ASEE
AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Wave and circulation modeling of infrastructure installation at Rota Harbor in Northern Marianna Islands

Lihwa Lin, Zeki Demirbilek, and Jessica Podoski
US Army Corps of Engineers

U.S.ARMY

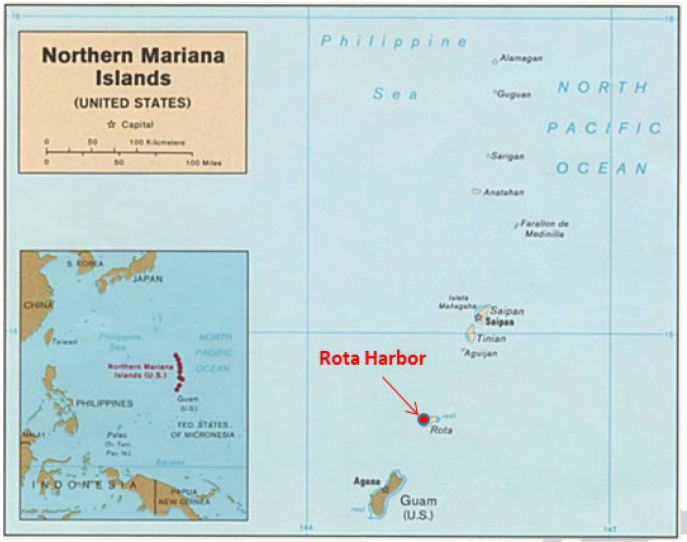
Mission Support Technology Transfer CIRP Research & Development

JSU JACKSON STATE UNIVERSITY

126TH ANNUAL CONFERENCE & EXPOSITION
JUNE 16-19, 2019 | TAMPA CONVENTION CENTER | TAMPA, FL

Outline

- Background & Objectives
- Numerical Models & Settings
- Wave & Hydro Simulations
- Modeling Alternatives
- Summary & Conclusions

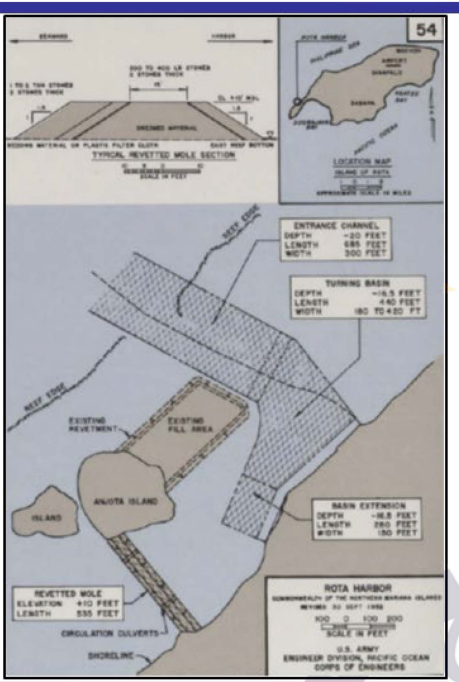


Background

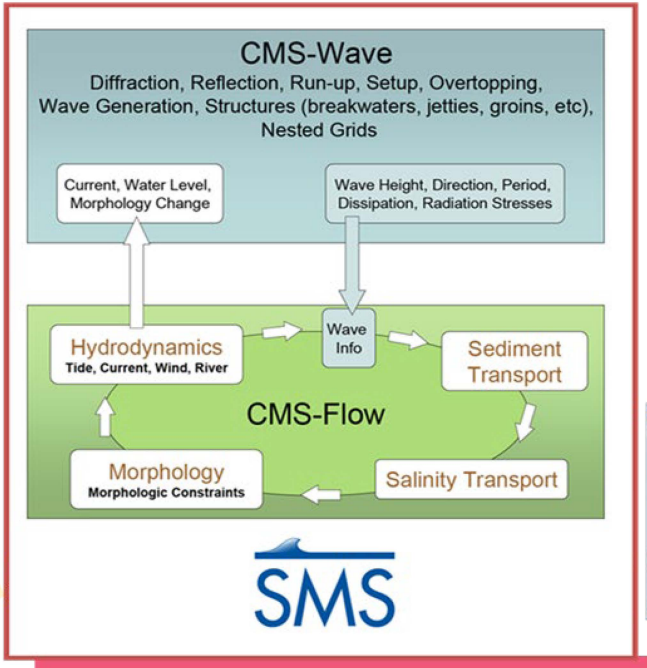
- Rota, approx. 60 km northeast of Guam, is the southernmost island of the Commonwealth of the Northern Mariana Islands (CNMI)
- Rota harbor, a small commercial harbor, located on the northwest coast of Rota was constructed by the US Army Corps of Engineers (USACE) between 1978 and 1985.
- The existing harbor has exposed to frequent high waves and strong currents affecting safe navigation and port operations.

