European Geosciences Union
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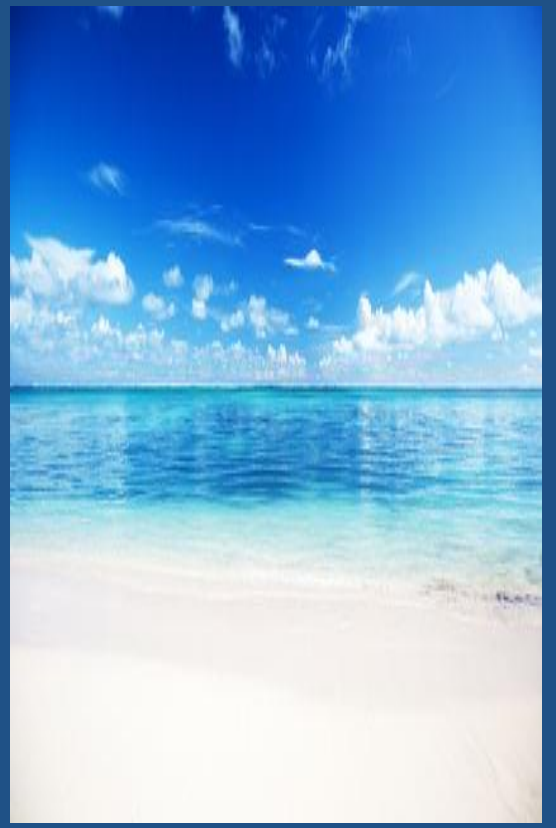
Vienna | Austria | 23–28 April 2017

The Investigation of Form and Processes in the Coastal Zone under Extreme Storm Events

The case study of Rethymno - Greece



Vasileios Afentoulis , Vasiliki Tsoukala - Laboratory of Harbour Works, National Technical University of Athens, Greece
Bijan Mohammadi - Institut Montpelliérain Alexander Grothendieck,Université de Montpellier, France

Methodology

- Definition of the Case study
- Climate conditions
- Numerical Simulation of Extreme Wave Events
- Identification of Hazard Areas
- Proposed Solutions

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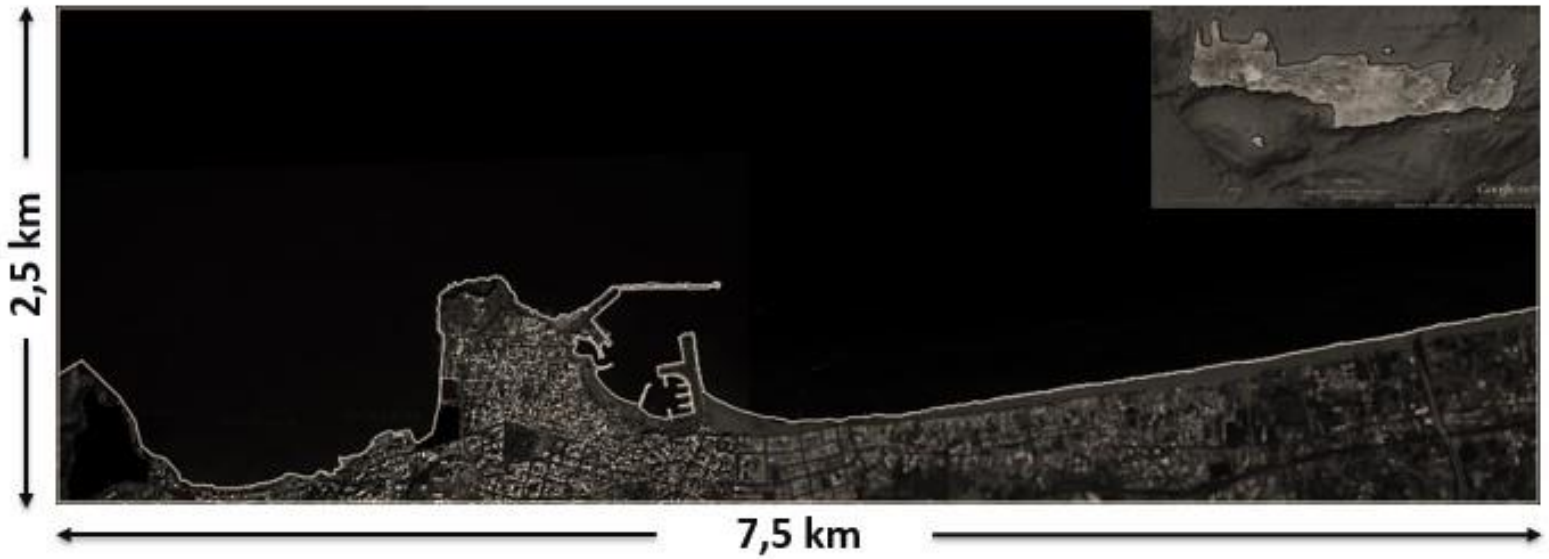
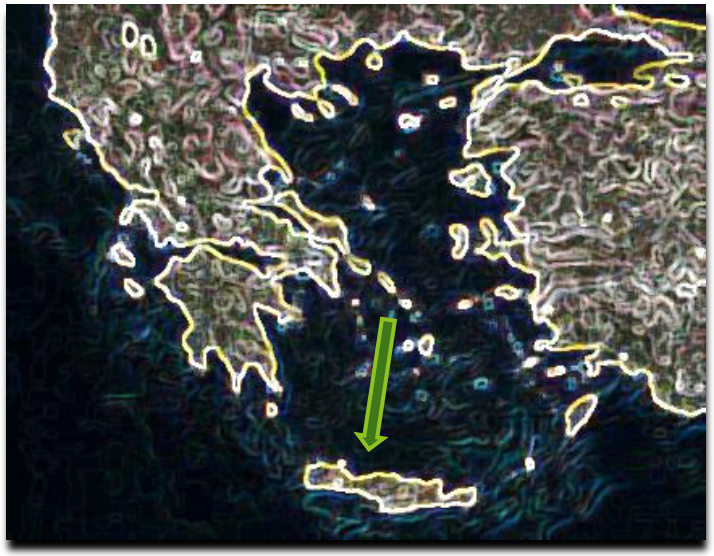
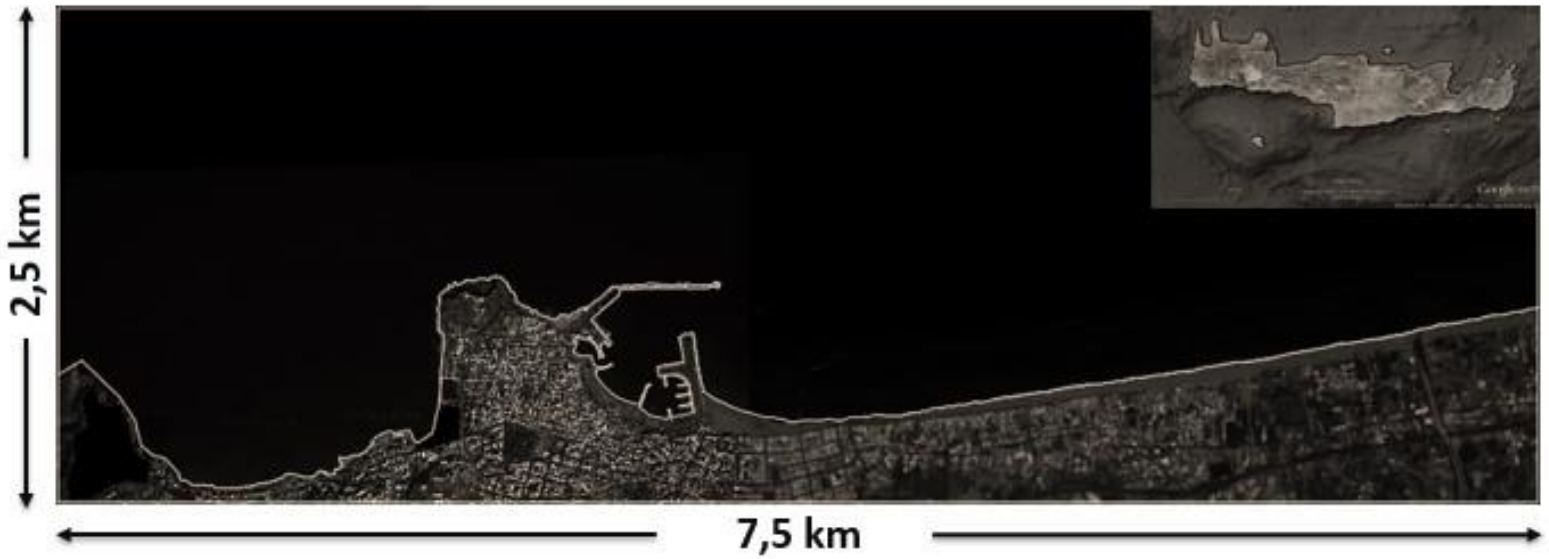
Case Study : Rethymno Crete





Case Study : Rethymno Crete



Location	Rethymno, Crete Greece
Demographics	3rd most populous urban area in Crete
Population	32.468 (census, 2011)
Total area	2,8 km^2
Length along the coastline	8,0 km
Mean absolute altitude	15,0 m

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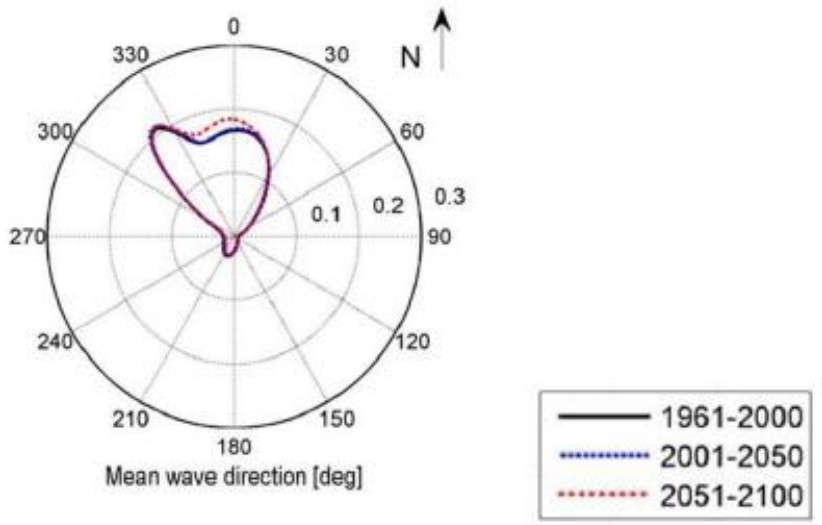
Wave and Climate Conditions

