ICCE 2018

36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018

Baltimore, Maryland | July 30 – August 3, 2018

The State of the Art and Science of Coastal Engineering

Resonant oscillations in small craft harbours

Observations and mitigation modeling examples from Atlantic Canada

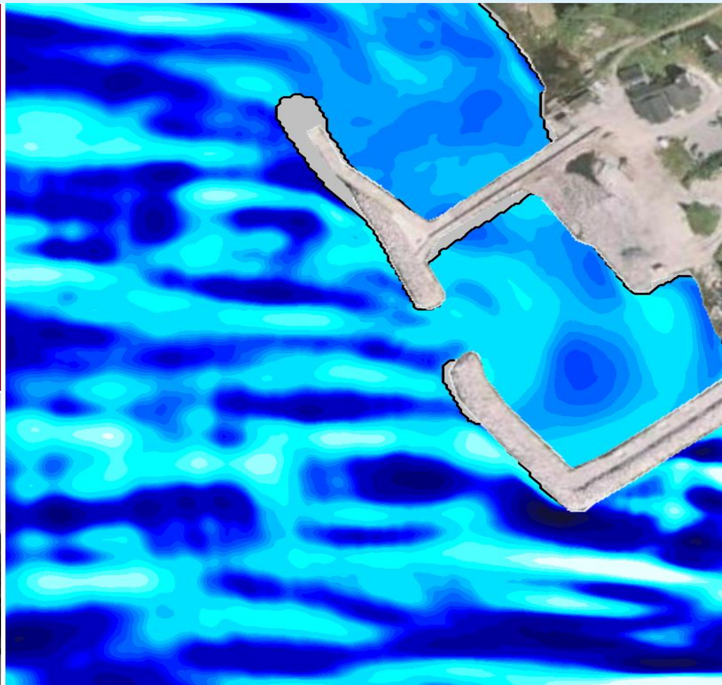
CBCL LIMITED
Consulting Engineers

Vincent Leys, Coastal Engineer

Halifax, Nova Scotia, Canada - vincentl@cbcl.ca

Co-authors: Victoria Fernandez, P.Eng.

Danker Kolijn, P.Eng.



Study area

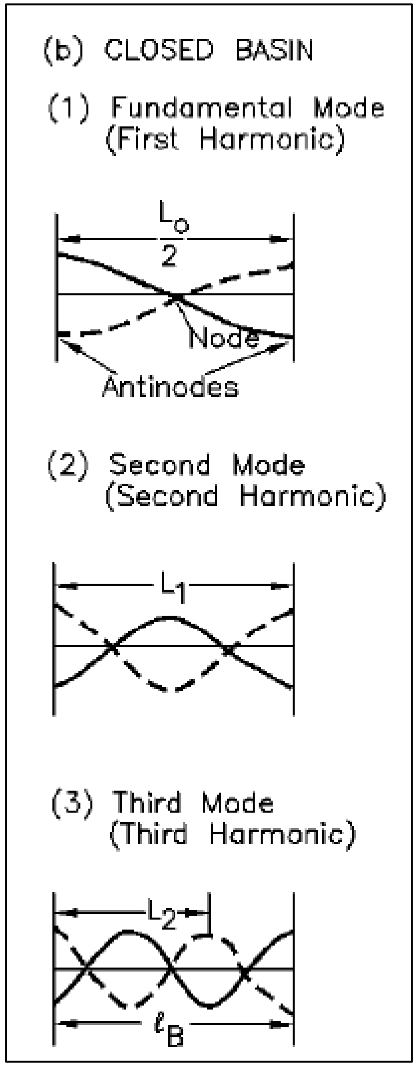

Prince Edward
Island
New Brunswick
Nova Scotia
Canada
Maine
USA
Bay of Fundy
Halifax
Atlantic
Ocean
I
H
G
F
E
B A
C
D
7 wave gauge study sites

Coastal issues at fishing harbours

- Aging infrastructure vs. expanding fleets, transient and non-commercial use
- Wave agitation
- Storm surges & sea level rise
- Maintenance dredging
- Loss of winter ice cover → winter wave exposure
- ***Long wave forcing***

Long wave forcing

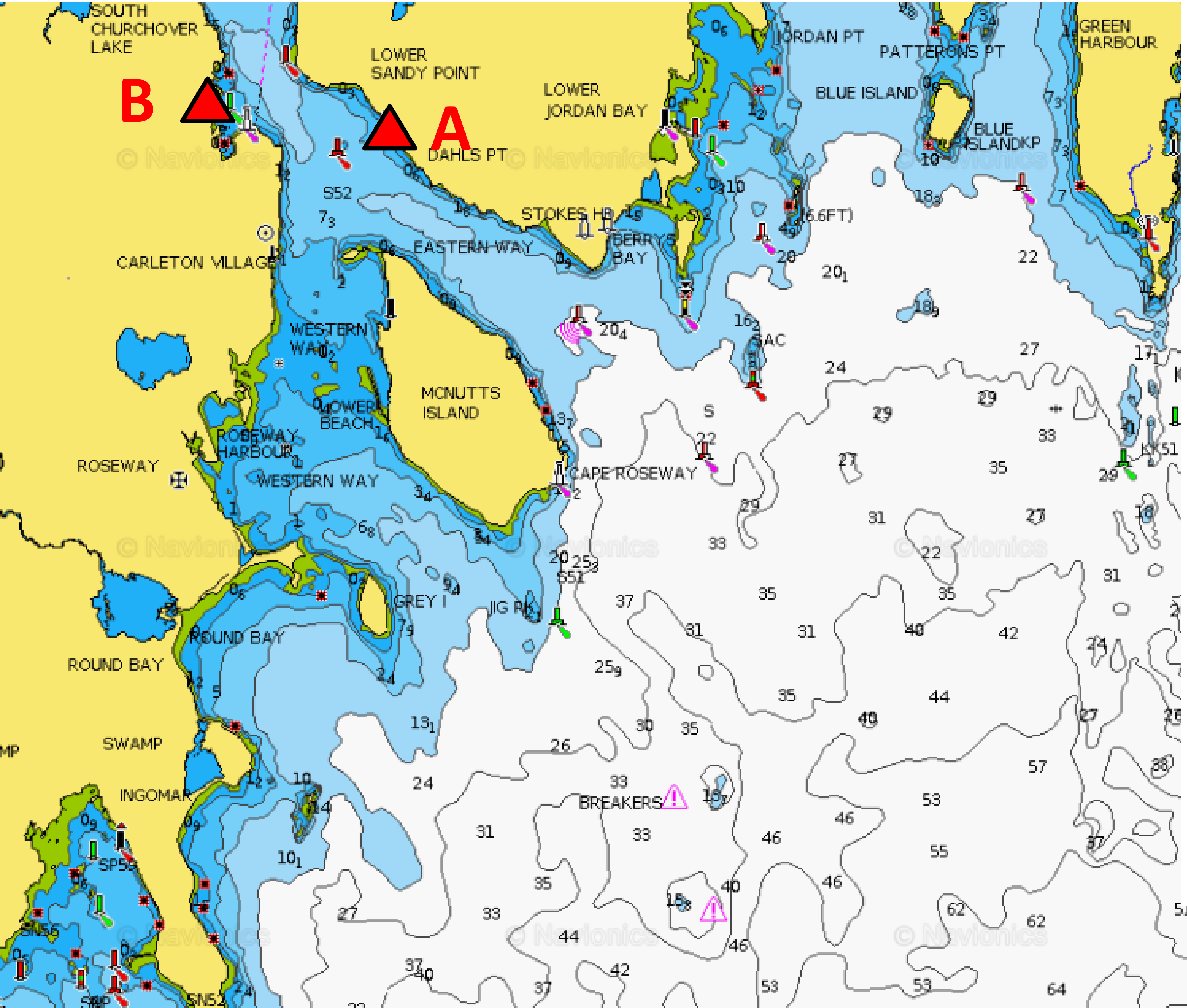
1. **Characteristics**
   - Referred to as “infragravity” waves
   - Low frequency (LF), typically period > 1min
   - Due to by meteorological forcing,
     non-linear swell interaction combined with bathymetry