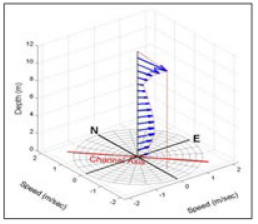
Objectives

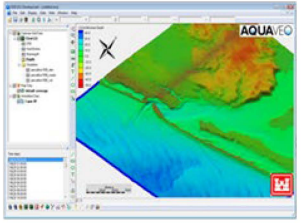
- Assemble survey and field data for input to numerical models
- Apply a Coastal Modeling System (CMS) wave and hydrodynamic models in the present study
- Conduct wave and flow modeling to evaluate proposed alternatives for improving navigation and harbor usability



Coastal Modeling System (CMS)

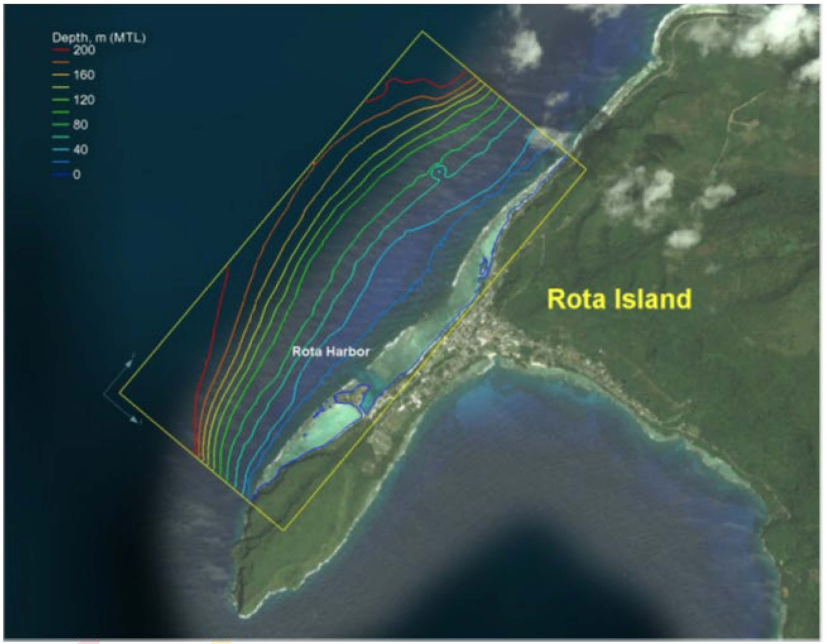






- A suit of time-dependent flow, salinity, wave, & mixed sediment transport models
- Physics-based to simulate complete coastal processes
- Integrated with visual interface thru Surface-water Modeling System (SMS)

