Restoration of Lake Erie Seawall to Accommodate Climate Change

Matthew Power, Coastal Engineer

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Outline

- Problem Definition
- Objective of project
- Development of 2D Reynolds Averaged Navier Stokes Volume of Fluid (RANS-VOF) model
- Spectral wave (SW) model
- Conclusions

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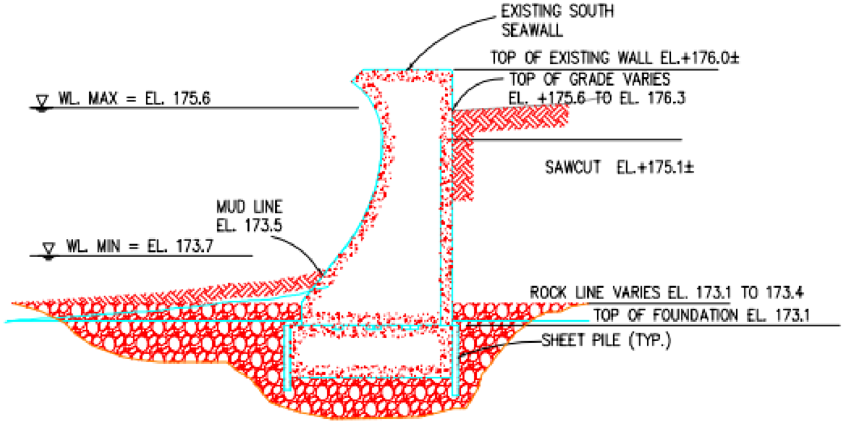
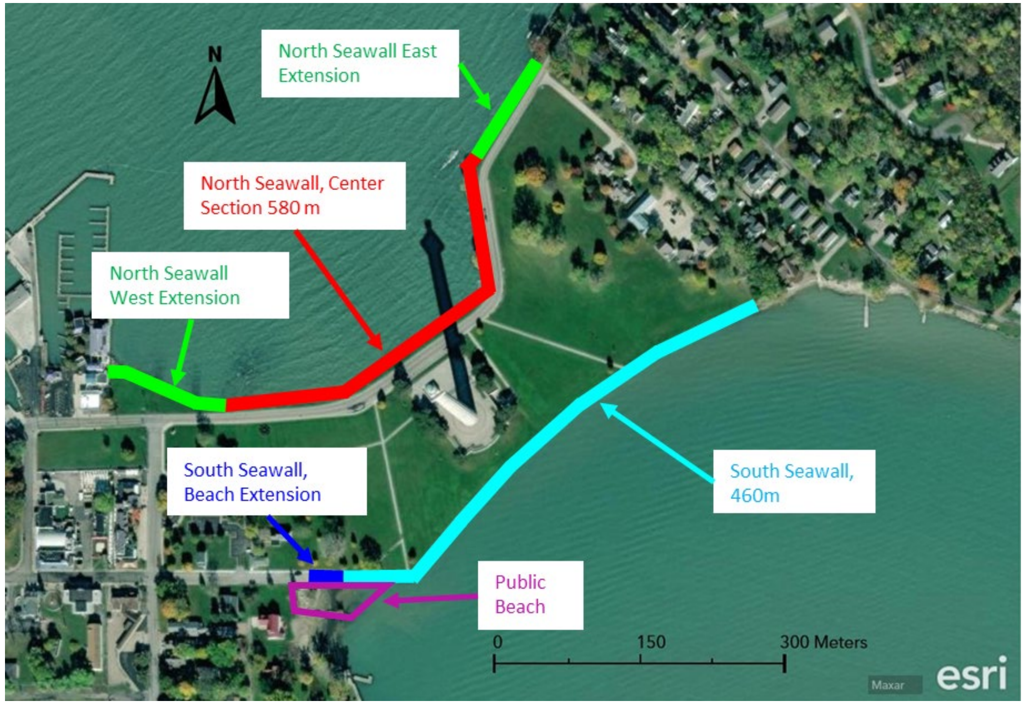
Problem Definition

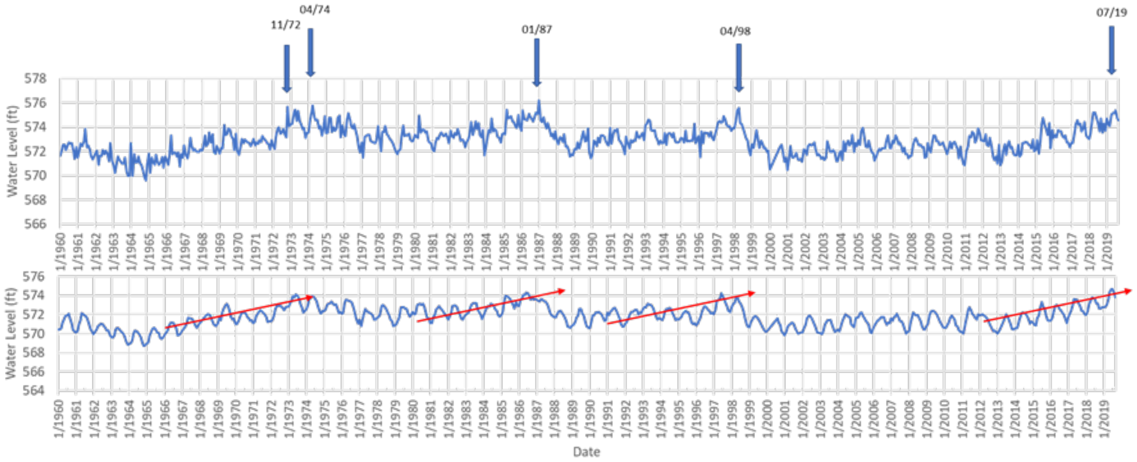
Damages to two Galveston-type seawalls caused by:

- Wave action along with cyclic lake level changes
- Undercutting of seawalls
- Ice loading
- Minimal repairs over design life