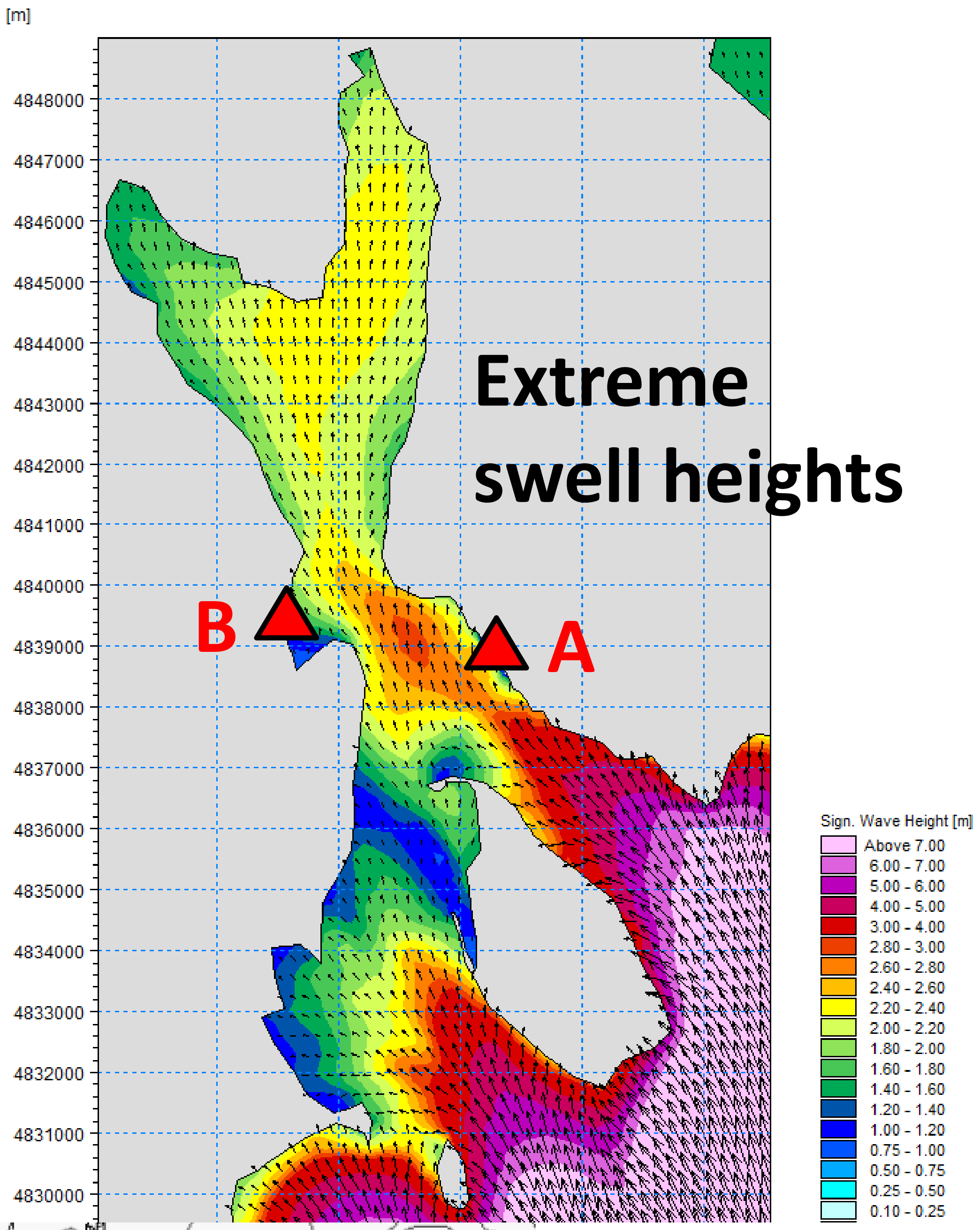


Source: USACE CEM

2. **Potential Impacts**
   - Basin resonance
   - Mooring problems (most references on large ports)
   - **Scour and undertow due to LF currents**