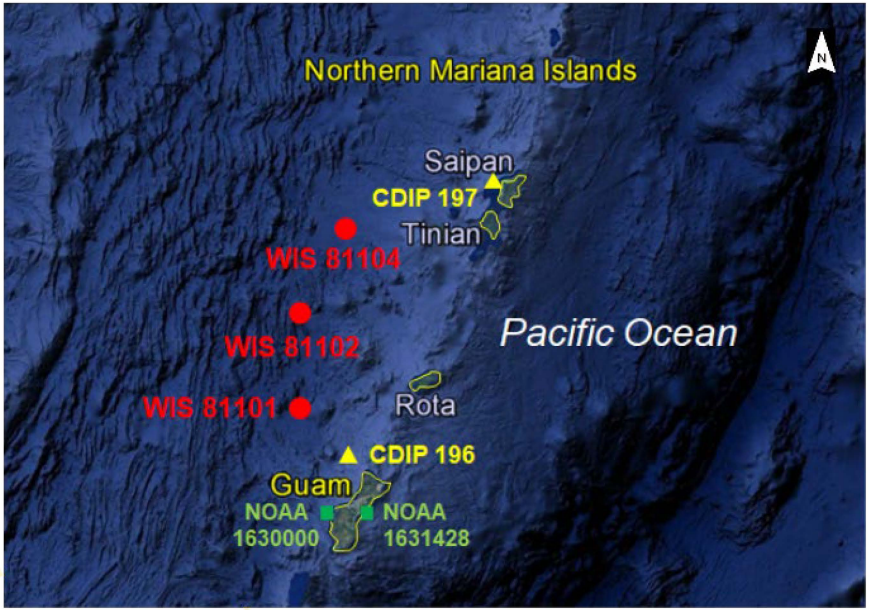
CMS Model Domain



A rectangular domain

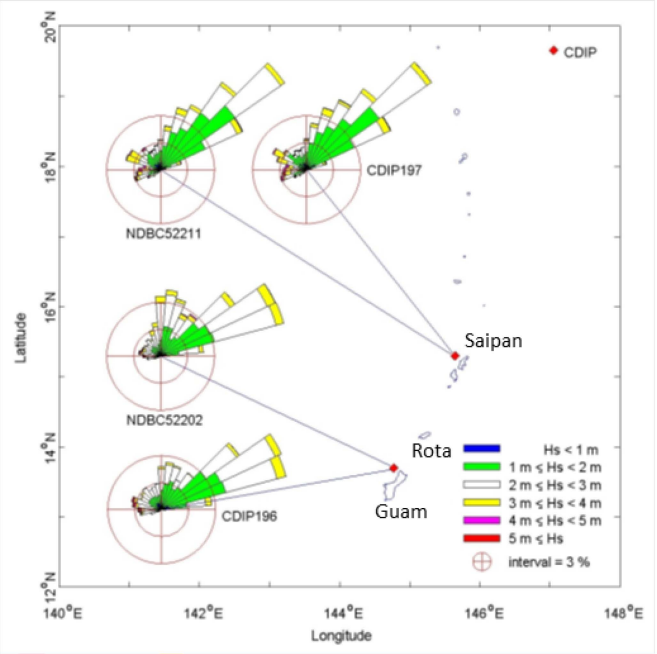
- ~ 2 km x 4.4 km
- extends offshore to ~ max 300-m isobath
- variable cell spacing ~ 4 m (harbor area) to 60 m (far field)
- vertical datum is in Mean Sea Level (MSL)
- horizontal coordinates in UTM 55

Available Data Stations near Rota



- **CDIP Buoys 196 & 197:** wave data available from 2012 to present
- **NOAA Stations 163000 (since 1976) &1631428 (since 2004):** wind & water level data
- **Wave Information Studies (WIS) hindcast:** hourly wind & wave database (1980-2011)
- **WaveWatch III (WW3) nowcast:** wind wave database (2005 to present)

Buoys 196 & 197 Wave Roses (2013 & 2014)

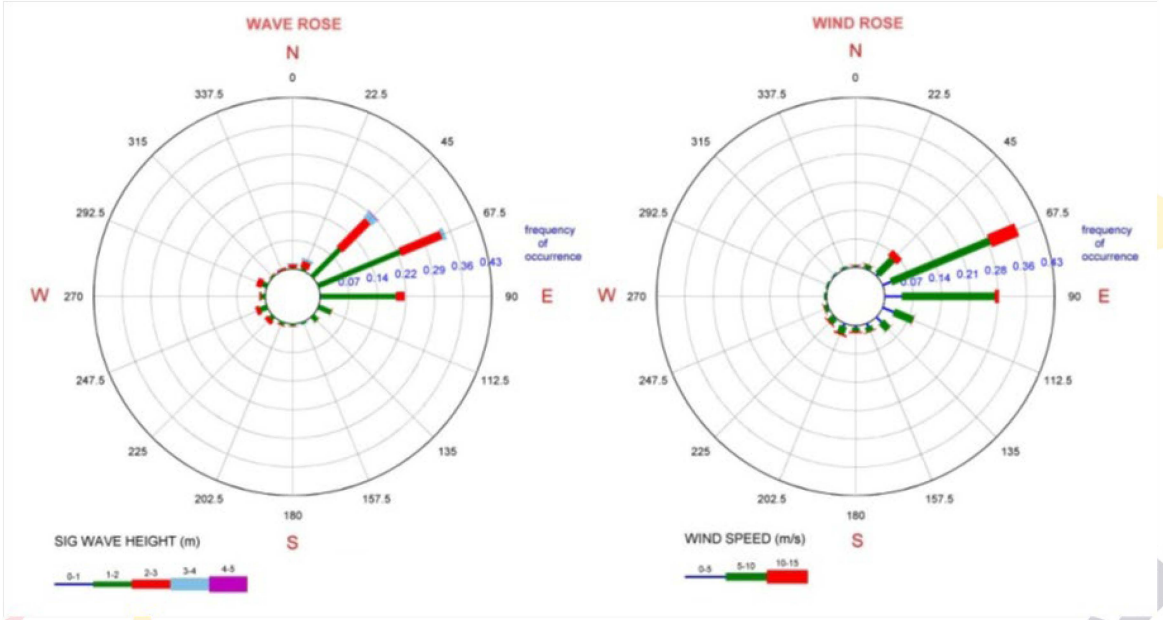


- Waves at Buoy 196 are sheltered by Guam
- Waves at Buoy 197 are sheltered by Saipan
- Trade wind effect is strong at both buoys

