Simulating Wave Overtopping with the indoor Wave Overtopping Simulator

Niels van der Vegt

1 July 2026

Consortium meeting FutureFRMTech

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Wave overtopping NW Germany (around 1954)

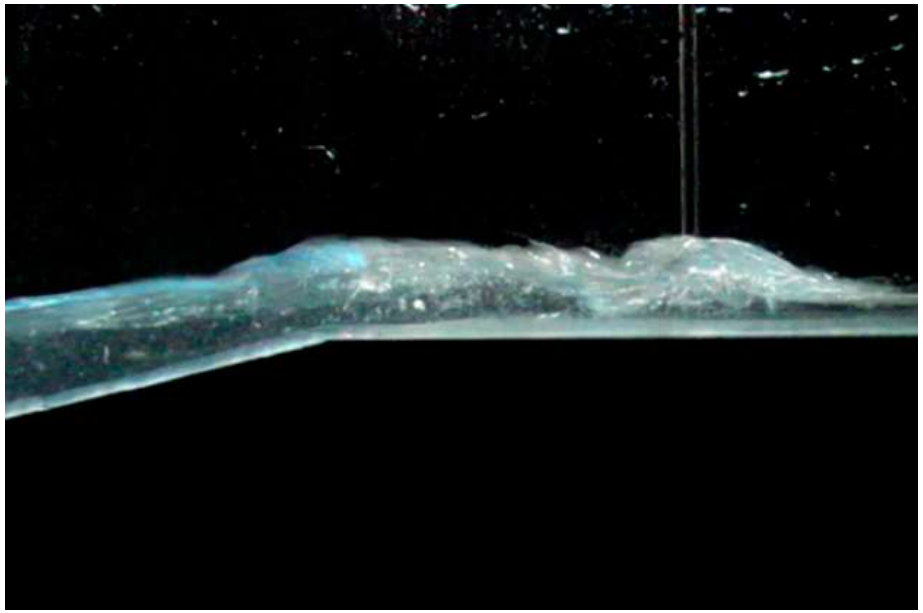


Wave overtopping

- Predict dike breaching

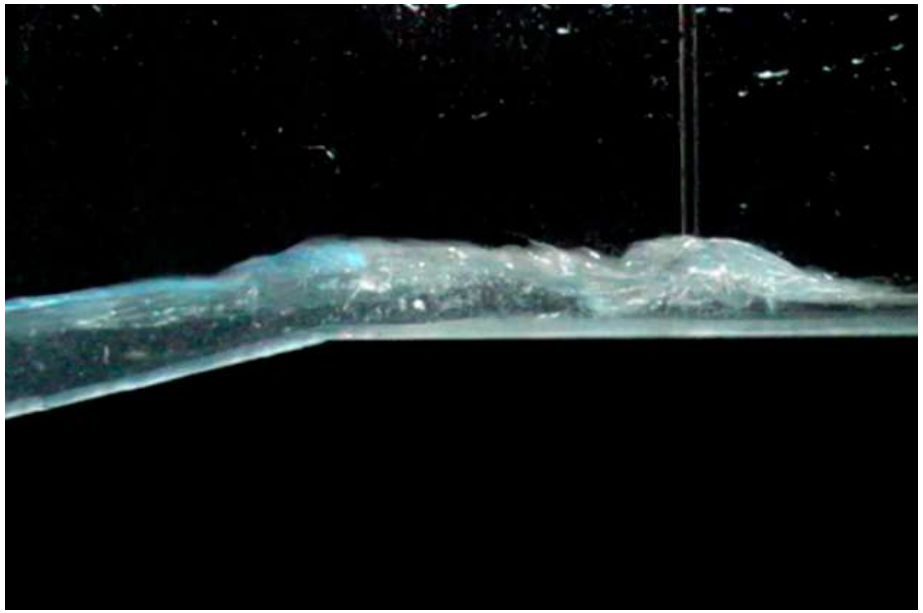


Experimental facilities



Small-scale flume experiments

Experimental facilities

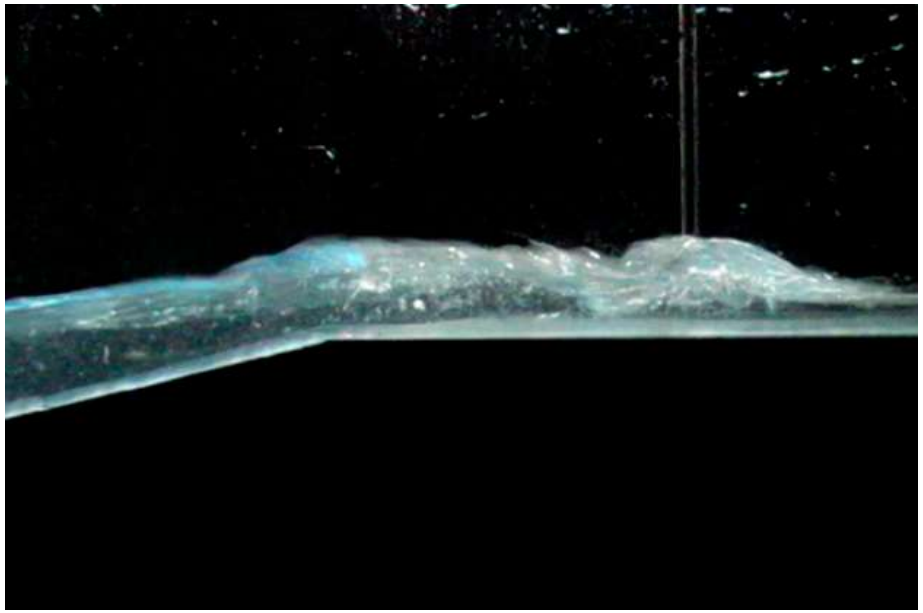


Small-scale flume experiments



Field experiments with WOS

Experimental facilities



?

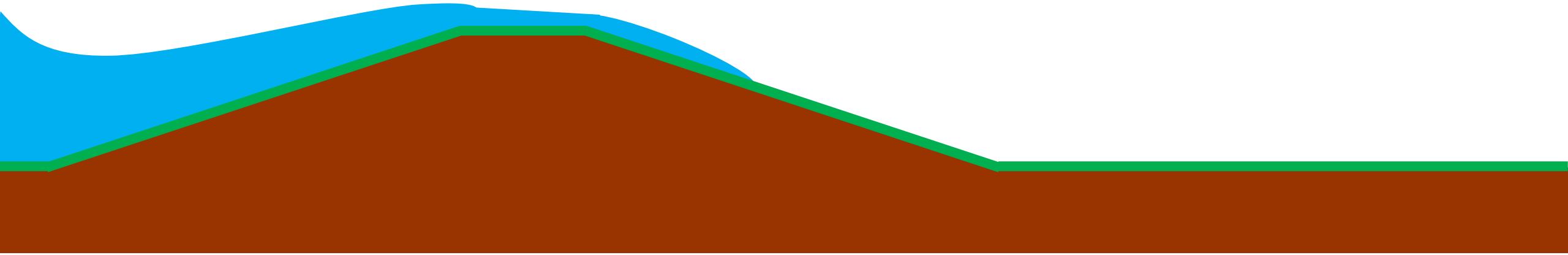


Small-scale flume experiments

Field experiments with WOS

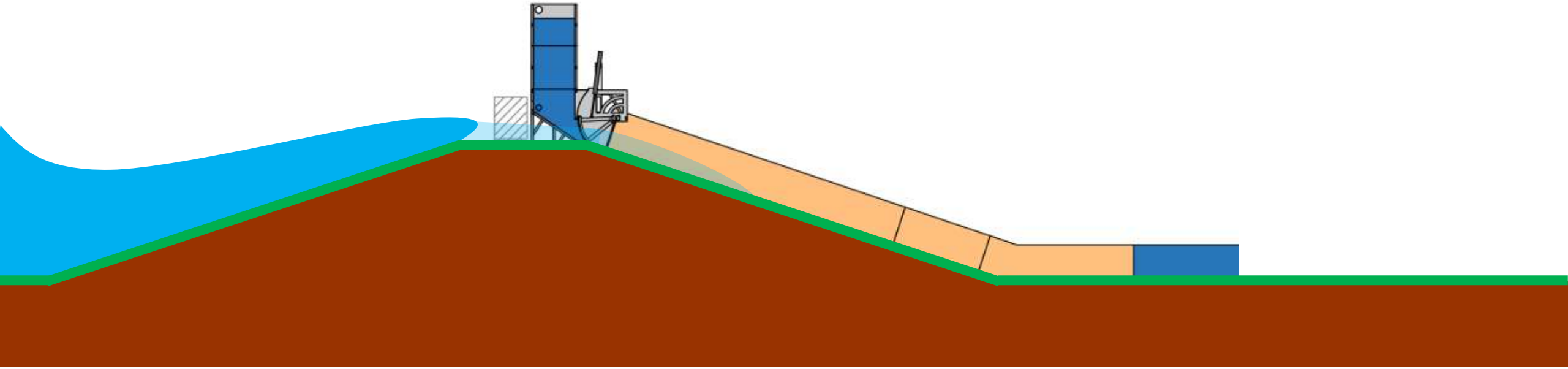
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The indoor Wave Overtopping Simulator (iWOS)