Harbours A, B



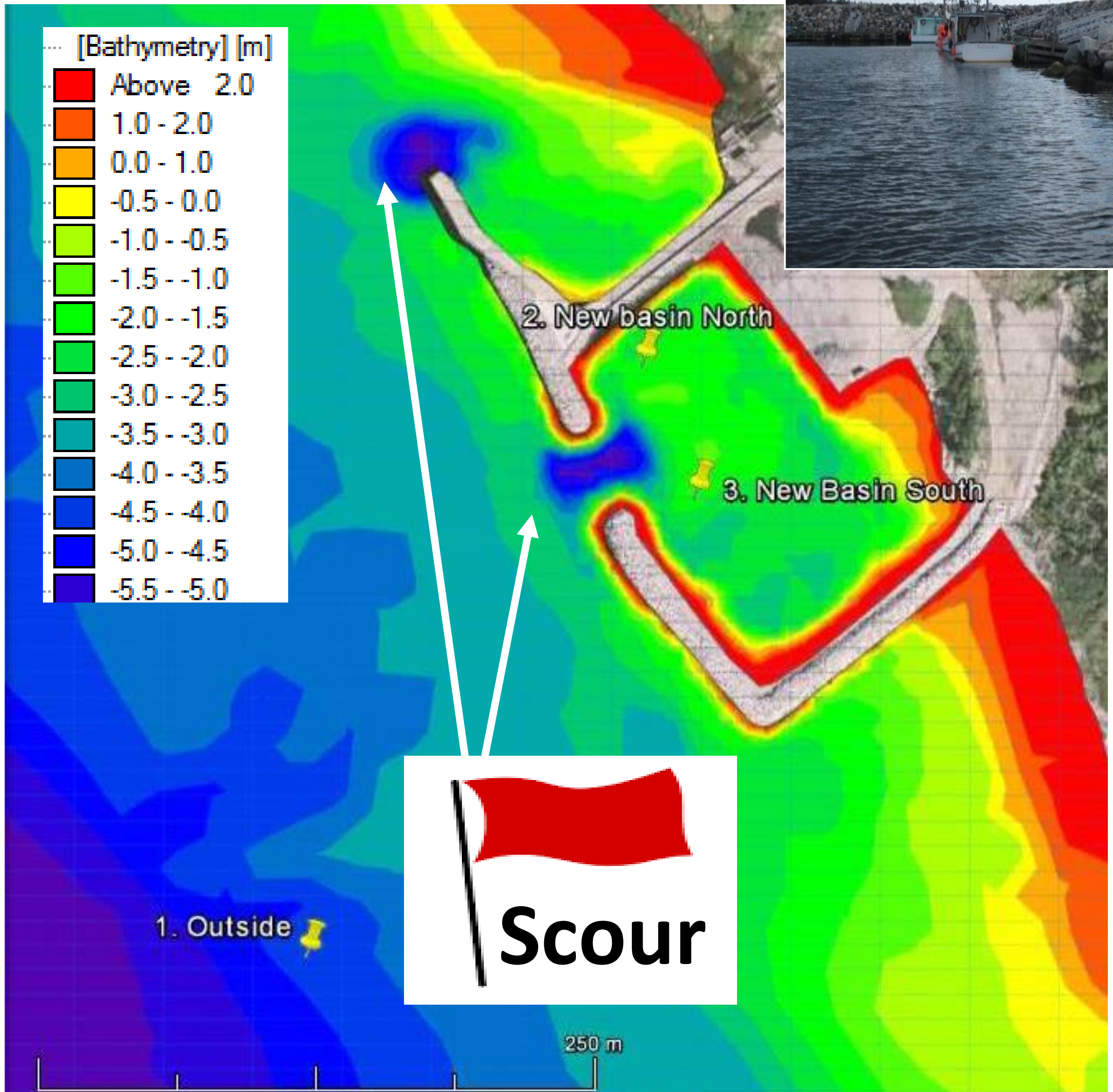


Extreme swell heights

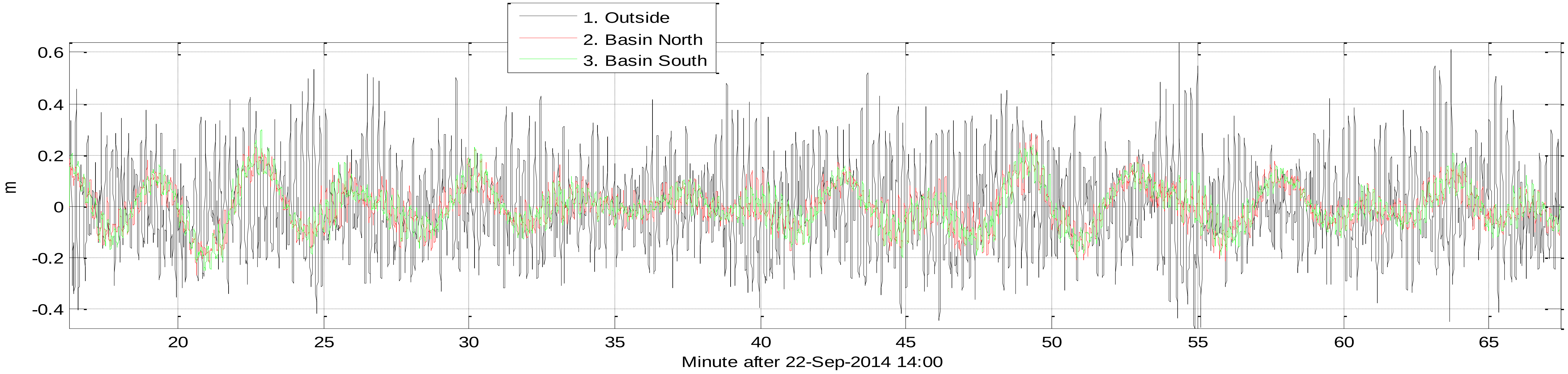
Harbour A

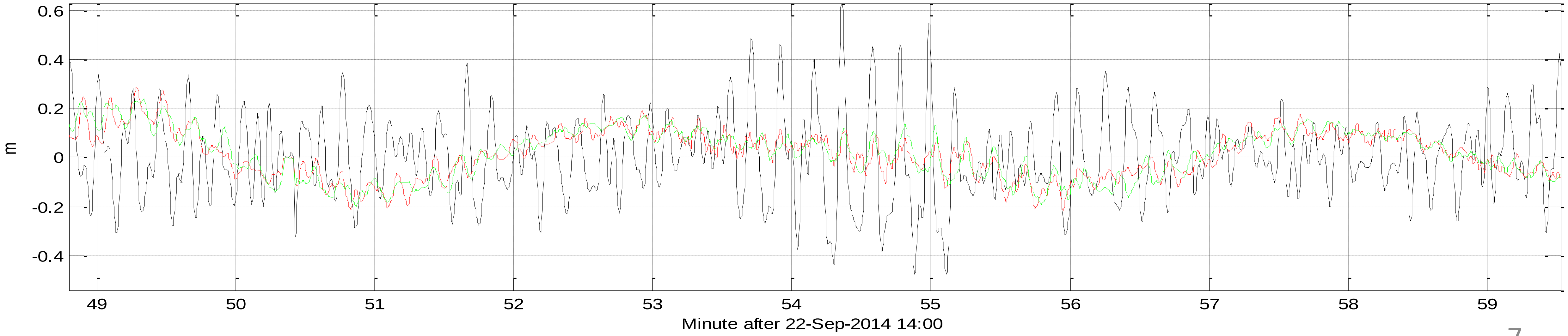
1. Initial wharf

2. "Rock box"

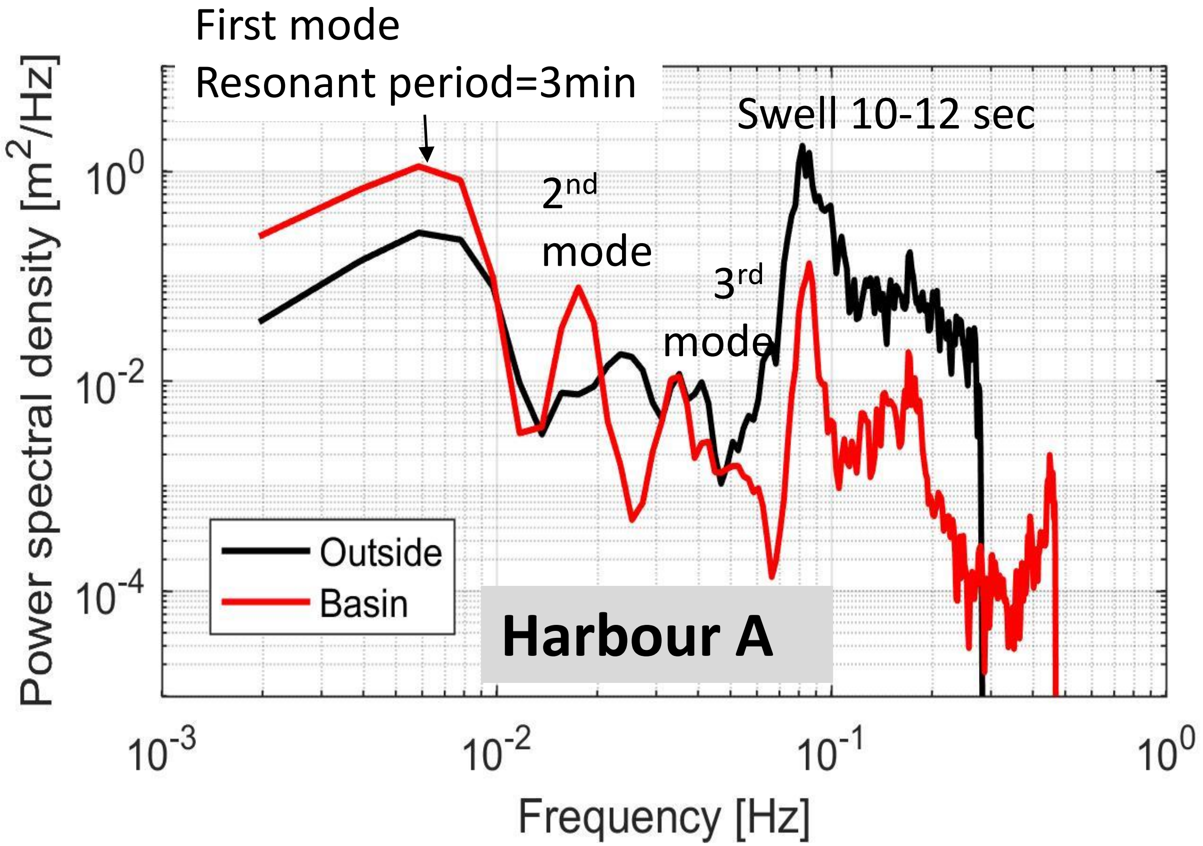


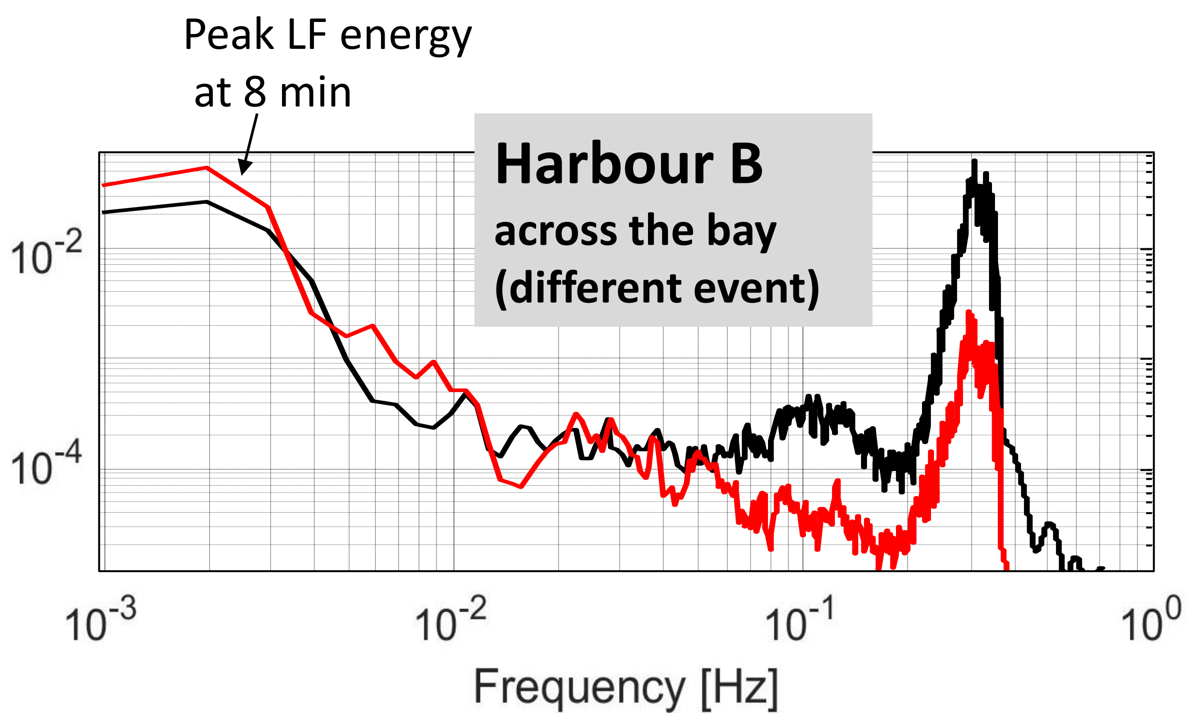
Sea surface timeseries, harbour A



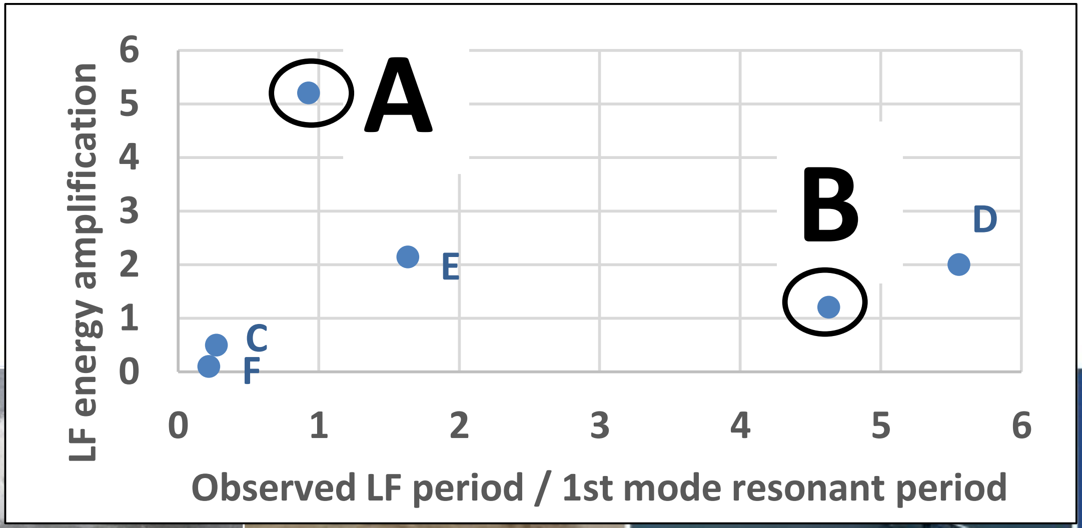


Frequency domain





Amplification from analytical equations



Tools to estimate resonant oscillations

ANALYTICAL EQUATIONS

Amplification at resonance = f(basin length, width, depth)

