TECHNISCHE UNIVERSITÄT DRESDEN

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Institut für Wasserbau und Technische Hydromechanik

2D hydrodynamic modelling of dam breaching and comparison with experimental results

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BASEMEMENT User‘s Meeting

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Outline

1. Introduction
2. Materials and Methods
3. Results and Discussions
4. Conclusions
5. References

Emergency of Hidroituango dam in Colombia © 2018, BBC news

Introduction
Motivation

- **Dam safety programs** aim to protect human lives, property and environment from dam break hazard

- **Dam breaching studies** are essential for dam safety programs

- Dam breaching studies are based on

  1. Statistics of breach parameters from real cases of dam breaks
  2. Physically based models
  3. Computational modelling

BASEplane

Introduction
Objectives

1. Identify the **key modelling factors** that affect the accuracy of simulations of dam breaching with BASEMENT

2. Assess the **accuracy of BASEMENT** in performing 2D hydro – morphologic simulations of dam breaching by **comparing simulated results with experimental observations** of a physical model developed by TU Dresden

1. Introduction
Experimental base

Conducted by Dr. Ing. Antje Bornschein
(TU Dresden) Between 2013 and 2016

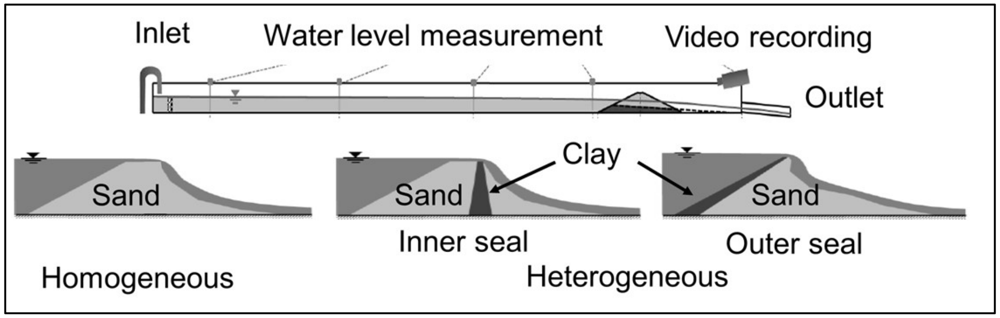


Figure 1. Schematic description of the experiment. Modified after Bornschein, 2014.

Figure 2. Experimental dam breaching
© 2014 Antje Bornschein.

Length of the channel: 14.6 m
Width of the channel: 2.0 m

Water filling up to elevation of standard initial breach

Measurements:
Outflow discharge and breach geometry

1. Introduction
Geometry and model diversity

Mesh type	Model type	Type of dam	No. Physical Experiments	Dam height (m)	Slope
1	1a	Homogeneous	2	0.4	1 : 2.50
	1b	Outer seal	2		
	1c	Inner seal	1		
2	2a	Homogeneous	3	0.4	1 : 4.00
	2b	Outer seal	1		
	2c	Inner seal	1		
3	3	Homogeneous (Initial breach 0.4 m)	1	0.4	
4	4a	Homogeneous	5	0.4	1 : 3.25
	4b	Outer seal	2	0.4	
	4c	Inner seal	2	0.4	
5	5	Homogeneous (smaller reservoir)	1	0.4	
6	6	Homogeneous	1	0.3	
7	7	Homogeneous	1	0.2	