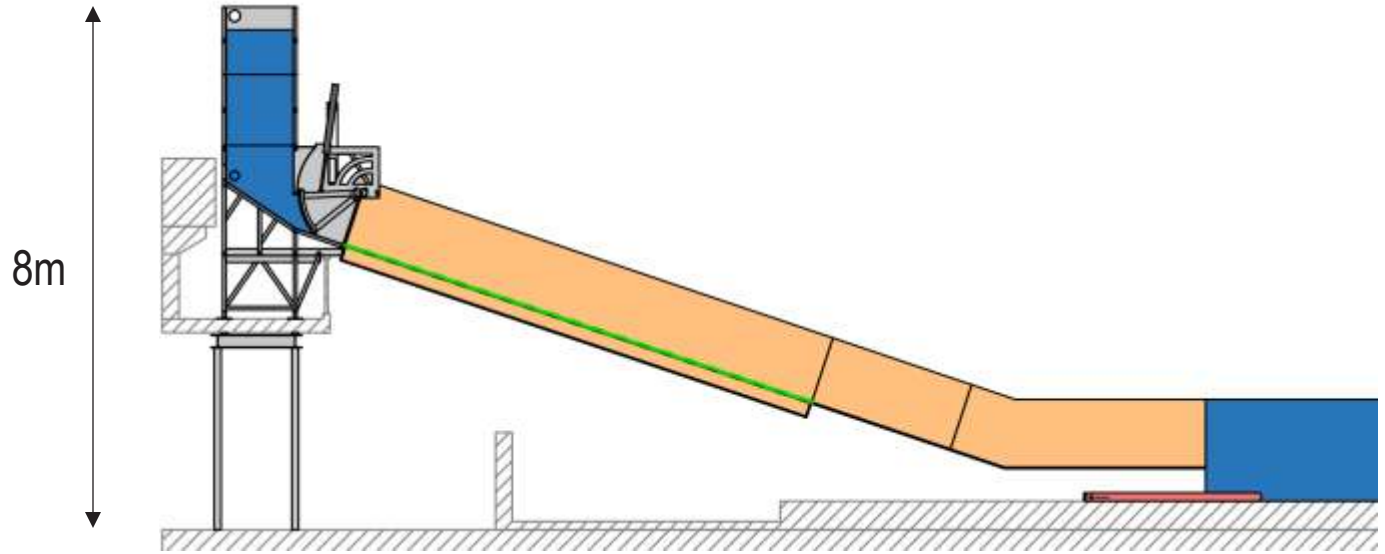
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The indoor Wave Overtopping Simulator (iWOS)



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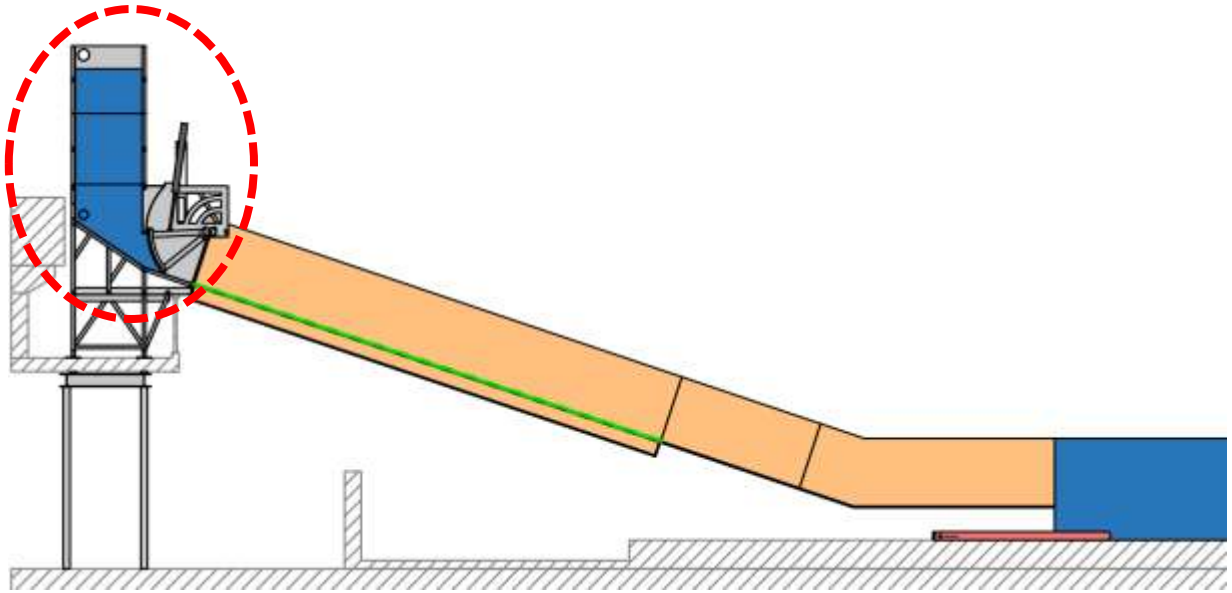
The indoor Wave Overtopping Simulator (iWOS)



The indoor Wave Overtopping Simulator (iWOS)

Wave overtopping simulator

- *Landward crest line*
- *Volumes up to 3.000 l/m*
- *Controllable release valve*

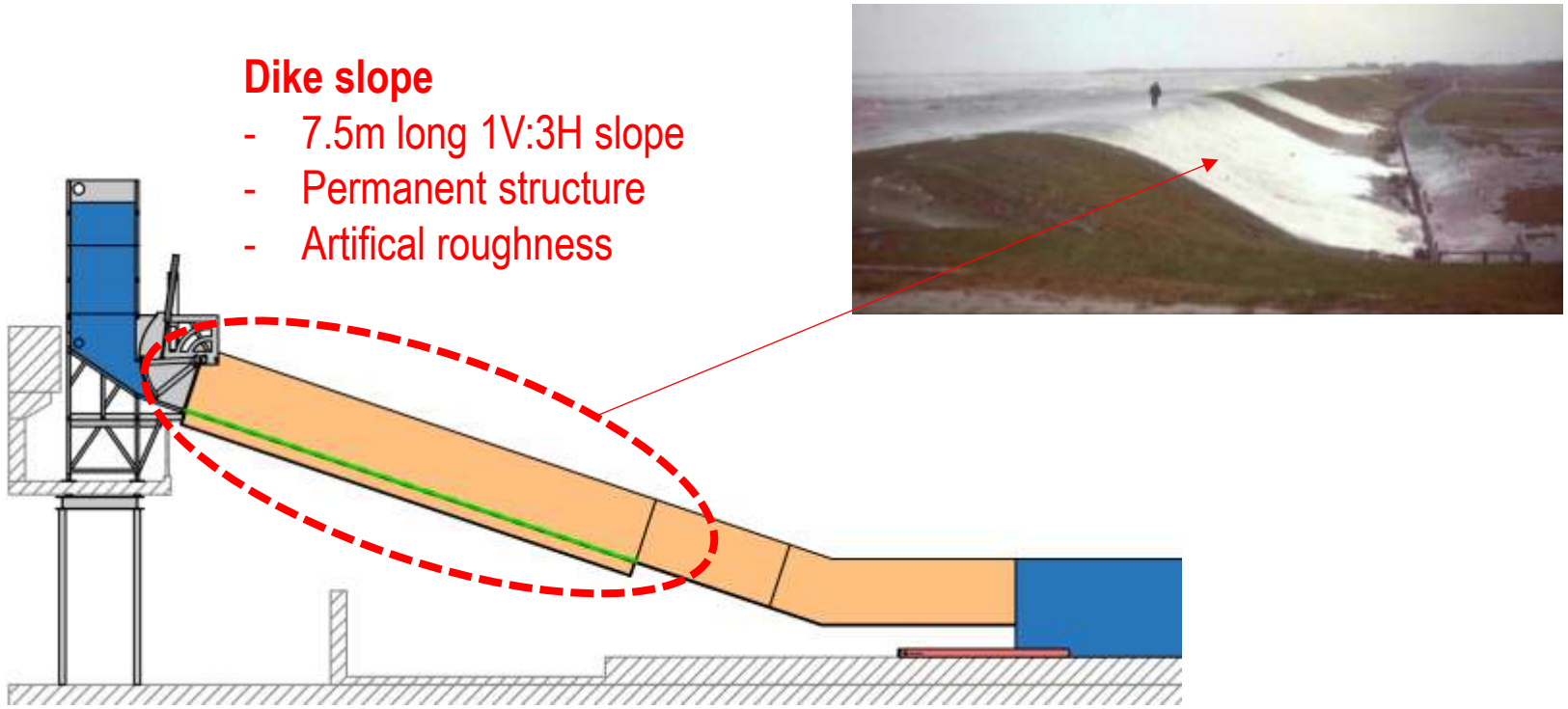


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Experimenteel onderzoek naar hydraulische belasting

Dike slope

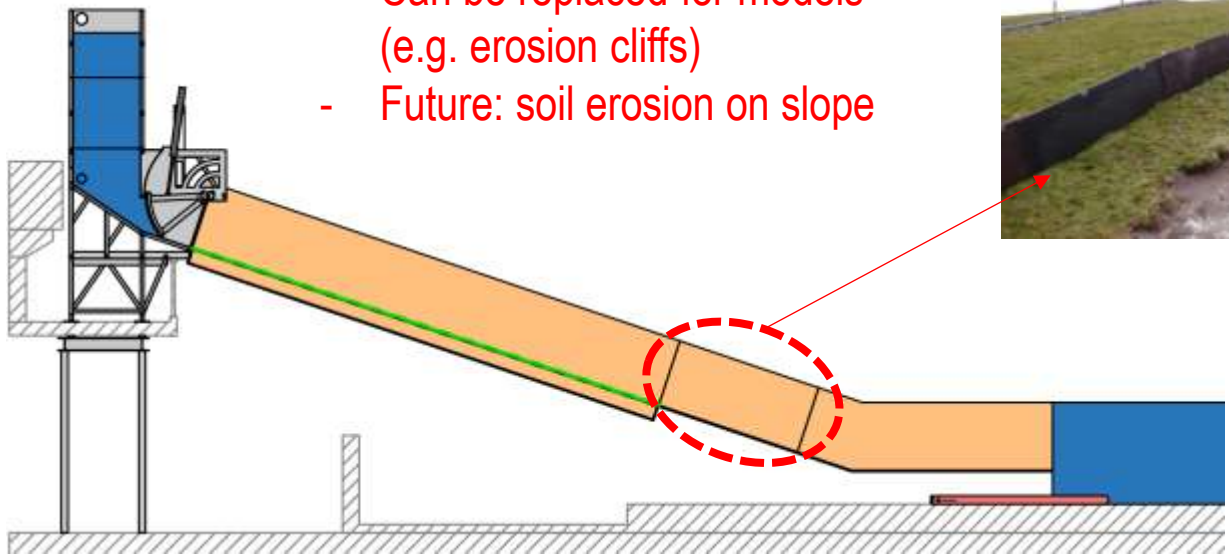
- 7.5m long 1V:3H slope
- Permanent structure
- Artifical roughness



The indoor Wave Overtopping Simulator (iWOS)

Replacable flume

- 2.2m long
- Can be replaced for models (e.g. erosion cliffs)
- Future: soil erosion on slope