See USACE CEM - For amplification to occur, energy has to be present in sea surface signal

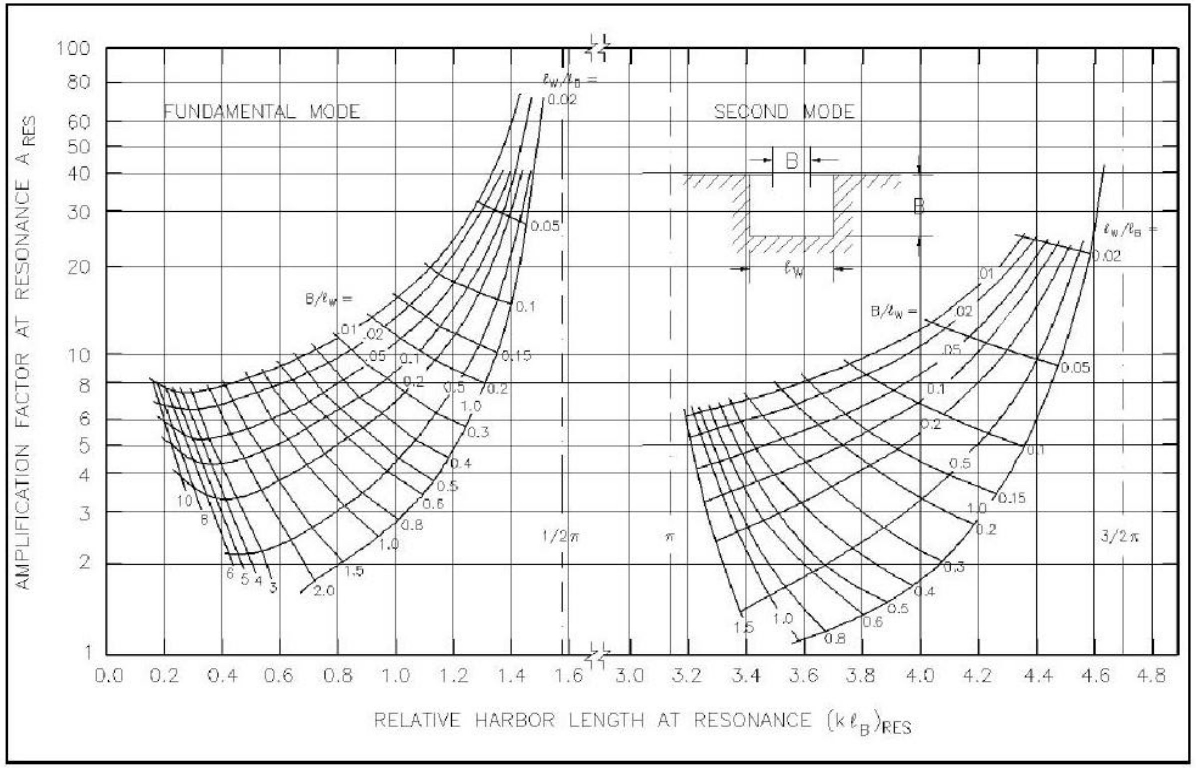
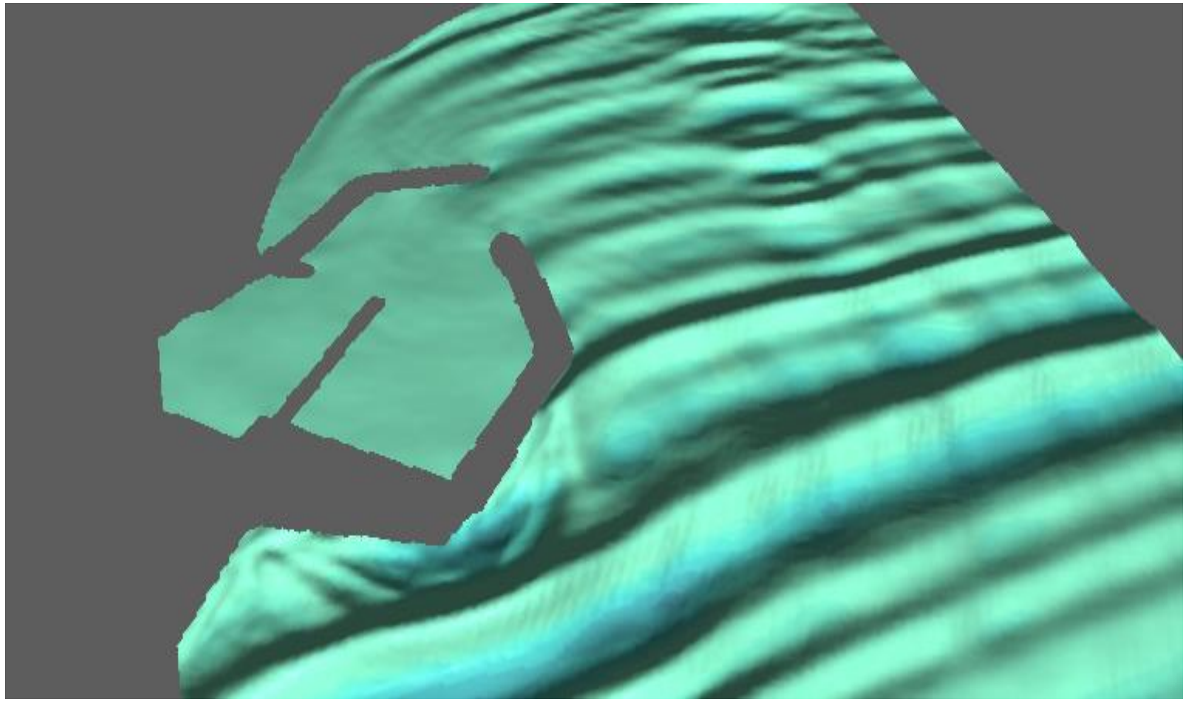


Figure II-7-31. Resonant length and amplification factor of symmetrical rectangular harbor (from Raichlen and Lee (1992); after Ippen and Goda (1963))

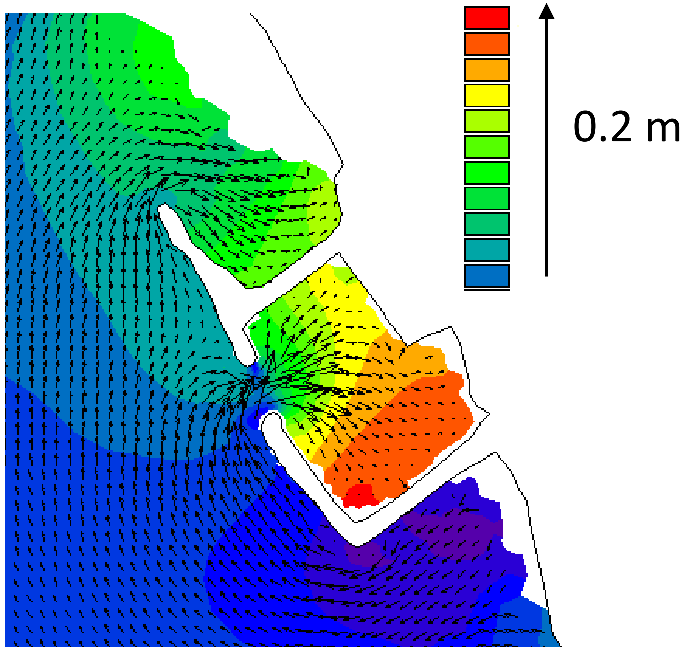
PHASE-RESOLVING BOUSSINESQ WAVE MODELS

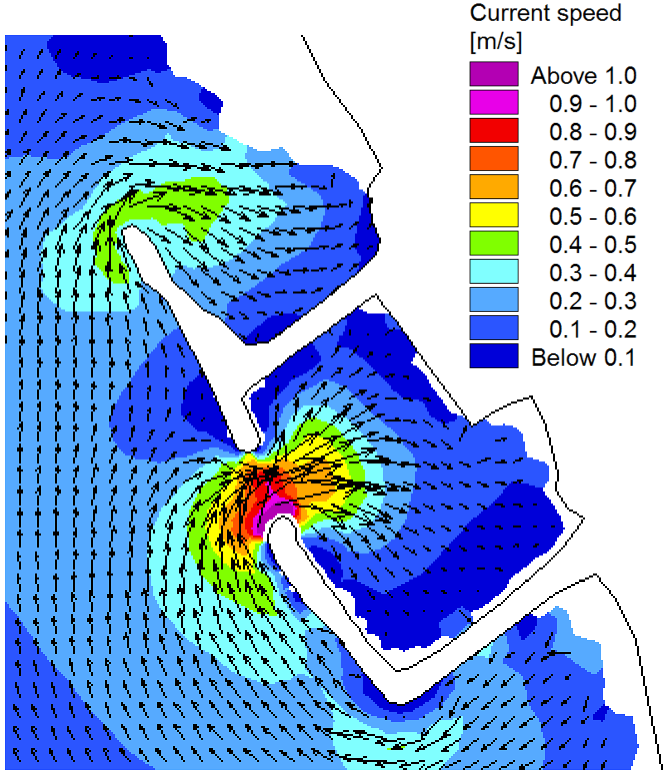
Must resolve non-linear interactions between different components of the primary wave spectrum, known to be important for the forcing of long waves.