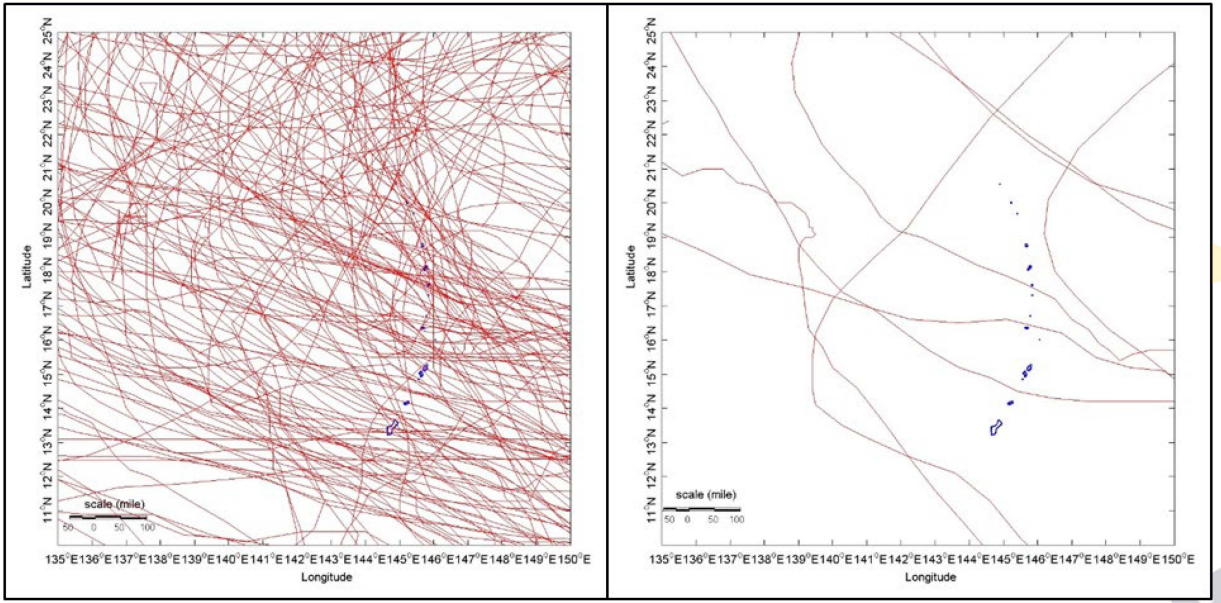
ASEE 2019 Annual Conference
CHARGED UP FOR THE NEXT 125 Years

WIS 81102 Wind & Wave Roses (1980-2011)

CIRP
Technology Transfer
Mission Support
Research & Development



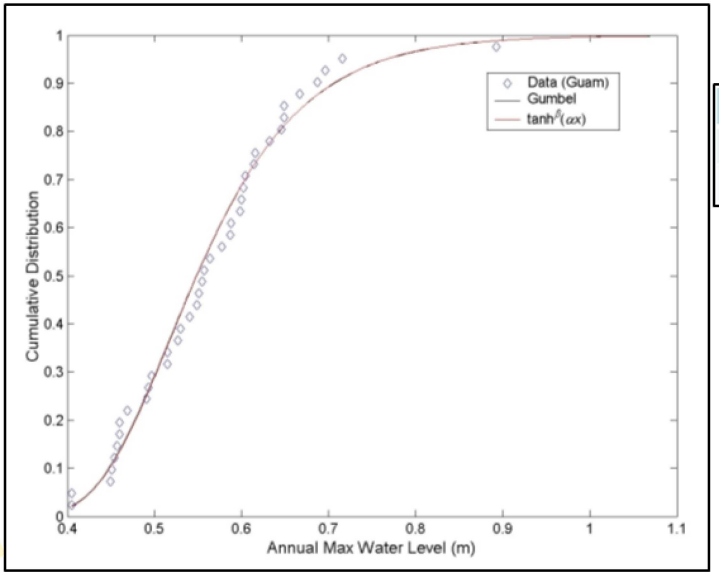
Northern Marianna Islands: A Typhoon/Hurricane Alley



CAT3 and above, 1945-2015 (45 tracks)

CAT5 and super typhoon, 2000-2010 (9 tracks)

NOAA 1630000 Apra Harbor, Guam Extreme Water level Curve (1977-2016)