Characteristics of equivalent annual waves (Karabas et al., 2010)		
Direction	**He (m)**	**Te (m)**
NW	1.86	6.45
N	2.19	6.83
NE	2.10	6.77

- A storm is defined as the event exceeding a minimum significant wave height (e.g. Hs > 2 m) and with a minimum duration of 6 h.
- The threshold of significant wave height (Hs) is considered to be 2 m in order to describe rare events with only 10% of total wave heights and thus defined as the 90th percentile of the data set. (Tsoukala et al., 2016)

Characteristic storm events simulated						
Scenario	**Direction**	**Hs range (m)**	**Tp range (s)**	**Hs Average (m)**	**Tp Average (s)**	**Event Duration (h)**
1	N	2.01-4.61	6.71-9.28	2.86	7.85	103.5
2	N	2.46-4.95	7.84-9.65	4.18	9.07	72
3	NW	2.43-3.03	7.41-8.16	2.79	7.87	39
4	NE	2.07-2.66	6.78-8.96	2.41	8.16	24



Wave and Climate Conditions

Impact of Extreme Storm Events

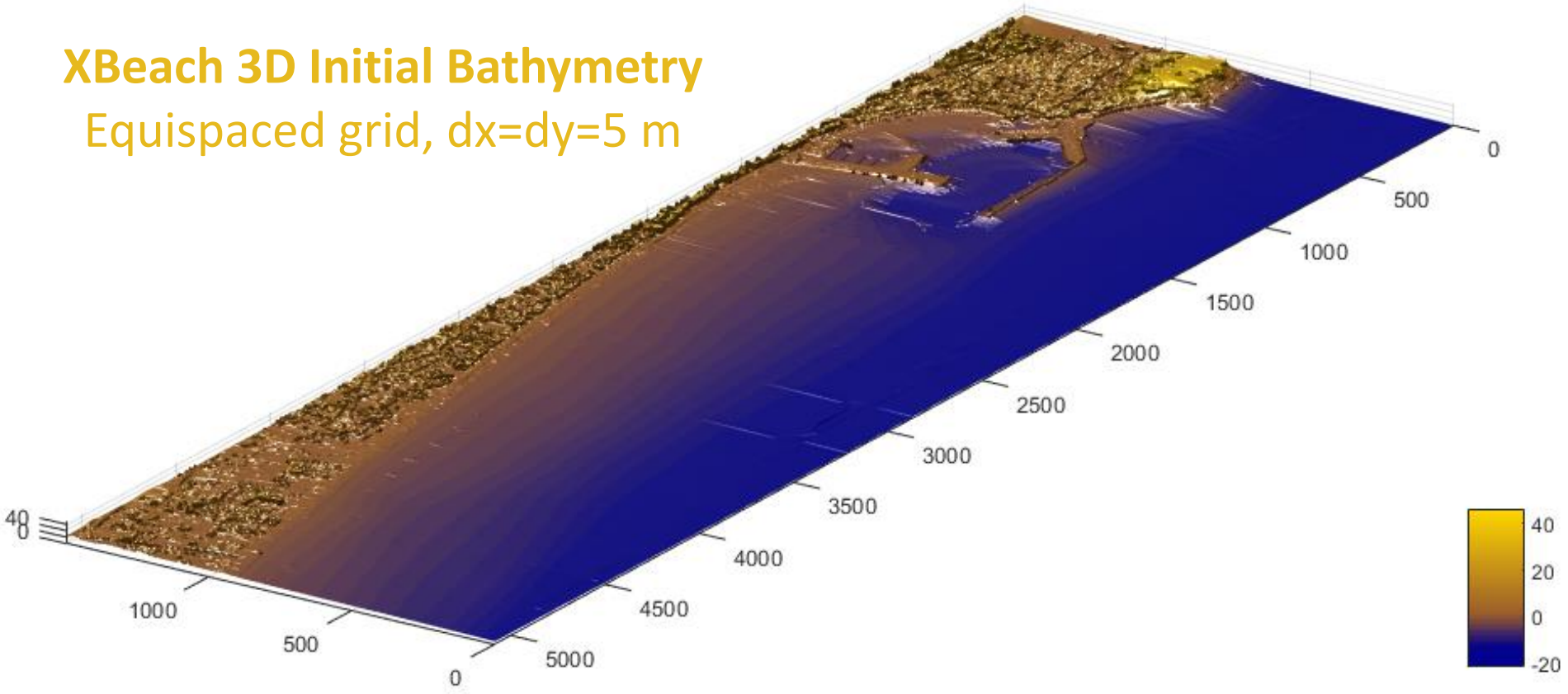
- Flooding and Serious damages in the Old Town of Rethymno
- Significant Erosion of the Shoreline

Recent Recorded Extreme Storm Events	Date
1	03/12/2013
2	11/12/2013
3	18/3/2014
4	24/10/2014
5	15/01/2015
6	10/02/2015