7 model types for homogeneous dams
6 model types for heterogeneous dams

2. Materials and Methods
Unstructured mesh

Software:
QGIS – Plugin BASEmesh

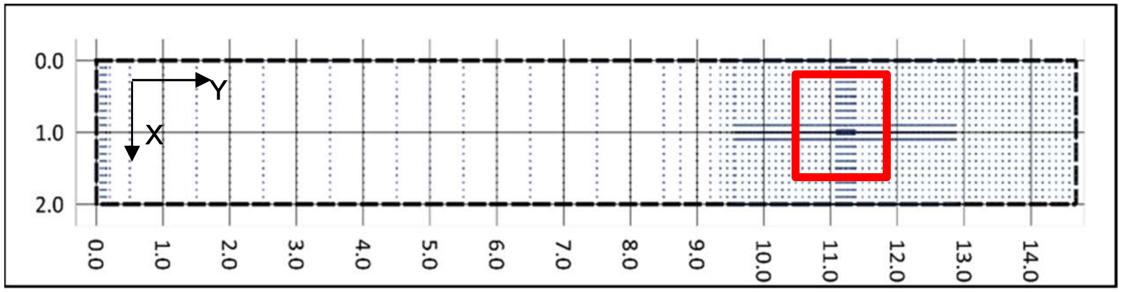


Figure 3. Domain of the model

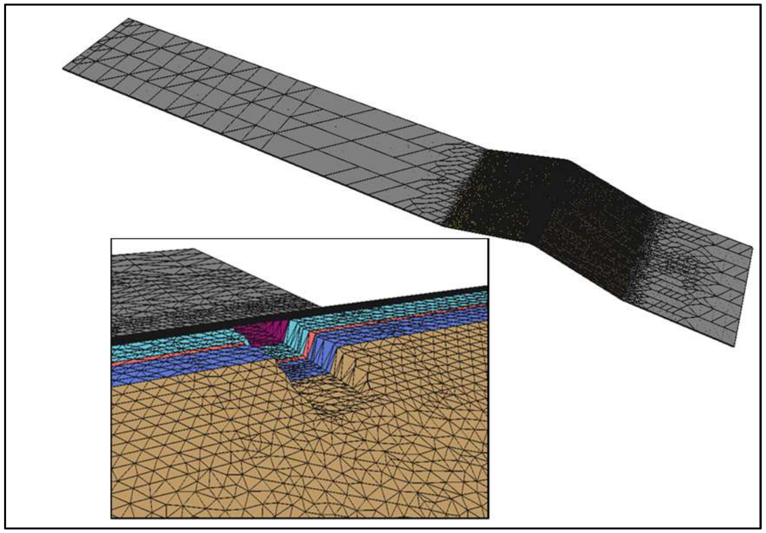


Figure 5. 3D view of the mesh

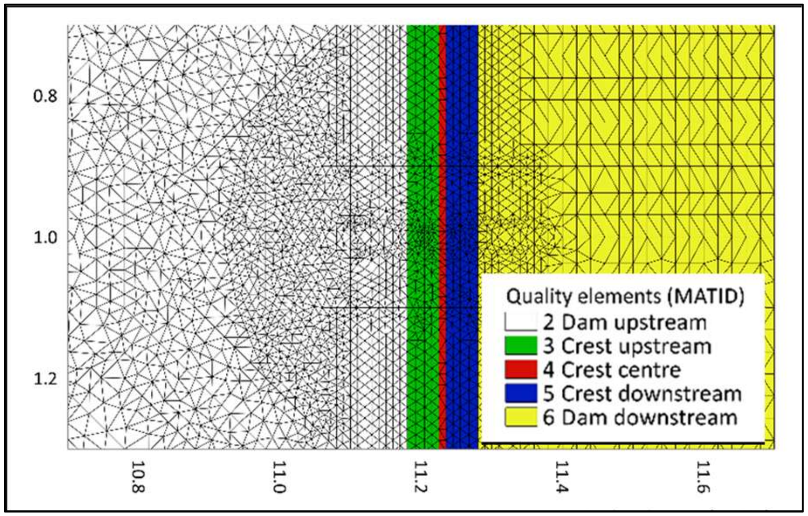


Figure 4. Unstructured mesh and material indexes (MATID)

Objective 1

2. Materials and Methods

BASEplane set up – Morphology - Main features

Homogeneous dams

- Bed material: Granulometry of sand
- Porosity: 38% (initial 46% + compaction factor)
- Sediment transport formula: Variable
- Bedload factor: 1
- Gravitational failure angles

1st approach: Dry: 34° (repose angle) Wet: 22° (observed)

2nd approach: Dry: 60° (> repose angle) Wet: 34° (repose angle) (additional simulations)

Heterogeneous dams (differences)

- Gravitational failure angles
  Dry and Wet: 45° - 80° in corresponding sealing region