Return Period (yr)	2	5	10	20	50	100
Gumbel, WL (m)	0.59	0.66	0.71	0.77	0.85	0.90
$\tanh^{\beta}(\alpha x)$, WL (m)	0.59	0.66	0.71	0.77	0.85	0.90

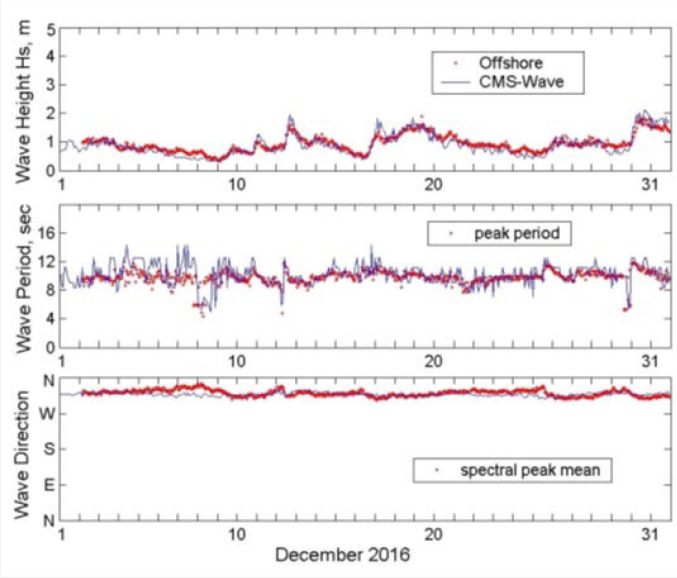
Mean tidal range ~ 0.5 m

Great diurnal range ~ 0.75 m

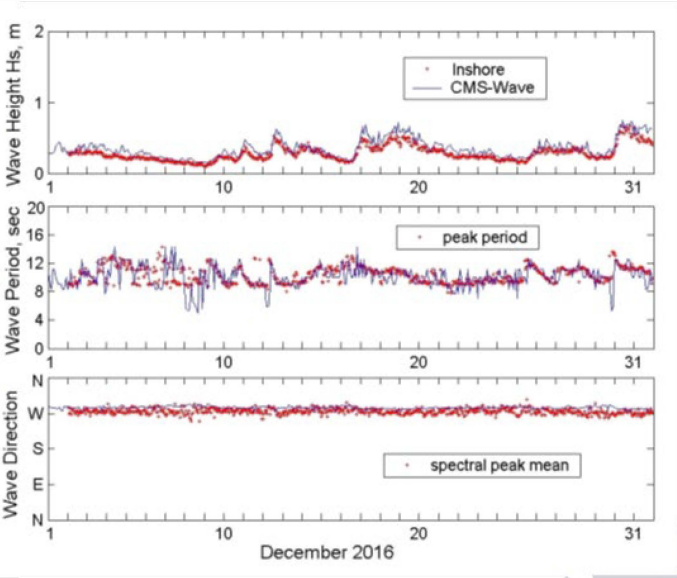
Field Data Collection
December 2016 – February 2017

- 3 ADCP instruments for wave measurements (offshore and inshore stations collected directional wave data while basin station wave data is non-directional)
- A solar powered anemometer collected wind data (Met Sta)
- Wind & wave data were used in model calibration

