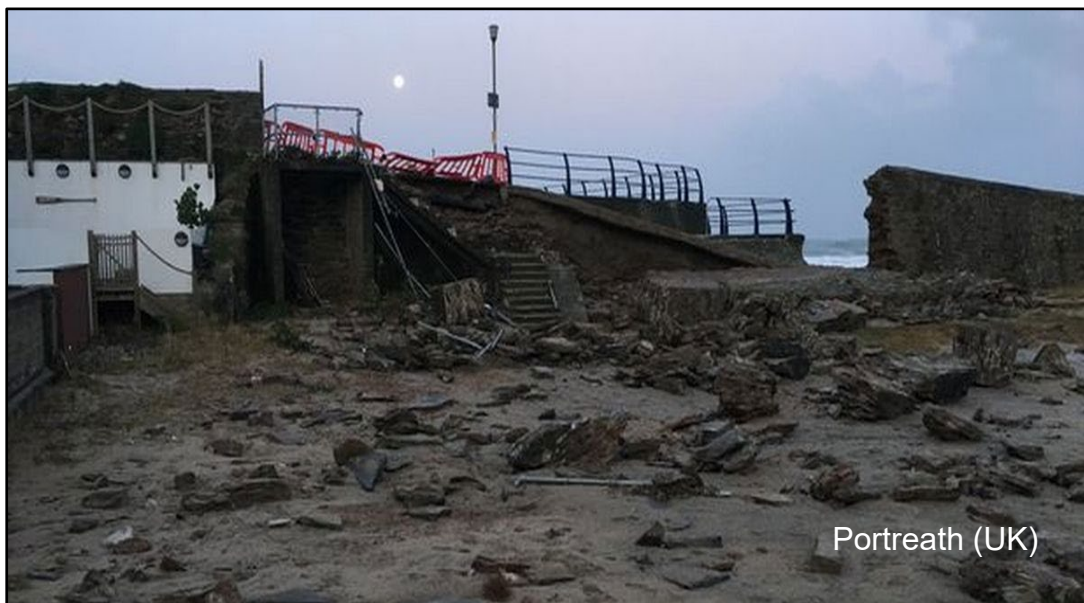# Wave Loads on Walls (WALOWA) - Large-Scale Experiments in the Deltares Delta Flume

Maximilian Streicher
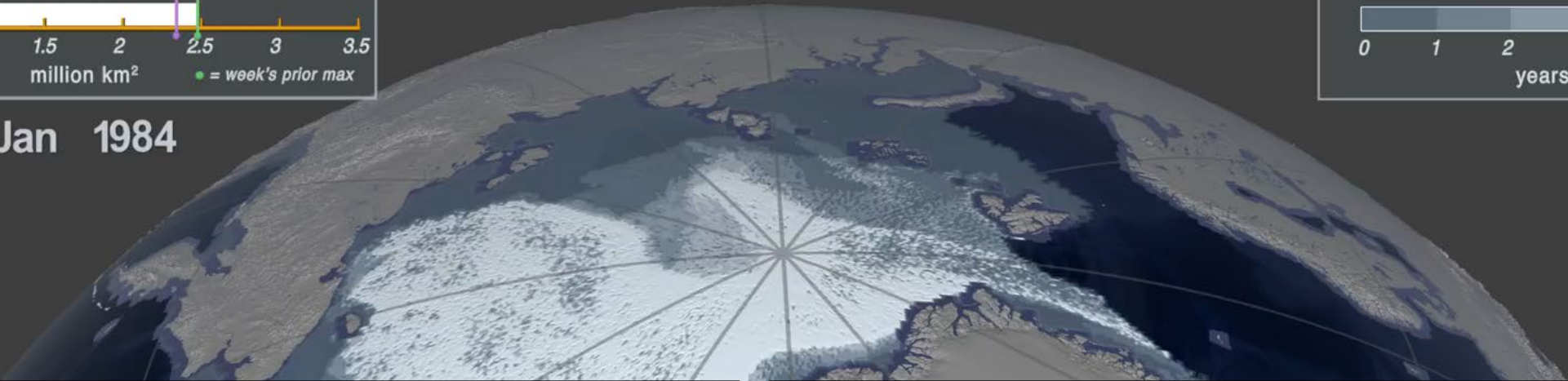
February 6th 2020, 2nd COB Seminar Oostende

GHENT UNIVERSITY

FACULTY OF ENGINEERING AND ARCHITECTURE

Department of Civil Engineering

Damage Due to Overtopping Waves

Sydney (Australia)

Dawlish (UK)

Portreath (UK)

La Coruña (Spain)

Sea Ice over 4 years old
0   0.5   1   1.5   2   2.5   3   3.5
• = week's 20-yr ave   million km²   • = week's prior max

Jan   1984

Sea Ice Age
0   1   2   3   4 >
years

source: Van Doorslaer (2018)

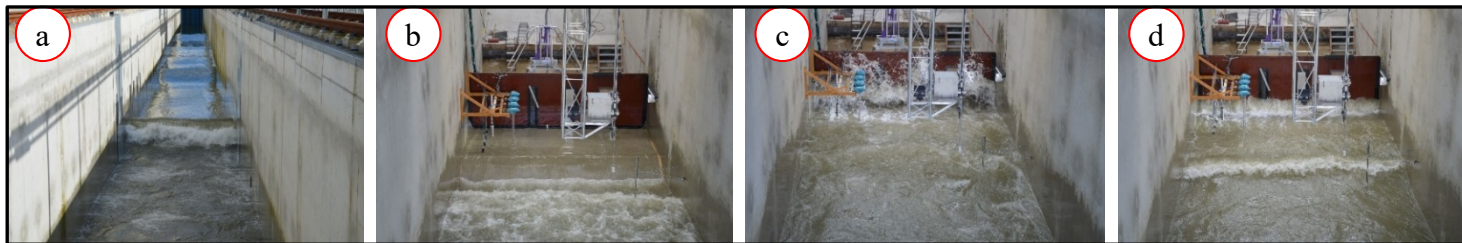source: AWW

Source: World Economic Forum 2020

How vulnerable is this set-up to sea level rise?

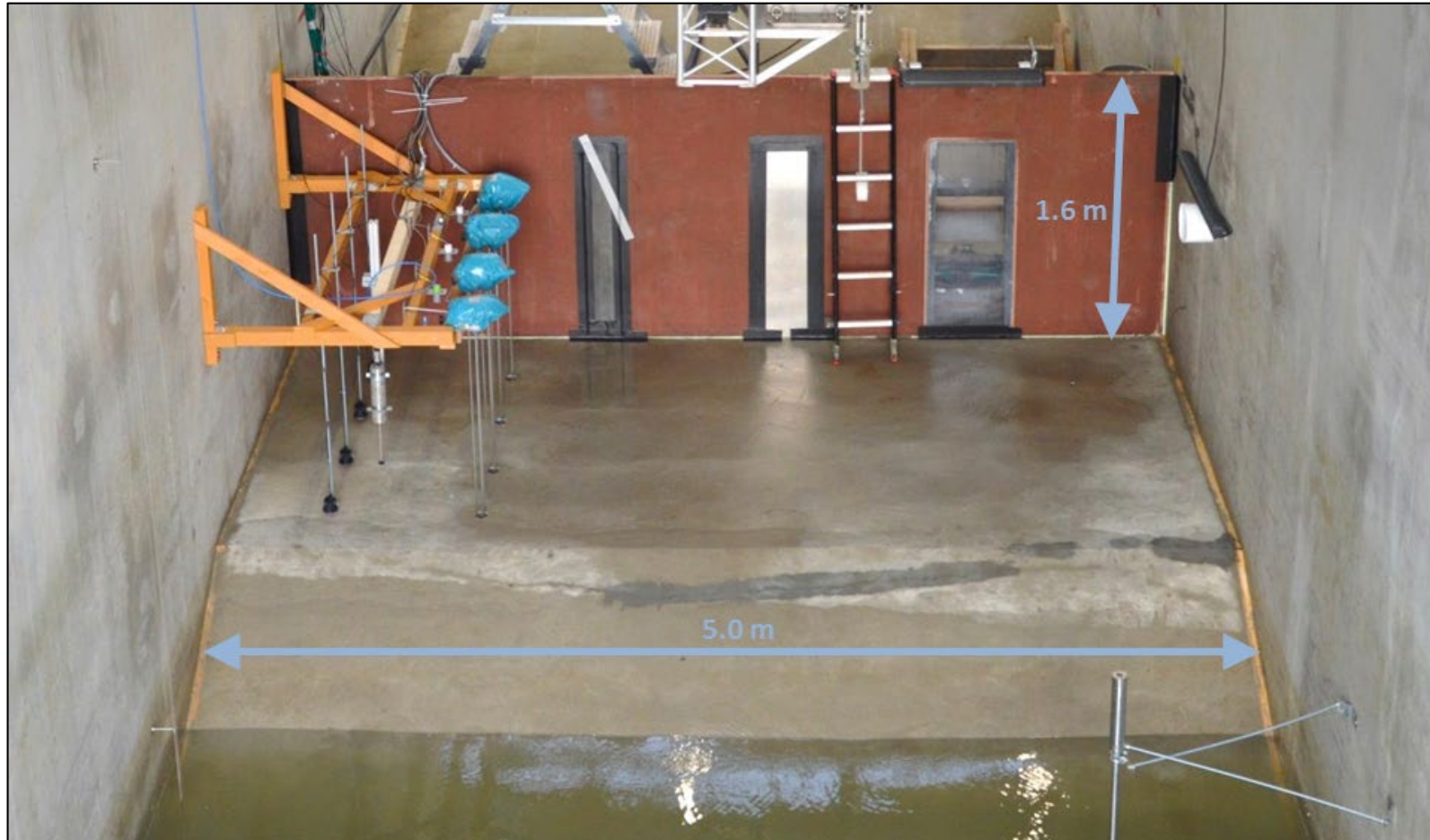What is the effect of overtopping waves?