Objective 2

2. Materials and Methods
Comparison with experiments

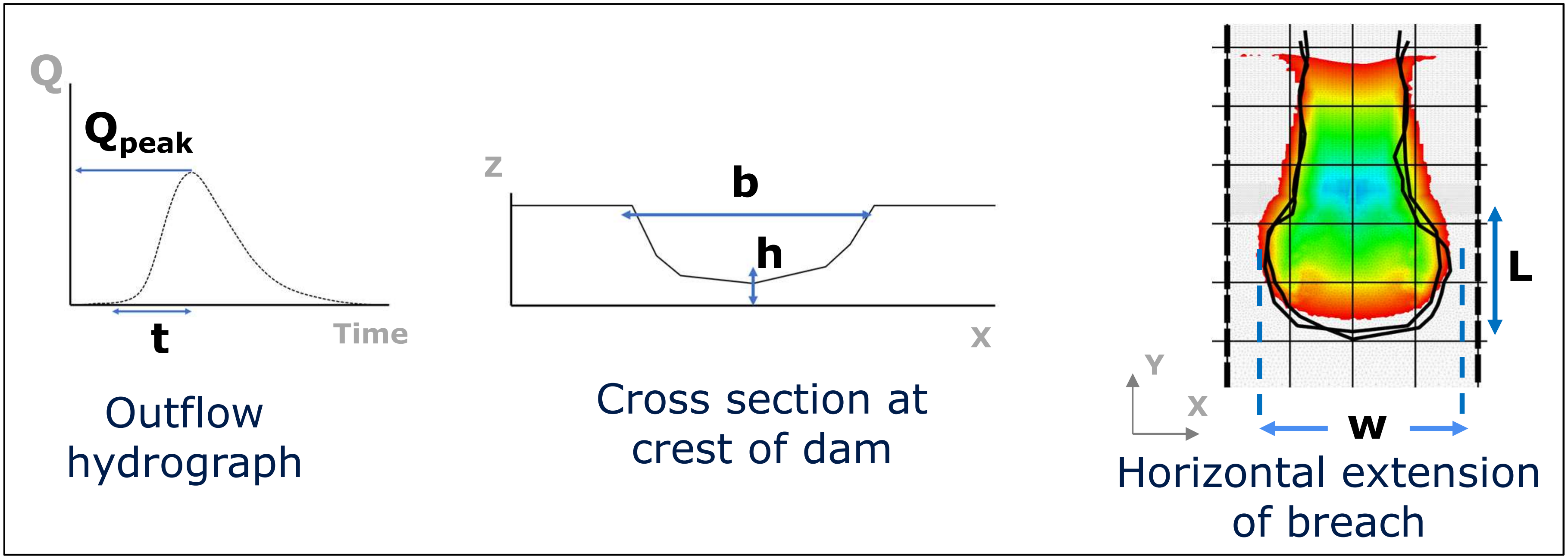


Figure 6. Parameters used to compare simulated results with experimental observations

Similarity when simulated result was:

+/- 10% experimental value (No. experiments = 1)
+/- 10% extreme values of experimental interval (No. experiments > 1)
+/- 20% as a second reference

Objective 1

3. Results and Discussions
Variation of model set up - parameters

Variation of bedload formula

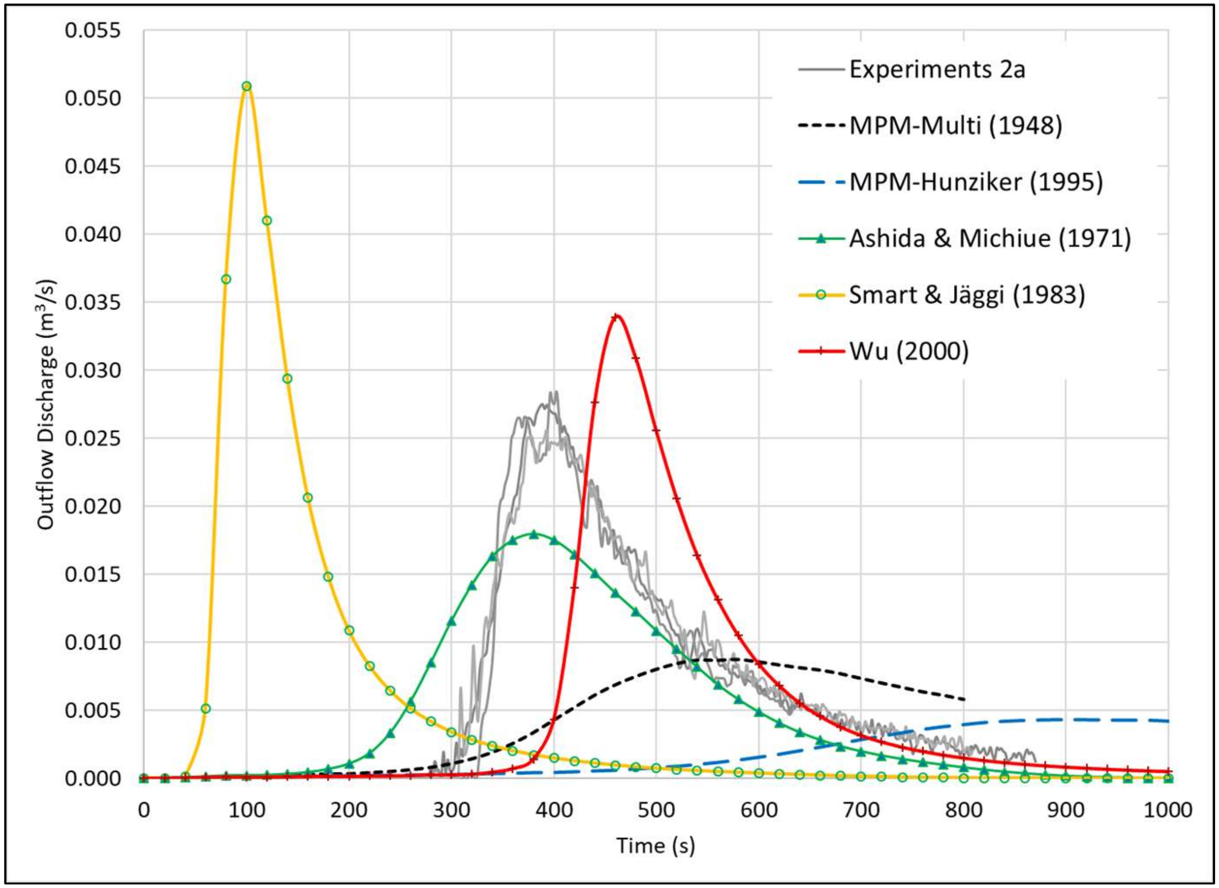
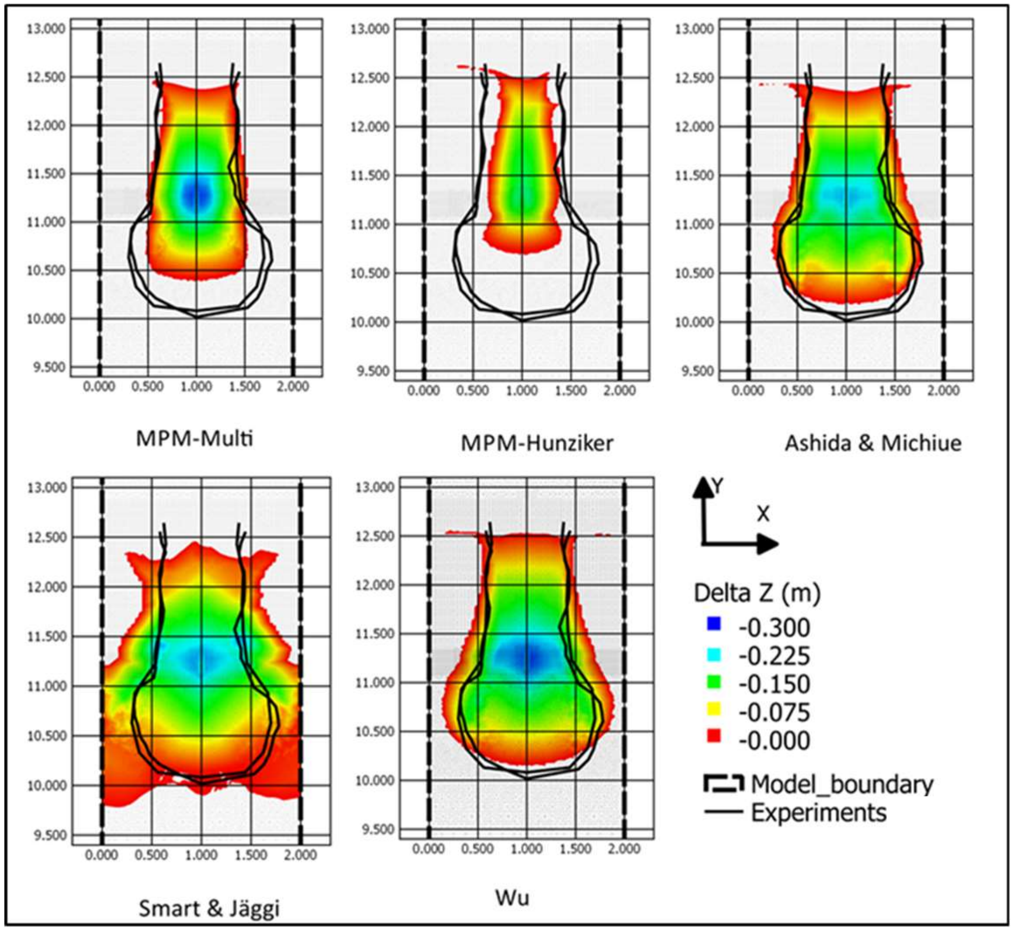


