MOTT MACDONALD

# Predicting and Mitigating Passing Ship Surge Effects in Harbors

AAPA American Association of Port Authorities
Alliance of the Ports of Canada, the Caribbean, Latin America and the United States

Facilities Engineering Committee

# Special Thanks

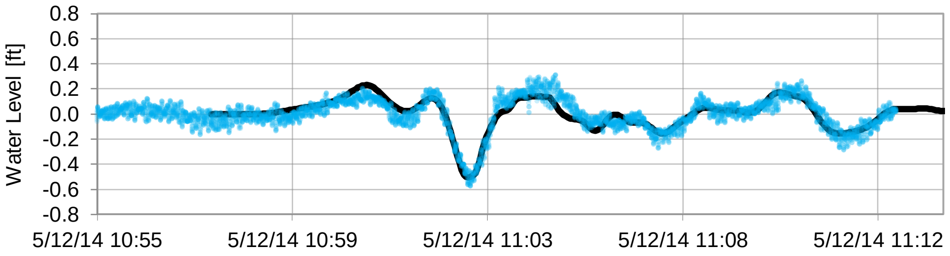
Bill Crowe, Canaveral Port Authority

Thanh Vuong/Edwin Draper, Port of Oakland

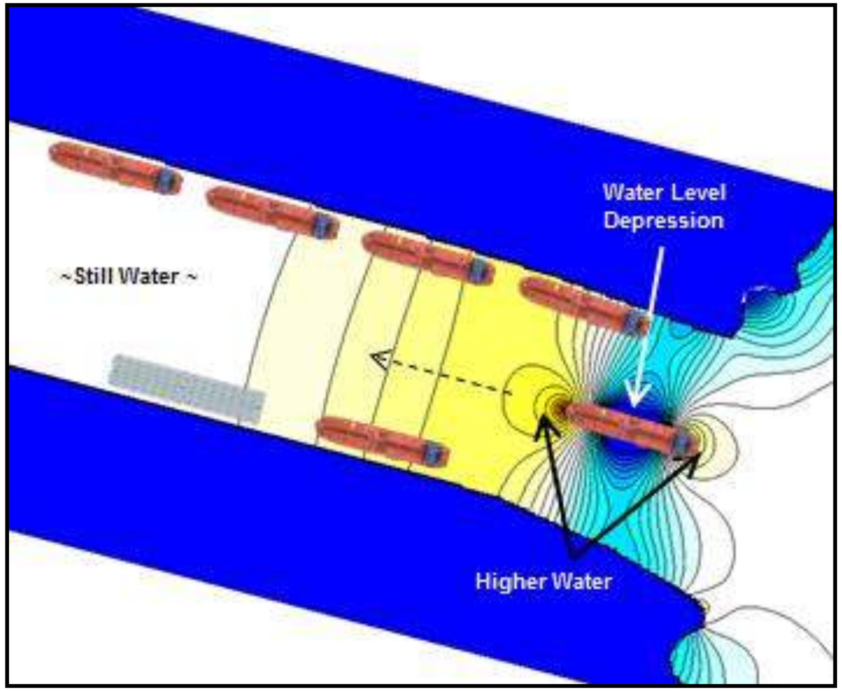
David Krams, Port Corpus Christi

# Outline

- Surge effects overview
- Development and validation of predictive tools
- Prediction and mitigation of surge effects
  - Larger vessel accommodation
  - Harbor development and improvement (dredging, mooring, ship-to-ship transfer)
  - Recreational/mixed use development
- Mitigations summary
- Conclusions

# Surge Effects




April 10, 1912 at Southampton

http://www.lostliners.com/content/flagships/Titanic/maiden.html

# Surge Effects

# Development and Validation of Predictive Tools

- 1970s - laboratory research published.  Limited datasets, not applicable to real-world problems.
- 1980s to 1990s - analytical models developed with many idealizations, difficult to apply to real-world problems.
- 1990s to 2000s - empirical load calculation methods developed based on laboratory data, only for open water.
- 2000s – numerical models utilized (linear and nonlinear shallow water equations, Boussinesq equations, other)
- Mid-2000s to present – successful validations with laboratory and field measurements, more numerical tools being developed

