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Physical scale modeling of tidal flow hydrodynamics at the port of Zeebrugge

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1. Introduction and problem definition

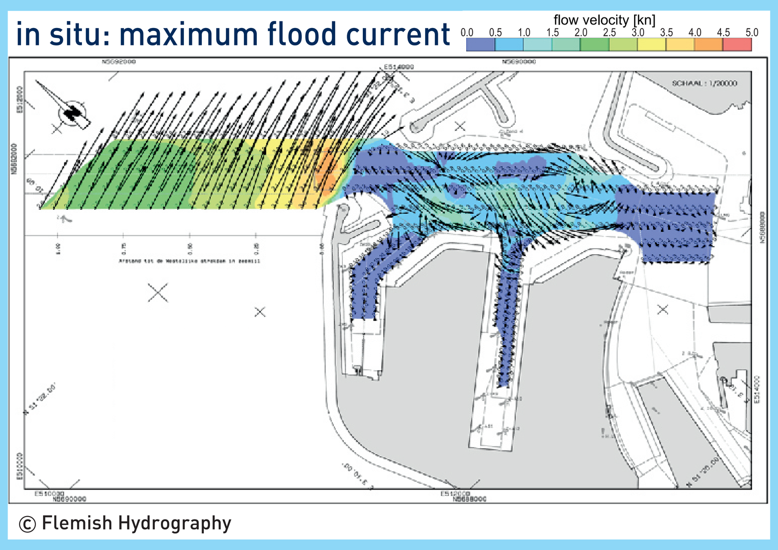
The port of Zeebrugge is a major port at the Belgium coast with direct access to the sea and partially located nearshore with two large breakwaters. Tidal variations in the North Sea play an important role in nearshore flow hydrodynamics and in the port of Zeebrugge. This study is crucial for the port due to its direct effects on actual port activities and future development.

Port of Zeebrugge

2nd port in Belgium (2013):
7651 ships; 42.8 million ton throughput;
2.03 million TEU containers; 1.94 million new cars;
LNG terminal: 15% of the Western European market;
Dredging activities: deepening navigation channel and outer port;
max ship draught 16 m.

Hydrodynamic conditions

High tidal range: spring tide: 4.30 m;
Strong tidal current across access channel: > 4 kn (> 2 ms^{-1}).
Criteria of safe navigation:
Containerships > 200 m: max cross flow 2 kn;
LNG carriers: max cross flow 1.5 kn.



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2. Optimization of maritime access of Zeebrugge and research methodology

The present study is part of the ongoing integrated research plan at the port of Zeebrugge initiated in 2009 at the request of the Maritime Access Division (Flemish Authorities)

- Safe navigation;
- Accessibility;
- Development of an integrated study approach:
  - Numerical models (hydrodynamics & sediment transport);
  - **Physical scale model (hydrodynamics);**
  - Ship simulator studies (real-time & fast-time).

3. Main objectives

(1) Better understanding of the existing flow/navigation problems in this region and near the port entrance;
(2) Determination of the best option to reduce tidal cross-currents at the port entrance;
(3) Assessment of the impact of the recommended design scenarios on navigation;
(4) Minimization of siltation rates inside the harbour and in the access channel;
(5) Providing data for improving numerical models of the complex water flow.

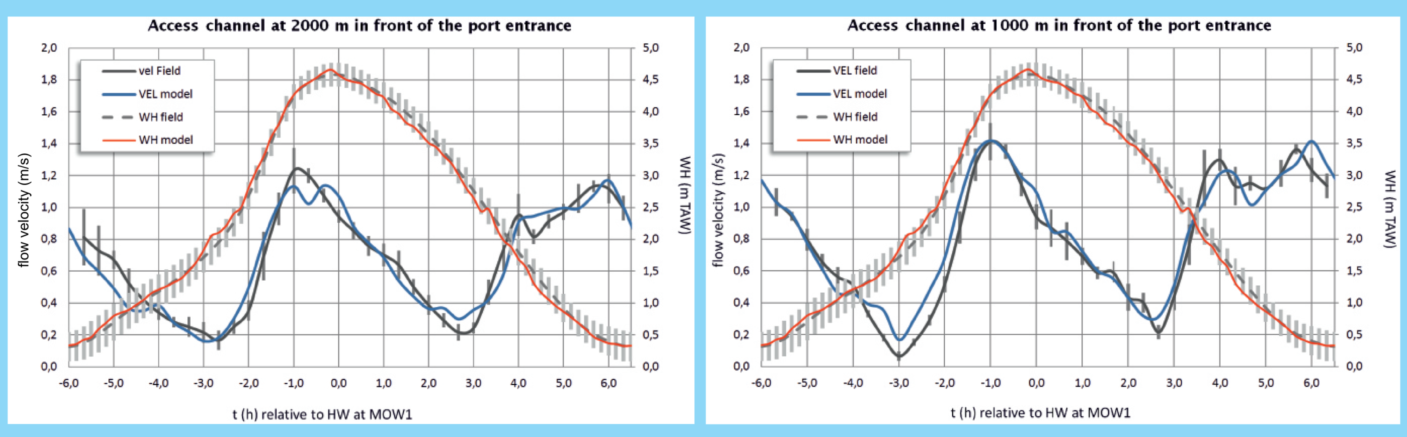
4. Zeebrugge physical scale model

• Large physical model (55m x 35m) • Scales : 1:300 horizontal and 1:100 vertical • Simulation of spring tidal flow • Model successfully calibrated (Willems et al., 2014) • New design scenarios (Hassan et al., 2014).