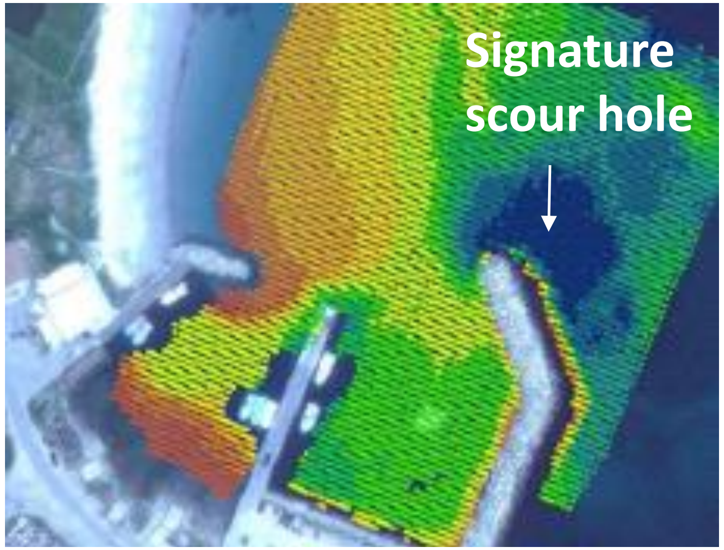
Low frequency currents

Even relatively small sea surface gradients can cause scour-inducing currents

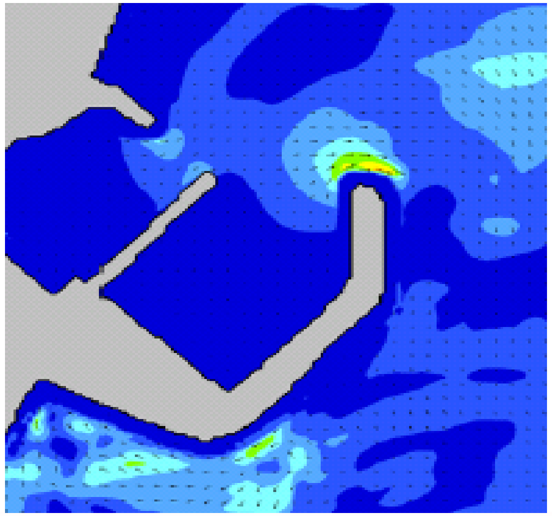




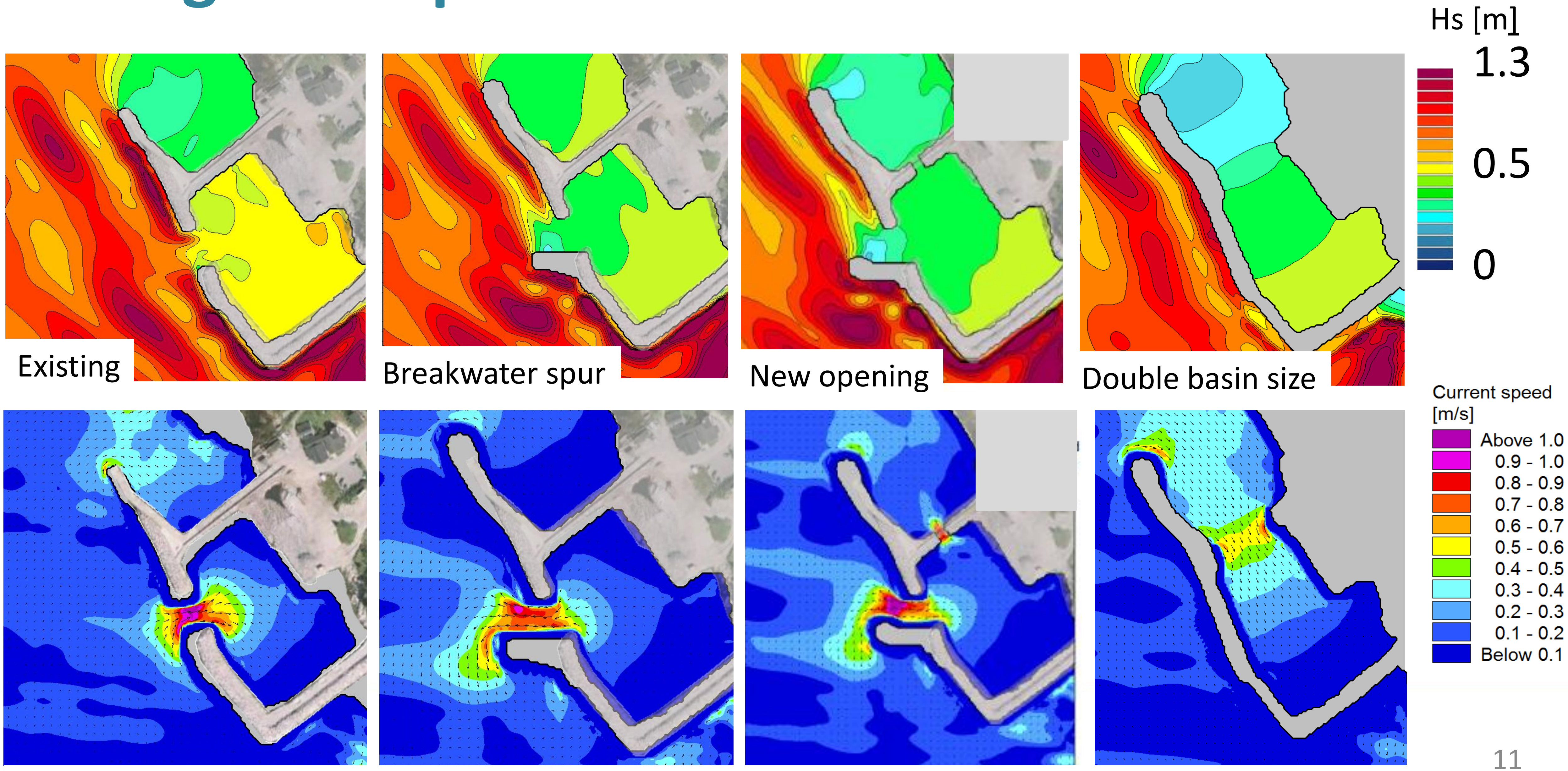
Harbour D bathymetry



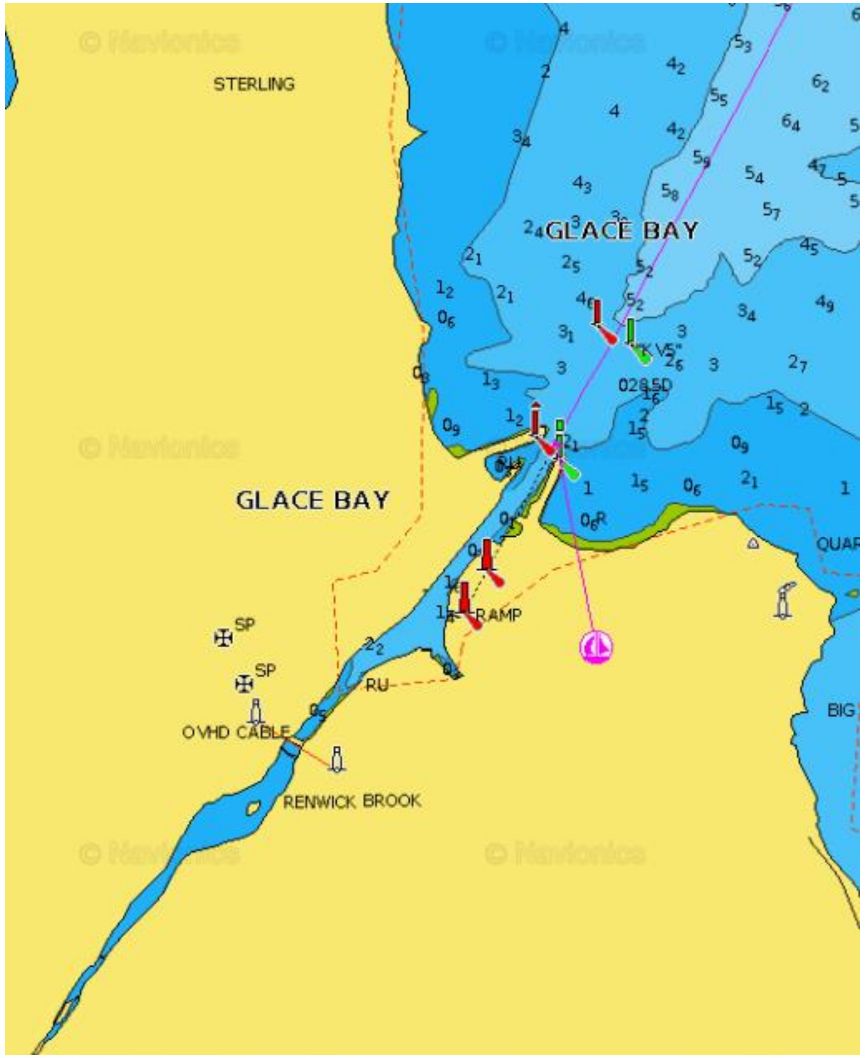
Harbour D currents

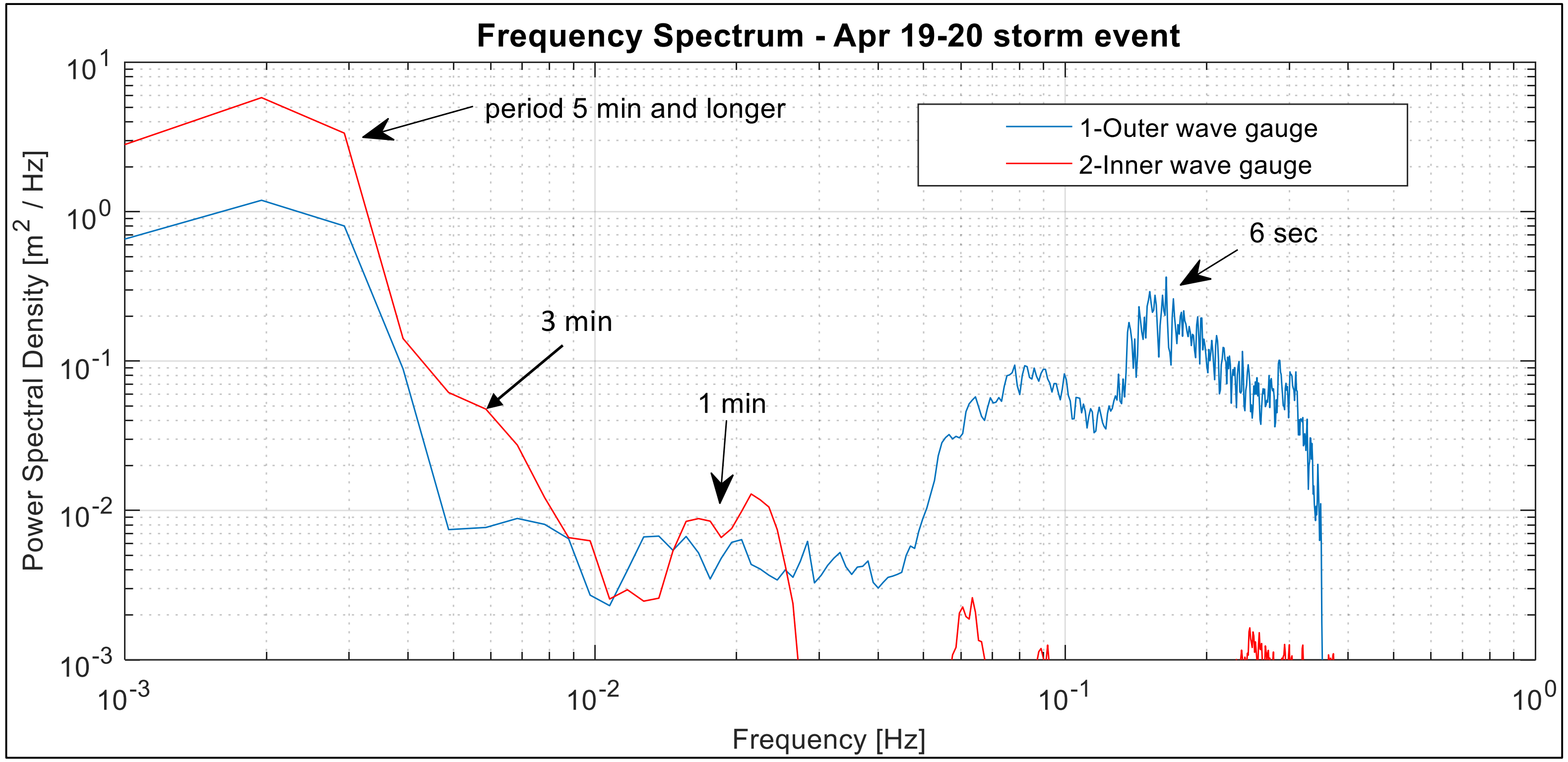


Mitigation options

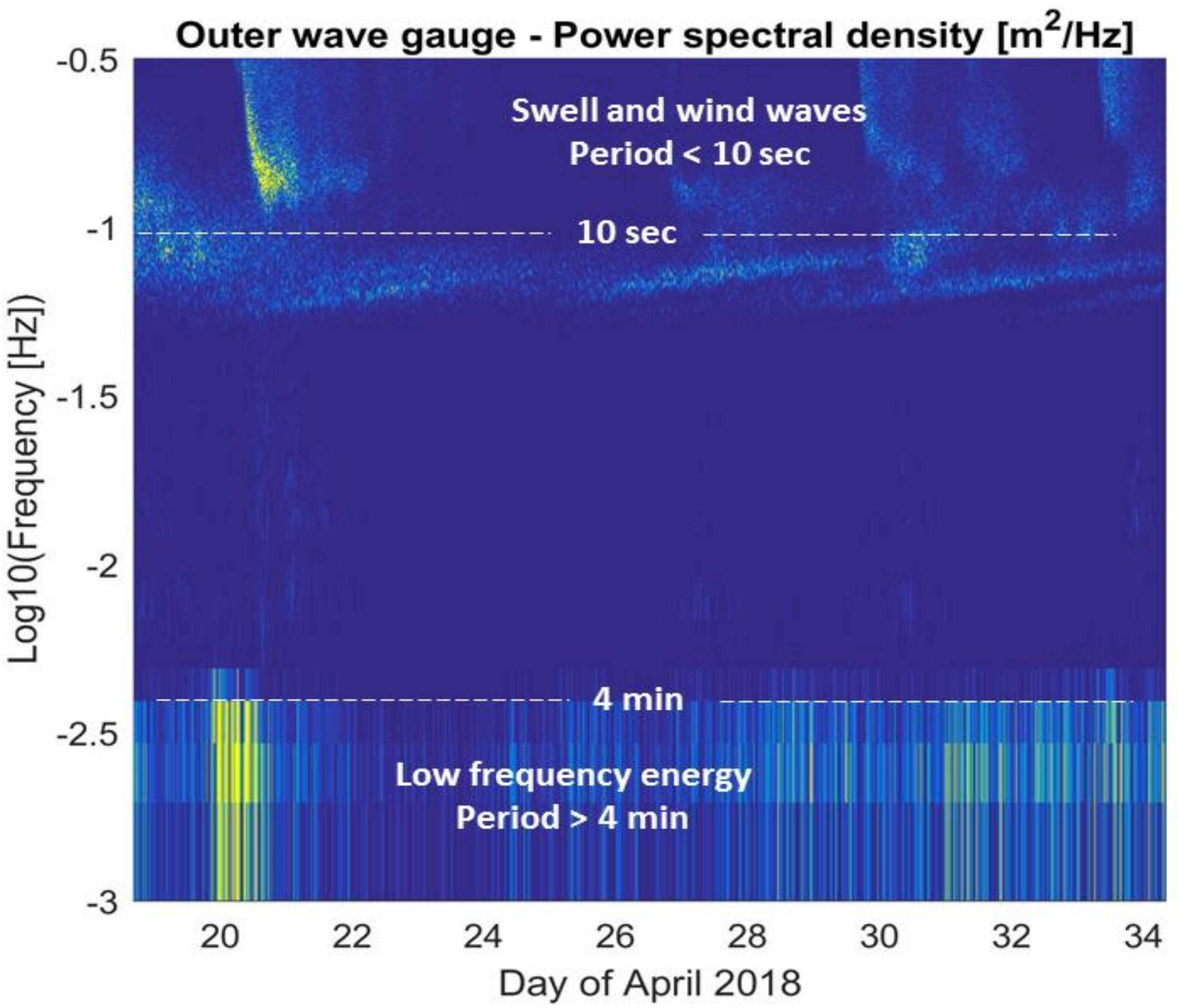


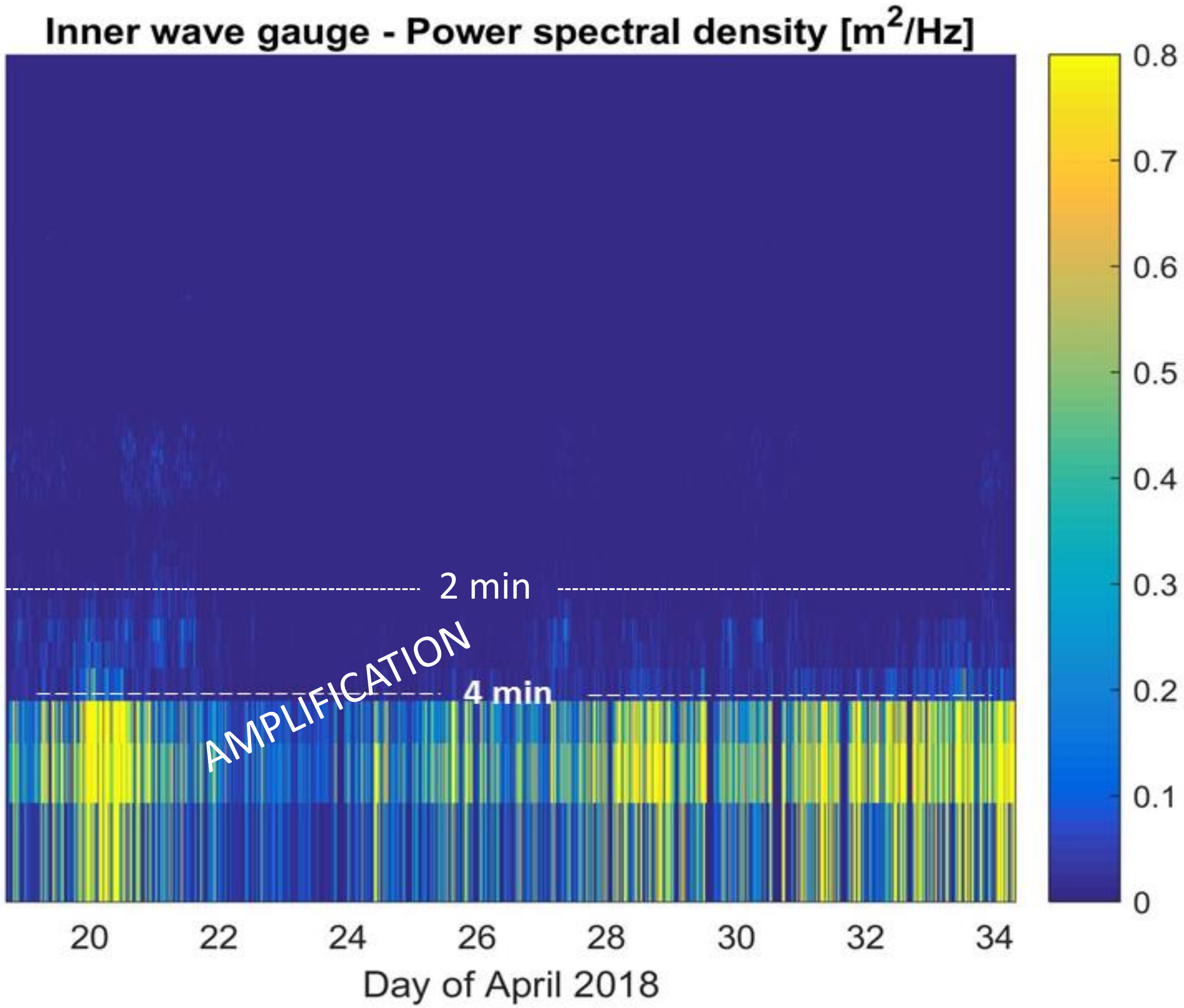
Harbour I – Elongated basin





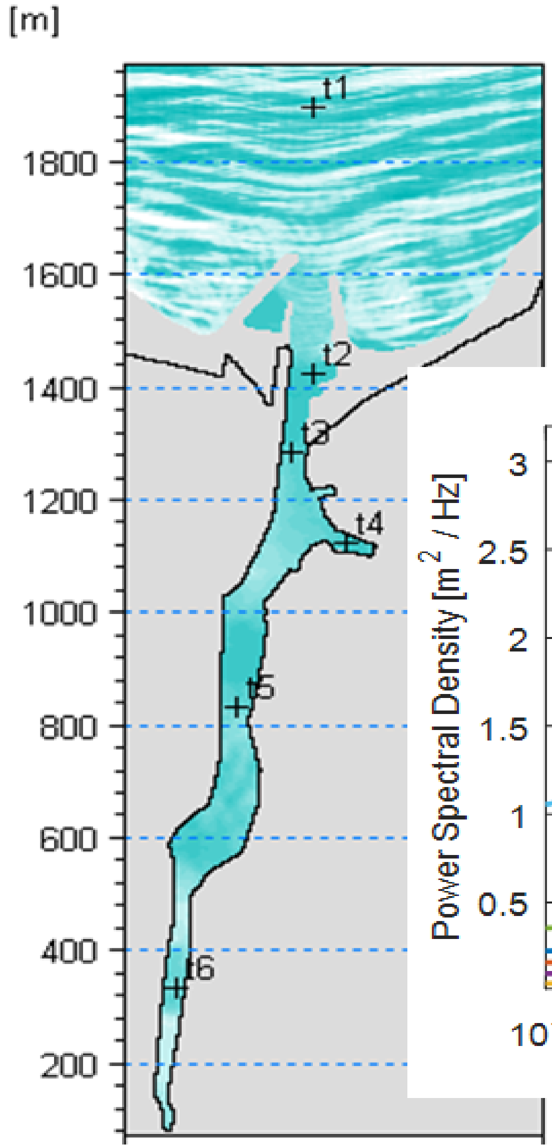
Wave spectra observations – full record

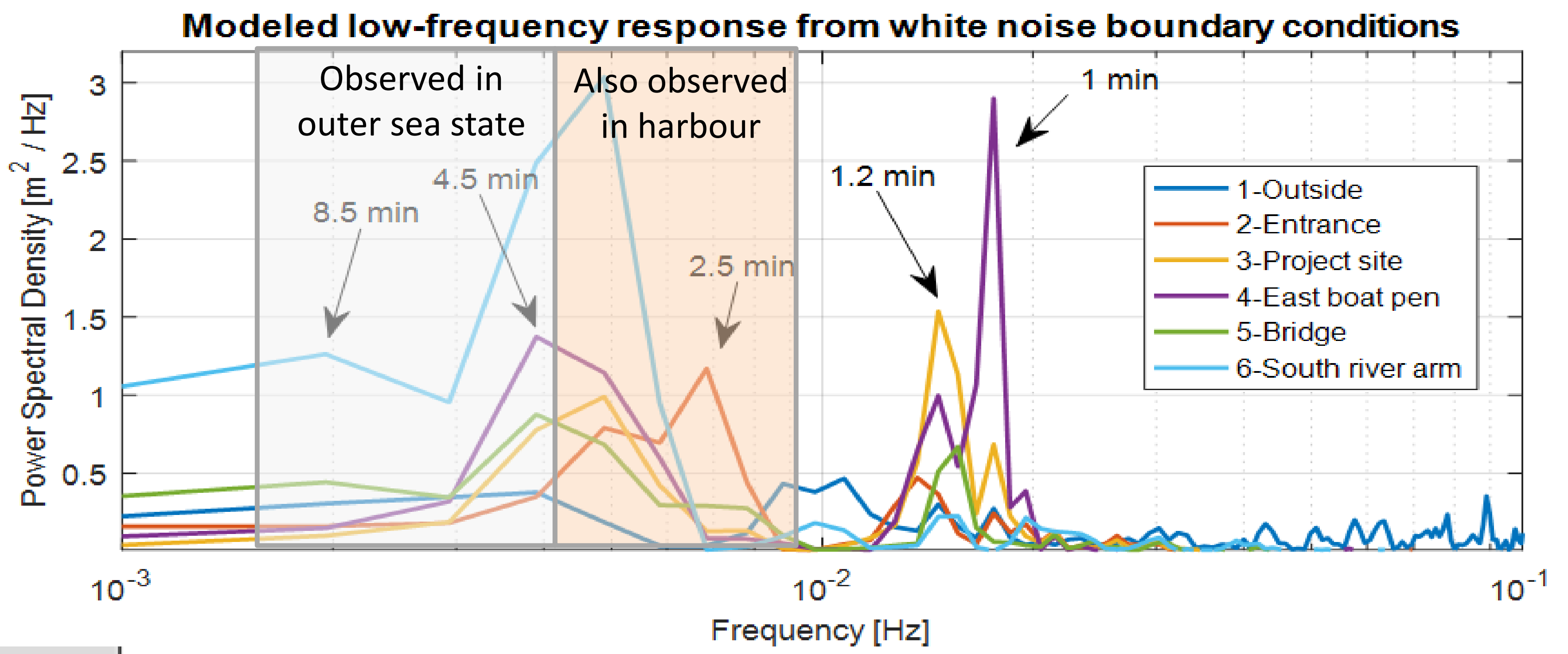


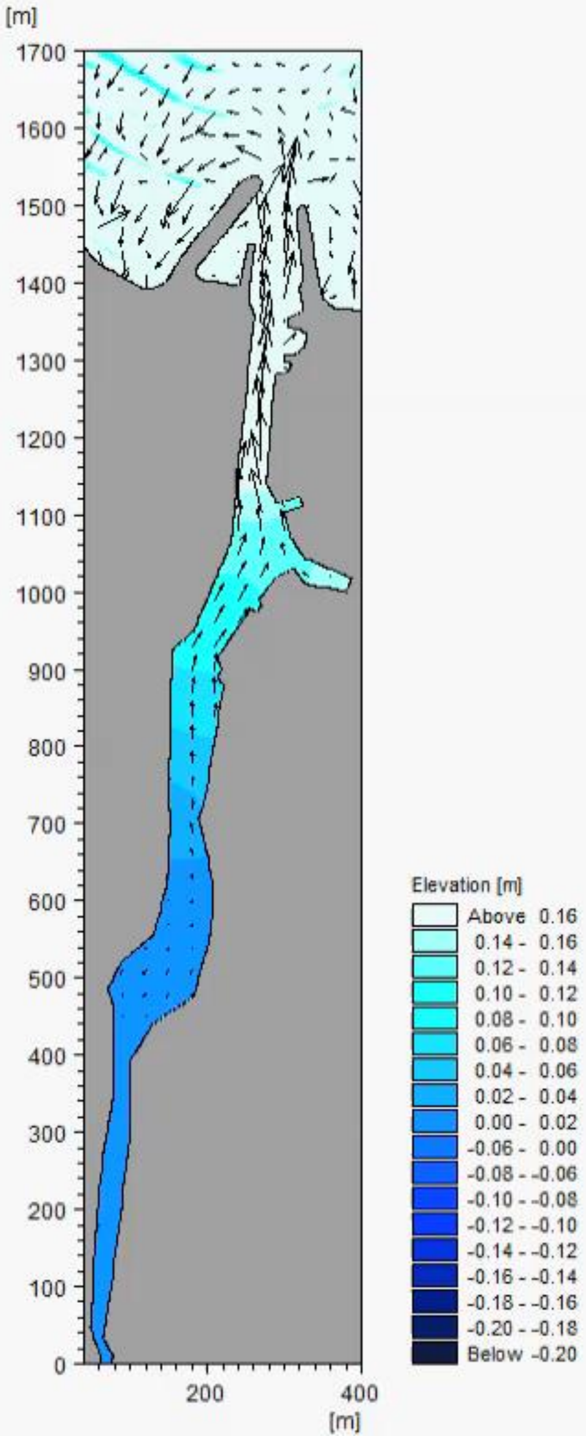


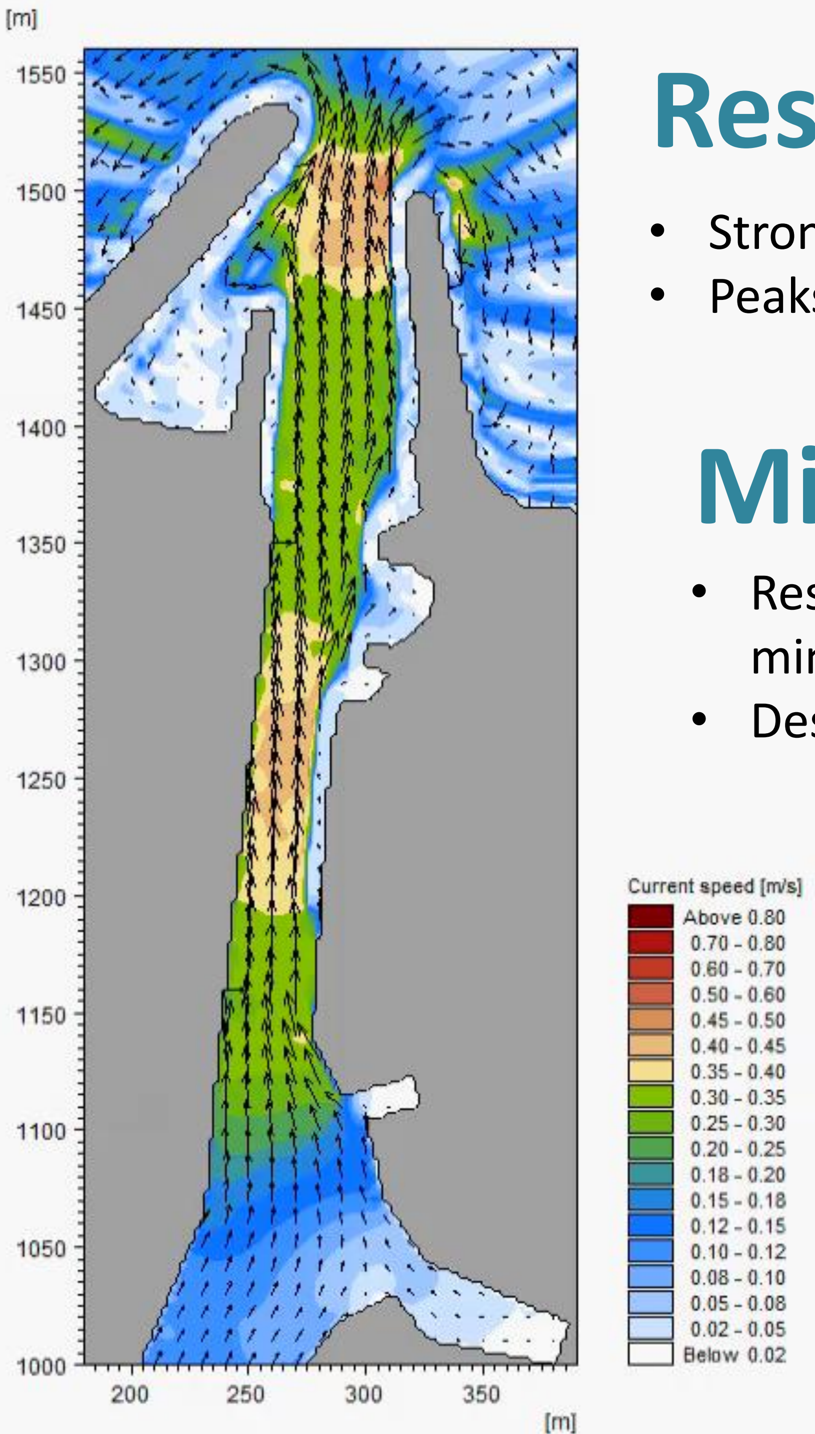