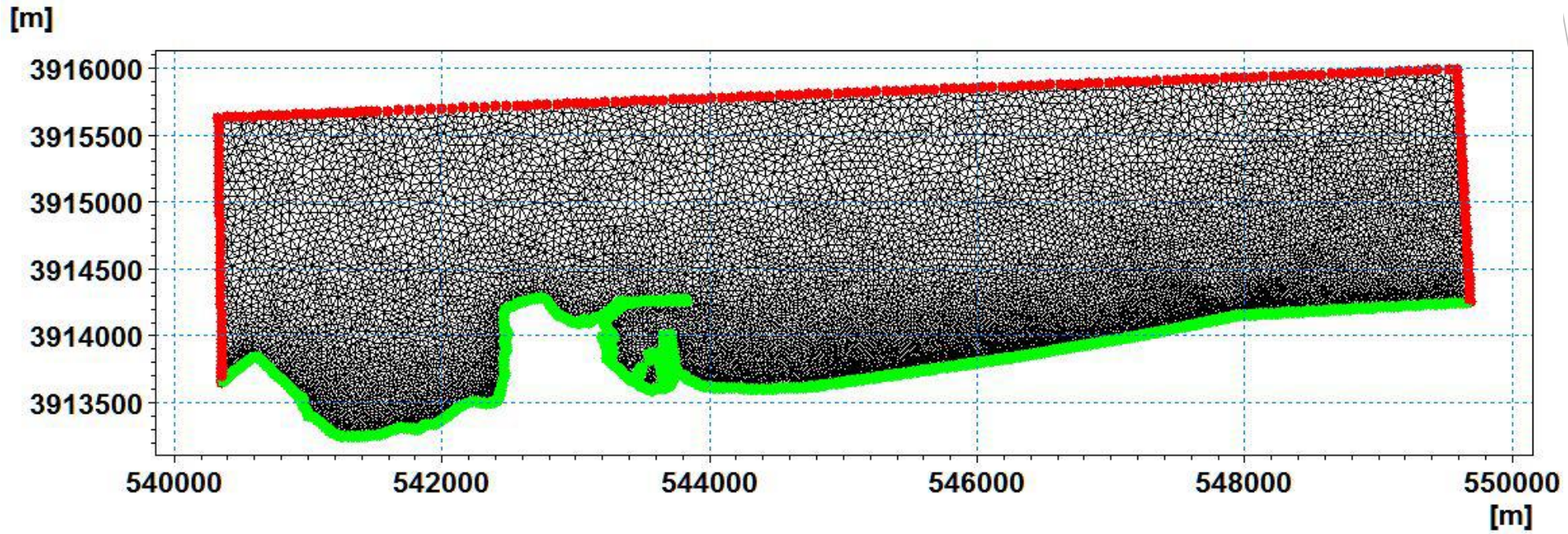
Model Applications

XBeach 3D Initial Bathymetry

Equispaced grid, dx=dy=5 m

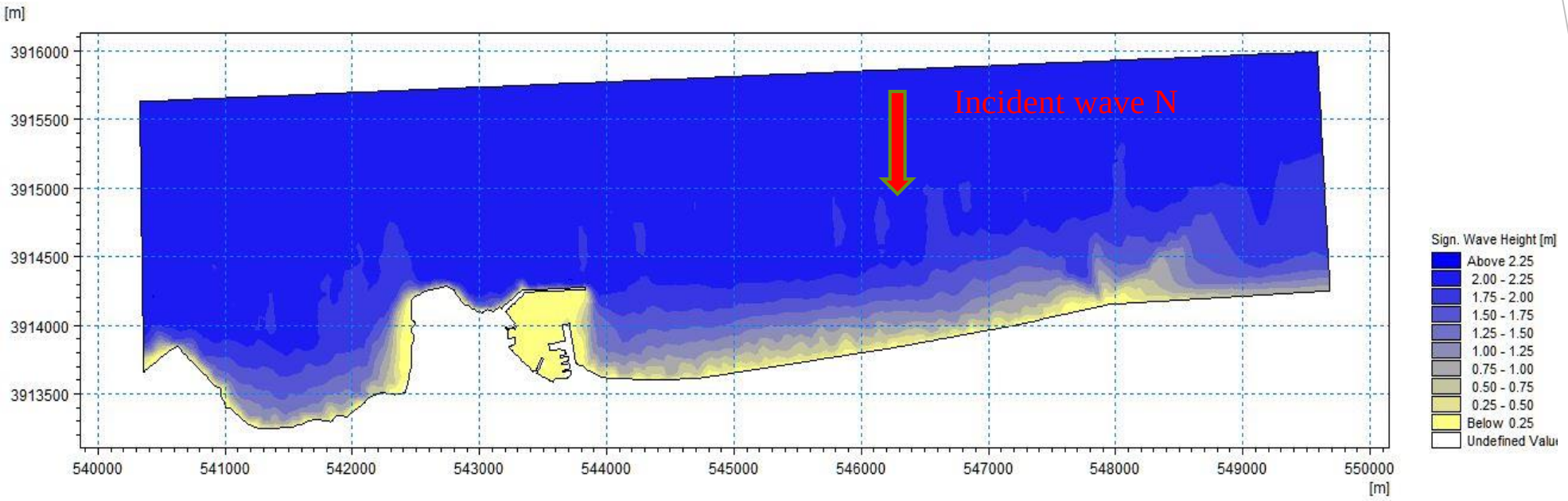


Model Applications



Mike 21 Unstructured Mesh with Boundary conditions

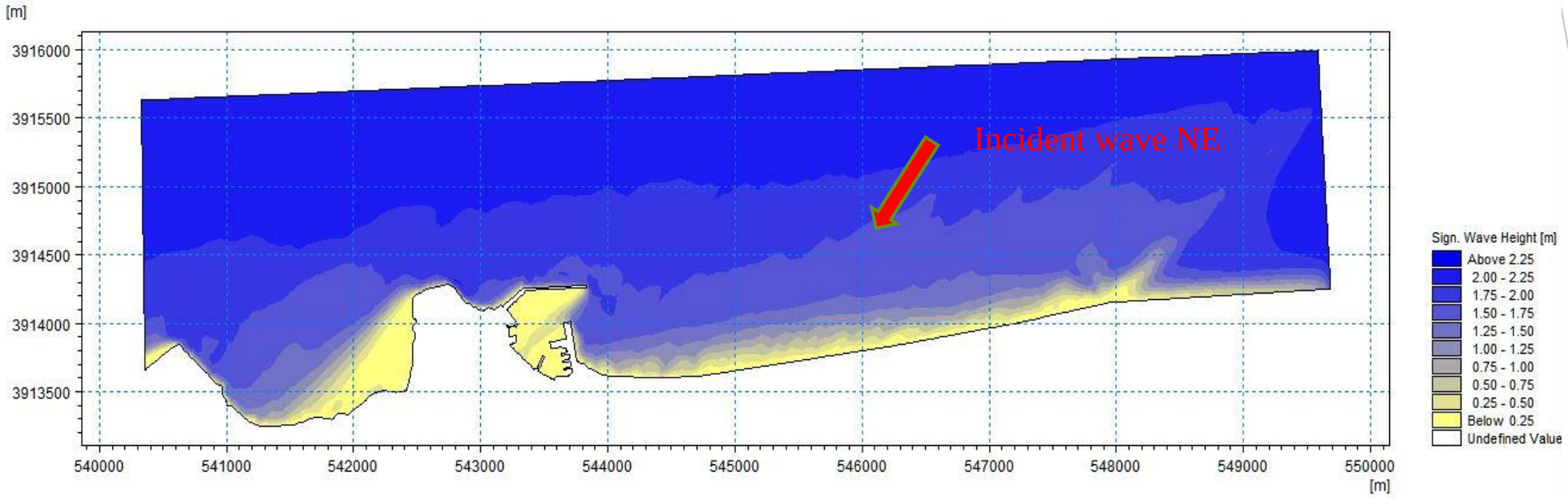
Model Applications



Scenario 2
Direction N
Duration 72h

Sign. Wave Height [m] - Mike 21 SW