Measuring instruments • Water level: ultrasonic sensor • Velocity: electromagnetic velocity meter (u,v); particle tracking velocimetry (PTV).

5. Model calibration

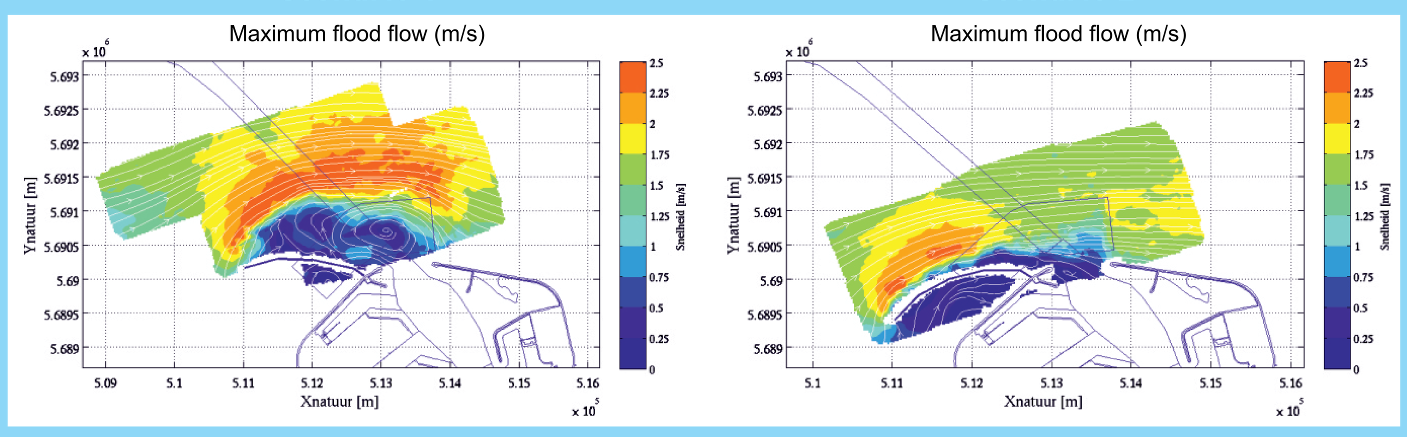
The figures show a comparison between the measured water levels and flow velocities of the calibrated model and prototype data at two different locations.



6. Tested scenarios in the physical model

- Existing situation;
- Excavated sand-pit in front of the port (10 m deep);
- New breakwaters at the eastern side of the port;
- New breakwaters at the western side of the port;
- Short breakwaters on both sides of the port.