SOUTH SEAWALL





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Problem Definition

- Concrete cracking & spalling
- Overtopping & flooding
- Erosion & debris

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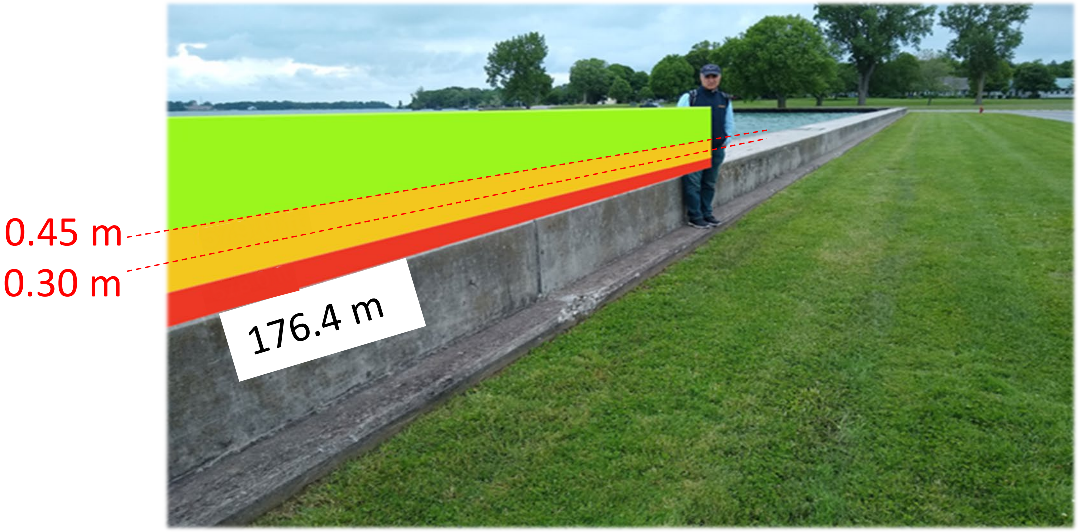
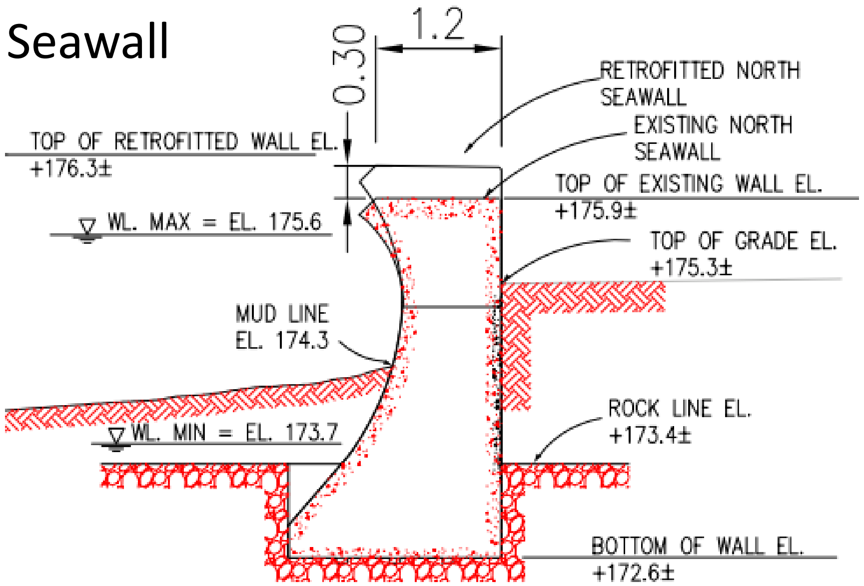
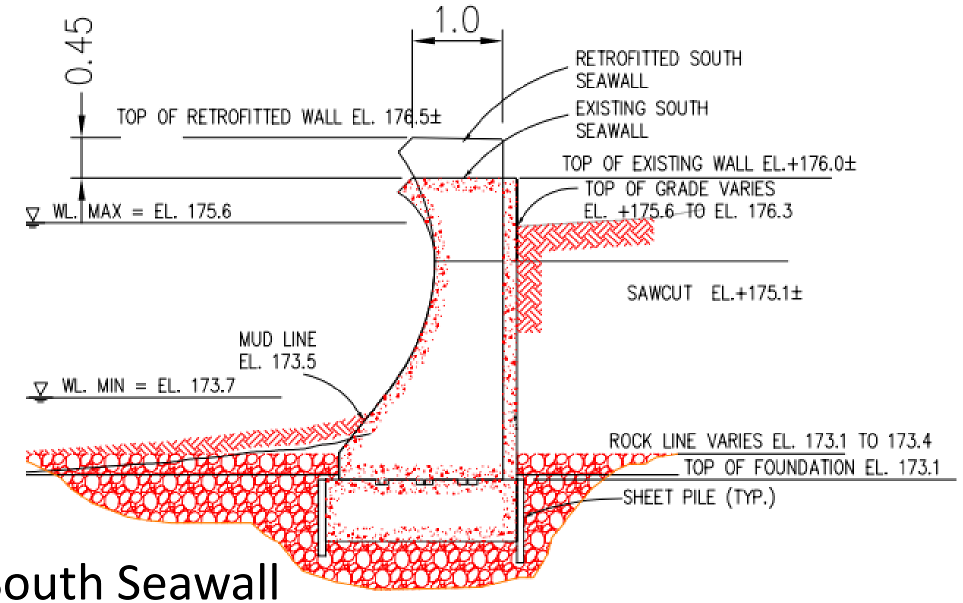
Project Objective

- Repair & restore 580 m of North and 460 m of South seawalls
- Raise seawalls to mitigate flooding
- Quantify volume of water overtopping seawall to inform stormwater modelling
- Assess the impact on neighboring properties due to raising and rehabilitating seawalls