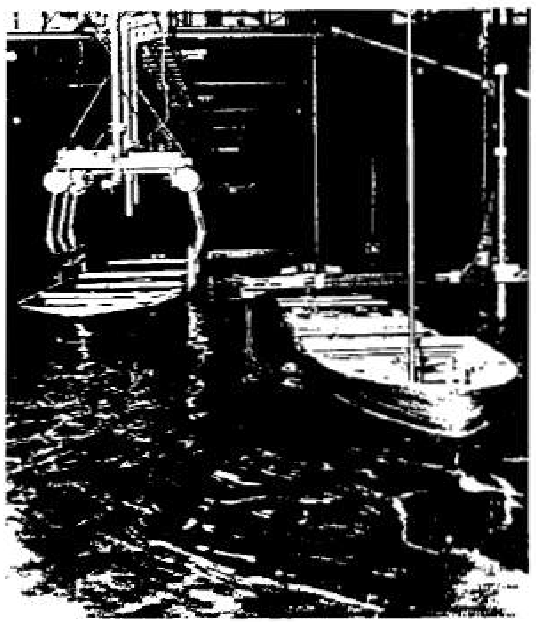
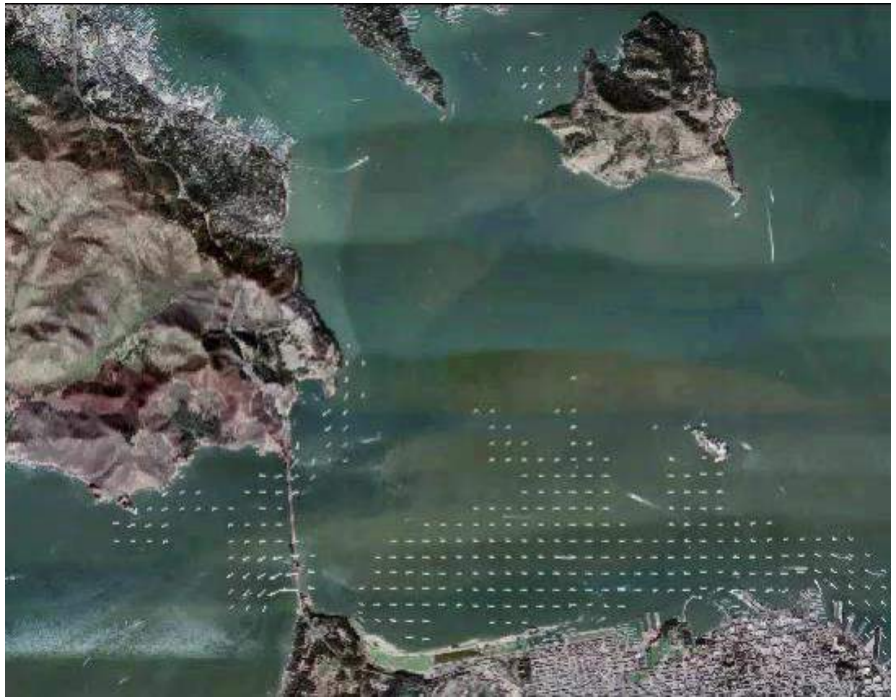
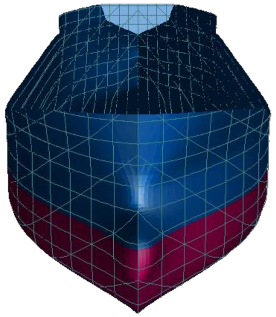


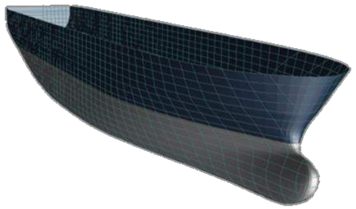
Fig. 17 - Photograph showing set-up for test with a flexible moored 100 MDWT tanker.