Knokke, Belgium
source: http://www.vliz.be

Experimental Set-up

275.75m

Wave gauge 2,3,4 — Wave gauge 7 — Wave gauge 11 — Wave gauge 13 — Wave gauge 14 — Wall

1.6m

0.53m

1/35 — Foreshore

1/10 — 1.95m — 1/2 — 3.73m

Paddle

Paddle — Foreshore — Dike — Promenade — Wall

Y — X

93.98m — 19.5m — 61.6m — 1.07m 2.35m

a — b — c — d

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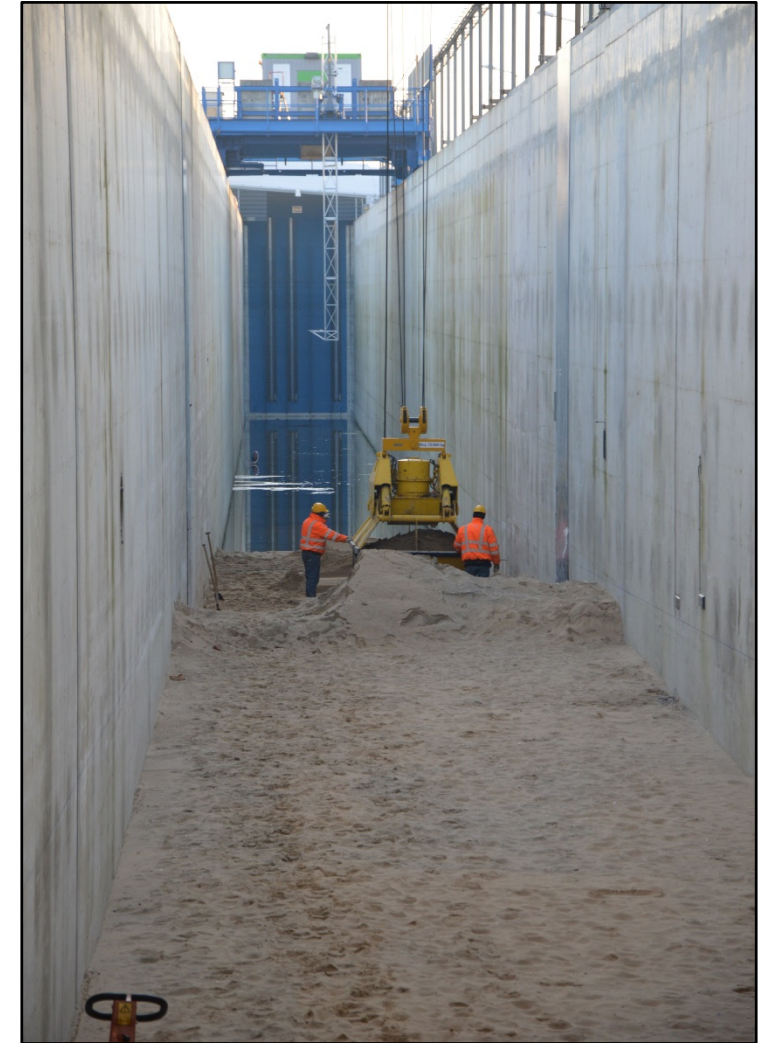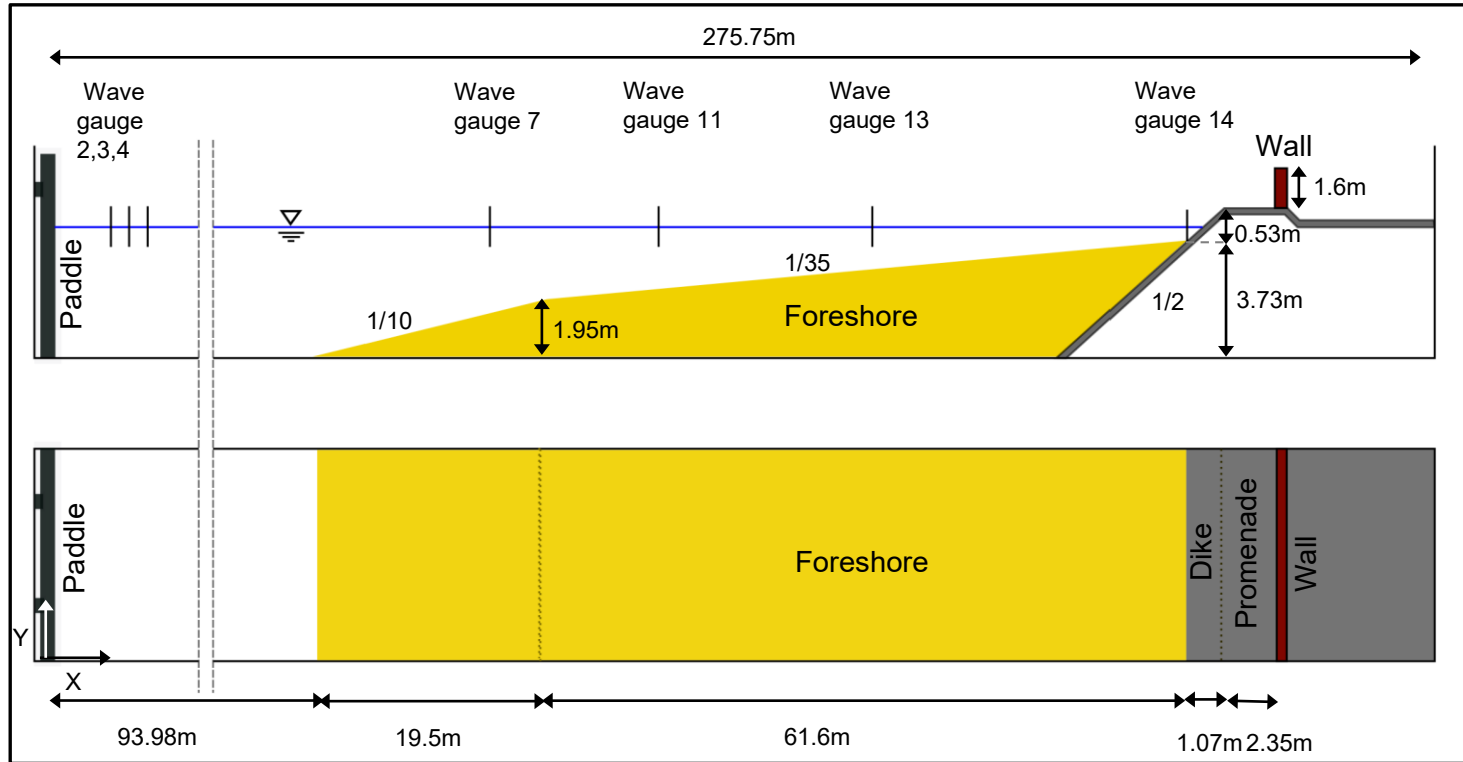
Instrumentation

Impact loads
- Load cells
- Pressure sensors

Layer thickness & velocity
- Resistive wave gauges
- Paddle wheels
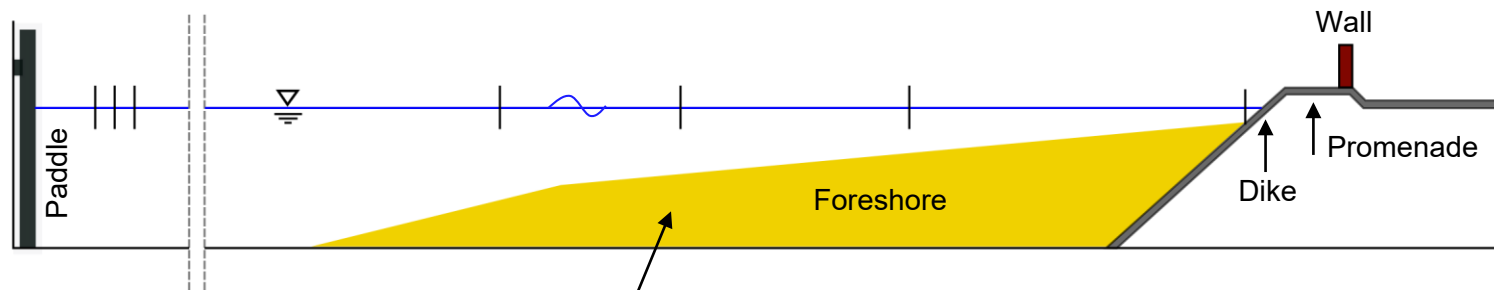- Electro-magnetic current meter
- Ultra-sonic distance sensor