North Seawall





South Seawall

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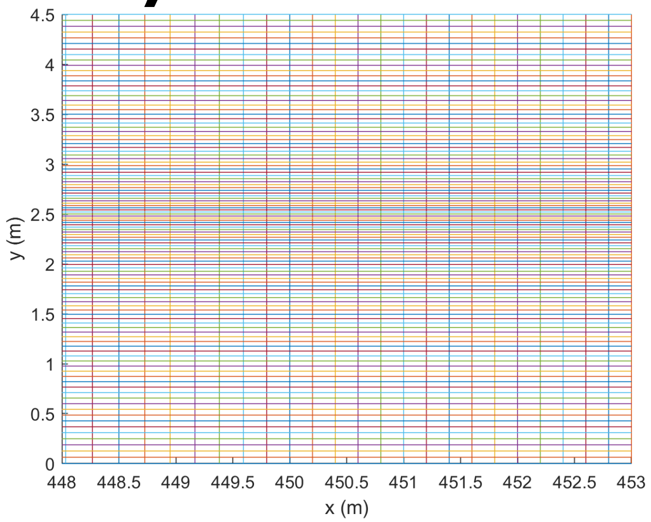
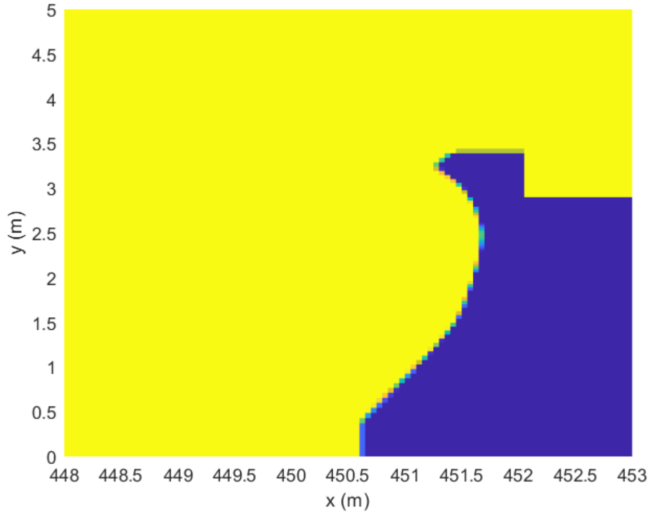
Development of RANS-VOF (Mongoose) Model

- To determine the wave overtopping for various return period events
- To determine wave pressures and resulting forces on the seawalls
- To calculate the wave reflection coefficients of the existing and proposed seawalls for use in Spectral Wave model



Cases	North Seawall			South Seawall		
	Water depth (m)	H_{m0} (m)	T_p (s)	Water depth (m)	H_{m0} (m)	T_p (s)
5-year	2.64	1.07	5.00	2.63	1.21	4.05
10-year	2.82	1.18	5.11	2.81	1.36	4.28
25-year	3.06	1.36	4.90	3.06	1.57	4.45
50-year	3.22	1.48	5.14	3.21	1.73	4.60



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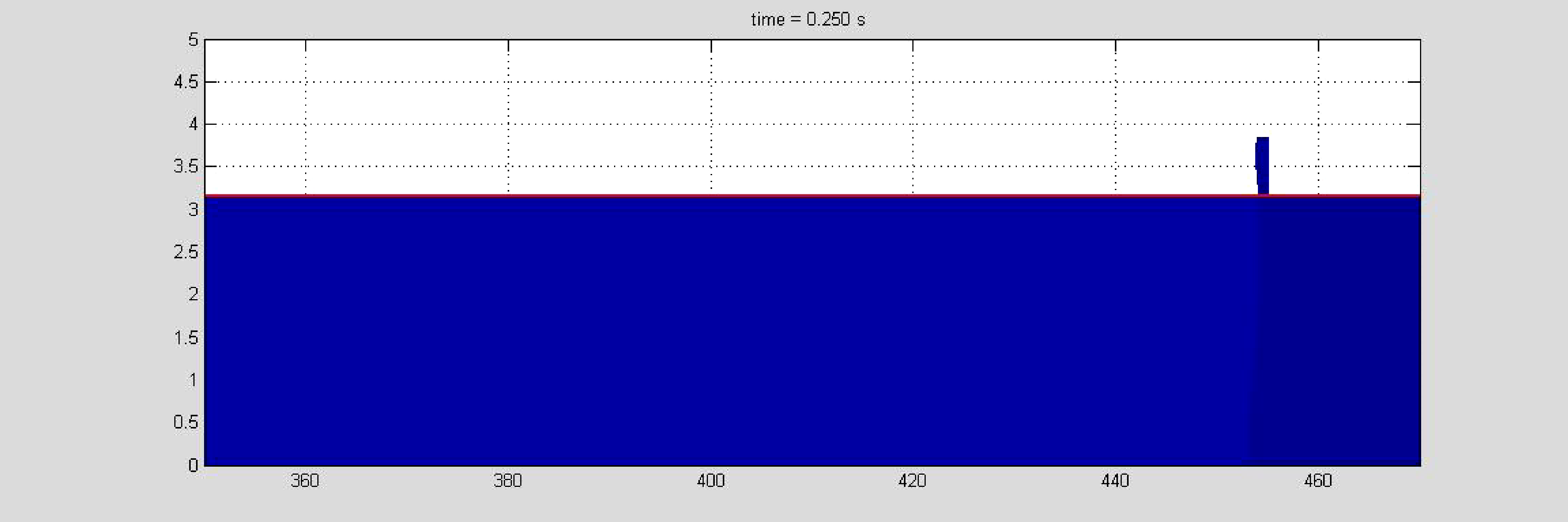
RANS-VOF Model: Wave Overtopping

South Seawall H_{m0}=1.7 m, T_p=4.6 s, d=3.06 (1 in 50 yr RP)