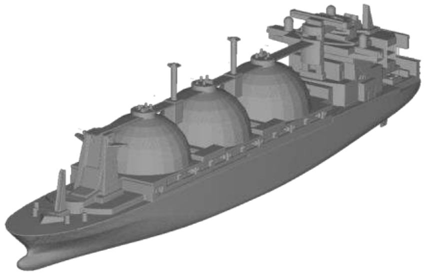
# Development and Validation of Predictive Tools

- Coastal processes modeling system used as foundation for surge model development
- Fully nonlinear, finite volume shallow water 2D model developed
- Structured/unstructured versions
- Typically 1-2m resolution
- Expanded to include real-world conditions and complexities
- Efficiency allows harbor-wide studies.









# Development and Validation of Predictive Tools

Remery 1974
Lab Tests at NSMB

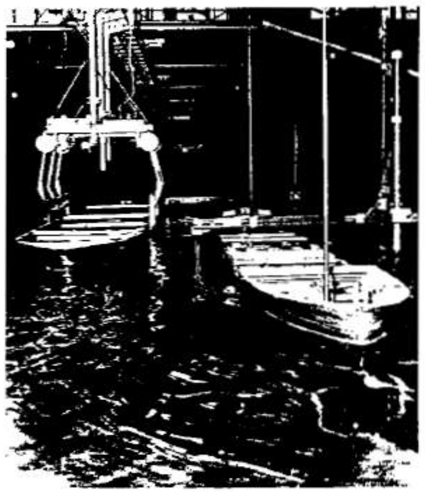
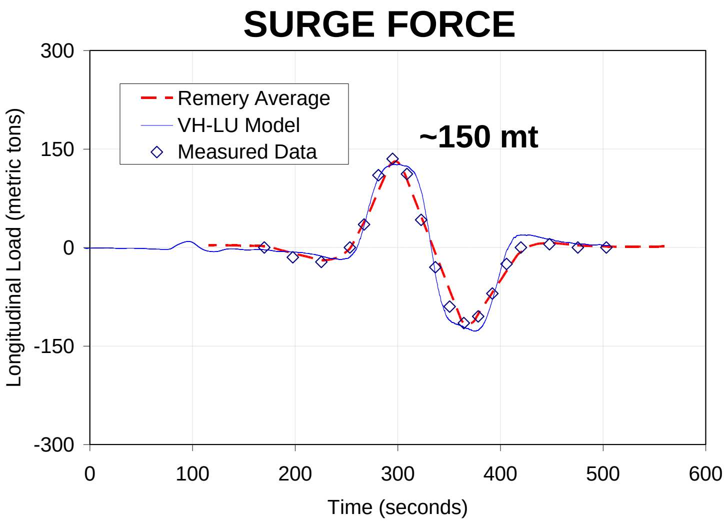
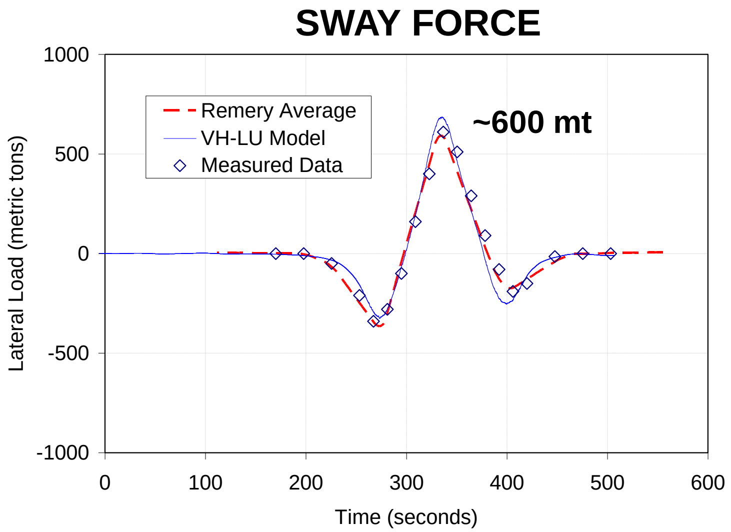
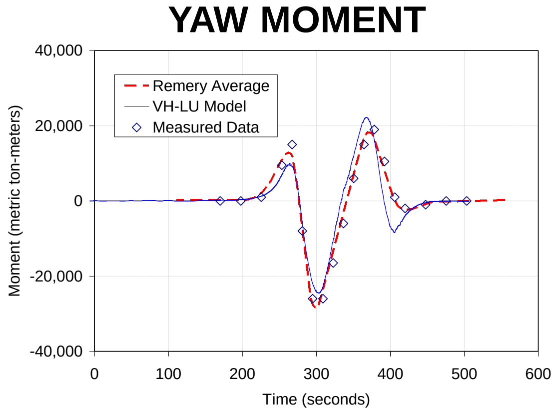