Morphological changes
- Bed profiler
- Sediment concentration meter

Additional
- Resistive wave gauges
- SICK Laser scanner
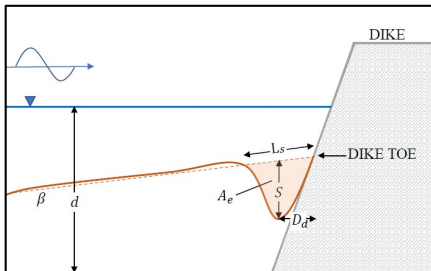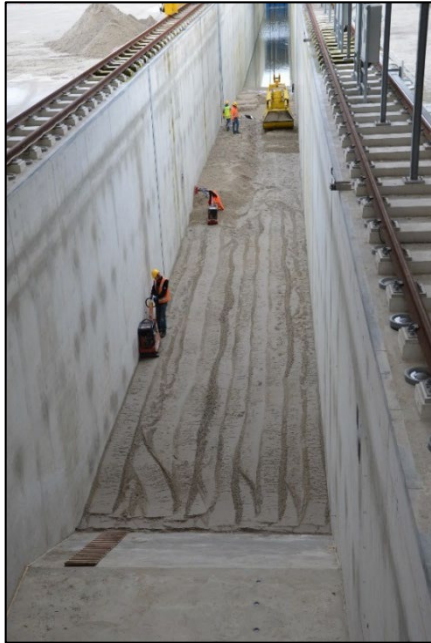- 3 GoPro cameras
- 1 High-speed camera
- Void-Fraction meter

Morphological Study of Sandy Foreshore

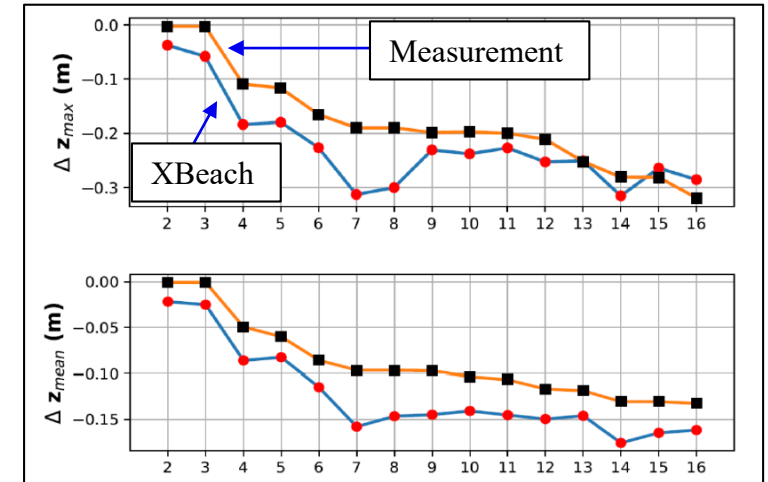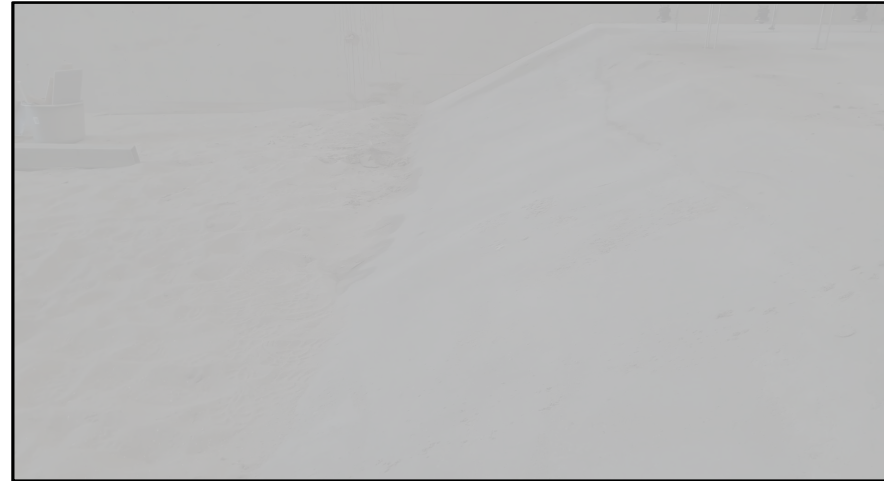# Morphological Study of Sandy Foreshore

- Mild foreshore comprised of ~1000m³ sand with D_{50} = 320μm
- Bed profiler and sand concentration meter measurements
- Xbeach to study expected erosion and vice versa the data for Xbeach validation

Morphological Study of Sandy Foreshore

- "XBeach reliably reproduces the general evolution of the bed layer."
- "Good prediction of general features of the scour for long time evolution (e.g. equilibrium score conditions)." [Saponieri et al. 2018]
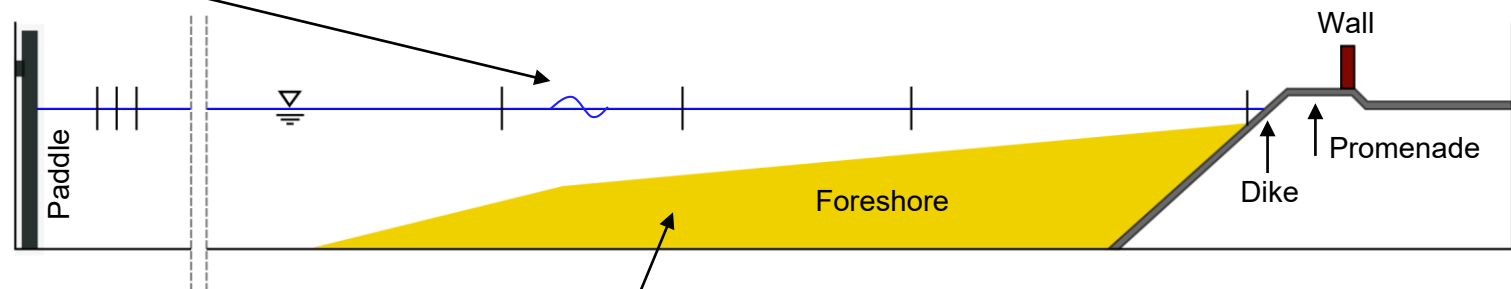
Measurement, Analysis & Results
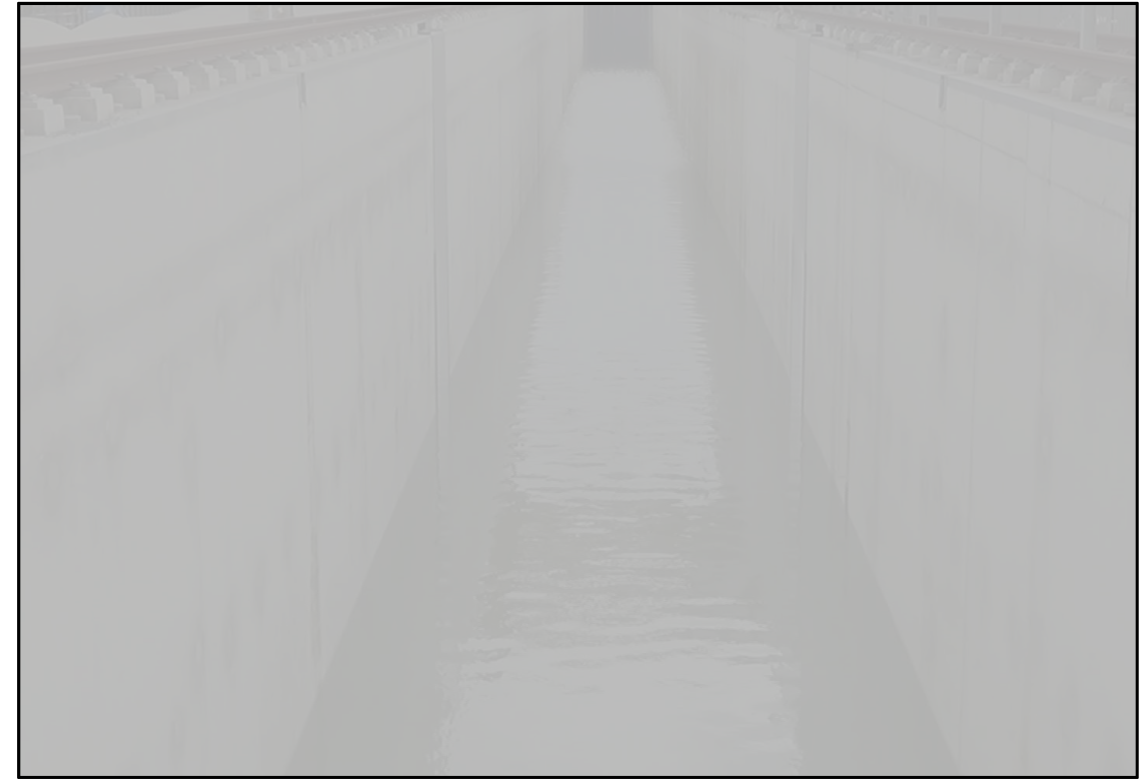