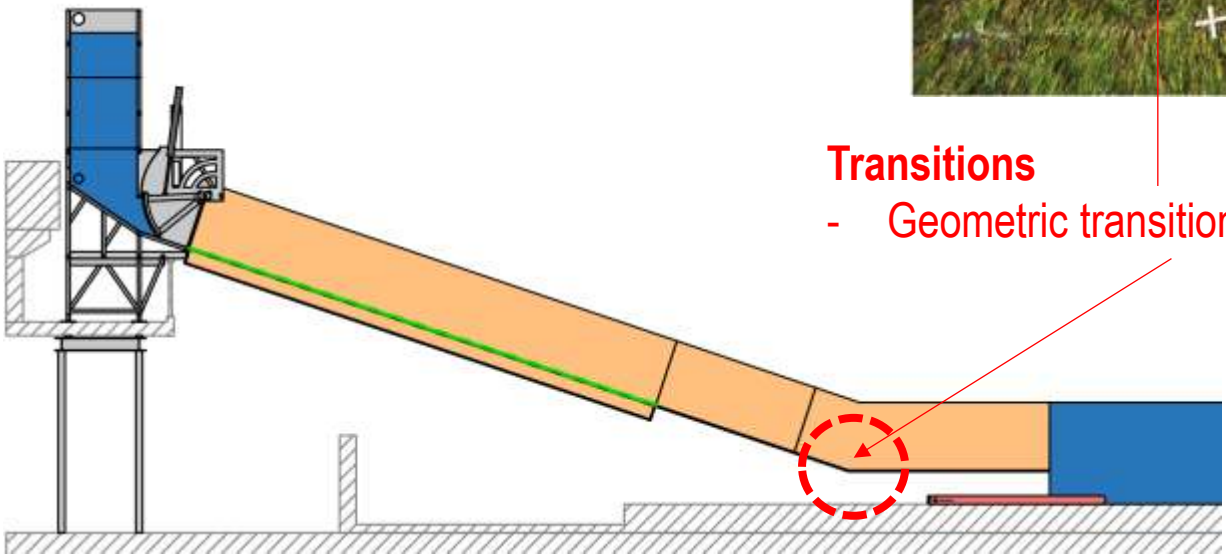


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The indoor Wave Overtopping Simulator (iWOS)



Photo: Infram Hydren



Transitions

- Geometric transition

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The indoor Wave Overtopping Simulator (iWOS)

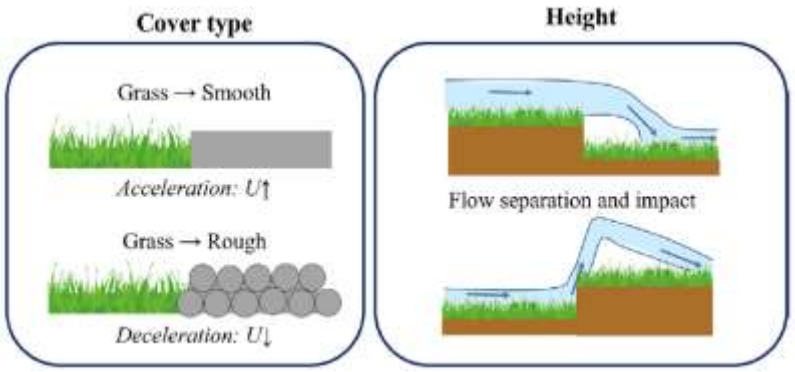


Illustration: van Bergeijk et al. (2022)

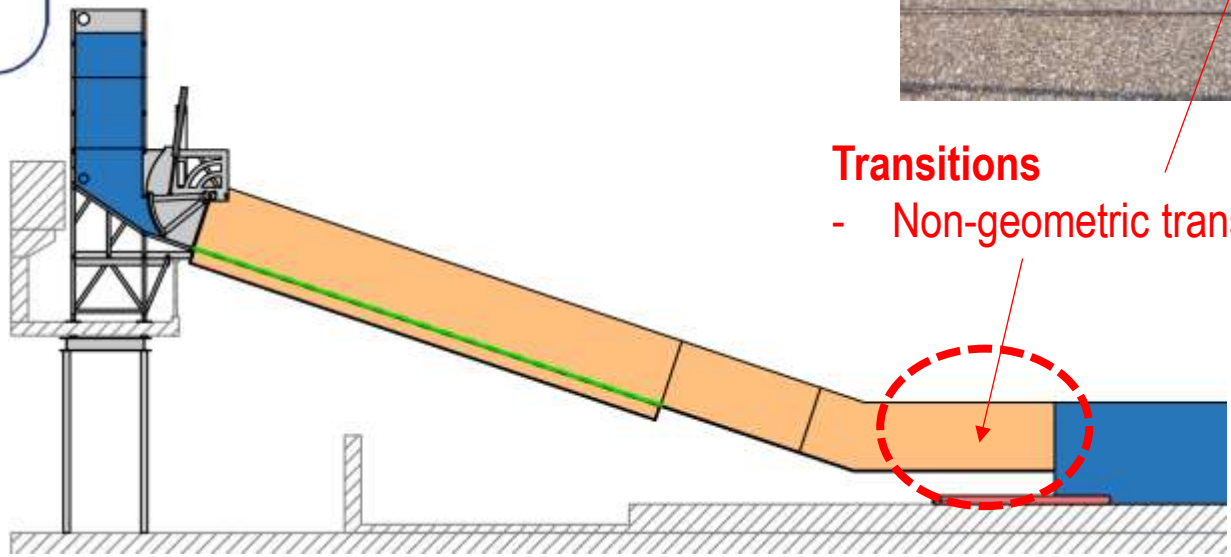




Photo: Infram Hydren

Transitions

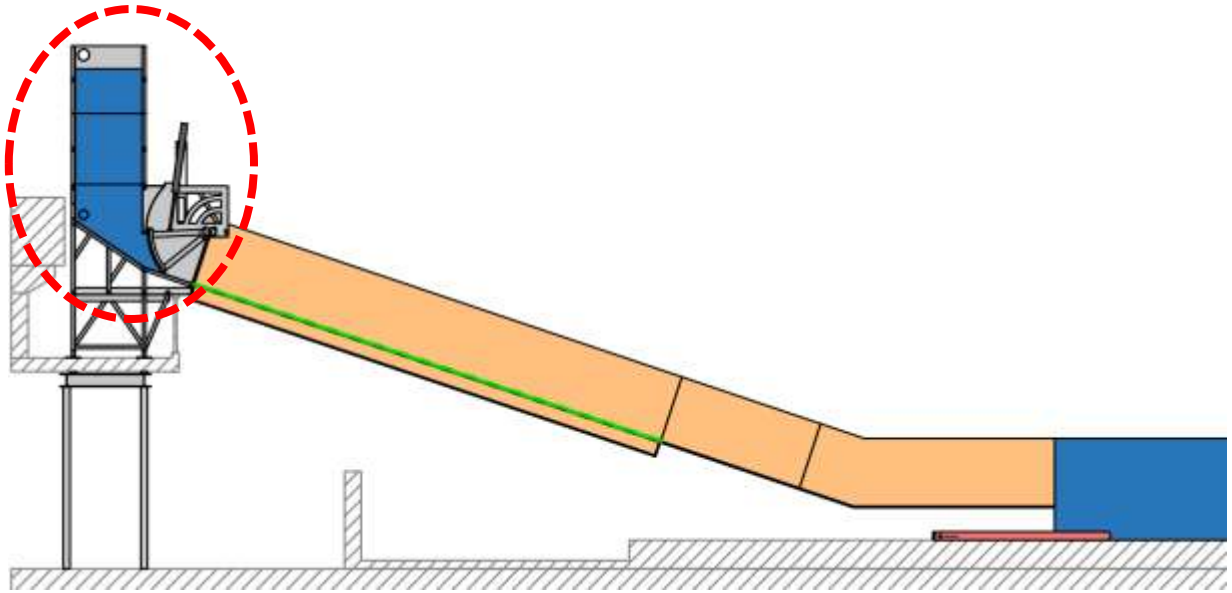
- Non-geometric transition

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The indoor Wave Overtopping Simulator (iWOS)

Design challenges:

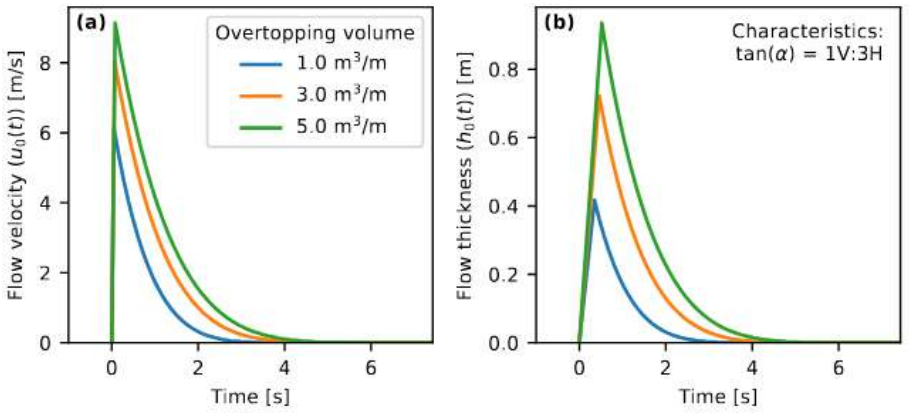
1. What does the overtopping flow look like on the waterside slope?
2. What is the effect of the crest and landward slope/geometry?