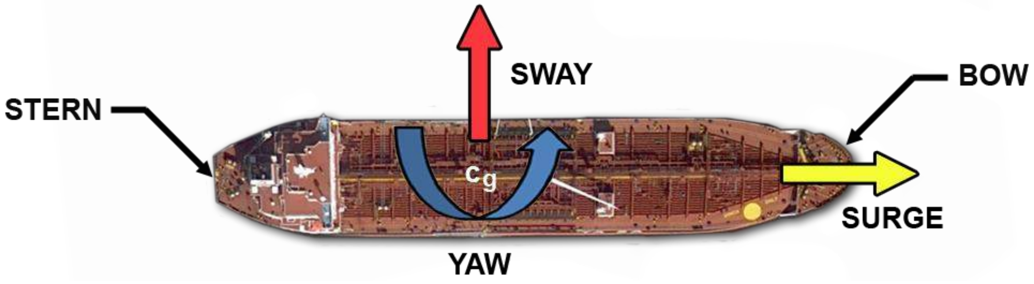
Fig. 17 - Photograph showing set-up for test with a flexible moored 100 MDWT tanker.



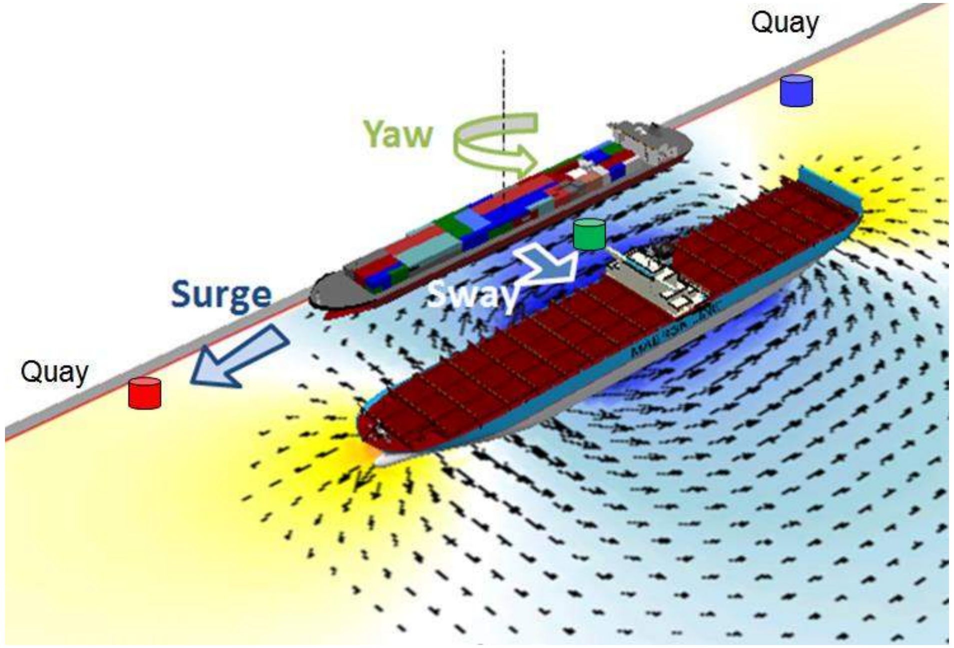