Study of Wave Parameters

Morphological Study of Sandy Foreshore

Study of Wave Parameters
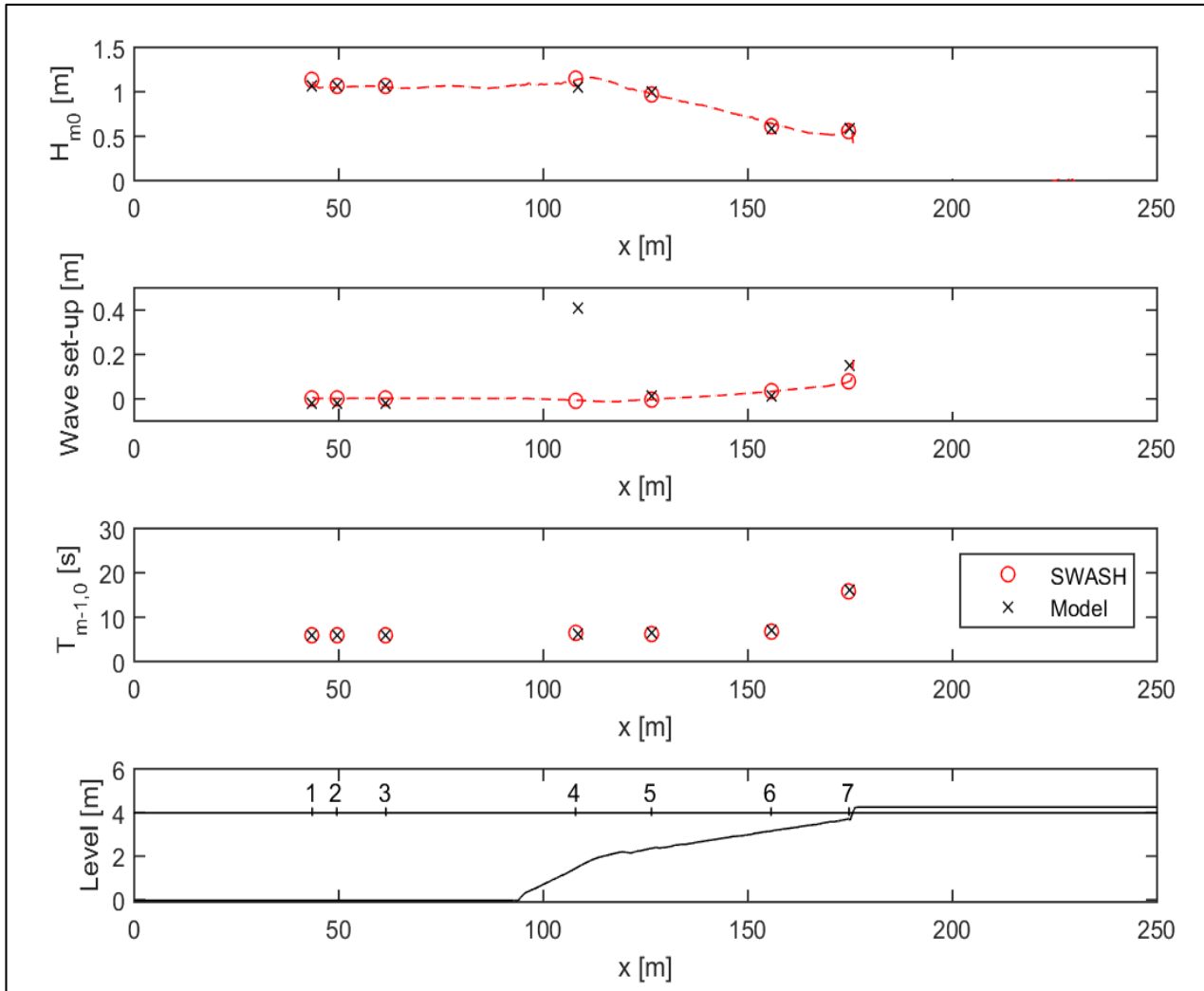
„Good agreement between SWASH and measurement results." [Streicher et al. 2017]

Measurement, Analysis & Results

Study of Wave Parameters

Study of Flow Parameters

Morphological Study of Sandy Foreshore

Paddle

Wall

Promenade

Dike

Foreshore

Study of Flow Parameters
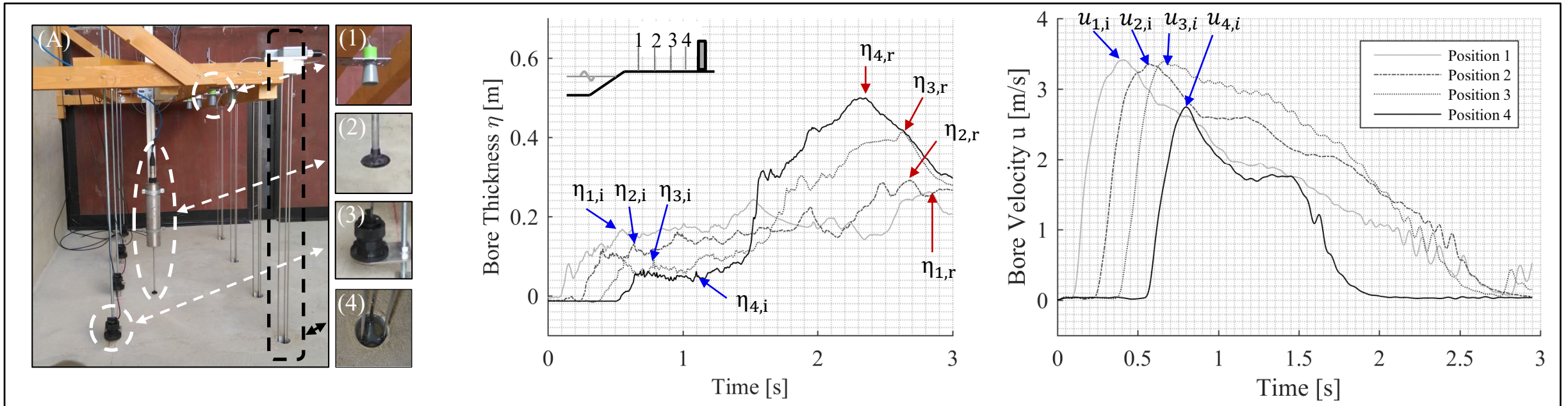
- Ultrasonic distance sensor (1), Electro-magnetic current meter (2), Paddle wheel (3), Wave gauge (4)
- Redundant measurement set-up (intrusive and non-intrusive)

„Incoming momentum flux closely related to wave impact loads." [Cappietti et al. 2018]

Study of Flow Parameters
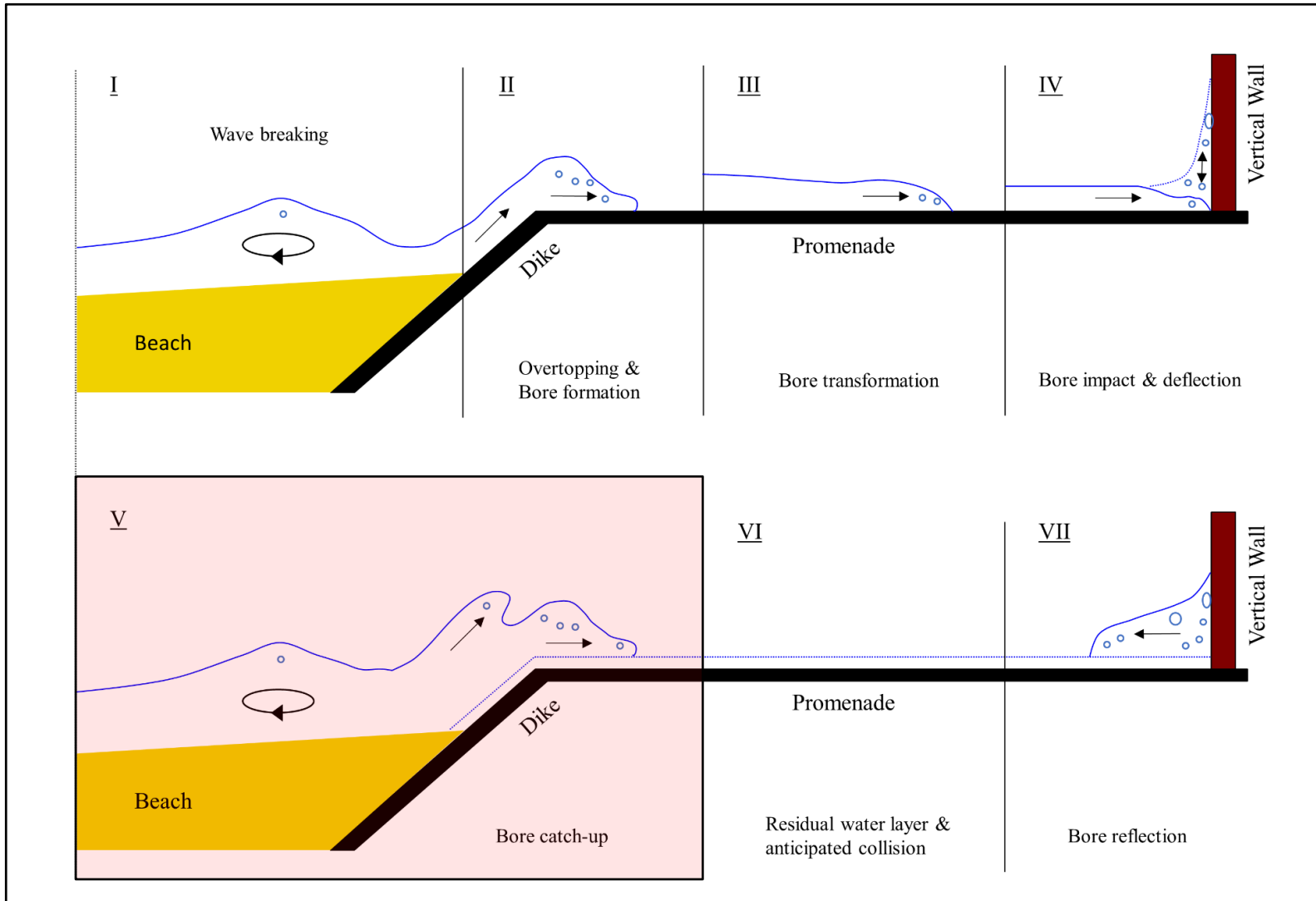
I. Wave breaking

II. Overtopping + bore formation

III. Bore transformation

IV. Bore impact + upward deflection

V. Bore catch-up

VI. Residual water layer + anticipated collision

VII. Bore reflection

Study of Flow Parameters (Non-Intrusive)

SICK LMS511 Laser Scanner

Catch-up bore pattern

- „5 Wave interaction patterns identified: *Regular*, *Collision*, *Plunging*, *Sequential* and *Catch-up wave pattern*."