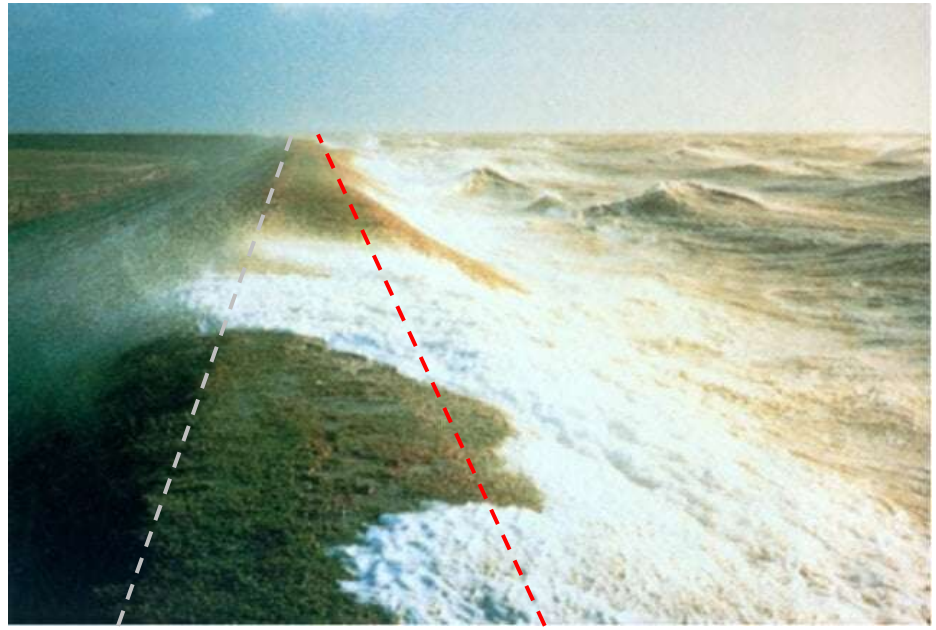


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Wave Overtopping at the Waterside Crest Line

- Many separate studies…
- Overtopping volume V important estimator for:
  - $u_{piek} = f(V)$
  - $h_{piek} = f(V)$
- Triangular temporal evolution $u(t)$ en $h(t)$
- Together:

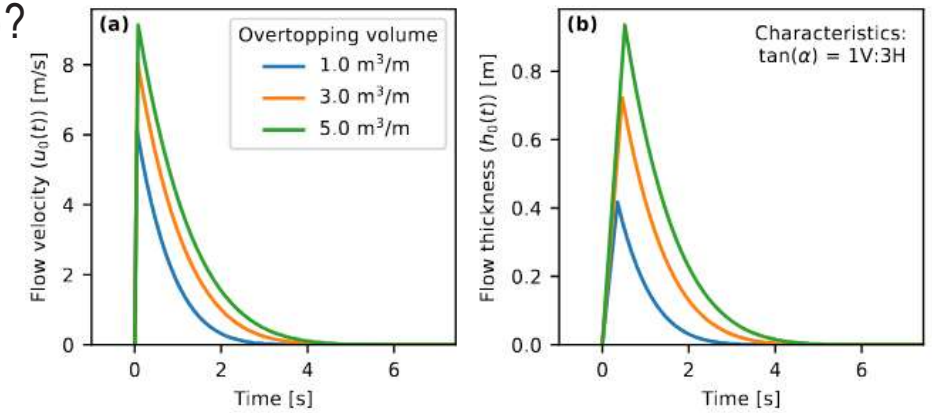




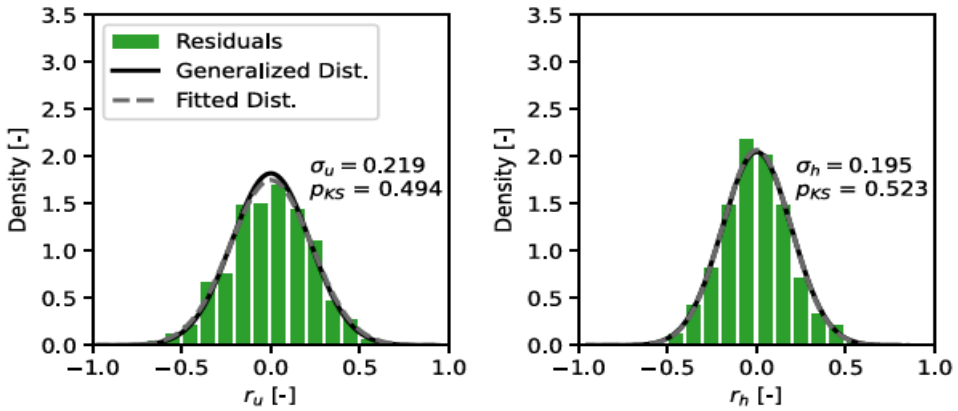
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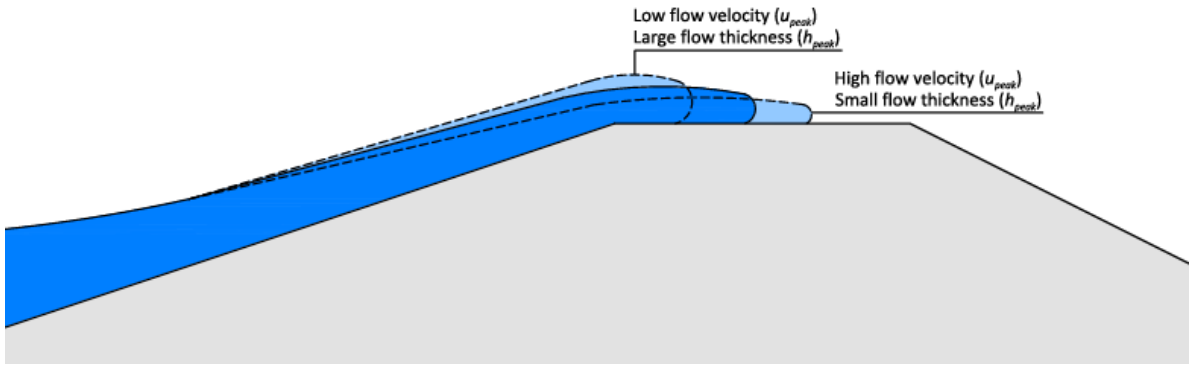
Wave Overtopping at the Waterside Crest Line

- However… Does each overtopping volume V has the same $u(t)$ and $h(t)$?
- No, natural variation exists:
  - u_{piek}
  - h_{piek}
  - Steepness wavefront α_{front}
- Kwantification with FlowDike data



Variation in flow velocity / thickness

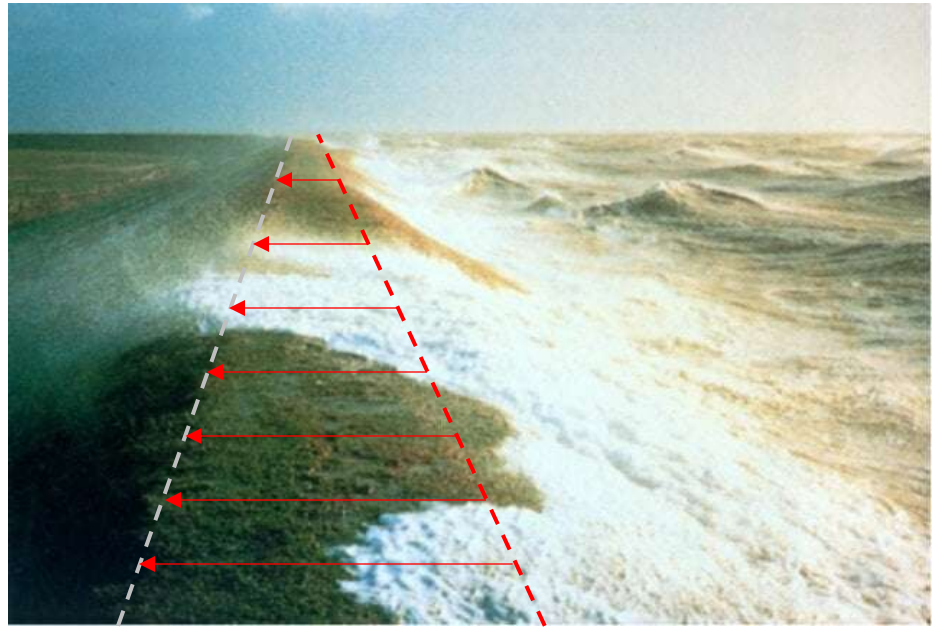




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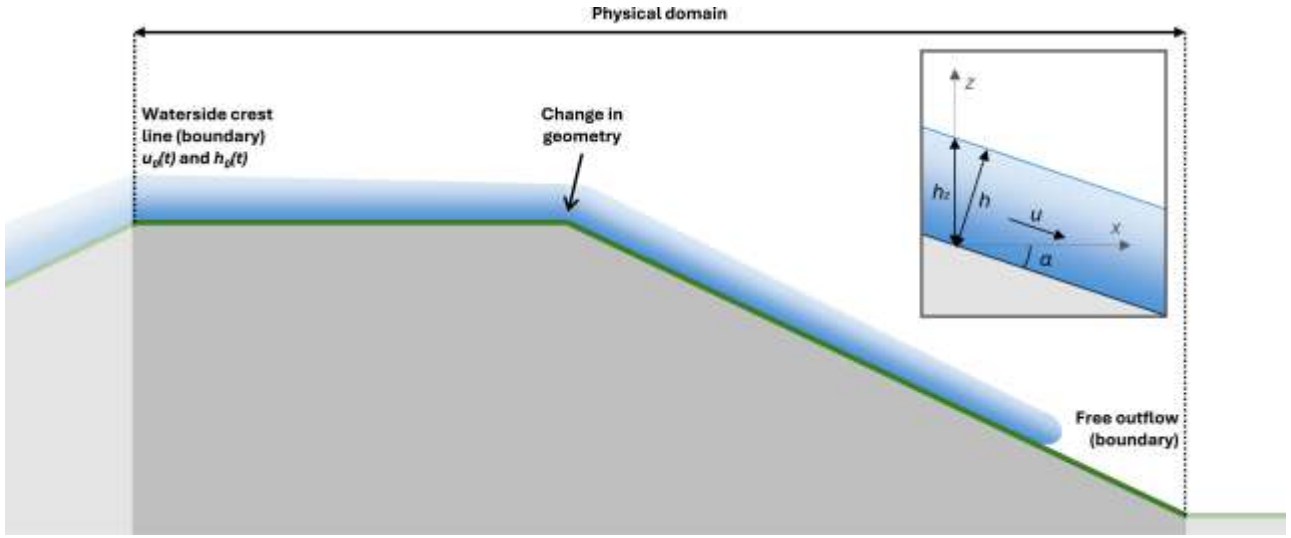
Wave Overtopping along the Crest and Landward Slope

- Schematisation $u(t)$ and $h(t)$ incl. natural variation done
- Effect of crest and landward slope