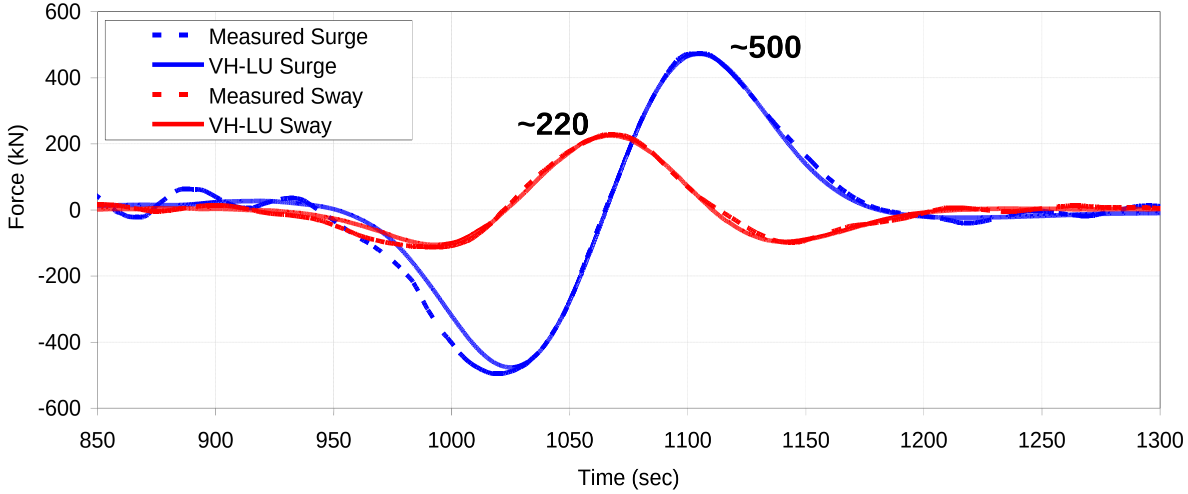

- 60:1 scale tankers
- Open water, parallel-passing only
- Tankers 30, 110, 160 MDWT
- Passing distances 30, 60, 120 m
- Passing speeds 4.0, 5.5 and 7.0 knots