- „Wave interaction patterns facilitate flow thickness, velocity and impact load measurement." [Streicher et al. 2019a]
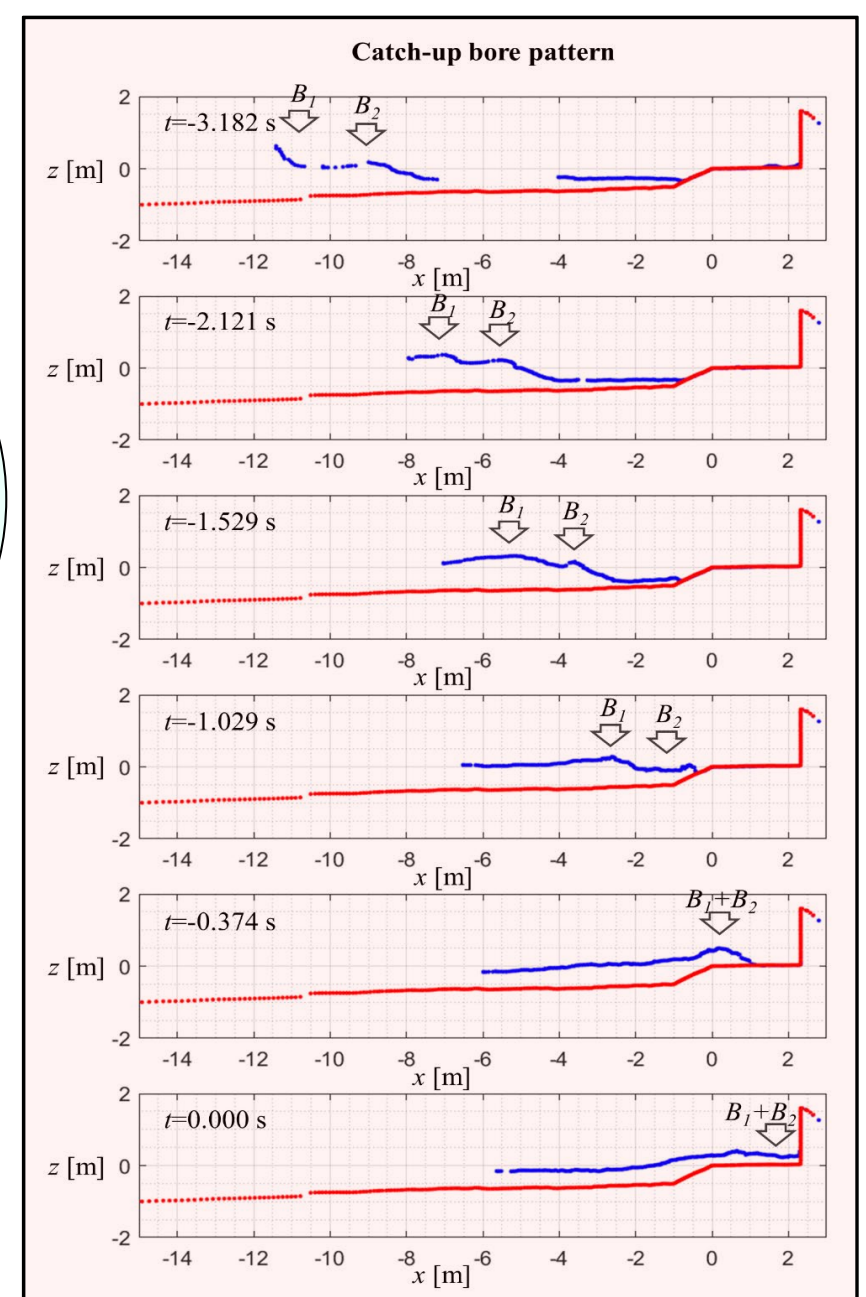
Catch-up bore pattern (source: Marinov 2017)

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Measurement, Analysis & Results

Study of Wave Parameters

Study of Flow Parameters

Study of Impact Loads

Morphological Study of Sandy Foreshore

Paddle

Foreshore

Wall

Dike

Promenade

Study of Impact Loads – Visualisation

Sideview camera

0.282 m

1.2 m

P13
P12
P11
P10
P09
P08
P07
P06
P05
P04
P03
P02
P01

Camera behind wall

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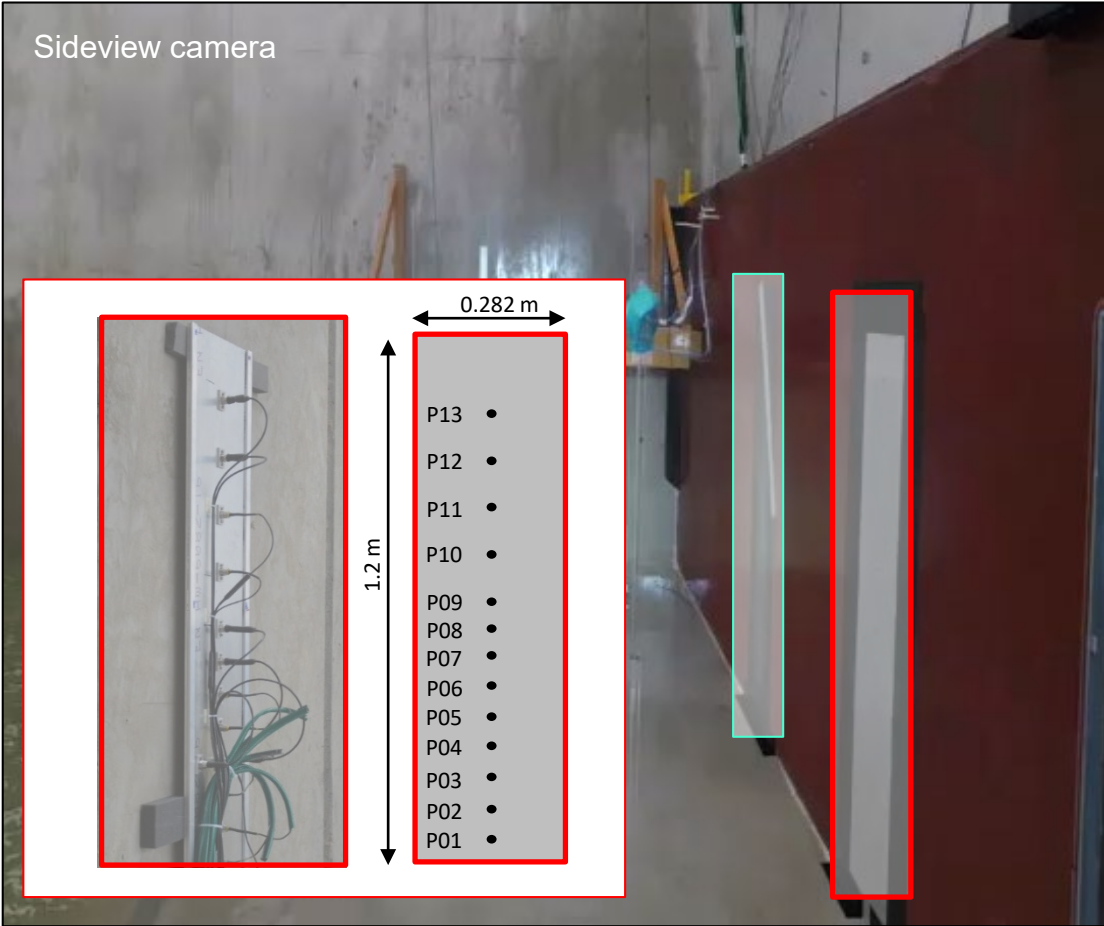
Study of Impact Loads - Process

First force peak (F_1): Dynamic impact.

Max. run-up and drop in force signal.

Second force peak (F_2): Quasi-static impact.

Hydrostatic force signal.