Wave Overtopping along the Crest and Landward Slope

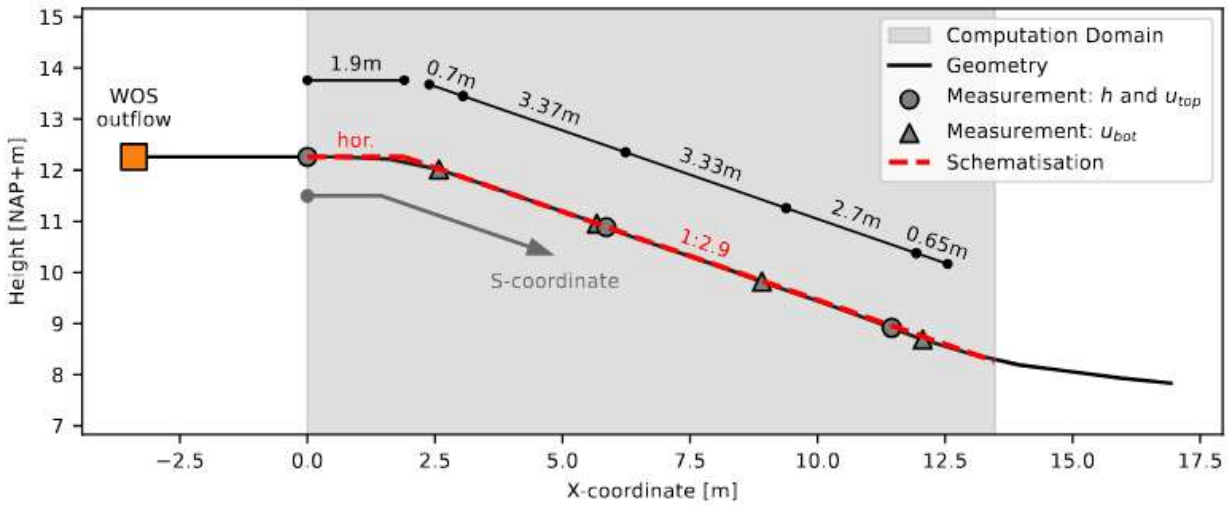
- Numerical model:
  - Steep-Slope Shallow Water Equations
- Yield $u(x,t)$ and $h(x,t)$

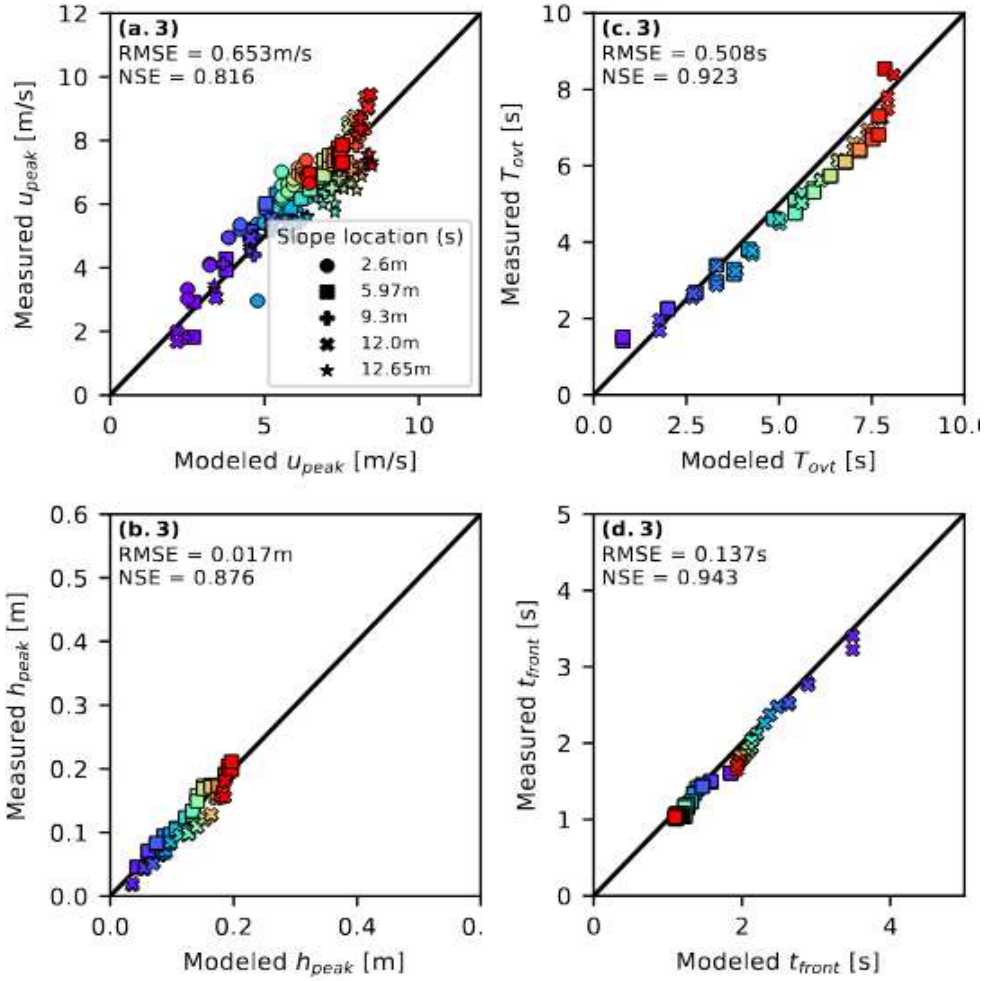


Wave Overtopping along the Crest and Landward Slope

- Validation with WOS experiments
  - Millingen a/d Rijn
  - Tholen
  - Future Dikes (Nijmegen)