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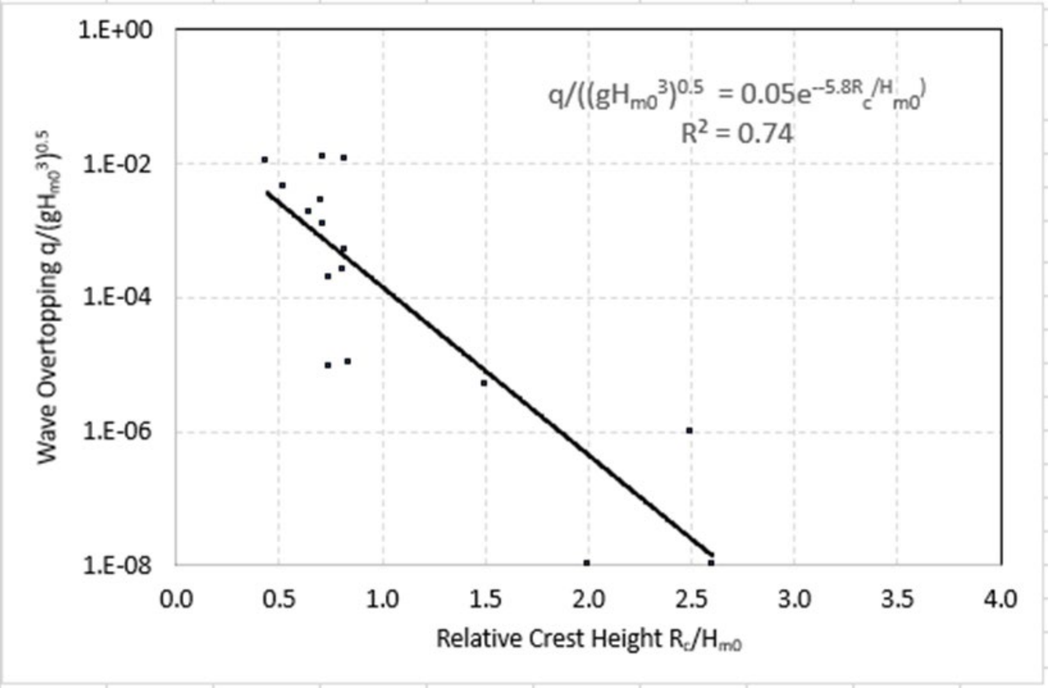
RANS-VOF Model: Wave Overtopping

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.05e^{-5.8R_c/H_{m0}}$$

For $0.5 \leq \frac{R_c}{H_{m0}} \leq 2.5$

Results:

- Significantly reduced wave overtopping for proposed case
- Results in same ballpark as empirical method
- A new wave overtopping formula for Galveston-type walls was developed



Wave overtopping rates

Return Period	Existing Condition EurOtop		Existing Condition Mongoose Model		Future Condition Mongoose Model	
	North Seawall ($m^3/s/m$)	South Seawall ($m^3/s/m$)	North Seawall ($m^3/s/m$)	South Seawall ($m^3/s/m$)	North Seawall ($m^3/s/m$)	South Seawall ($m^3/s/m$)
5-year	0.00191	0.00278	0.00004	0.00004	0	0
10-year	0.00361	0.00472	0.00081	0.00890	0	0
25-year	0.01194	0.01638	0.05580	0.02740	0.00260	0.00153
50-year	0.02282	0.03666	0.07090	0.07540	0.00680	0.00197

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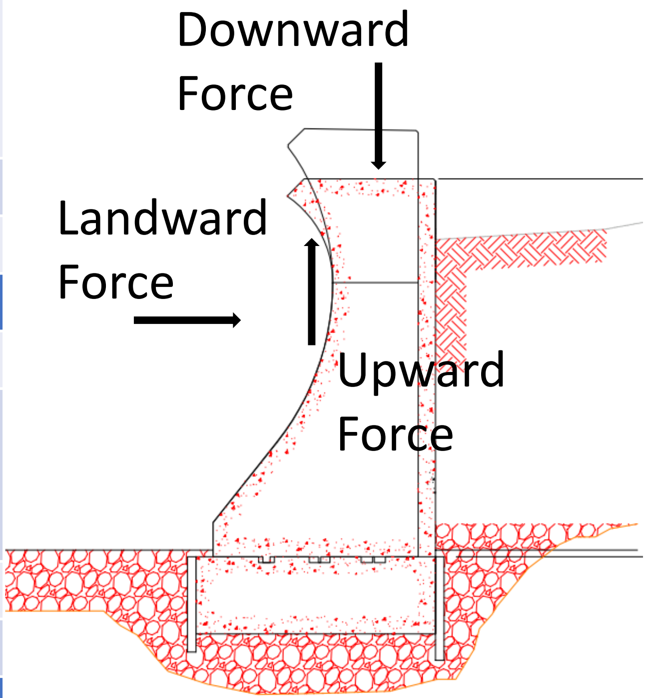
RANS-VOF Model: Wave Forces

Return Period	Mongoose Model					
	North Seawall			South Seawall		
	Upward Force (kN/m)	Downward Force (kN/m)	Landward Force (kN/m)	Upward Force (kN/m)	Downward Force (kN/m)	Landward Force (kN/m)
50-year	2.4	27.9	68.3	2.7	29.0	59.8
100-year	2.8	29.7	73.8	3.0	30.7	63.8
Return Period	**Goda Method**					
	North Seawall			South Seawall		
	Upward Force (kN/m)*	Downward Force (kN/m)*	Landward Force (kN/m)	Upward Force (kN/m)*	Downward Force (kN/m)*	Landward Force (kN/m)
50-year	N/A	N/A	69.9	N/A	N/A	68.0
100-year	N/A	N/A	73.7	N/A	N/A	70.1

Note: *Goda formula can predict only vertical and horizontal loads; therefore, the upward and downward forces cannot be calculated by the Goda method.