Study of Impact Loads - Classification
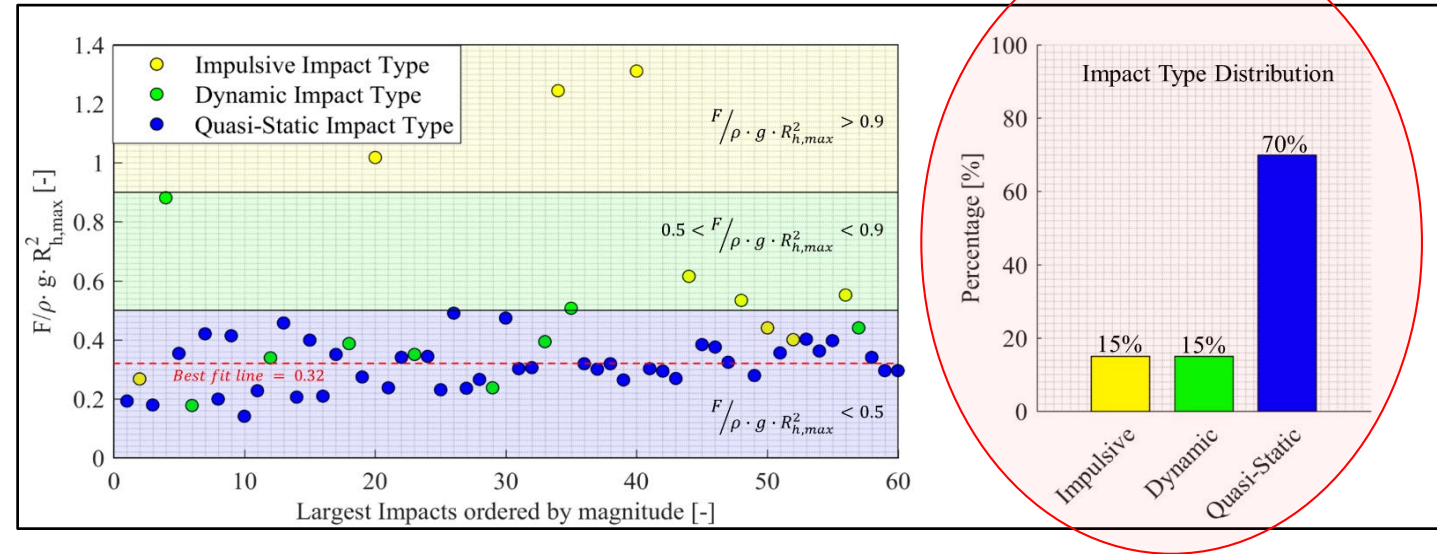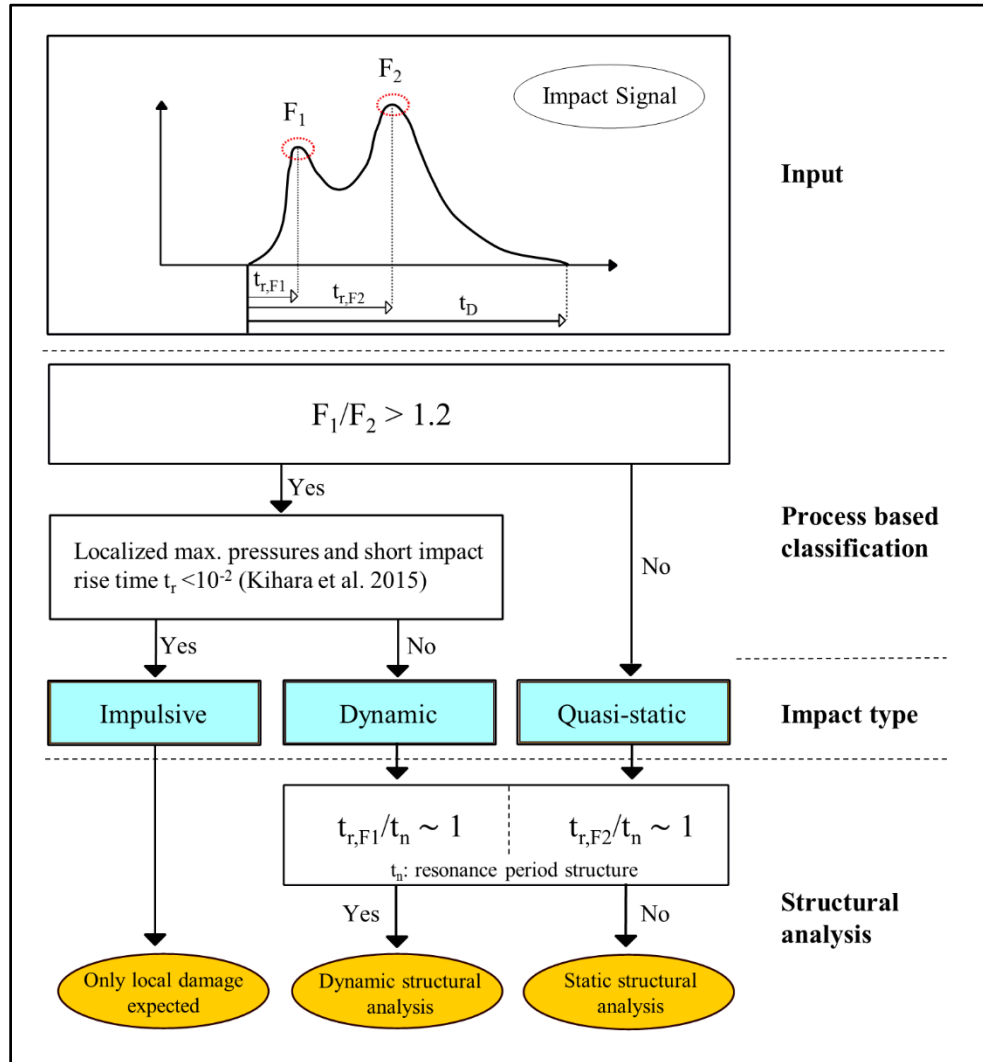
- „*Twin Peaks* impact signal shape." [Streicher et al. 2018]

- „3 Impact types: *Impulsive*, *Dynamic* and *Quasi-Static*."

- „Majority (2/3) and largest impacts are *Quasi-Static impact types.*" [Streicher et al. 2019a]

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Study of impact loads – Prediction
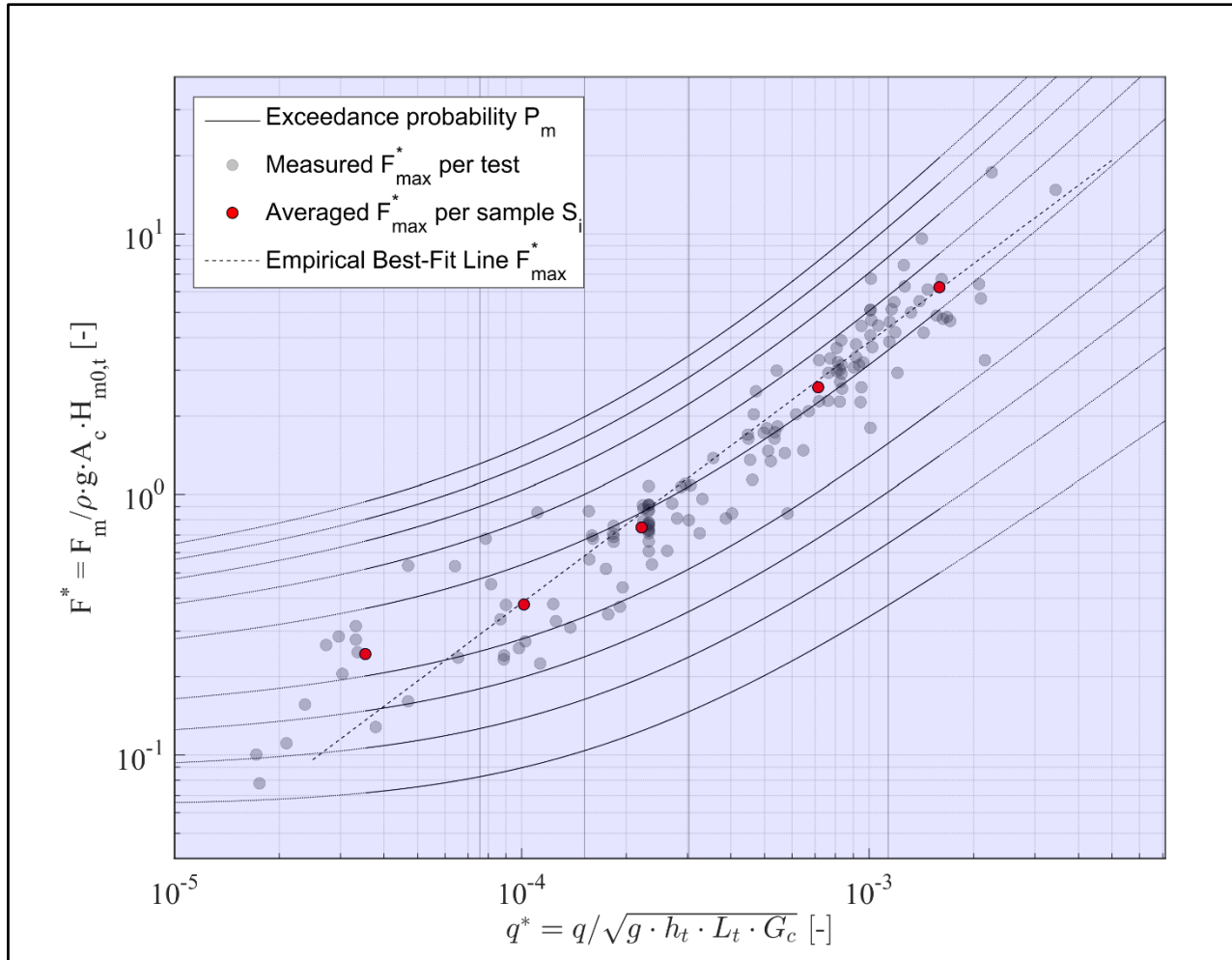
"Combined empirical and statistical method to predict the impact force." [Streicher et al. 2019b]
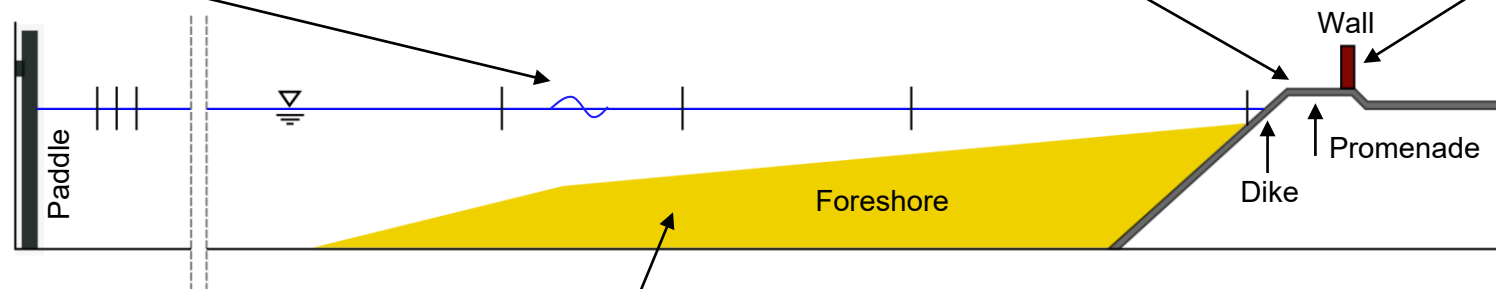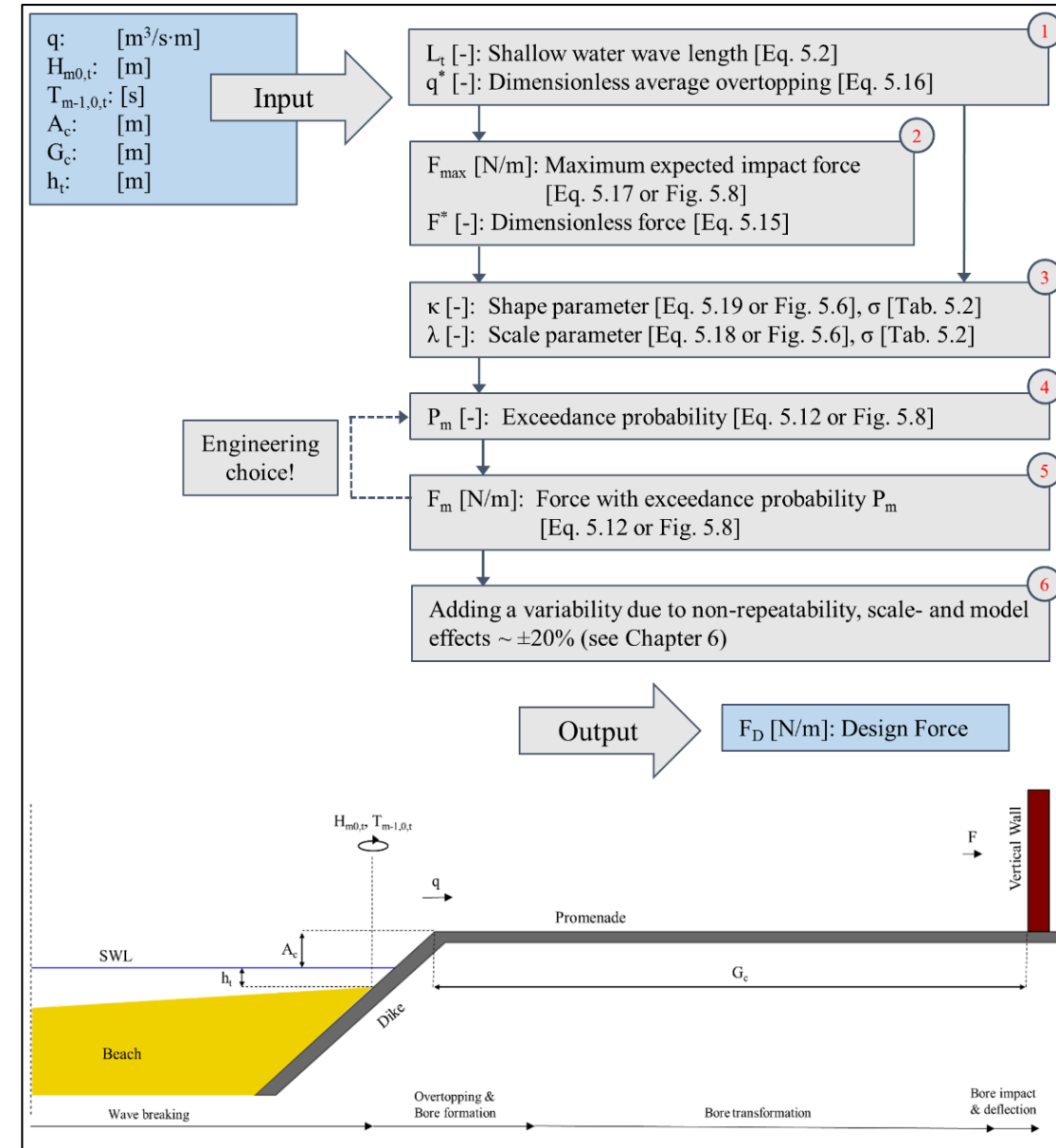
Measurement, Analysis & Results