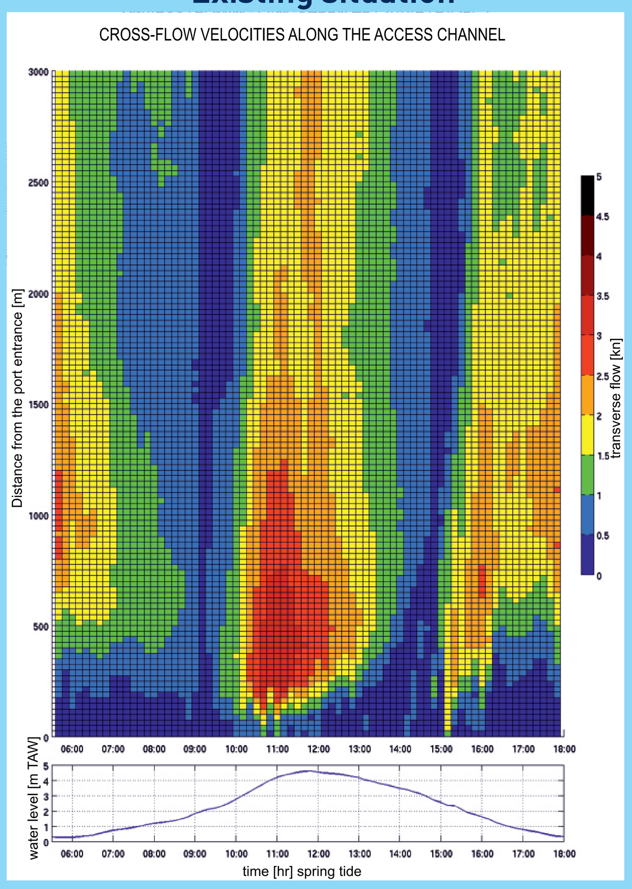
scenario 1 scenario 2



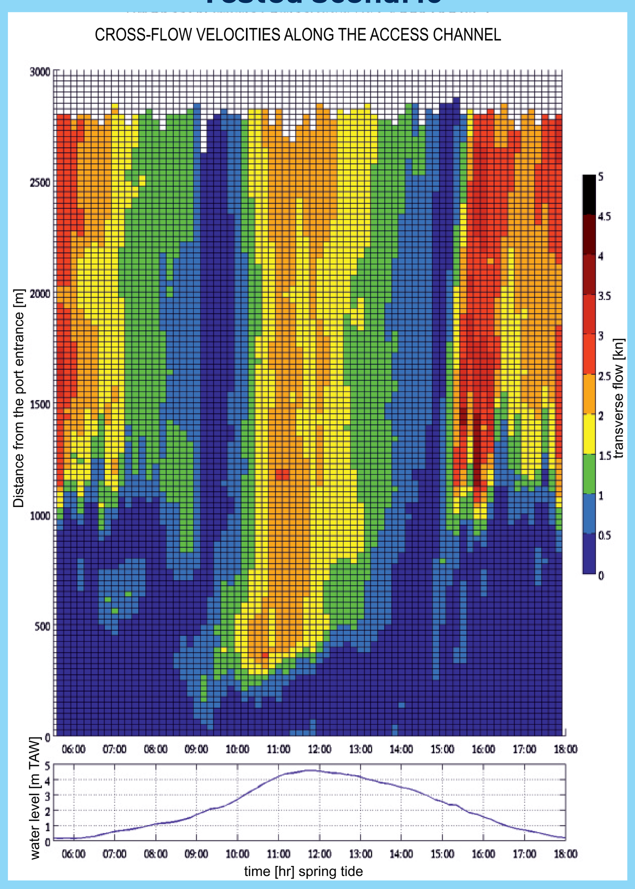
7. Overview of cross-flow velocities along the access channel

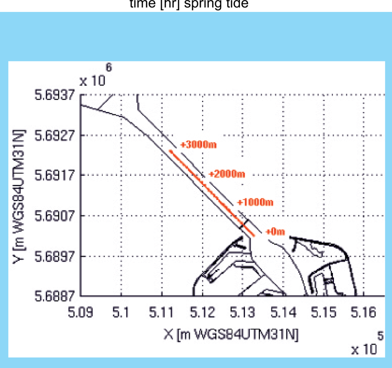
The maximum cross-flows (in knots) at the center line of the navigation channel during the full tidal cycle of the existing situation. In these figures we can easily identify the unsafe sailing windows (cross-flow velocities > 2 knots) in which ships cannot enter the port. Similar plots were produced for all tested scenarios to examine the main differences between all layouts.

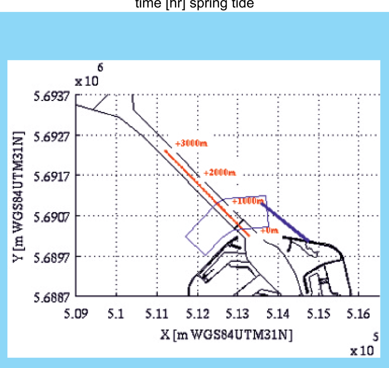
Existing situation



Tested scenario







8. Conclusions

- A distorted physical scale model was constructed and successfully calibrated at Flanders Hydraulics Research (Willems et al., 2014) using the hydrodynamic prototype data (Vlaamse Overheid Afdeling Kust, 2011) of the spring tidal cycle;
- The main goal of the study is to find the best layout to reduce the magnitude of the cross-flows in the access channel close to the port entrance (nearest 2 km);
- Excavating a deep sand-pit (10 m below the original sea bed) leads to a general reduction of the flow velocity close to the port entrance;
- In general scenarios with long breakwaters lead to shifting the position of the high flow velocities in seaward direction;
- Scenarios with long breakwaters at the eastern side of the port reduce considerably flow velocities during the flood phase in front of the port entrance(≈1000 m), but at the same time lead to higher velocities during the ebb phase;
- Long breakwaters on the western side of the port generate higher velocities during flood flow and lower flow velocities during ebb flow at about 1500 m from the port entrance.

References

Hassan W., Willems M. and Troch P. 2014. A detailed hydrodynamic study on tidal flow at the port of Zeebrugge. 5th International conference on the application of physical modelling to port and coastal protection - Coastlab14, 29 Sep 2014 – 02 Oct 2014, Varna, Bulgaria.

Willems M., Hassan W. and Heyvaert G. 2014. Calibration of the large physical model of the port of Zeebrugge. 3rd IAHR Europe Congress, book of proceedings, 2014, Porto–Portugal.