Model Wave Calibration
December 2016

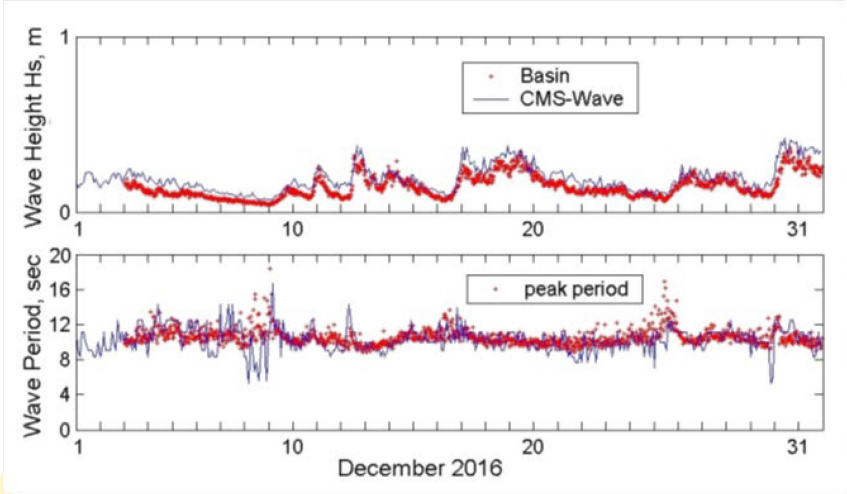


Offshore ADCP Station

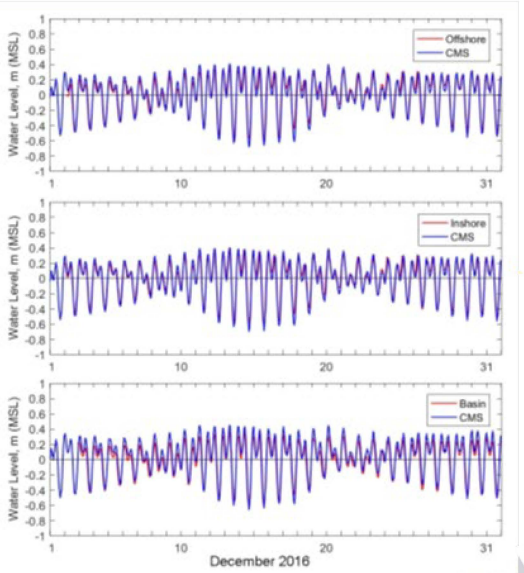


Inshore ADCP Station

Model Wave & Water Level Comparison
December 2016

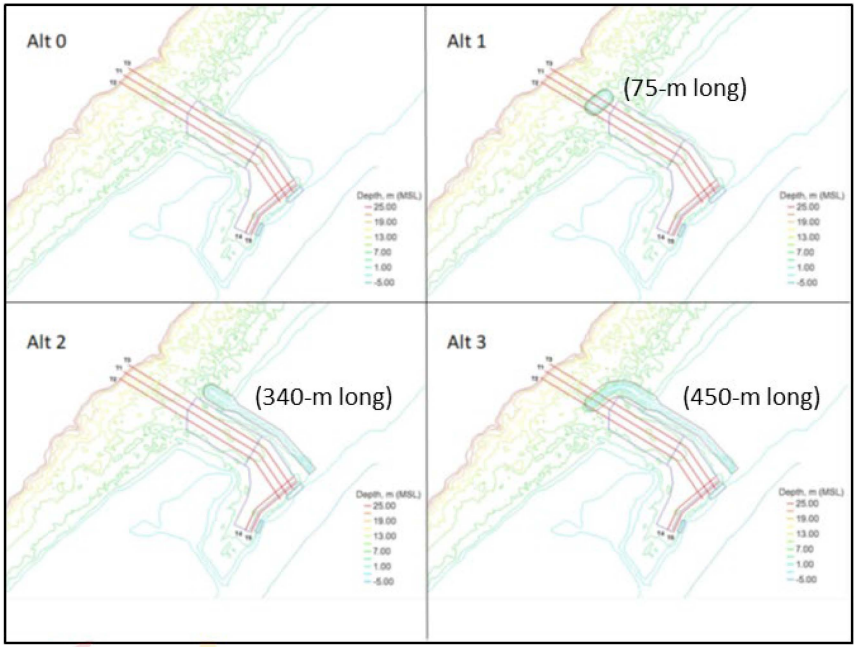


Basin ADCP Station



@ 3 ADCP Stations

Alts 0 to 3 Configurations (5 Transects: T1 – T5)



Alt 0 – existing configuration

Alt 1 – add a detached breakwater*

Alt 2 – add an attached north breakwater*

Alt 3 – connect Alt 1 and Alt 2 breakwaters

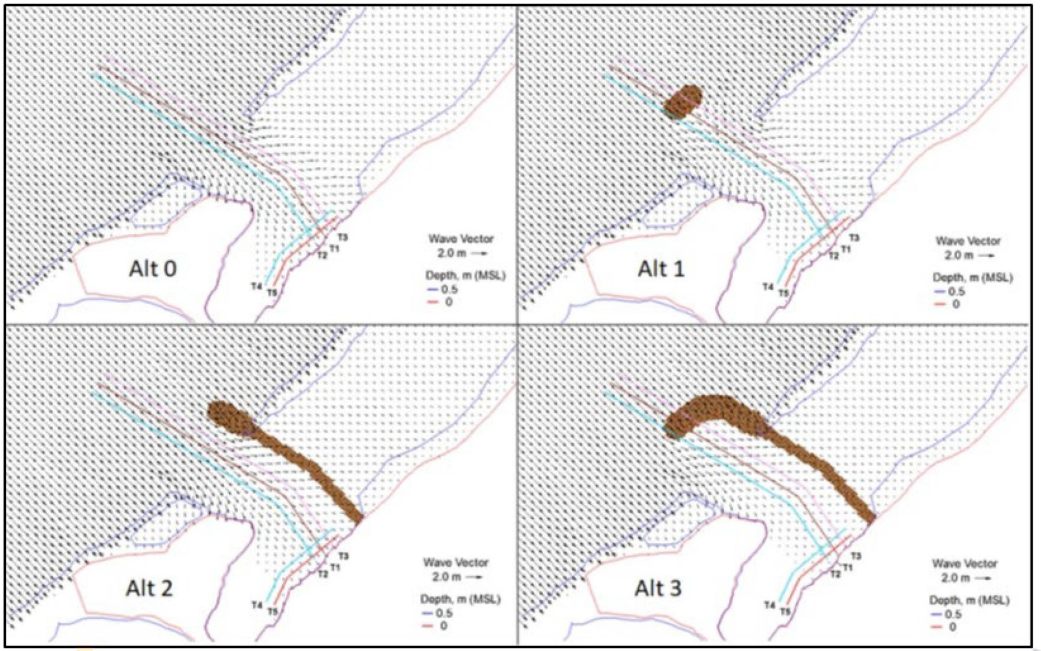
* Breakwater elev.
= 3.25 m in Alt 1
= 2 m in Alt 2