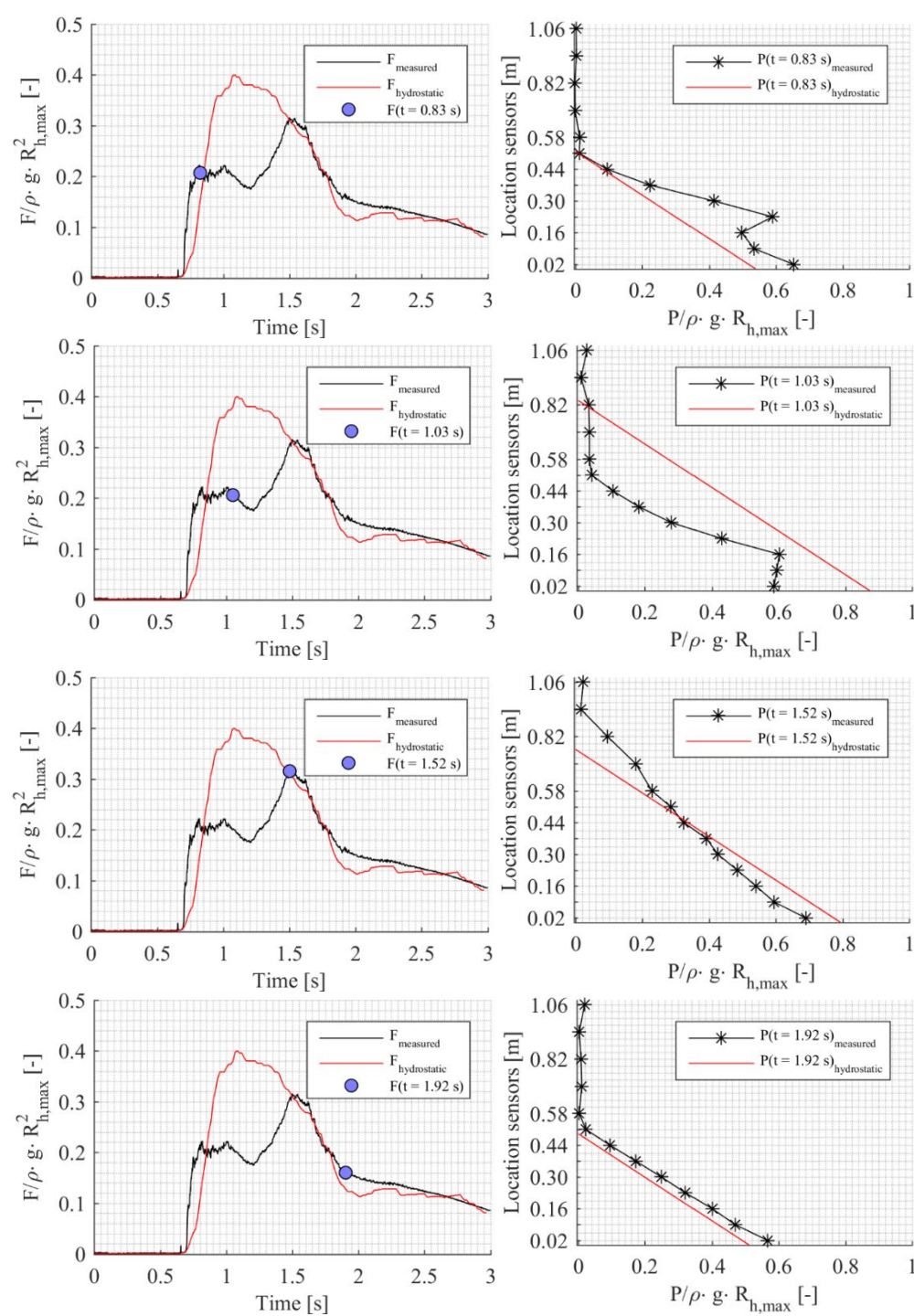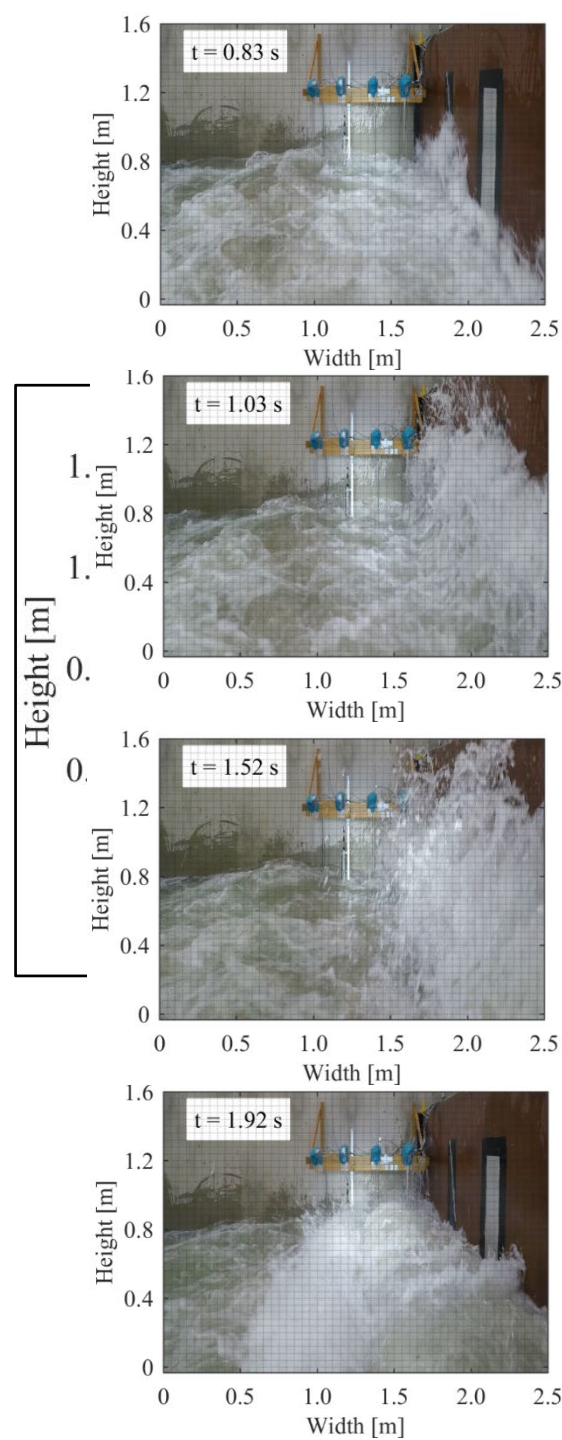Study of Wave Parameters