Figure 7. Outflow hydrographs obtained by different sediment transport formula

Objective 1

3. Results and Discussions
Variation of model set up / parameters

Variation of bedload formula



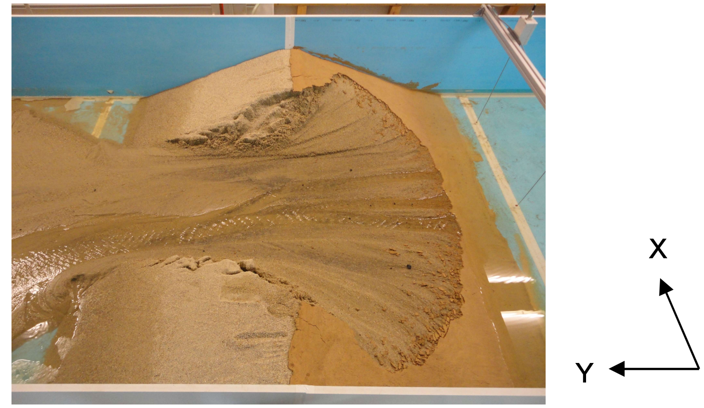


Figure 9. View of a breached dam in the experiment. © 2014, Antje Bornschein.

Best fit to experimental results with:

- Wu (2000)
- Ashida & Michiue (1971) "A-M"

Figure 8. Elevation change in the dam by employing different sediment transport formula.
QGIS – Plugin Crayfish.