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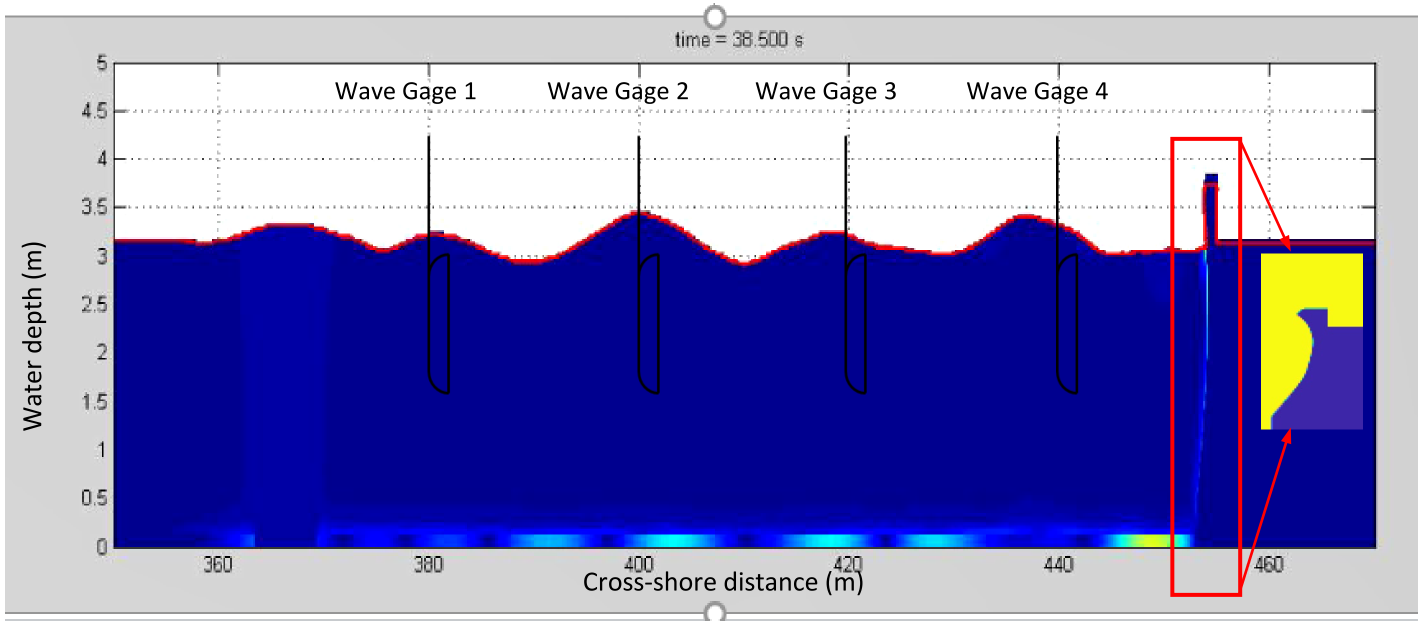
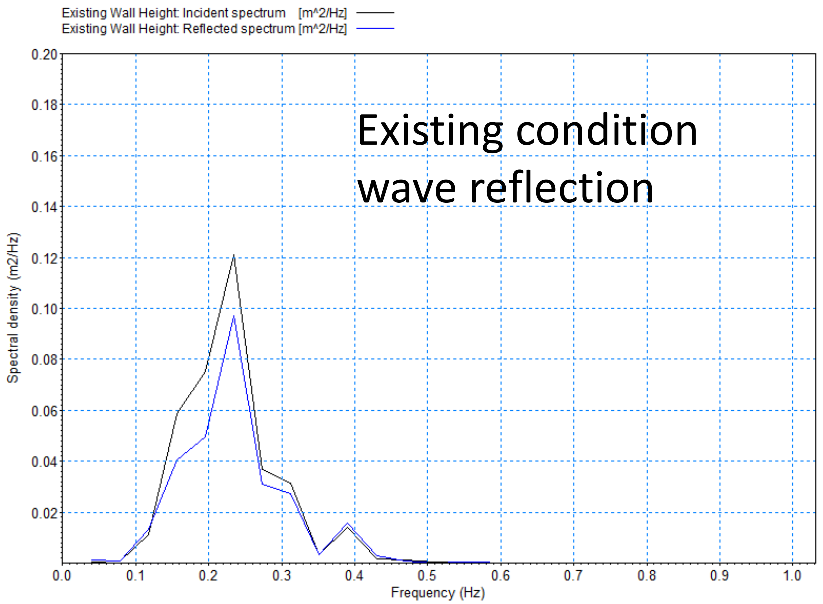
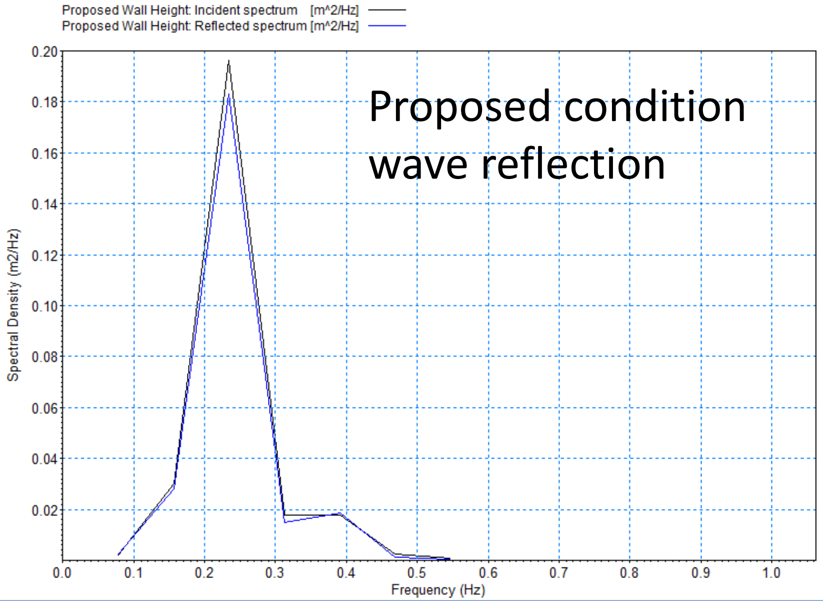
RANS-VOF Model: Wave Overtopping