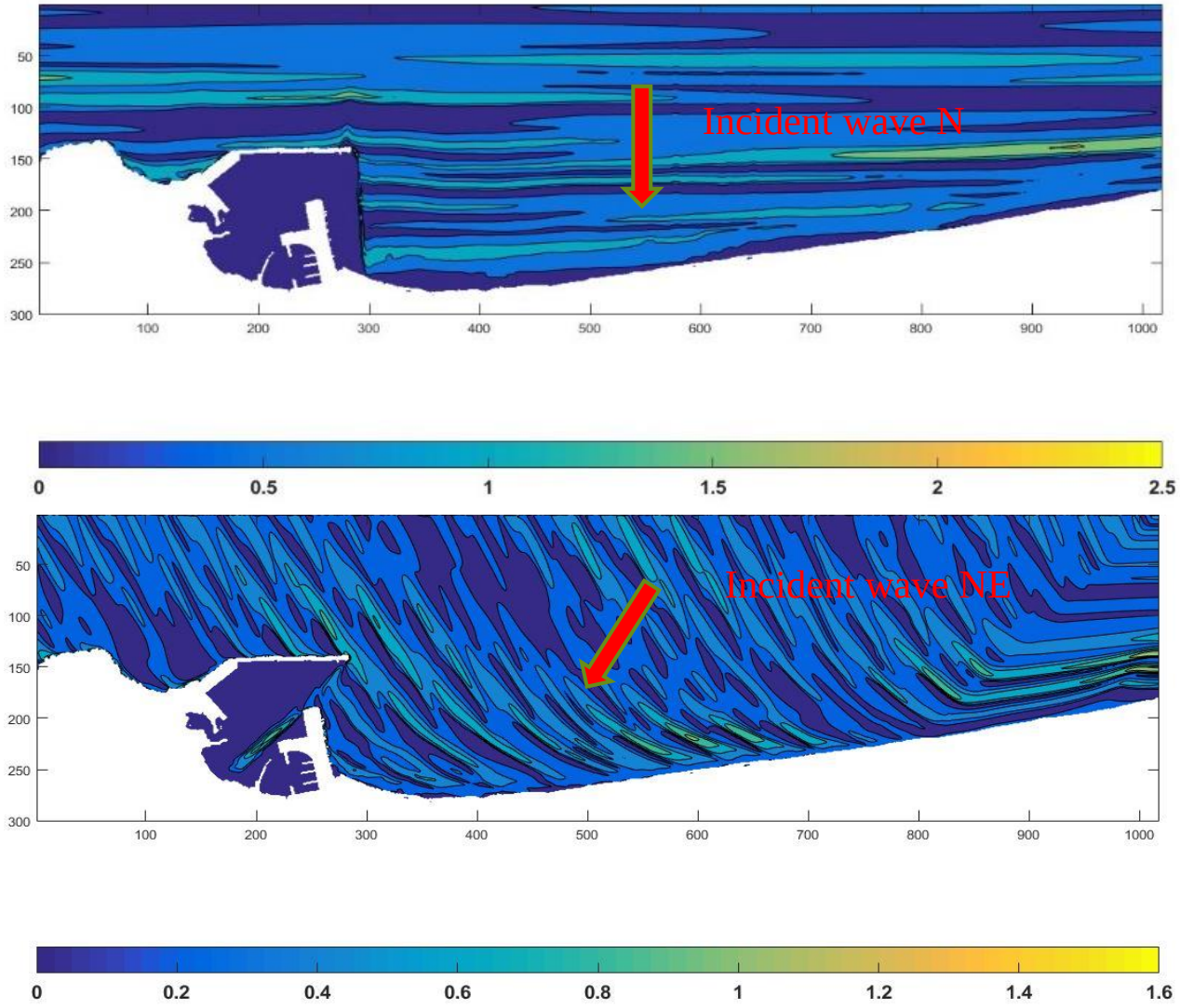
Model Applications



Scenario 4
Direction NE
Duration 24h

Sign. Wave Height [m] - Mike 21 SW

Model Applications



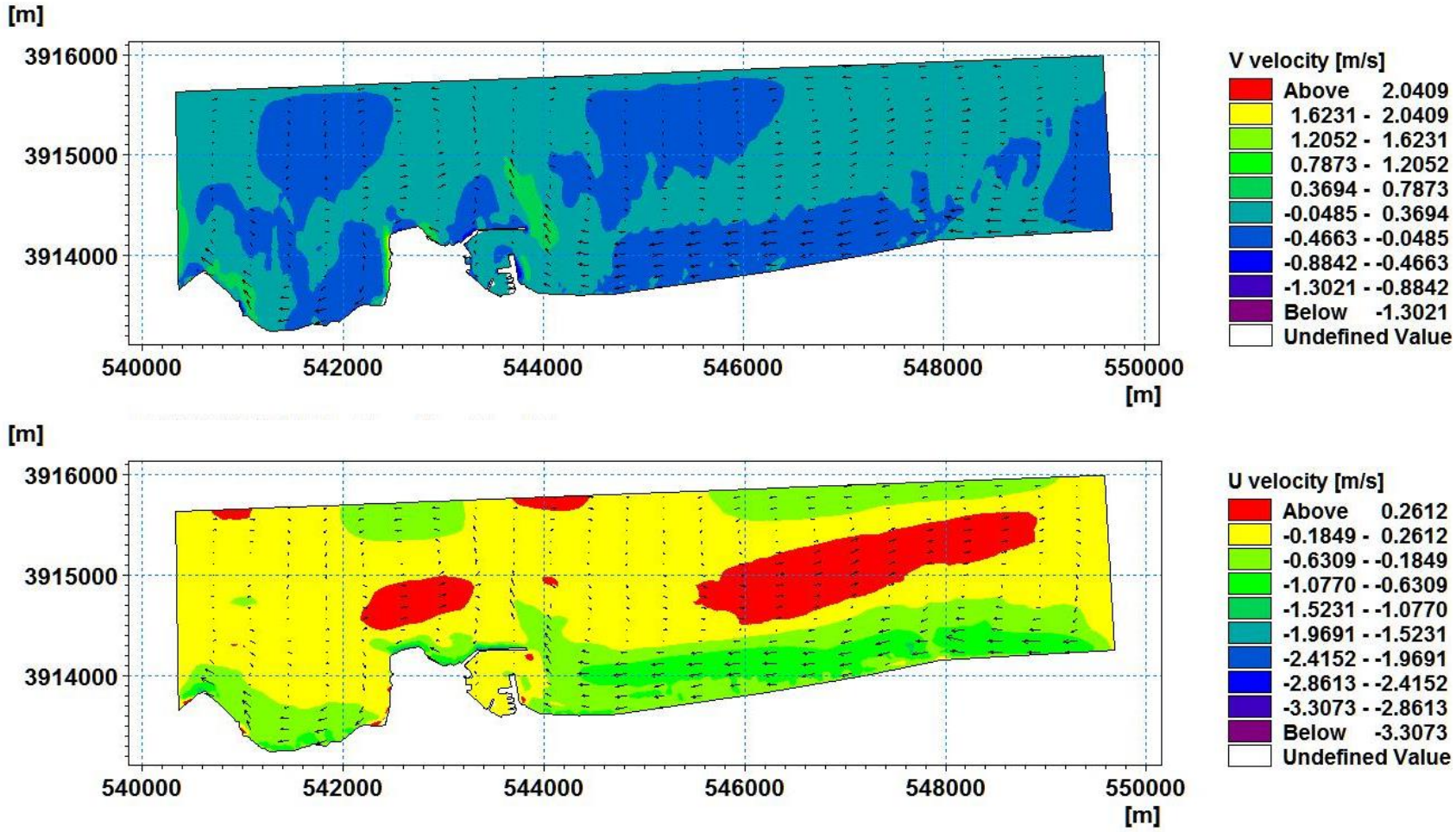
Scenario 2
Direction N
Duration 72h

Sign. Wave Height [m]
XBeach Model

Scenario 4
Direction NE
Duration 24h

Model Applications

Current velocities along x, y directions

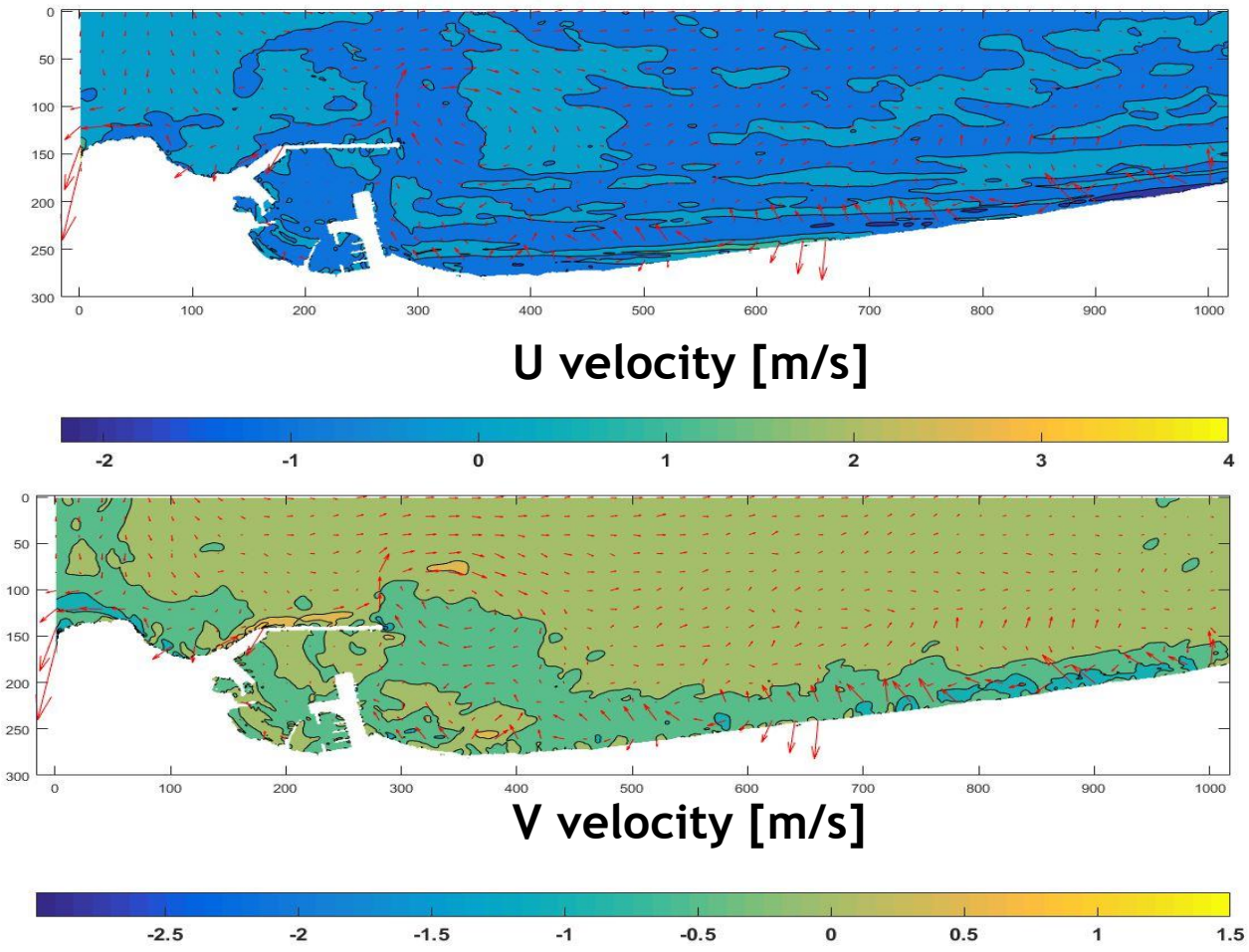