Objective 1

3. Results and Discussions
Variation of model set up / parameters

Variation by neglecting components of the bedload flux

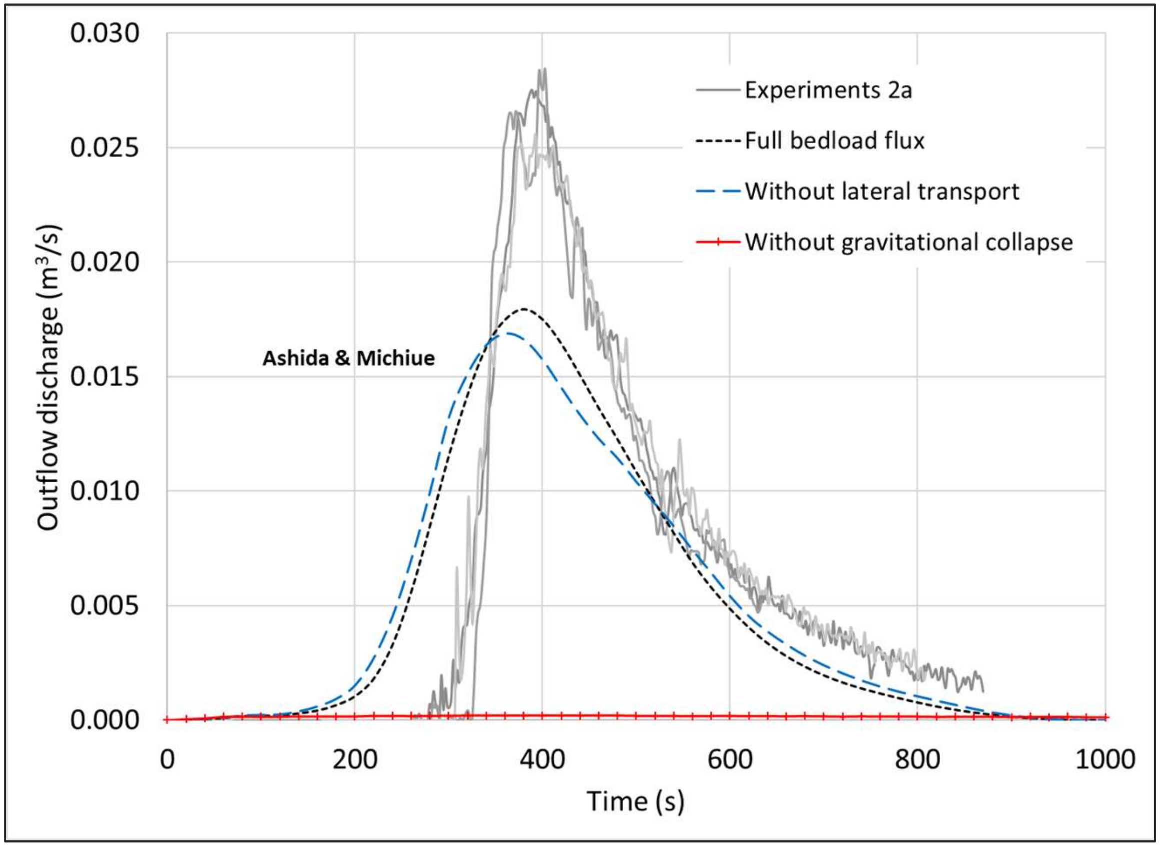


Figure 10. Outflow hydrographs obtained by neglecting components of sediment transport