White noise modeling analysis

- Goal: investigate **potential** for seiching
- White noise boundary spectrum is a synthetic sea state with equal amounts of energy at all frequencies
- Actual development of resonance depends on the frequencies present in the outer sea state.









Resonance currents

- Strongest through narrow channel sections
- Peaks likely > 1 m/s

Mitigation

- Resonance cannot be significantly reduced by minor harbour layout or entrance modifications
- Design for strong currents

Small harbour resonance – Takeaways

1. **LF energy is highly variable** even within small geographical area (most LF energy observed along Atlantic coast) → Use wave gauges

2. **Natural harbour frequencies** can be reasonably predicted based on basin size, then simulated more accurately with numerical modeling.

3. **Mitigation strategies**
    - Wave dissipating inner harbour slopes
    - Design for strong currents → Scour protection, mooring systems
    - Substantial rearrangement of the harbour layout.

      If not practical, limit swell penetration and design for LF currents.



Acknowledgements

Public Services and Procurement Canada
Department of Fisheries and Oceans, Small Craft Harbour Program

References

- Rabinovitch A.B. (2010). Seiches and Harbour Oscillations. In: Handbook of Coastal and Ocean Engineering, World Scientific, pp. 193-236.
- Sorensen R., Thompson E.F. (2012). Harbor Hydrodynamics. In: USACE Coastal Engineering Manual, EM 1110-2-1100 Chap. II-7.
- Gierlevsen T., Hebsgaard M., Kirkegaard J. 2001. Wave disturbance modeling in the port of Sines, Portugal – with special emphasis on long period oscillations. Int'l Conf. on Port and Maritime R&D Technology, Singapore, 2001.



ICCE 2018

36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018

Baltimore, Maryland | July 30 – August 3, 2018

The State of the Art and Science of Coastal Engineering

Thank you - Questions / discussion

CBCL LIMITED

Consulting Engineers

Vincent Leys, Coastal Engineer

Halifax, Nova Scotia, Canada - vincentl@cbcl.ca

Co-authors: Victoria Fernandez, P.Eng.

Danker Kolijn, P.Eng.