Mike 21 Flow Model

Scenario 2
Direction N
Duration 72h

Model Applications

Current velocities along x, y directions



XBeach Model

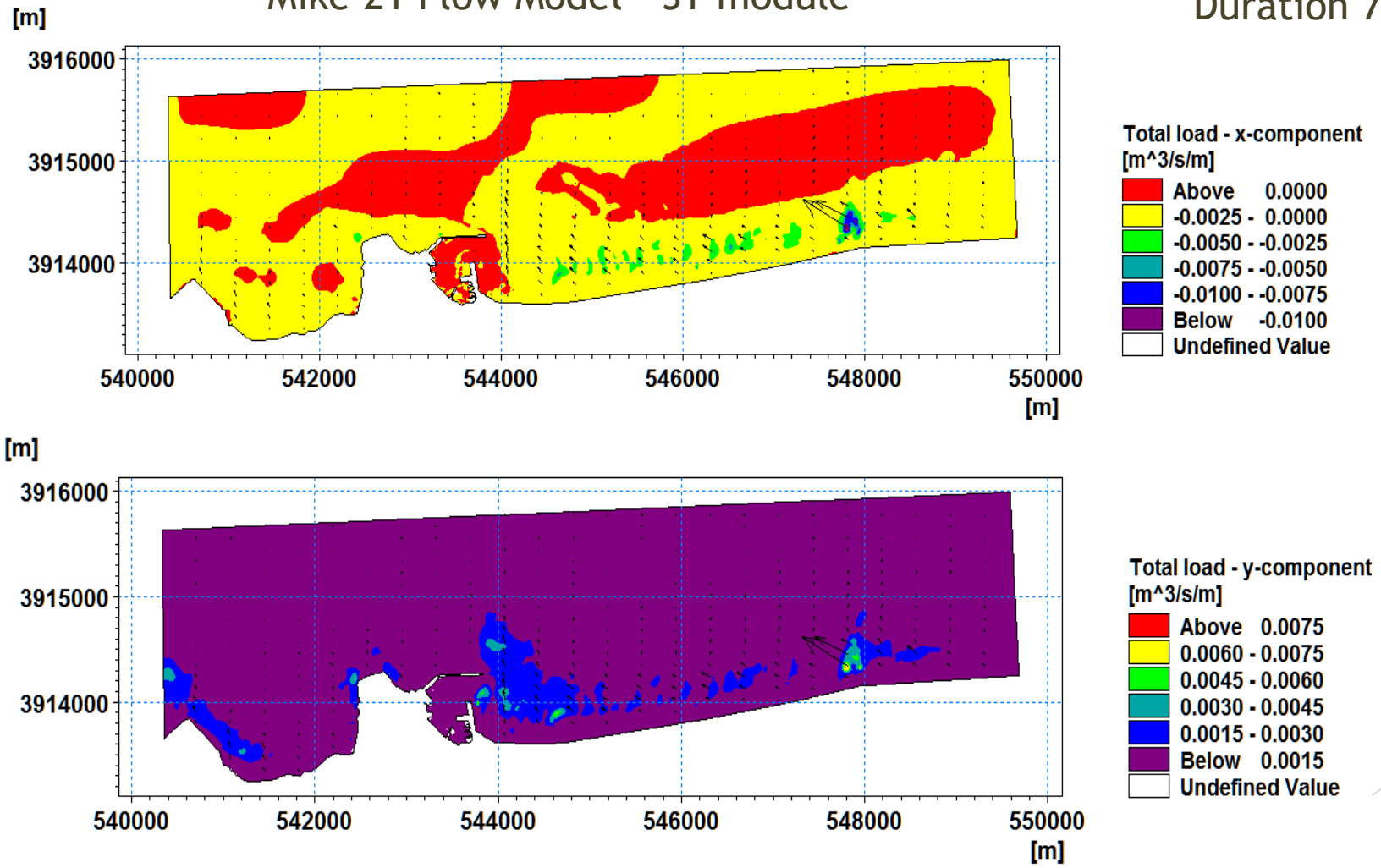
Scenario 2
Direction N
Duration 72h

Model Applications

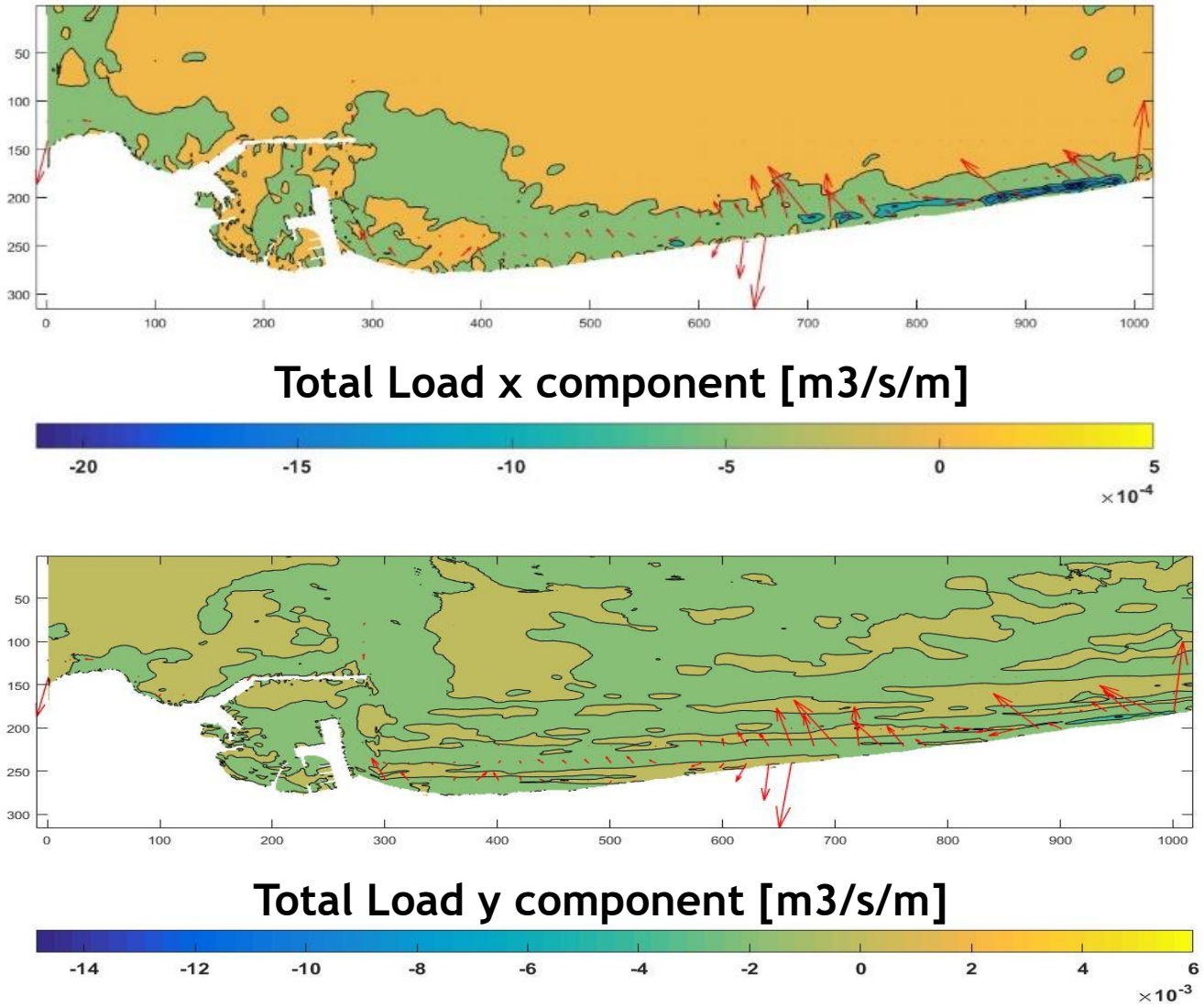
Total load along x, y directions

Mike 21 Flow Model - ST module

Scenario 2
Direction N
Duration 72h