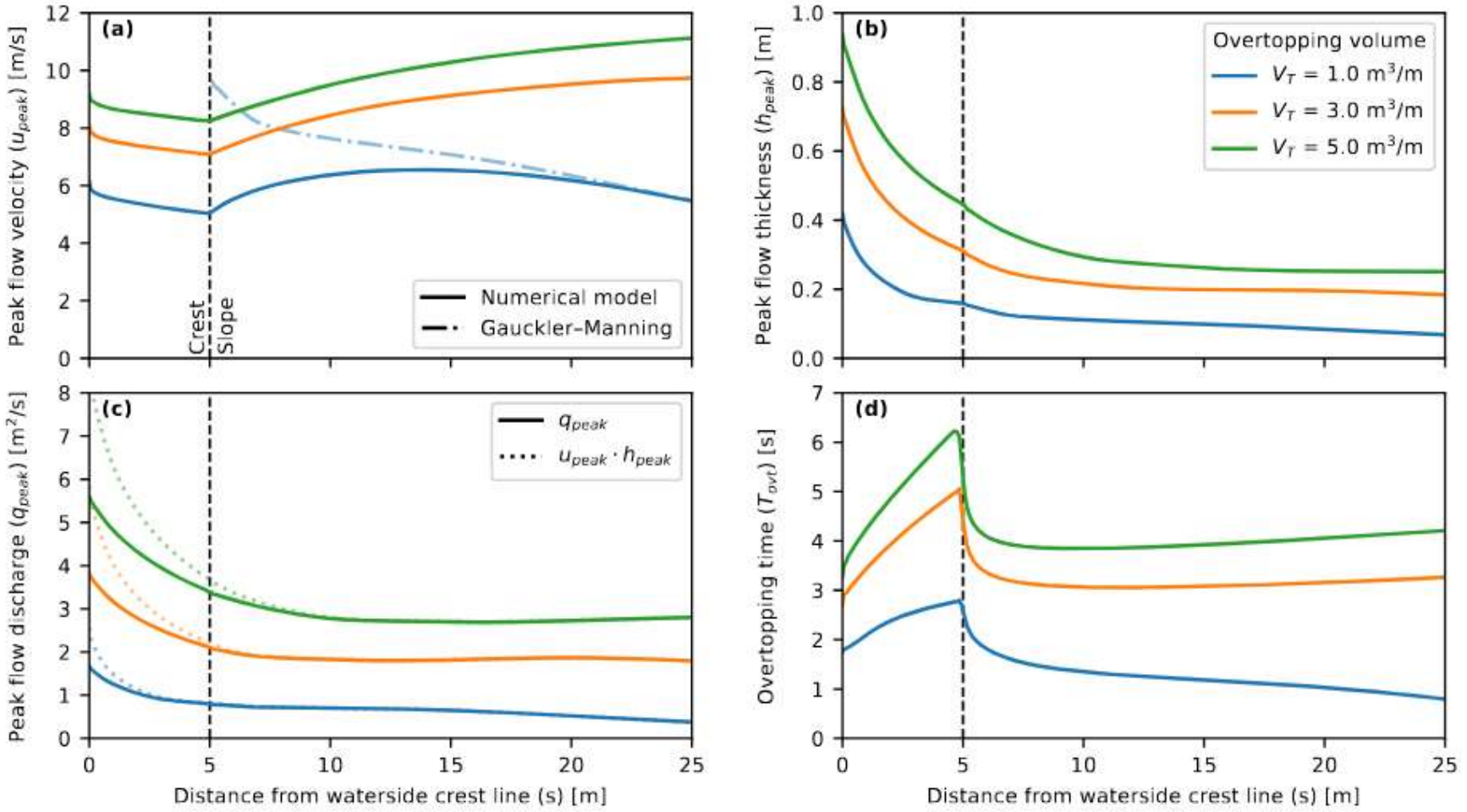
Future Dikes

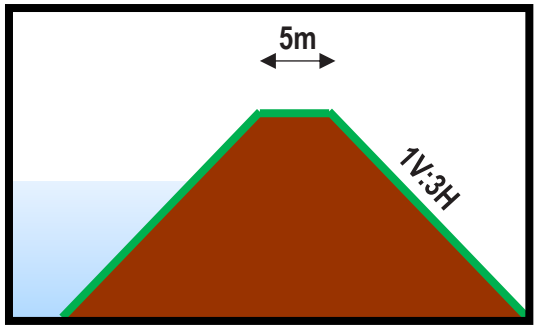




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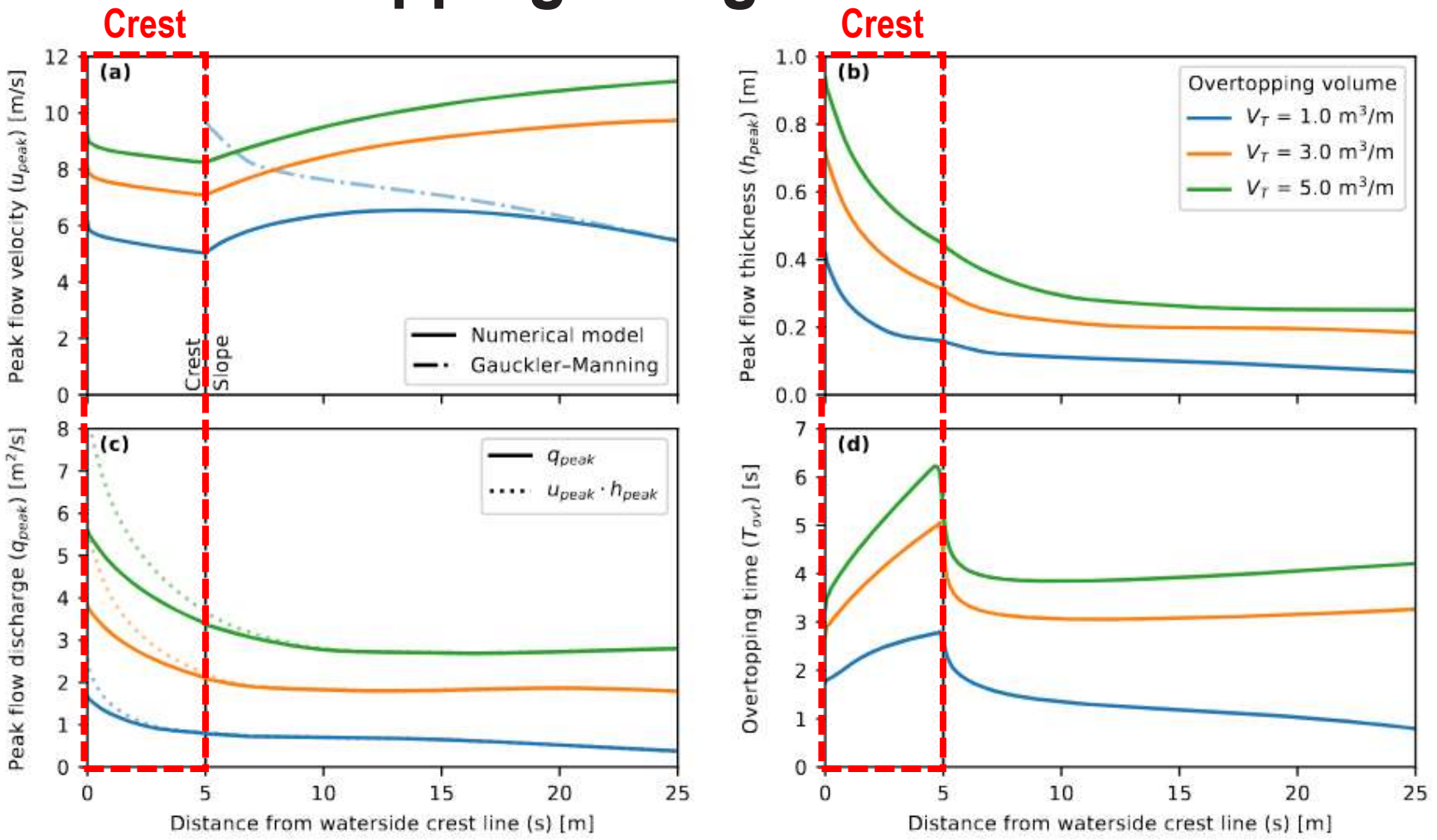
Wave Overtopping along the Crest and Landward Slope

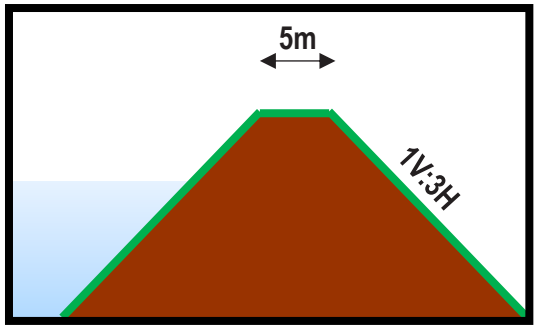




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Wave Overtopping along the Crest and Landward Slope





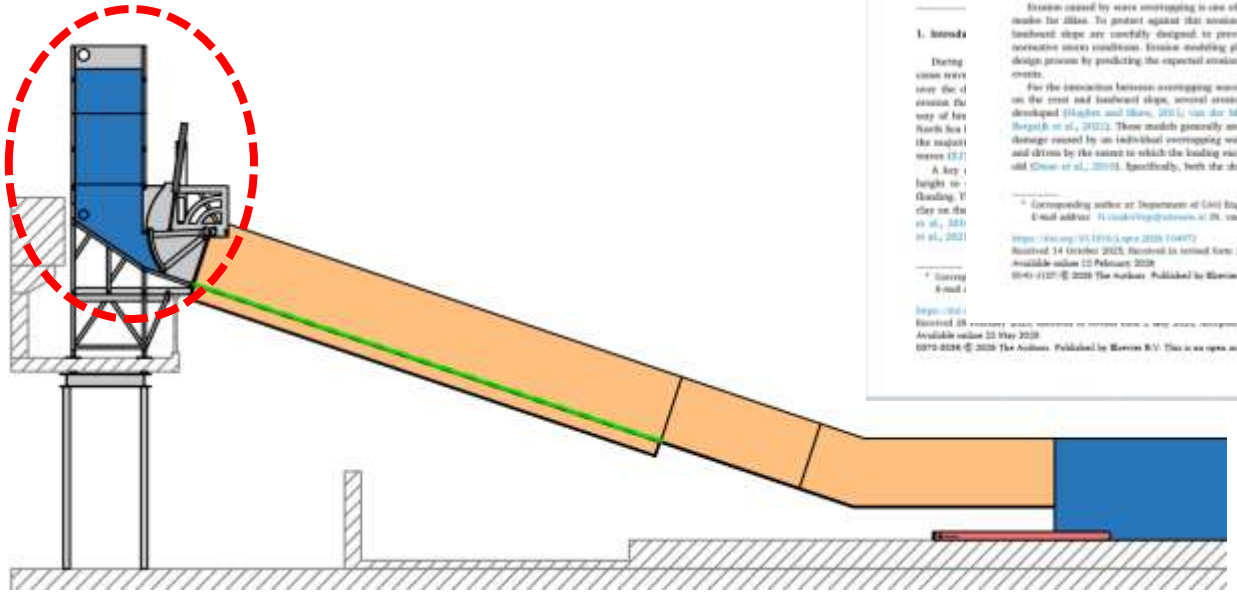
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The indoor Wave Overtopping Simulator

Design challenges:

✓ 1. What does the overtopping flow look like on the waterside slope?

✓ 2. What is the effect of the crest and landward slope/geometry?





Applied Ocean Research

Research paper

Spatiotemporal numerical modeling of wave overtopping flow over dike crests and landward slopes

Niels van der Vegt, Bas Hofland, Vera M. van Bergeijk, Suzanne J.M.H. Hulscher, Jord J. Warmink

ARTICLE INFO

ABSTRACT

Variation in flow characteristics of overtopping waves on dike crests
https://doi.org/10.1016/j.coastaleng.2025.104772

Spatiotemporal numerical modeling of wave overtopping flow over dike crests and landward slopes
https://doi.org/10.1016/j.apor.2026.104972

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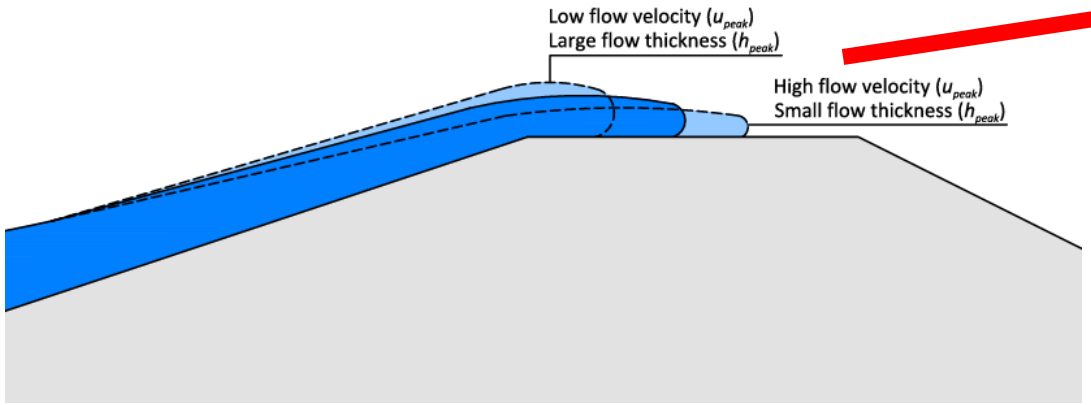
Design

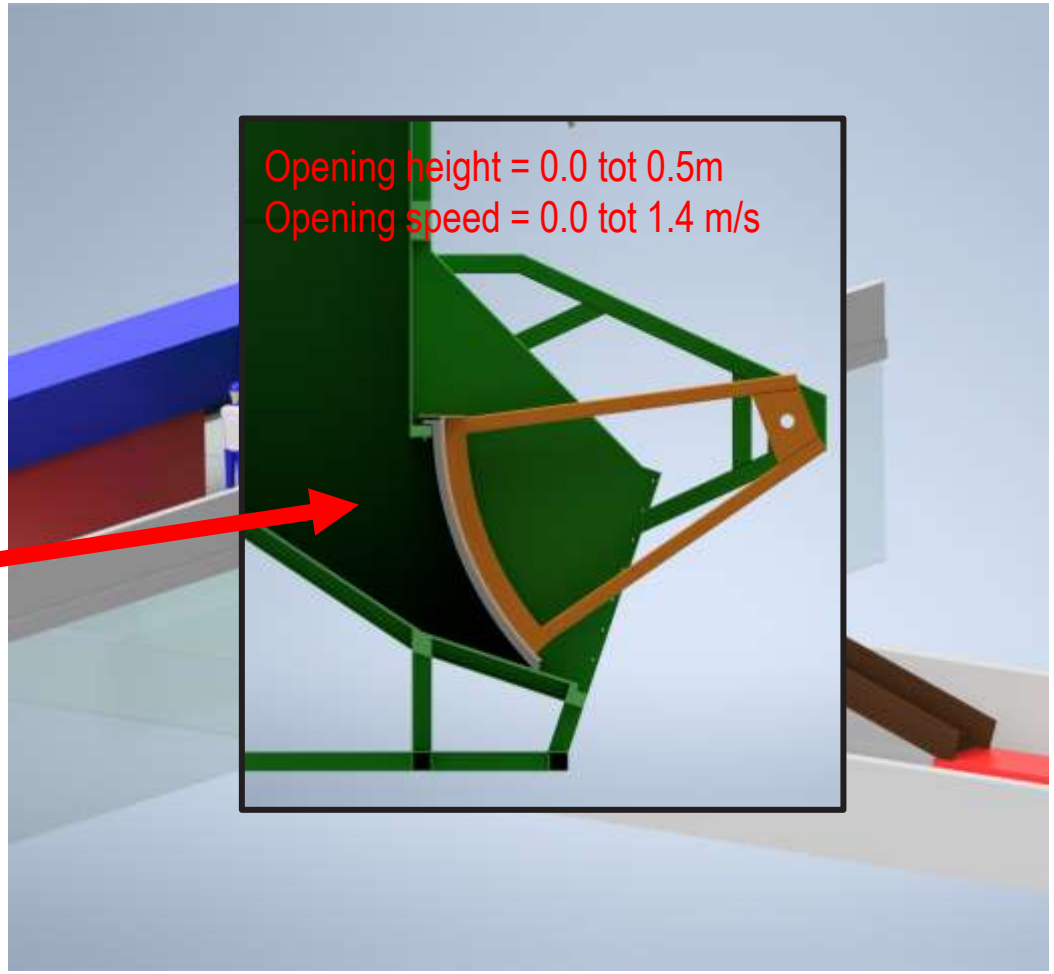
- Location: Hydraulic Engineering laboratory @ TU Delft