Objective 1

3. Results and Discussions
Variation of model set up / parameters

Variation of porosity

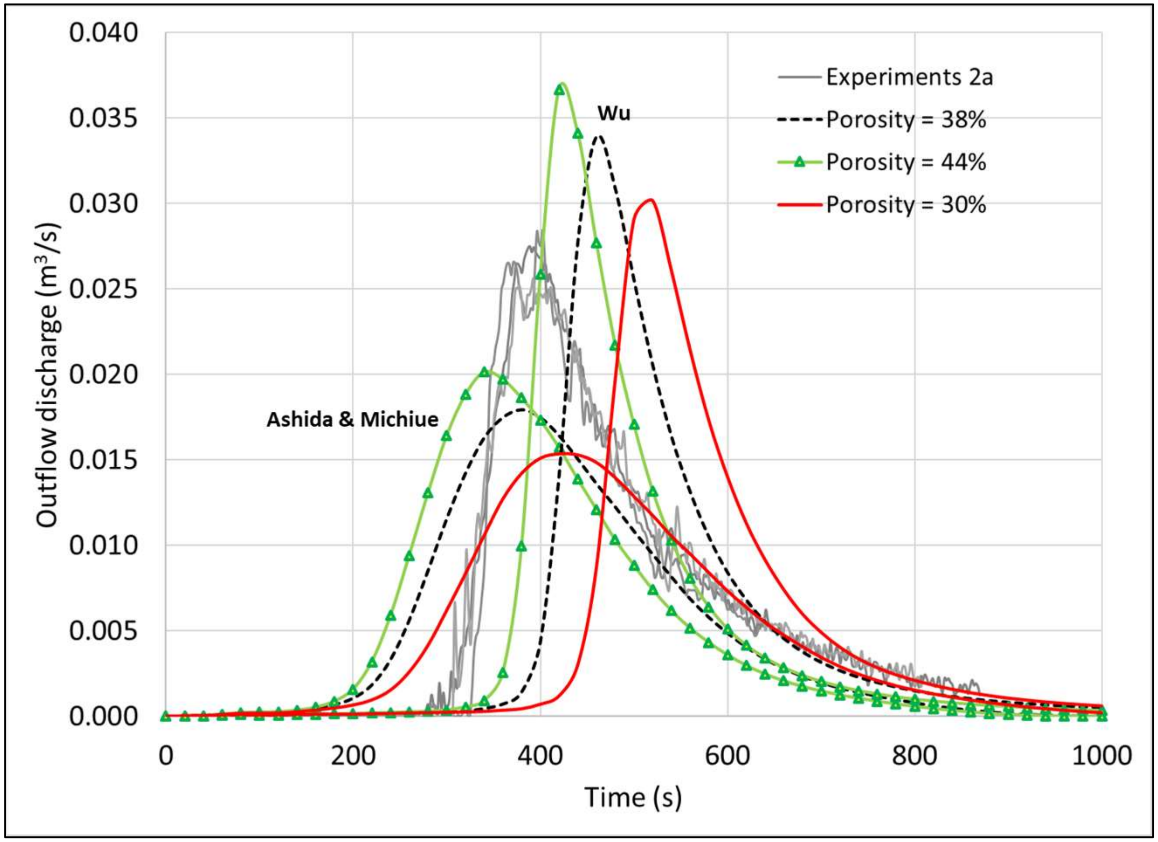


Figure 11. Outflow hydrographs obtained by different porosity

Objective 1

3. Results and Discussions
Variation of model set up / parameters

Variation of bedload factor

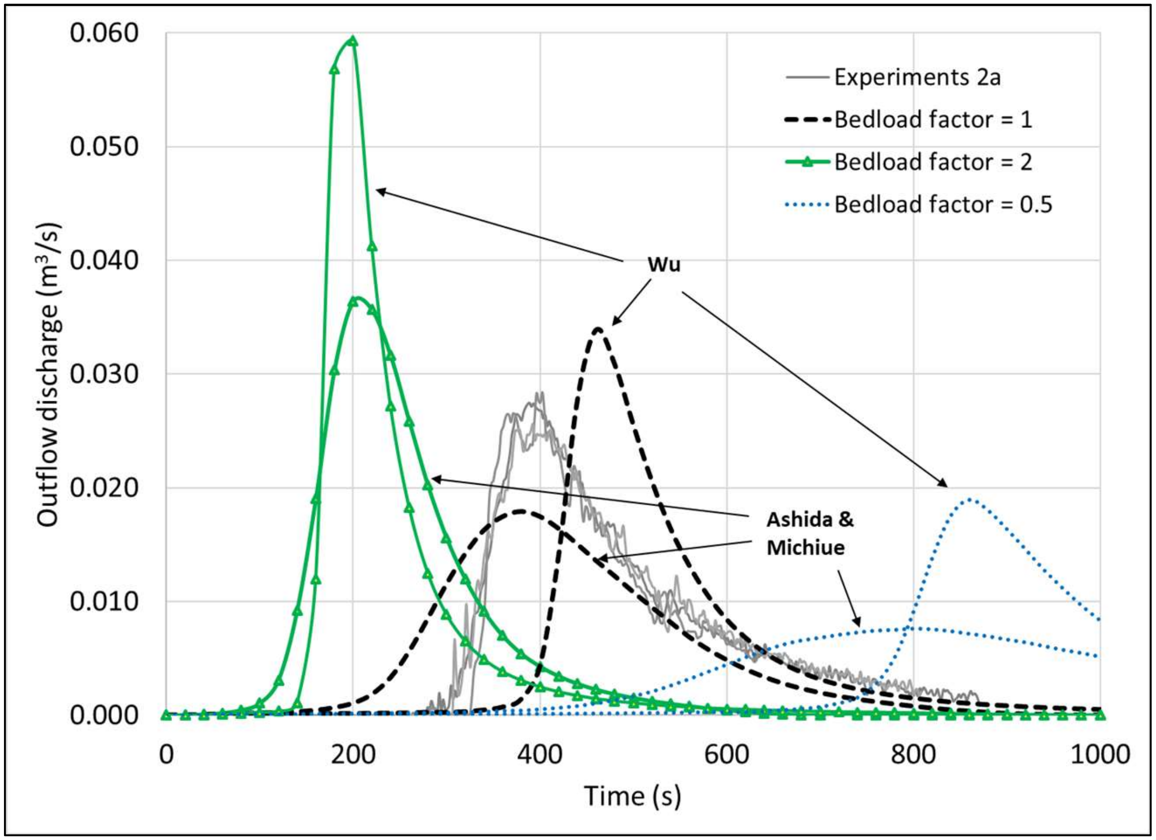


Figure 12. Outflow hydrographs obtained by different porosity