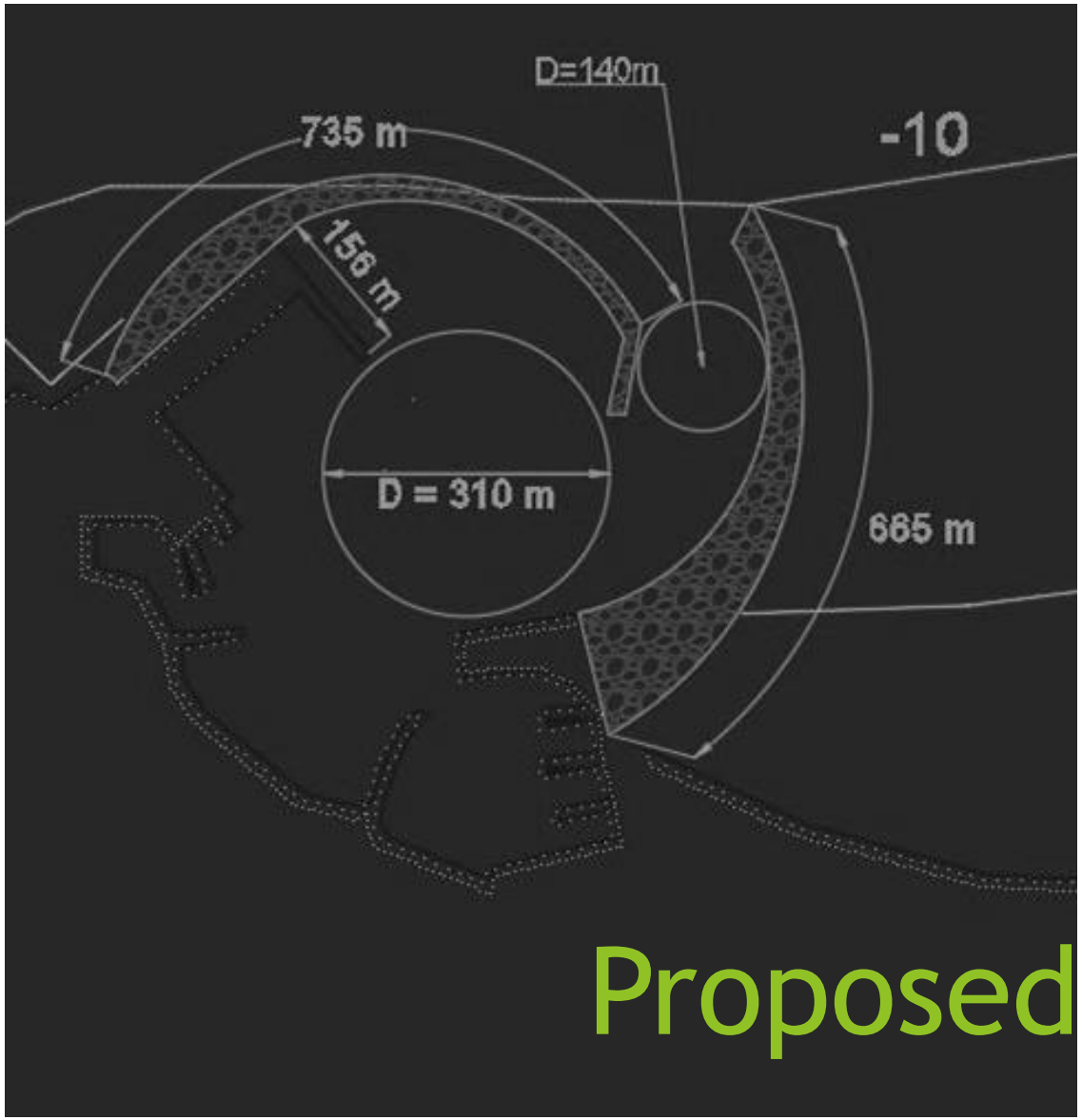
Model Applications



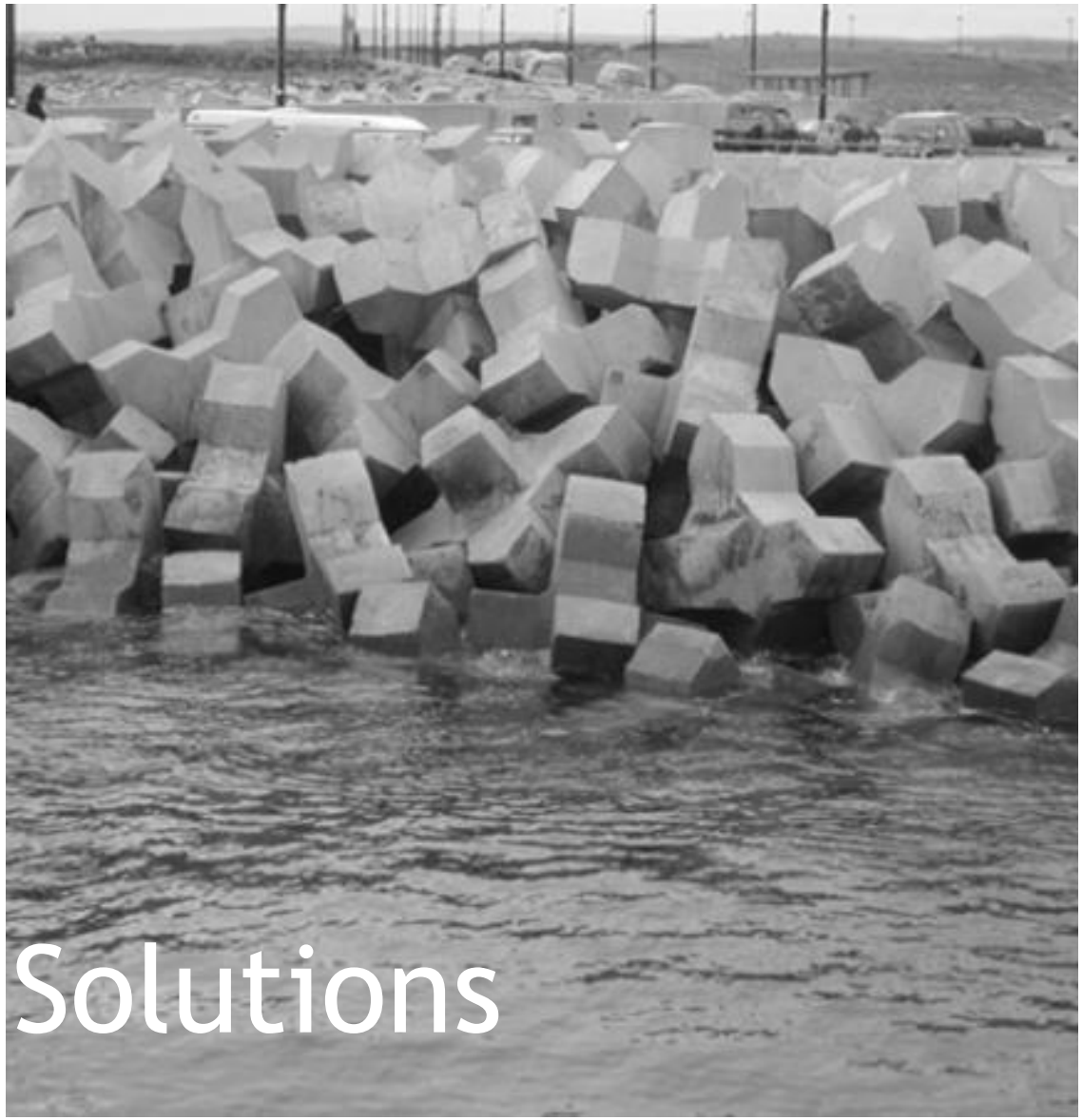
XBeach Model

Scenario 2
Direction N
Duration 72h

Identification of Vulnerable areas



Proposed Solutions



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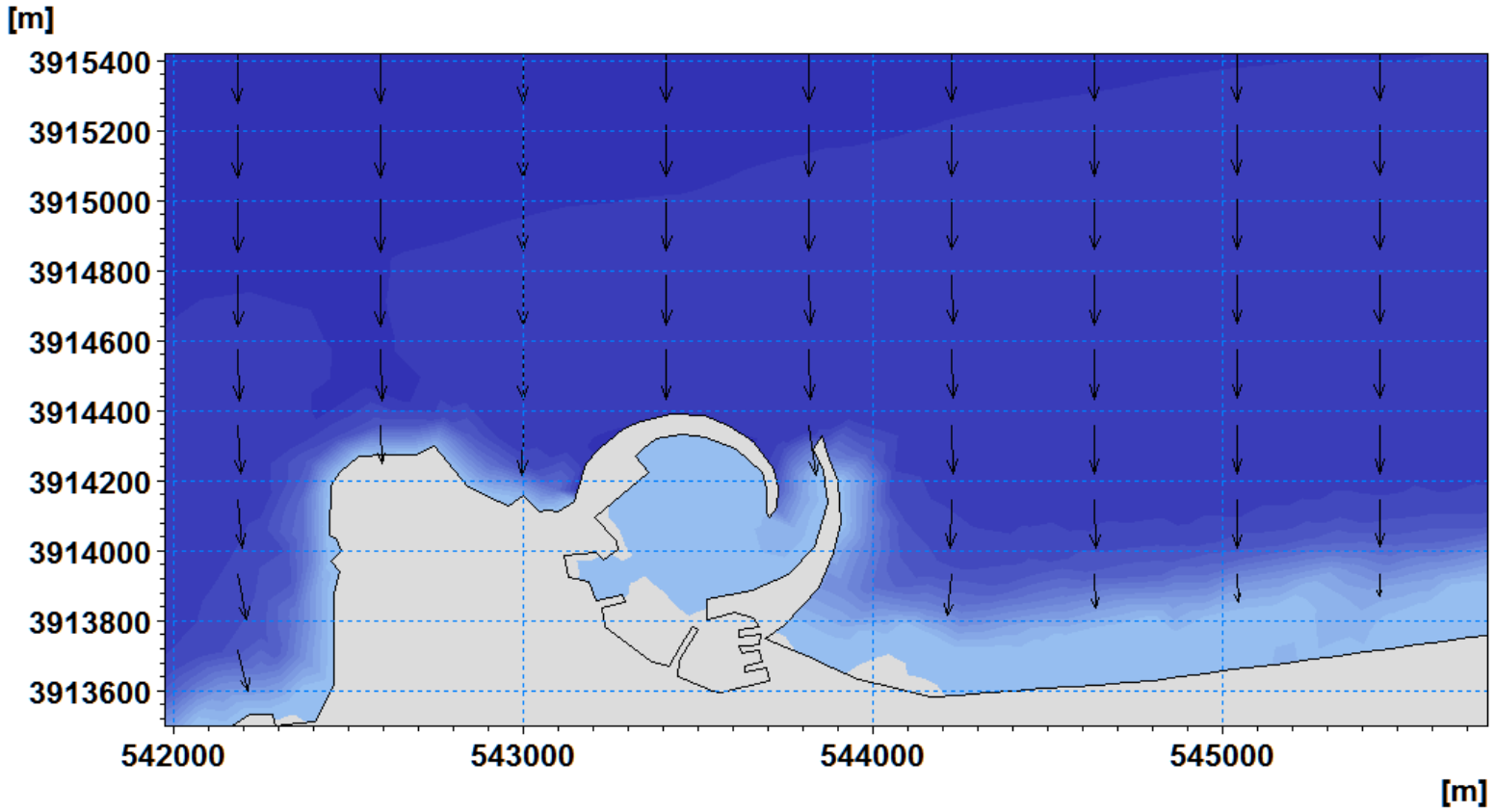
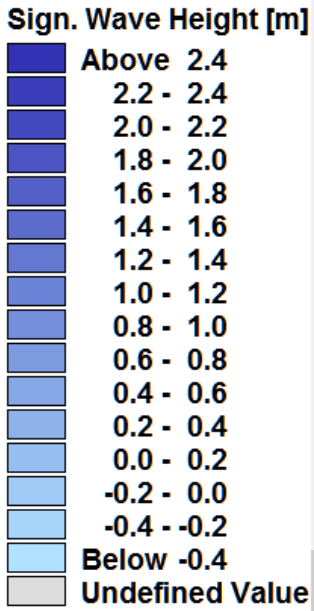
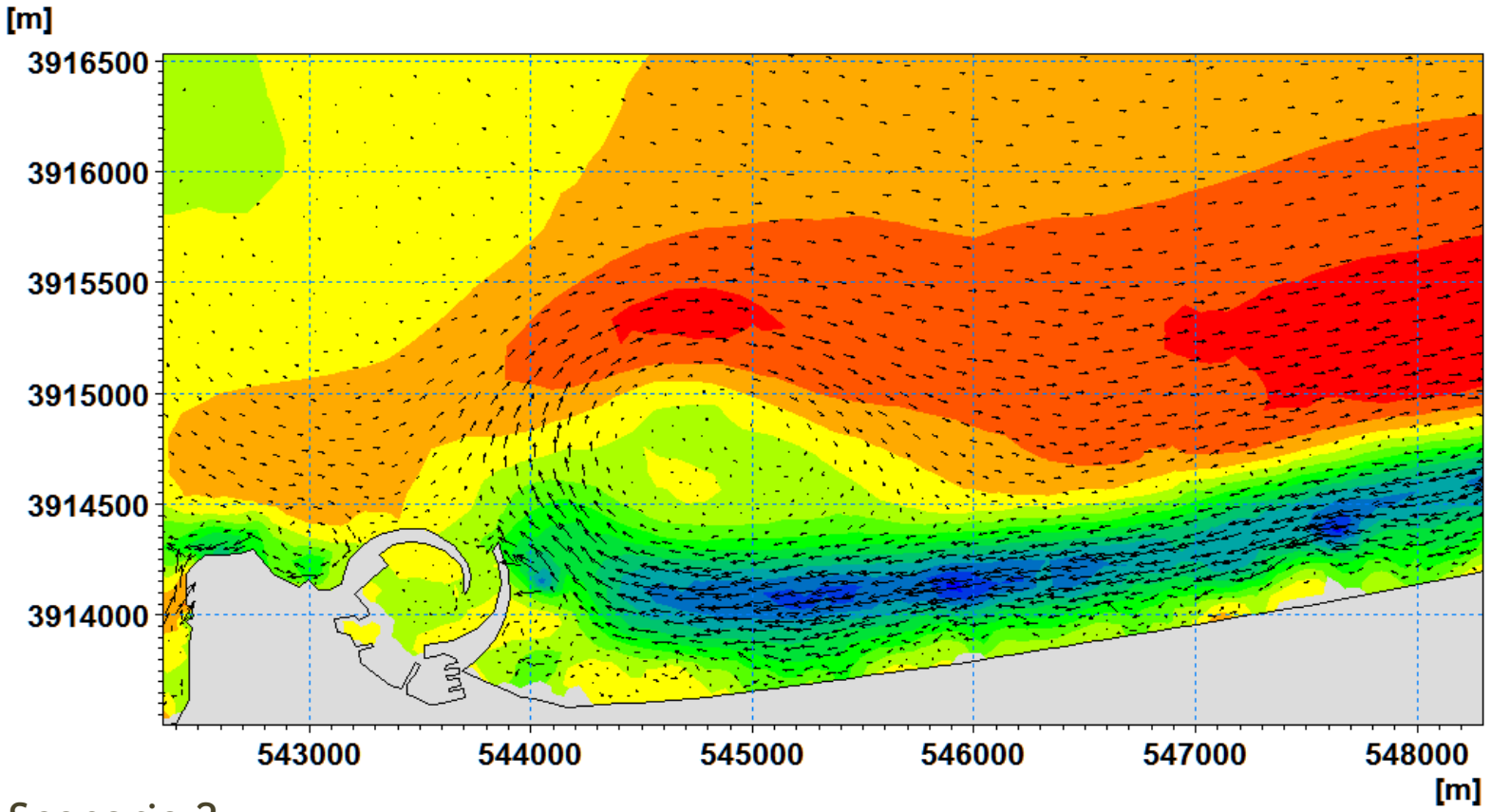