Wave energy reflection



Reflection Coefficient: 89% Existing Wall Height
97% Proposed Wall Height





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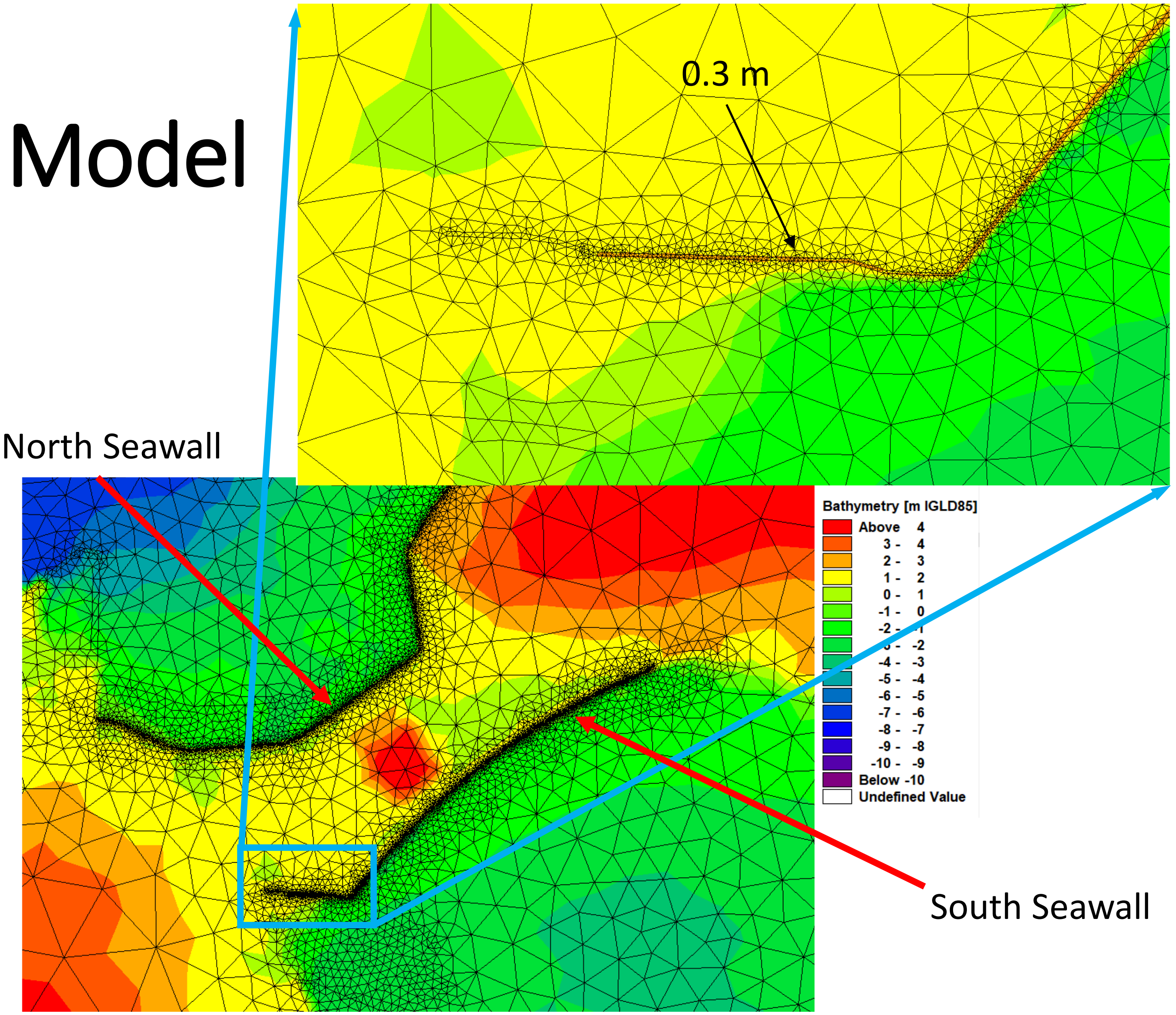
SW Transformation Model