Design

- Wave Overtopping Simulator
  - Overtopping waves up to 3.000 l/m
  - 3,5m x 1,0m x 0,8m
  - Innovative radial release valve



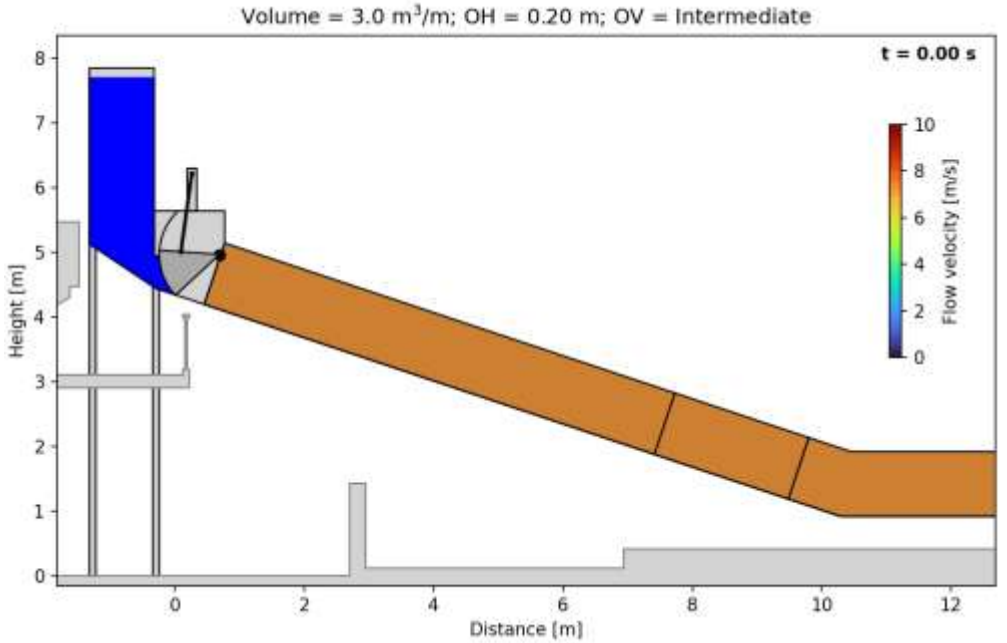


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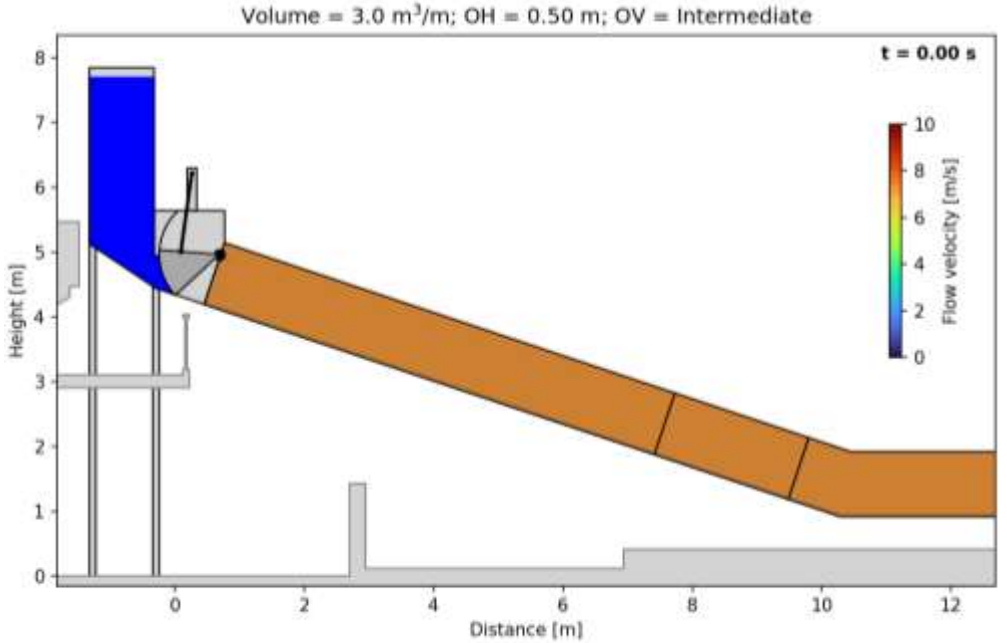
Release valve

- Introduce natural variation
  - **Opening height**
  - Opening speed

Opening height = 20 cm



Opening height = 50 cm

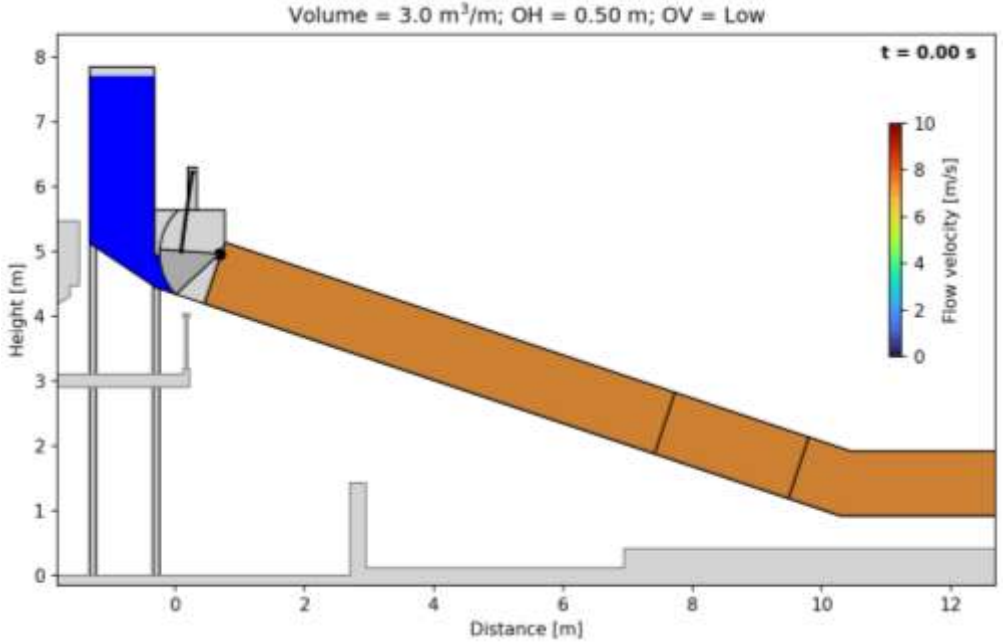


Model: Boreflow (https://doi.org/10.1016/j.apor.2026.104972)

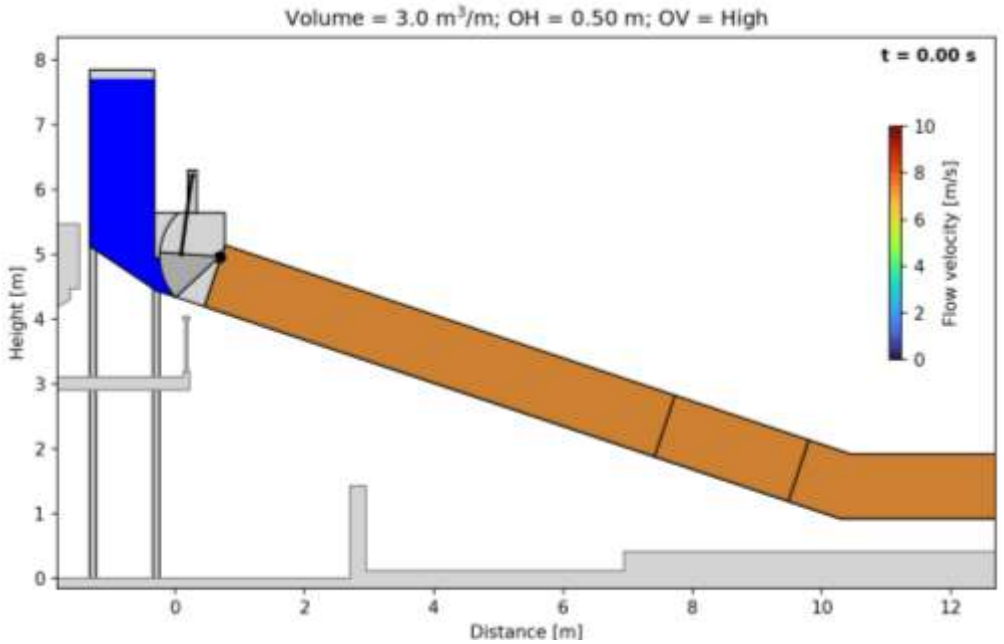
Release valve

- Introduce natural variation
  - Opening height
  - **Opening speed**

Opening speed = low
(actuator retraction = 0.2 m/s)



Opening speed = high
(actuator retraction = 0.8 m/s)

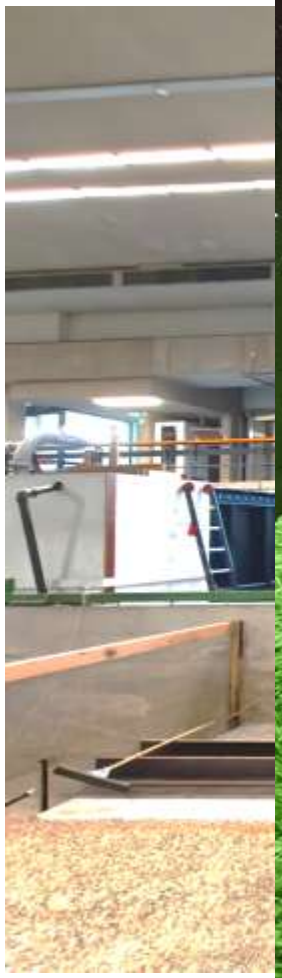


Model: Boreflow (https://doi.org/10.1016/j.apor.2026.104972)

