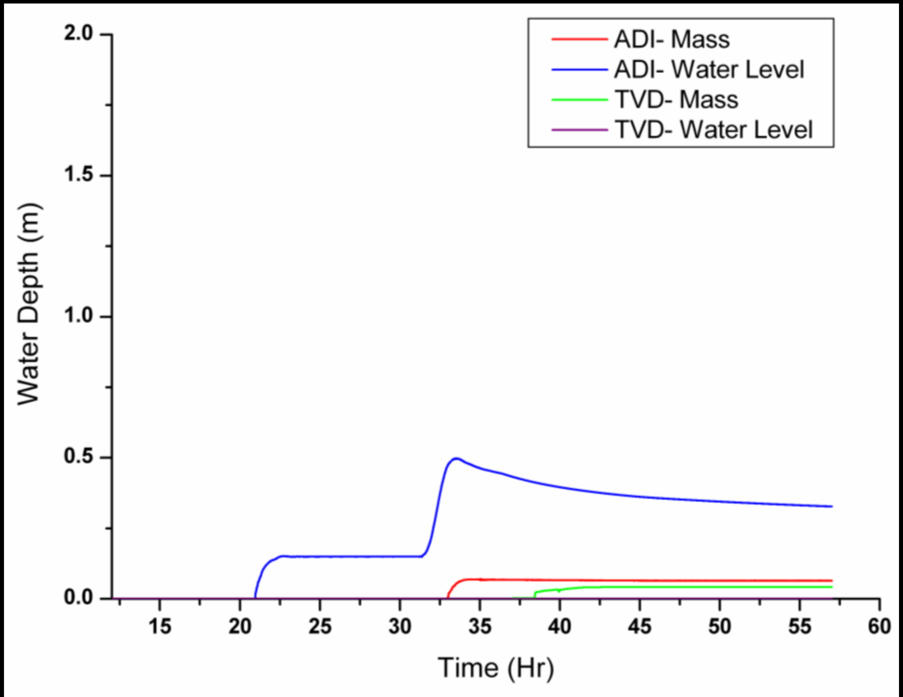
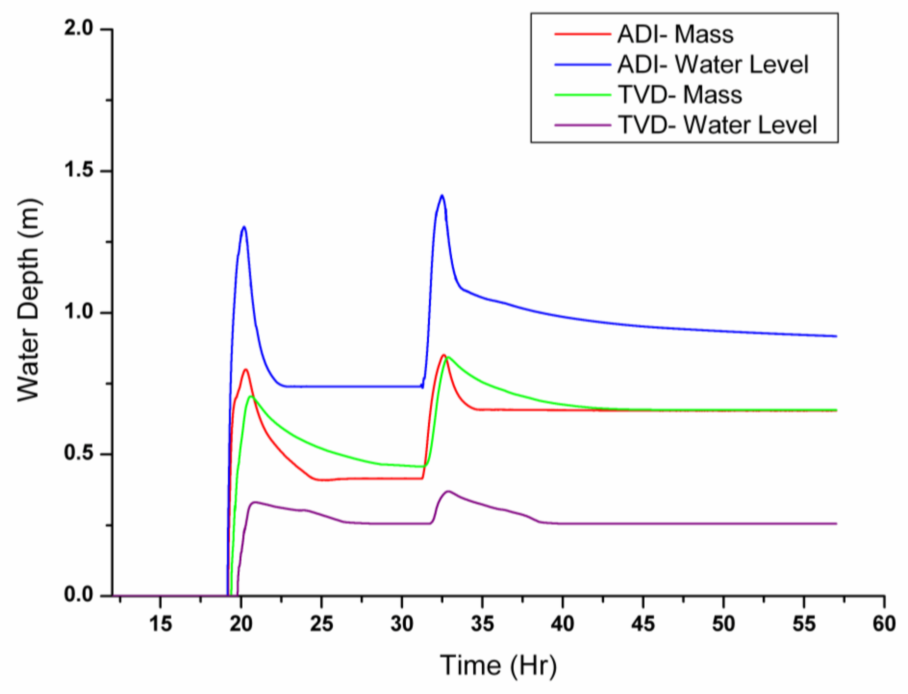
Differences in inundation levels of 1D/2D Linked Models



Point 6



Point 3

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Summary

- In torrential or flashy river basin or catchment (i.e. S > 1%), flood inundation modelling should be predicted using shock-capturing (or similar) models, since these models:
  - Enable the computation of any shock waves as part of the numerical solution and thus prevent the emergence of spurious numerical oscillations
  - Ensure the stability of the computational process for all types of flow regimes
  - Preserve the peak flood wave throughout the entire simulation process

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