Study of Flow Parameters

Study of Impact Loads

Morphological Study of Sandy Foreshore

Numerical Simulation

Paddle

Foreshore

Wall

Promenade

Dike
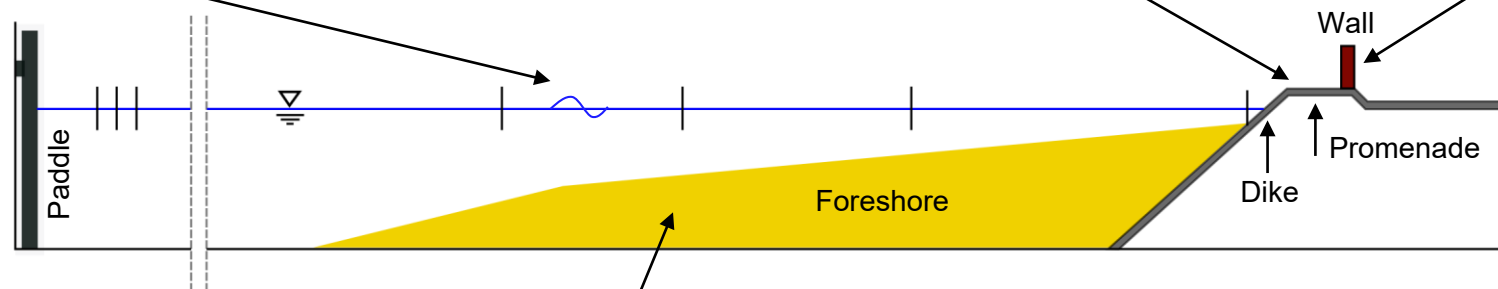
Numerical Simulations – OpenFOAM, SPH, SWASH
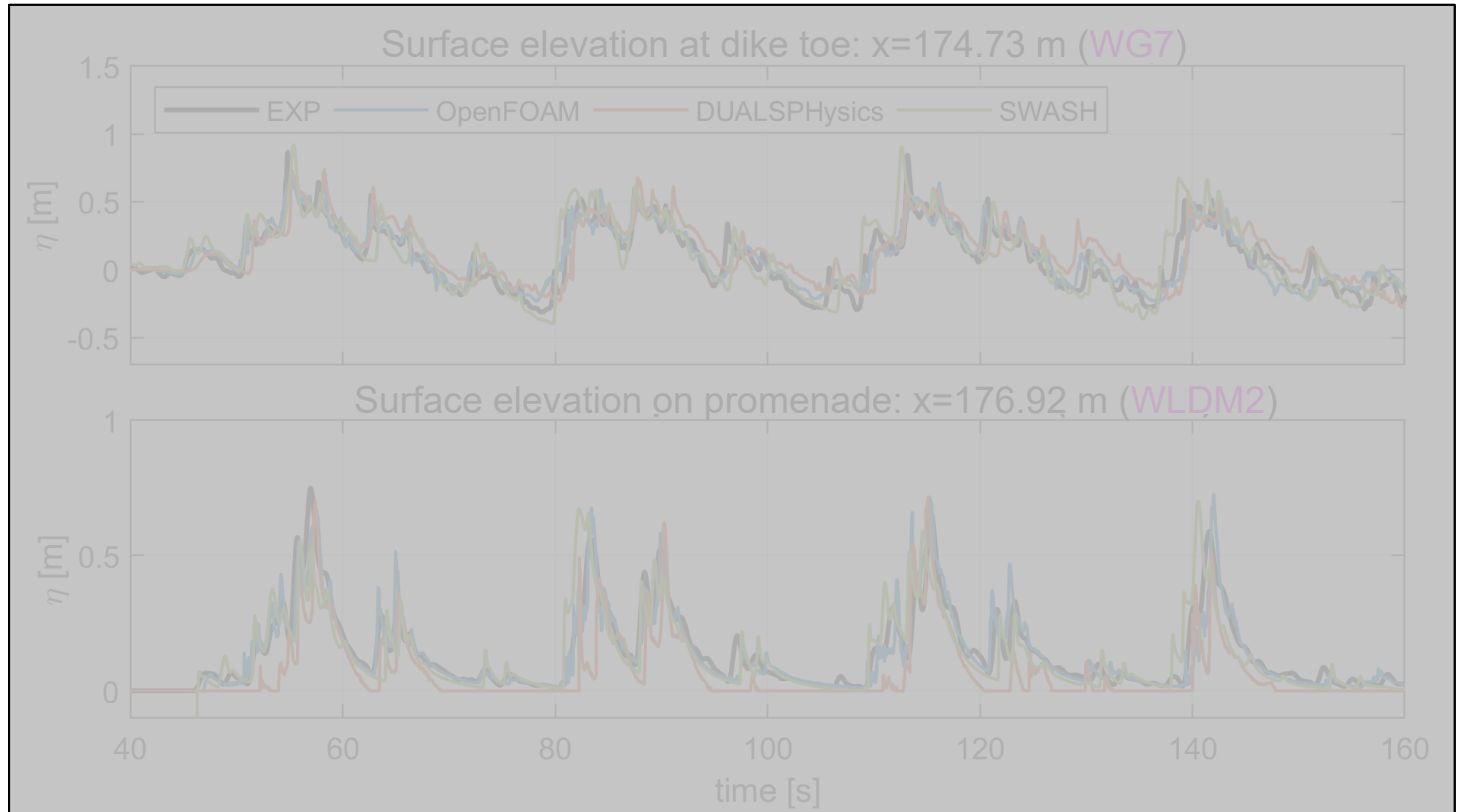
„Comparison of OpenFOAM, DualSPHysics and SWASH in terms of wave height at the dike toe, flow thickness & flow velocity and impact loads." [Gruwez et al. 2019]

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References

[**Cappietti, L**., Simonetti, I., Esposito, A., Streicher, M., Kortenhaus, A., Scheres, B., Schuettrumpf, H., Hirt, M., Hofland, B., Chen, X., 2018. Large-scale experiments of wave-overtopping loads on walls: Layer thicknesses and velocities. 37th International conference on ocean, offshore and arctic engineering, Madrid, Spain, p. 6.]

[**Gruwez, V.,** Altomare, C., Suzuki, T., Streicher, M., Cappietti, L., Troch, P., Kortenhaus, A., (in preparation). Applicability of different numerical models to wave impacts on sea dikes with shallow foreshore]

[**Saponieri, A.,** Di Risio, M., Pasquali, D., Valentini, N., Aristodemo, F., Tripepi, G., Celli, D., Streicher, M., Damiani, L., 2018. Beach profile evolution in front of storm seawalls: A physical and numerical study. 36th International conference on coastal engineering, Baltimore, US, p.13]

[**Streicher, M**., Kortenhaus, A., Gruwez, V., Hofland, B., Chen, X., Hughes, S., Hirt, M., 2018. Prediction of dynamic and quasi-static impacts on vertical sea walls caused by an overtopped bore. 36th International conference on coastal engineering, Baltimore, US, p. 15]

[**Streicher, M.,** Kortenhaus, A., Marinov, K., Hirt, M., Hughes, S., Hofland, B., Scheres, B., Schüttrumpf, H. 2019a. Process based classification of short-duration overtopped bores impacting a dike mounted vertical wall, *Coastal Engineering Journal*]

[**Streicher, M**., Kortenhaus, A., Altomare, C., Gruwez, V., Hofland, B., Chen, X., Marinov, K., Scheres, B., Schüttrumpf H., Hirt, M., Cappietti, L., Esposito, A., Saponieri, A., Valentini, N., Tripepi, G., Pasquali, D., Di Risio, M., Aristodemo, F., Damiani, L., Willems., M., Vanneste D., Suzuki, T., Klein Breteler, M., Kaste, D., 2017. "WALOWA (Wave Loads on Walls) – Large-scale experiments in the Delta Flume". Proceedings of the 8th SCACR conference 3rd – 6th October, Santander, Spain, p 11.]

[**Streicher, M.,** 2019b. Loads induced by overtopping bores on vertical walls at the end of sea facing promenades – A laboratory study. PhD thesis, Ghent University]

[**Kortenhaus, A**., Streicher, M., Gruwez, V., Altomare, C., Hofland, B., Chen, X., … Klein Breteler, M., 2019. WALOWA (WAve LOads on WAlls) - Large-scale Experiments in the Delta Flume on Overtopping Wave Loads on Vertical Walls. Zenodo. http://doi.org/10.5281/zenodo.2843140

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