Prototype *mini*WOS

- Work by M.Sc. student Simon van Leent
- Scale: 1/10 in volume







De indoor Wave Overtopping Simulator

- Start construction summer 2025

Reinforcing the HE-lab





Reinforcing the HE-lab





Welding of the iWOS





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Arrival at the TUDelft





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iWOS release valve





Construction and Testing





Construction and Testing





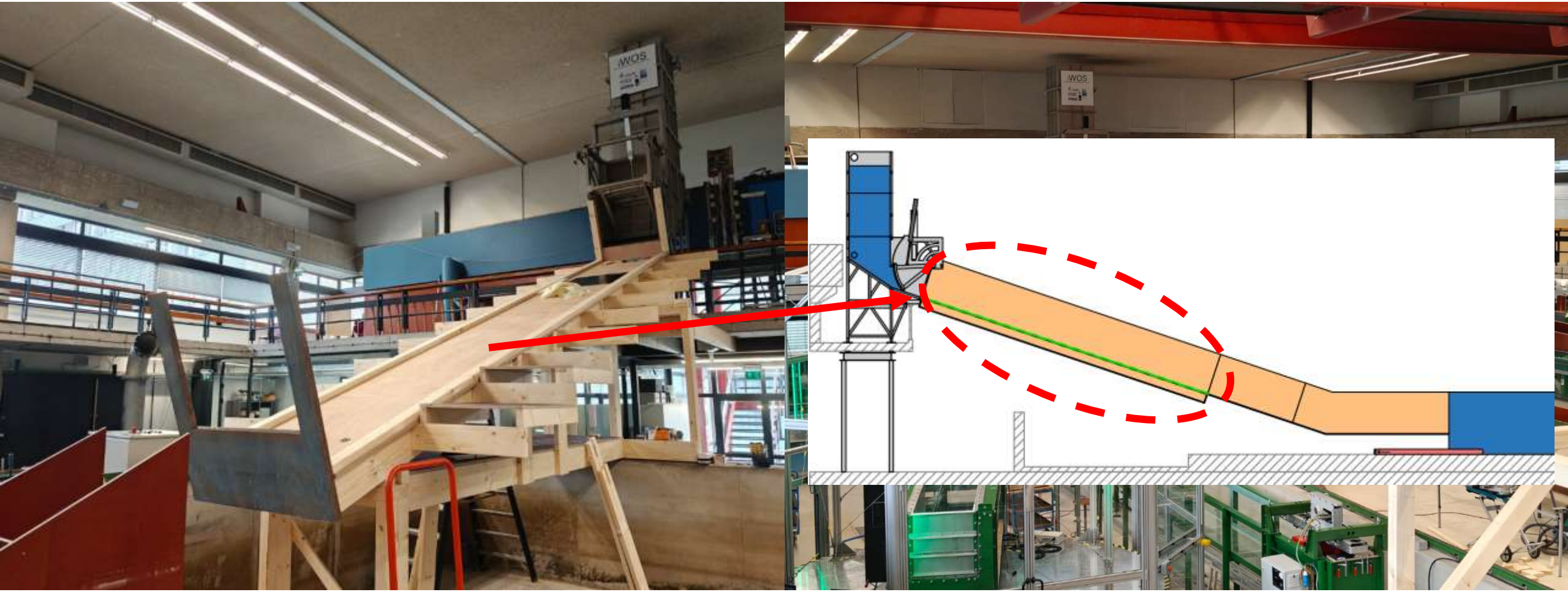
Construction and Testing





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Dike slope / Flume

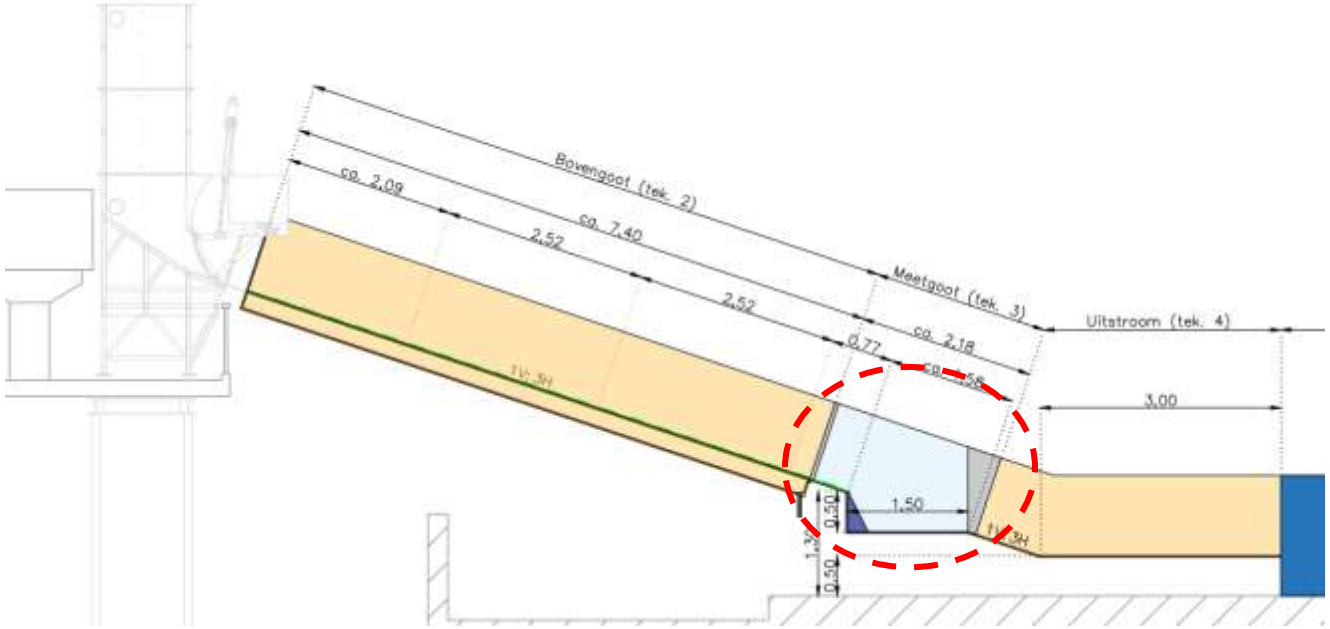


Dike slope / Flume

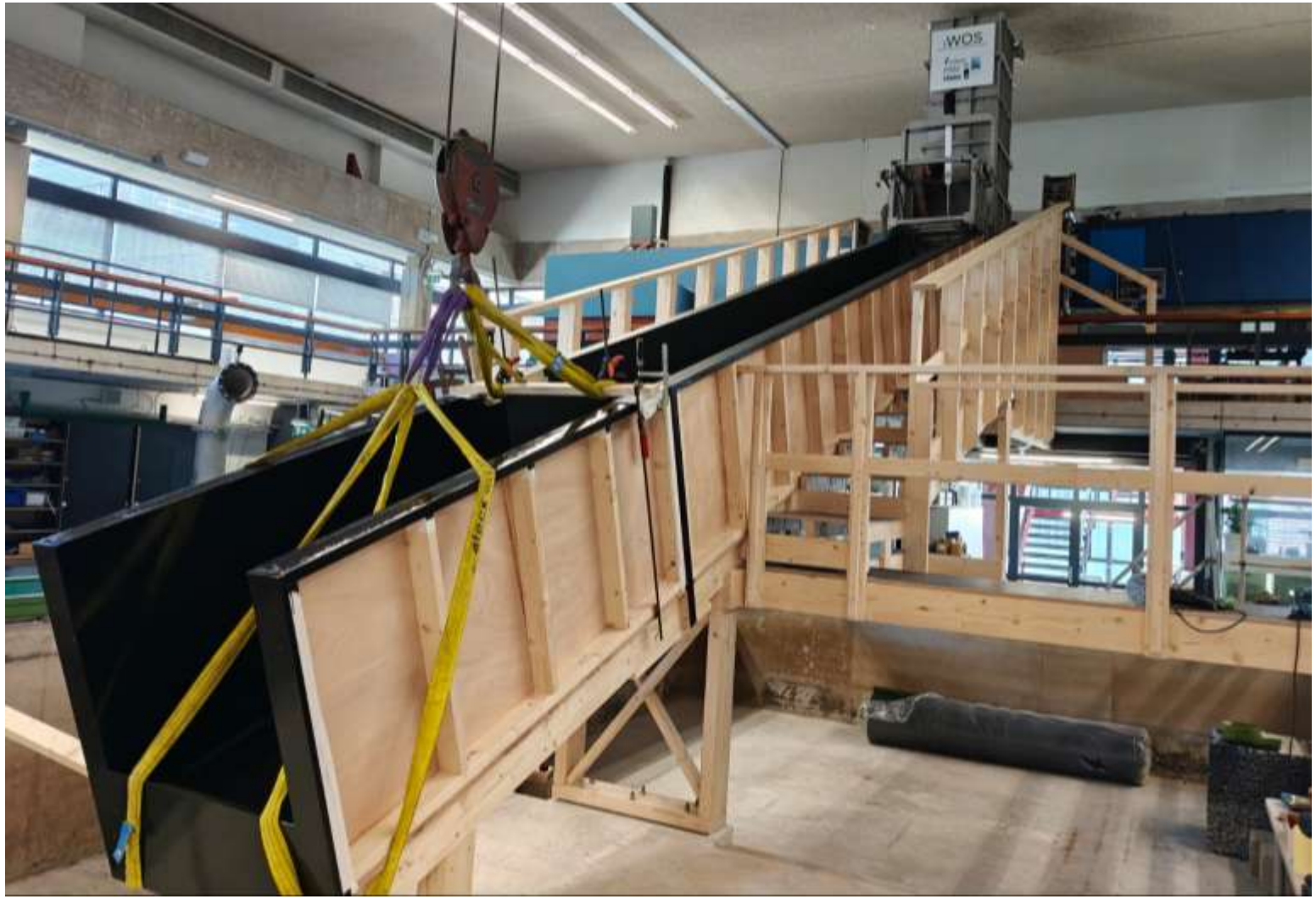


Planning

- First experiments: end July / August
  - Effect of variation in flow characteristics on erosive power
- Later this year (Q3/Q4 2026):
  - Hydraulic loading inside erosion pits measured using PIV



Thank you!



- Niels van der Vegt
  n.vandervegt@utwente.nl

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