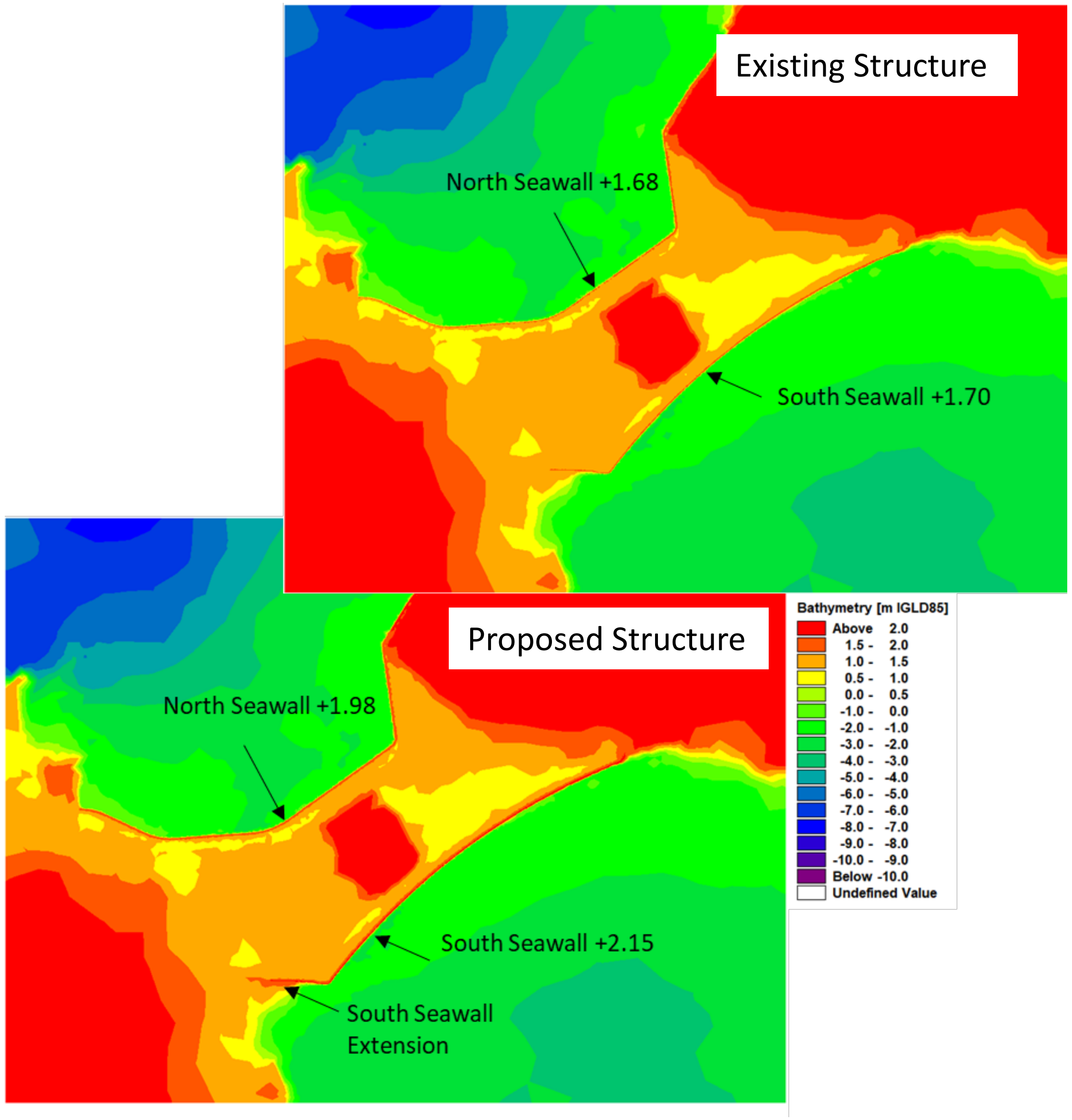
Spectral wave modeling

- Performed in DHI Mike
- To determine the nearshore wave climate for four scenarios:
    - Existing & Proposed conditions under high water
    - Existing & Proposed conditions under low water
- Models validated/calibrated with Acoustic Doppler Current Profiler (ADCP) data

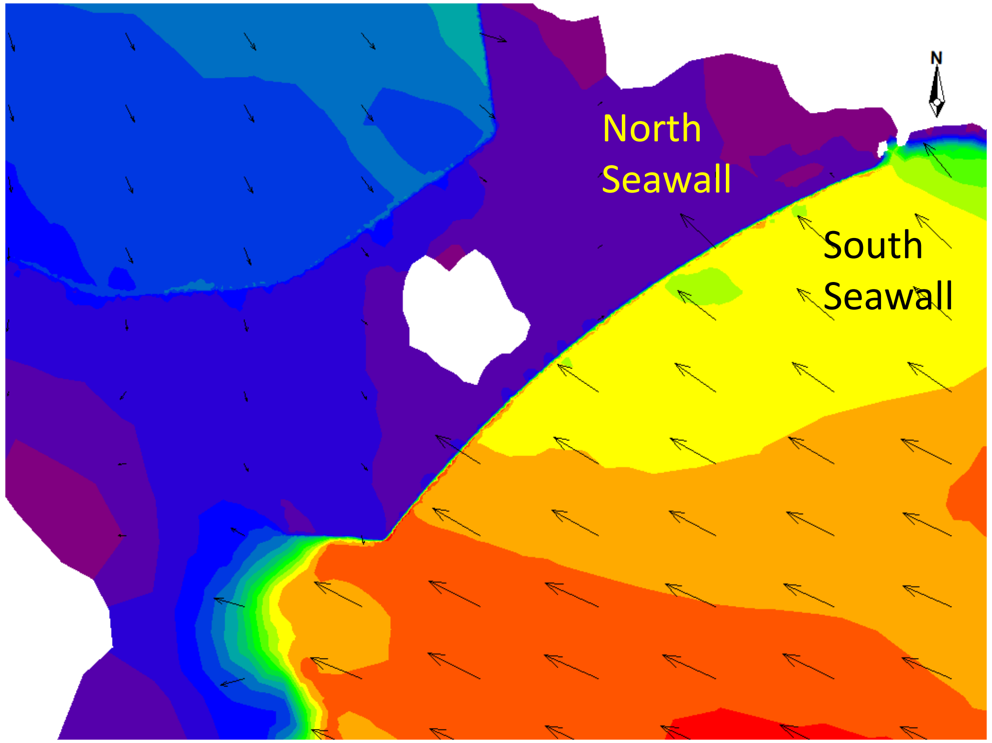


SW Transformation Model

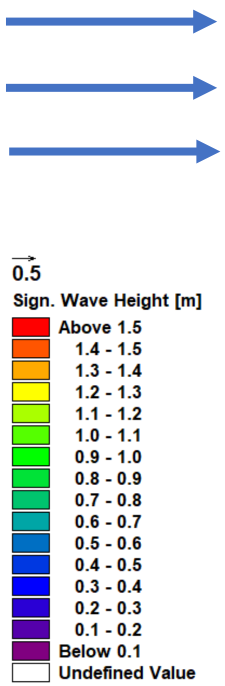
- The same mesh and bathymetry are used for existing and future conditions
- The crest of the seawalls is increased for the proposed condition and includes the South Seawall extension
- The seawalls are reflective boundaries which were calculated from Mongoose:
  - 89% for existing conditions
  - 97% for future conditions