Incident Wave Conditions

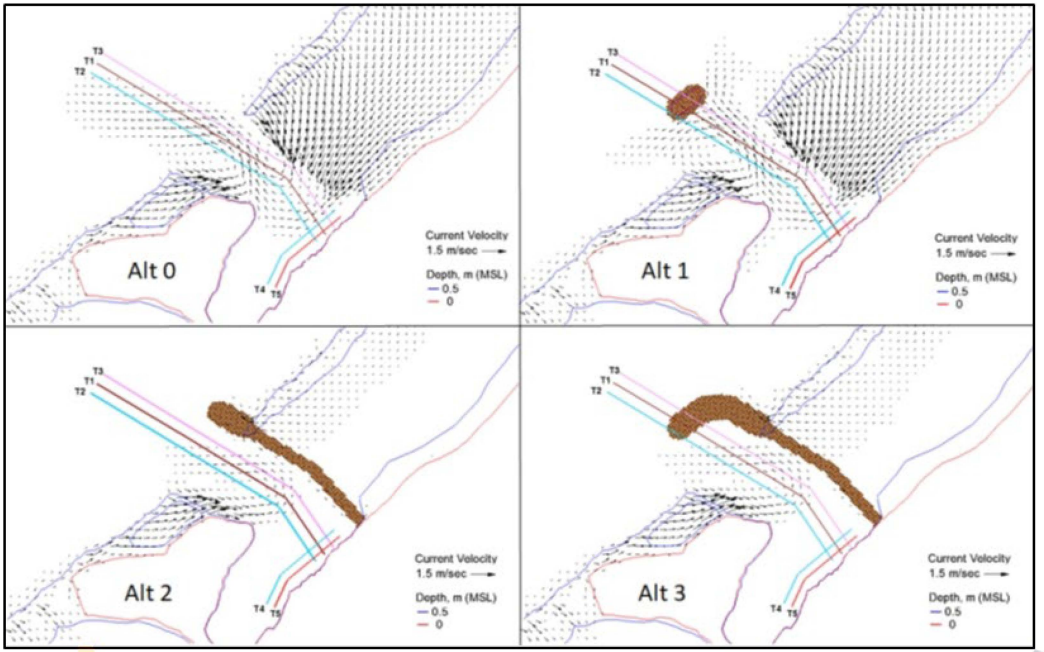
Offshore Wave Forcing Parameters	Increments
Significant Wave Height (m)	0.61*, 0.91, 1.22, 1.52, 1.83**
Corresponding Peak Period (sec)	11, 13, 14, 14, 14
Mean Direction (deg, meteorological)	300, 320^{+}, 330
Water Level, MSL (m)	0, 0.3^{++}

* Maximum wave height for safe harbor access at entrance channel
** Storm wave height for breakwater design
\+ 320° wave direction is aligned with harbor entrance channel centerline
++ Mean Higher High Water (MHHW)