Mike 21 SW Model

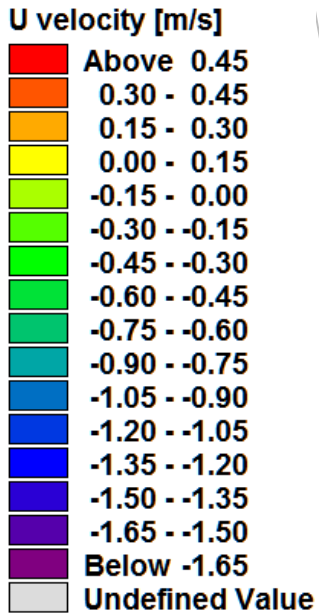


Scenario 2
Direction N
Duration 72h

Proposed Solutions



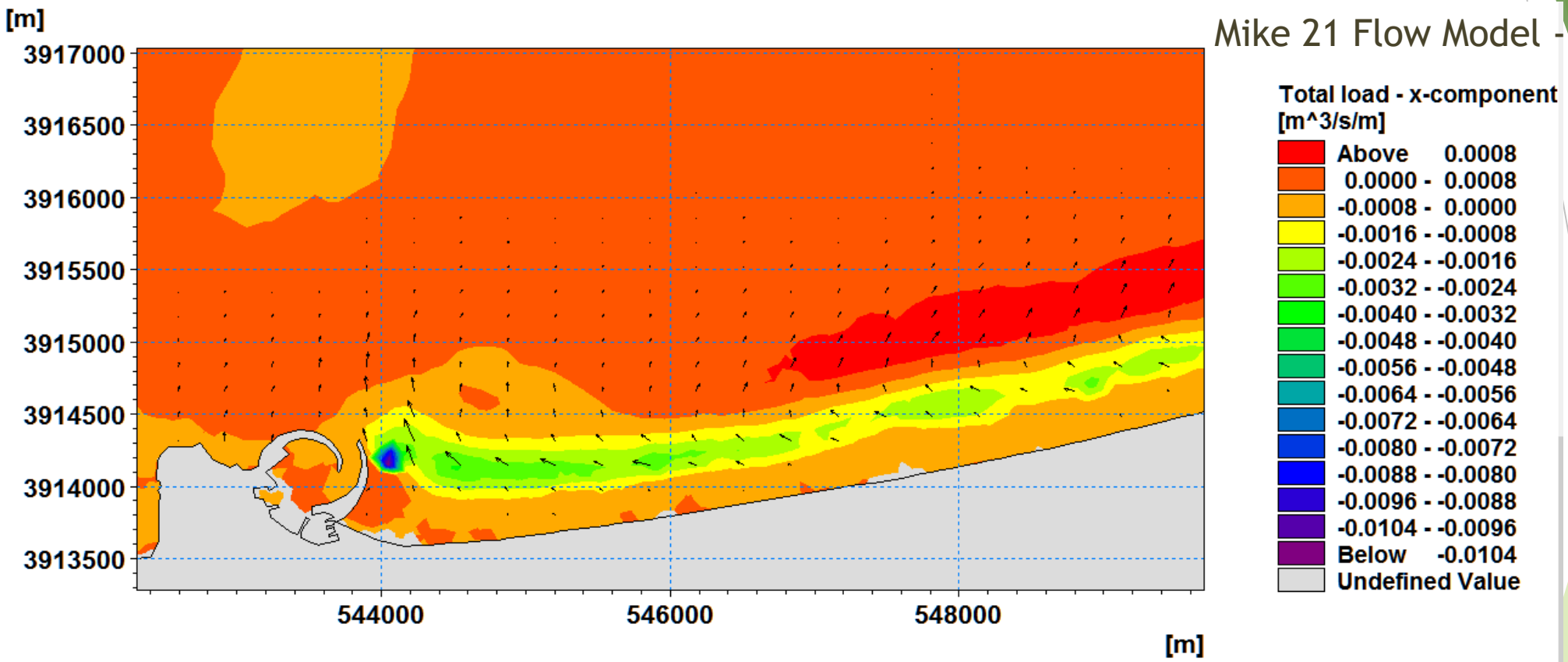
Mike 21 FM Model



Scenario 2
Direction N
Duration 72h

Current velocities along x direction

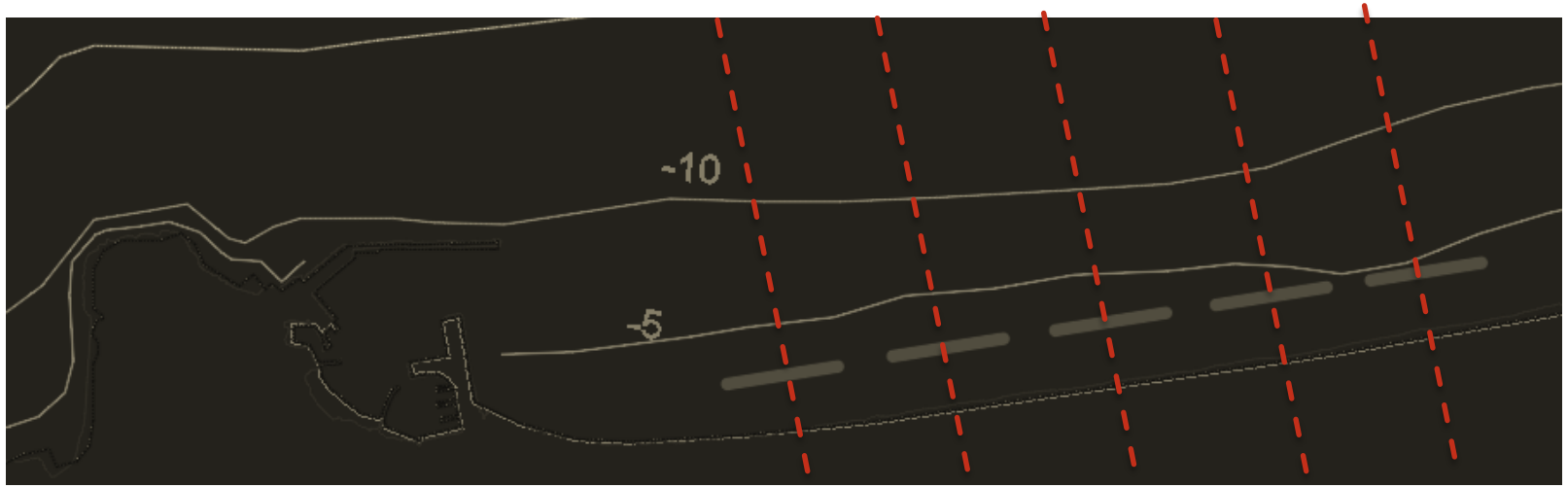
Proposed Solutions



Scenario 2
Direction N
Duration 72h

Total Load along x direction

Proposed Solutions
Shape Optimization of Detached Breakwater System



Simulation of the Bottom evolution Using a sophisticated Numerical Model developed by Afaf Bouharguane and Bijan Mohammadi (2013)

Proposed Solutions
Shape Optimization of Detached Breakwater System

Saint-Venant Equations

$$\begin{pmatrix} u \\ hu \\ hu \end{pmatrix}_t + \begin{pmatrix} hu \\ hu^2 + \frac{1}{2}gh^2 \\ huv \end{pmatrix}_x + \begin{pmatrix} hv \\ huv \\ hv^2 + \frac{1}{2}gh^2 \end{pmatrix}_y = \begin{pmatrix} 0 \\ -gh\psi_x \\ -gh\psi_y \end{pmatrix}$$

$$J(\psi) = \int_\Omega \frac{1}{2}\rho_w g A^2 d\omega + \int_{t-T}^{t} \int_\Omega \rho_s g(\psi(\tau) - \psi(t-T))^2) d\tau d\Omega$$

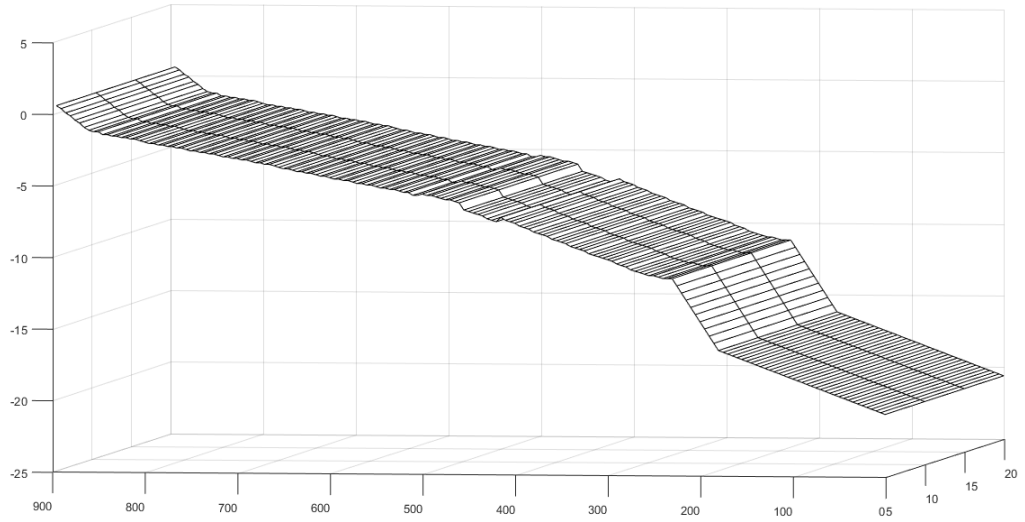
Ω : the physical domain
ρ_w : water density
ρ_s : sand density
$A(x, y, \psi) = max_{t\in[t-T,t]}(\eta((x, y, \psi, t))$

minimization of J can be seen as a solution of

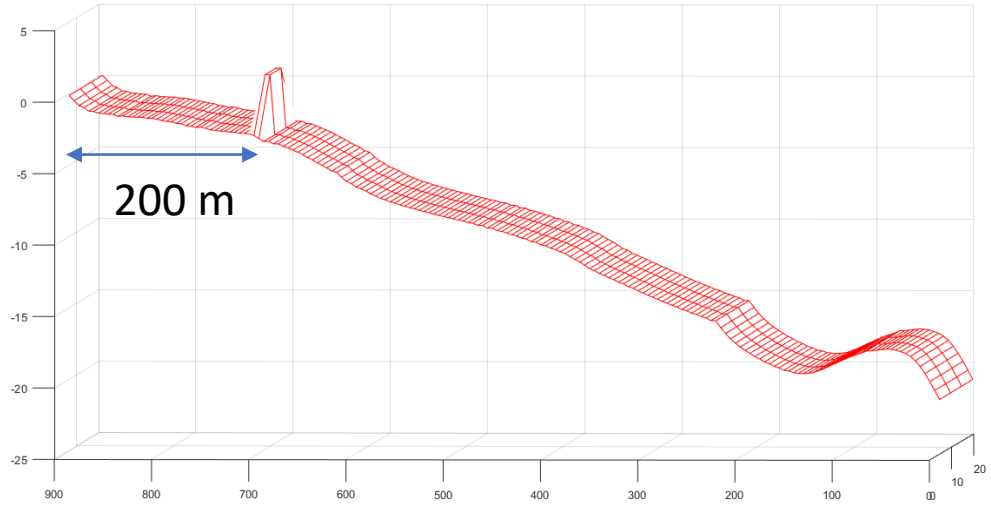
$$\begin{cases} \partial_t \psi = -\rho(t,x)\nabla_\psi J(\psi) \\ \psi(t=0,x) = \psi_0(x) = given \end{cases}$$