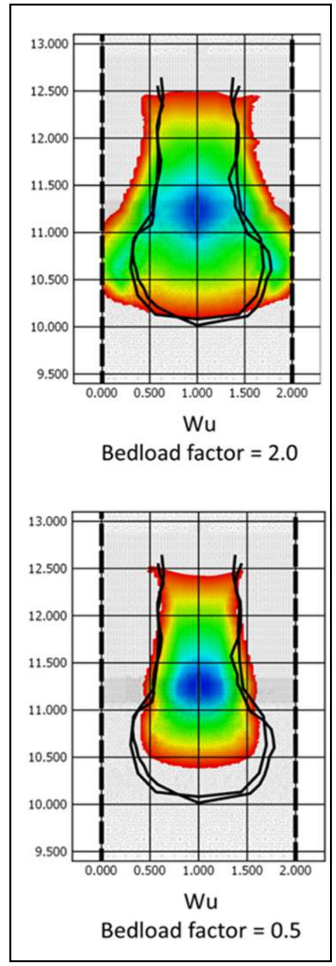


Figure 13. Elevation change by employing different bedload factor

Objective 2

3. Results and Discussions
Similarities with experimental observations

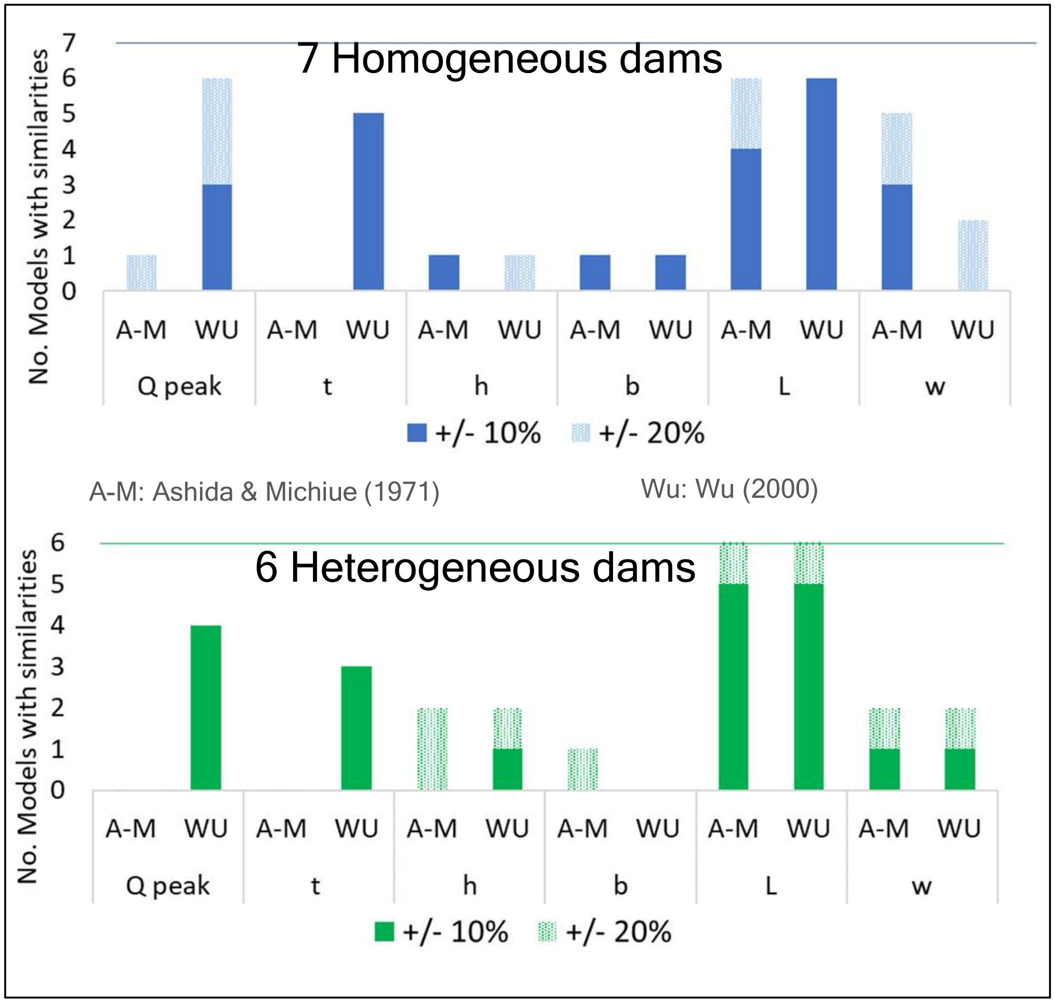


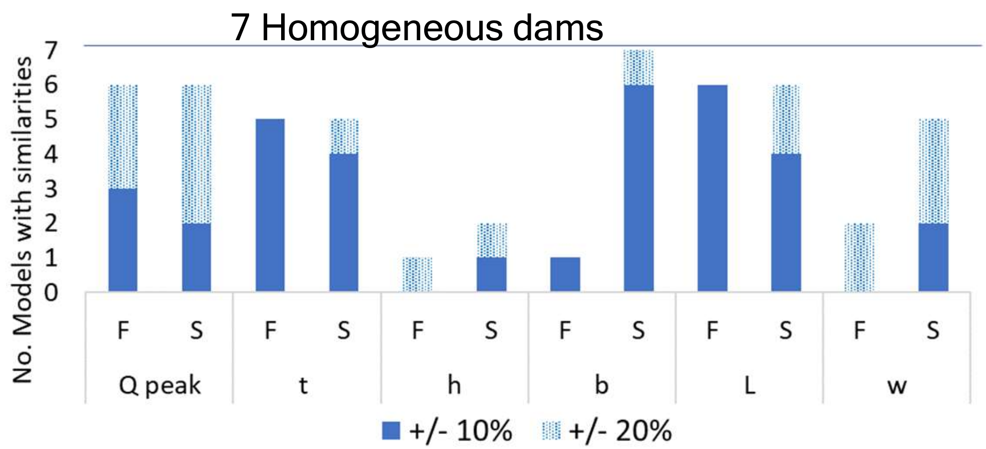
Figure 14. Number of models with similarities between simulated results and experimental observations