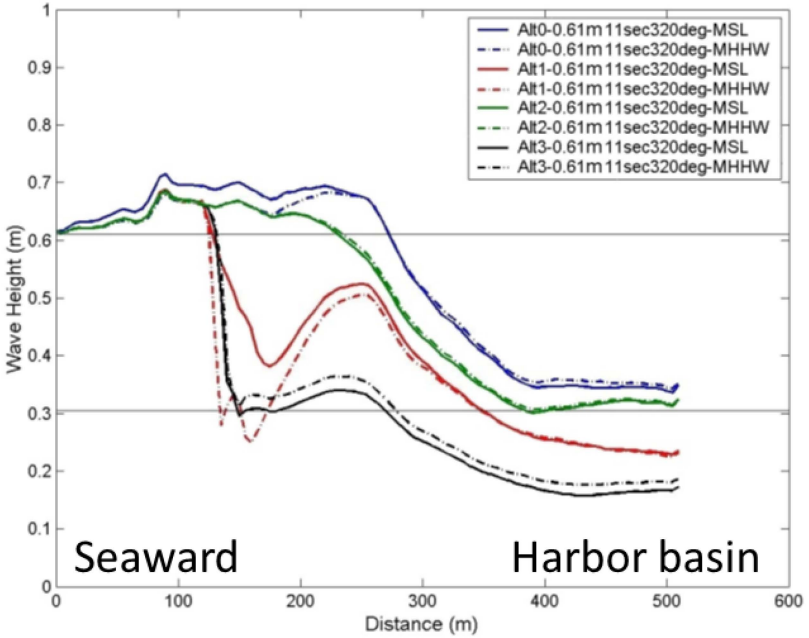
Example of Model Wave Fields (Input Wave: 1.22m, 14sec, 320°)



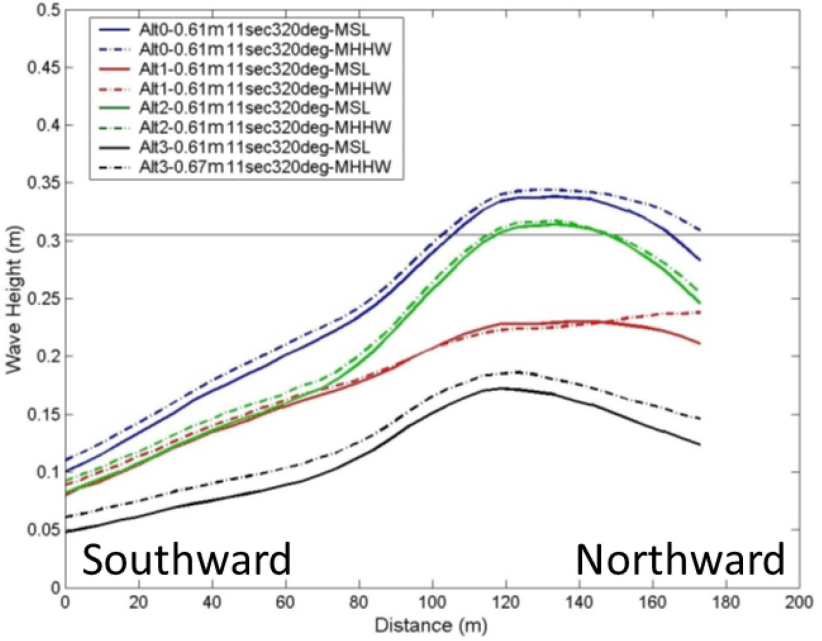
Example of Model Current Fields (Input Wave: 1.22m, 14sec, 320°)



Model Wave Heights along T1 (Input Wave: 0.61m, 11sec, 320°)



Model Wave Heights along T5 (Input Wave: 0.61m, 11sec, 320°)



Harbor 12-Hr Daytime Usability (Based on WIS 81102 – 32 Yr data)

Alt	Percent usable (1980-2011)*	Percent usable (worst year)*
0	82.8 %	71.8 % (1997)
1	86.5 %	76.8 % (2004)
2	83.6 %	73.6 % (1997)
3	91.4 %	83.8 % (2004)

* Include 0 and 0.3 m water level input, and all incoming wave directions between 230 and 360 deg, and between 0 and 50 deg.

- Hs < 0.61 m (2 ft) in the entrance channel
- Hs < 0.3 m (1 ft) at harbor docks and marina

Summary & Conclusions

- The CMS modeling was conducted for the existing Harbor (Alt 0), with a detached breakwater (Alt 1), the north breakwater (Alt 2), and the dogleg breakwater (Alt 3).
- Model results show wave breaking on adjacent reef flat causing return flow in the entrance channel. The magnitude of return flow is approximately proportional to the breaking wave height.
- Alts 2 and 3 outperform Alts 0 and 1 in terms of wave height and return flow reduction in the entrance channel.
- Alt 3 provides the best percentage of harbor usability. However, the cost of breakwater construction & maintenance can be high.
- Alternatively, a shorter structure in Alt 3 may be considered.

ASEE 2019 Annual Conference
CHARGED UP FOR THE NEXT 125 Years

Thank You!

CIRP
Technology Transfer
Mission Support
Research & Development

Questions?

Lihwa Lin, Email: Lihwa.Lin@usace.army.mil
Zeki Demirbilek, Email: Zeki.Demirbilek@usace.army.mil