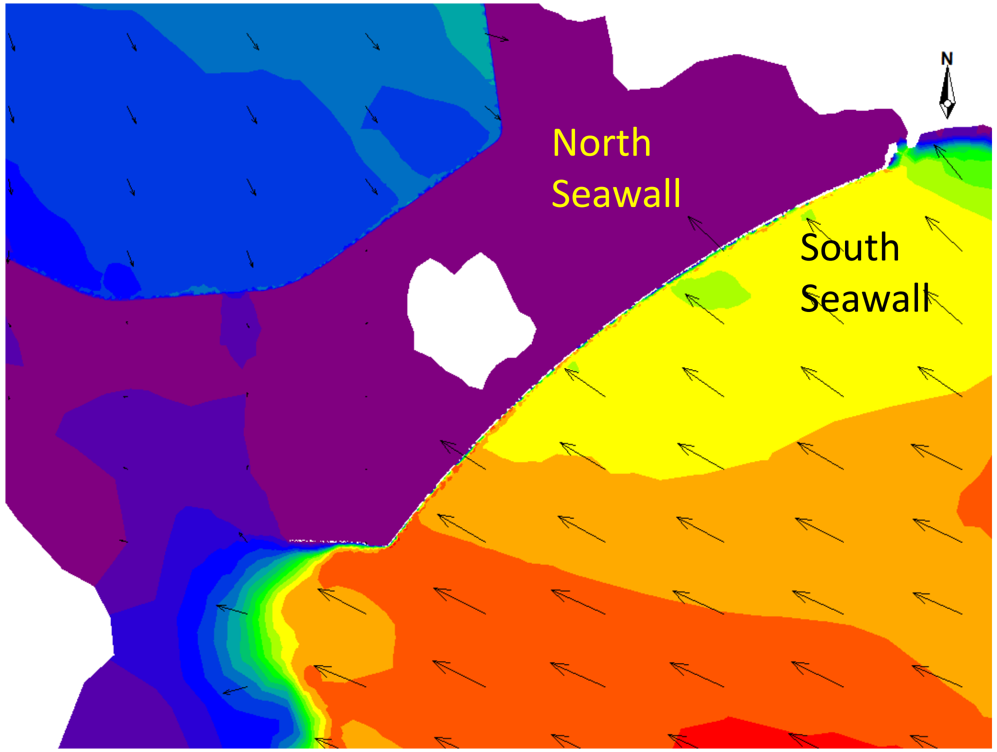


SW Transformation Model: South Seawall



Existing





Proposed

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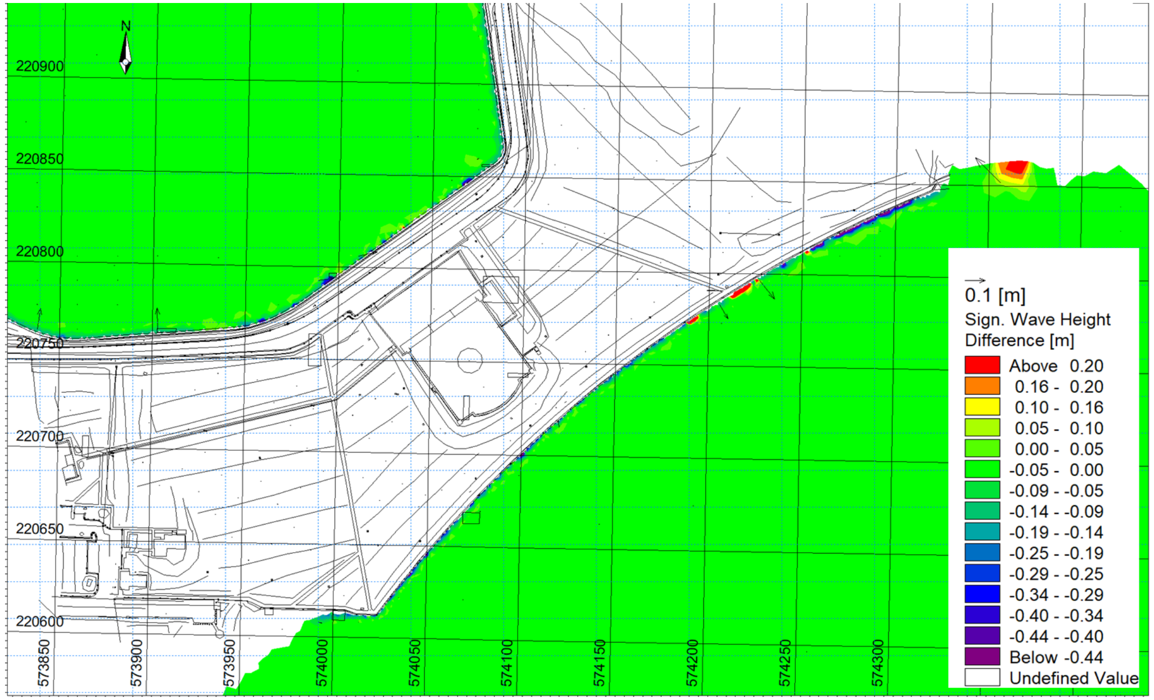
SW Transformation Model: South Seawall

Wave height difference map:

- Subtract existing from proposed
- Cool colors denote a decrease in wave height
- Warm colors denote increase
- Minor decrease in wave energy near public beach
- Minor increase in wave energy near northeast properties



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Conclusions

Mongoose Model:

- Raising the walls significantly reduced wave overtopping
- Results are in same ballpark as widely accepted Eurotop calculations
- Proposed case reflects 9% more wave energy than existing case
- Model verified by empirical wave force calculations

Wave Transformation Model:

- Negligible difference to adjacent properties
  - Southwest corner- decreased wave heights and overtopping
  - Southeast corner- decreased wave heights near the public beach
  - Northwest corner- slightly decreased wave heights, significant decrease in overtopping
  - Northeast corner- Mostly decreased wave heights with slight increase north of wall

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Q&A