[Bouharguane A., Mohammadi B. (2013)]
[Mohammadi B., Bouchette F. (2013)]

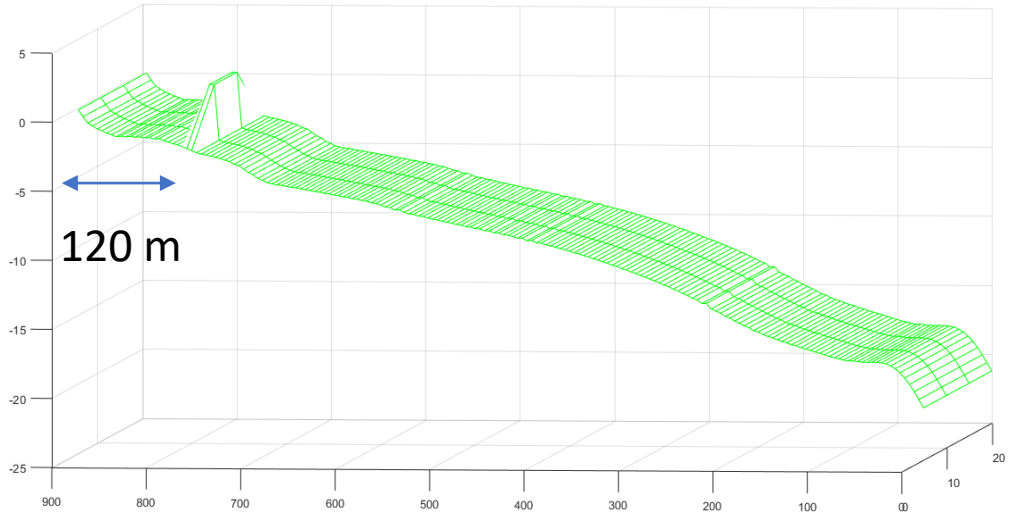
Initial



Scenario 2 Direction: N - Duration: 72h



Scenario 2 Direction: N - Duration: 72h



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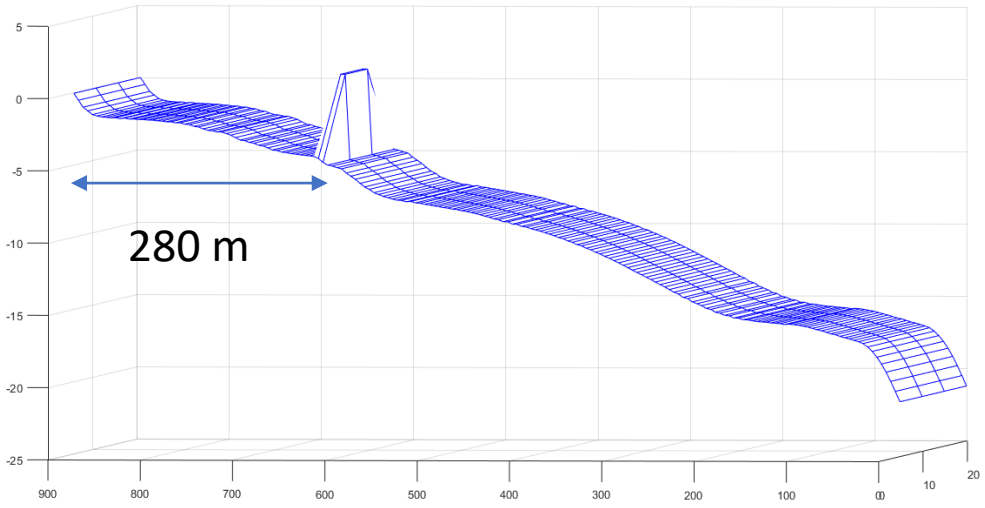
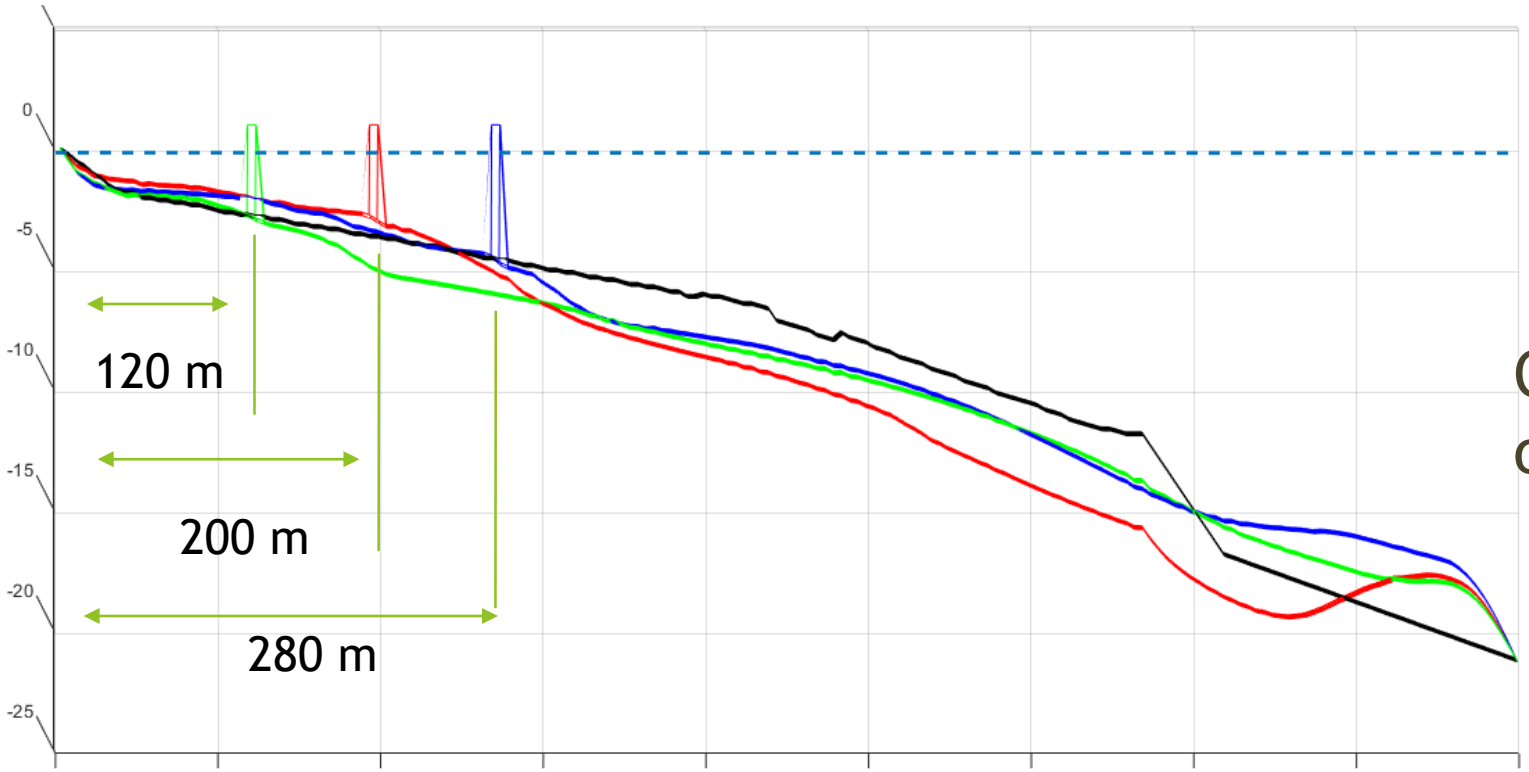


Proposed Solutions
Shape Optimization of Detached Breakwater System



Overview Diagram of Bed Evolution

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Acknowledgement

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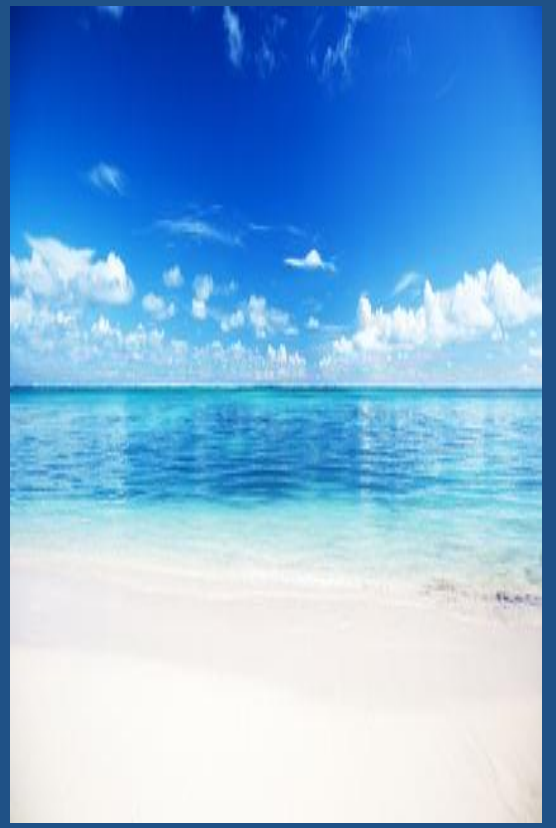
Thank you for your attention



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