3. Results and Discussions

Objective 1

Objective 2

Sensitivity of similarities to gravitational failure angles



All simulations with formula Wu (2000)

Gravitational Failure Angles Approaches

F: 1st approach
Dry: 34° (repose angle) Wet: 22° (observed)

S: 2nd approach
Dry: 60° (> repose angle) Wet: 34° (repose angle)

How to define the value of gravitational failure angles?

Figure 15. Number of models with similarities between simulated results and experimental observations. Comparison by two approaches of gravitational failure angles

3. Results and Discussions

Gravitational Failure Angles Approaches

1st approach
Dry: 34° (repose angle) Wet: 22° (observed)
2nd approach
Dry: 60° (> repose angle) Wet: 34° (repose angle)

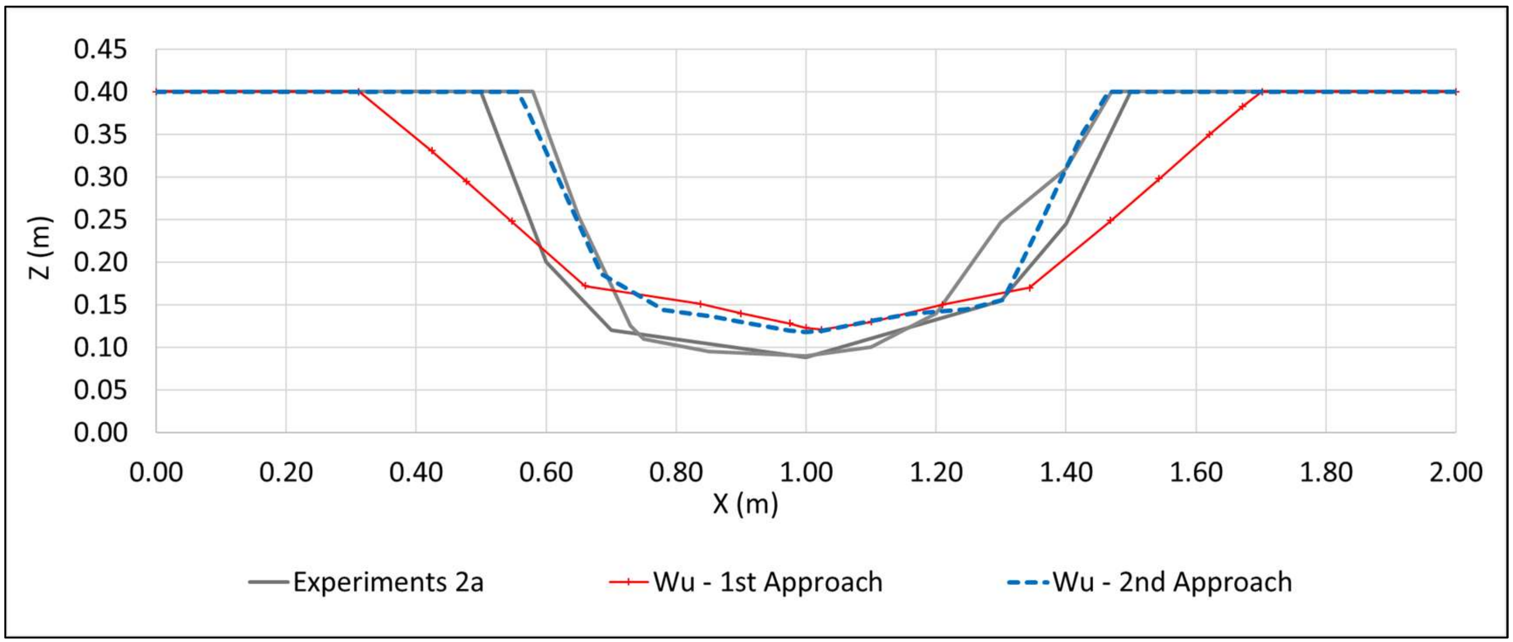


Figure 16. Comparison of cross sections obtained by two different approaches of gravitational failure angles.

4. Conclusions

- Empirical formula of sediment transport and gravitational collapse function play an influential role in simulations. Gravitational failure angles in relation to physical parameters deserve attention in further research.

- Bedload factor can modify considerably results. Use should be restricted to calibration purposes. Recommended only a value of 1.

- Porosity influences results of peak outflow discharge. It is recommended to reduce the uncertainty of porosity to increase reliability of results.

- Overall, the study was able to simulate the reference experiment by employing BASEMENT. Accuracy varied among parameters.

5. References

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THANK YOU

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IWD Institut für Wasserbau und Technische Hydromechanik