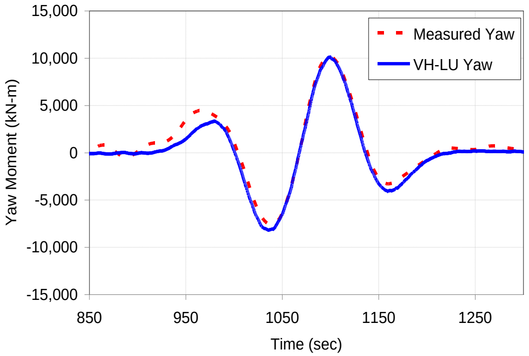


# Development and Validation of Predictive Tools

van Wijhe et al. 2008
Lab Tests at MARIN



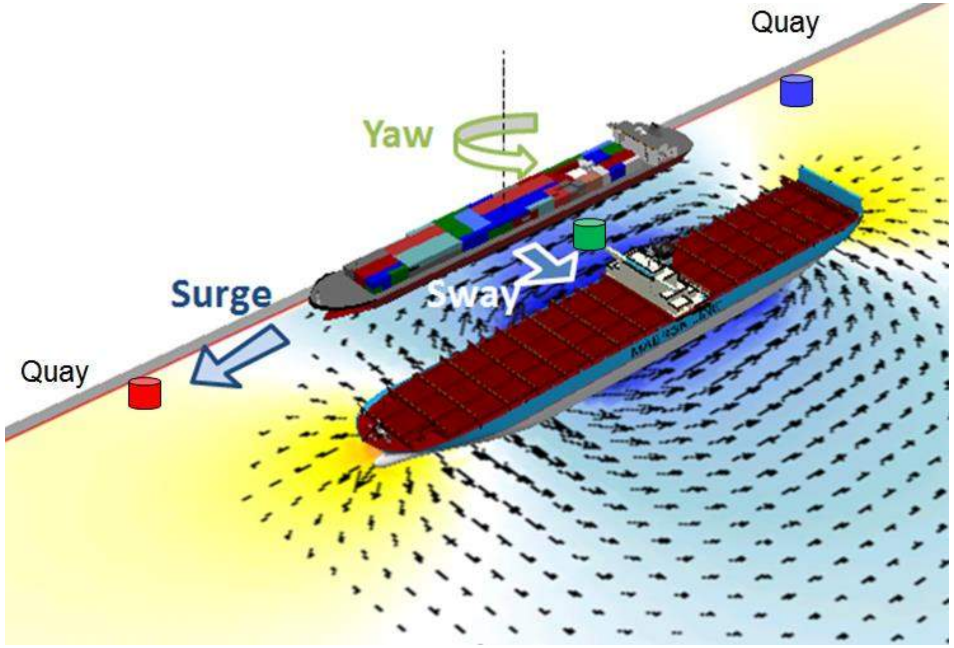



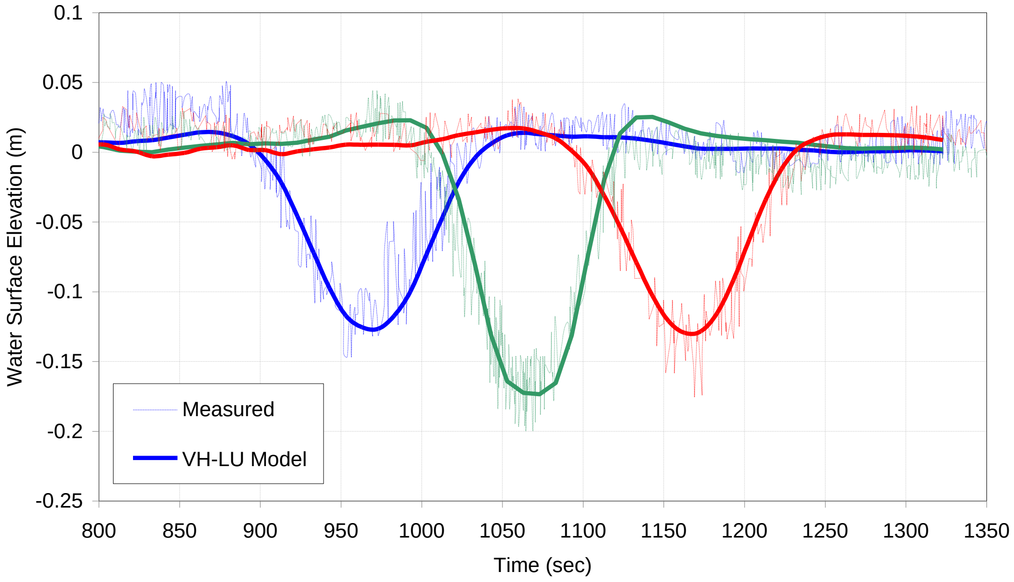




- 38:1 scale containerships
- Vertical quay
- Parallel-passing only
- Passing Ship Speed: 5.5 knots
- Passing Ship Distances: 75 m

# Development and Validation of Predictive Tools

van Wijhe et al. 2008
Lab Tests at MARIN

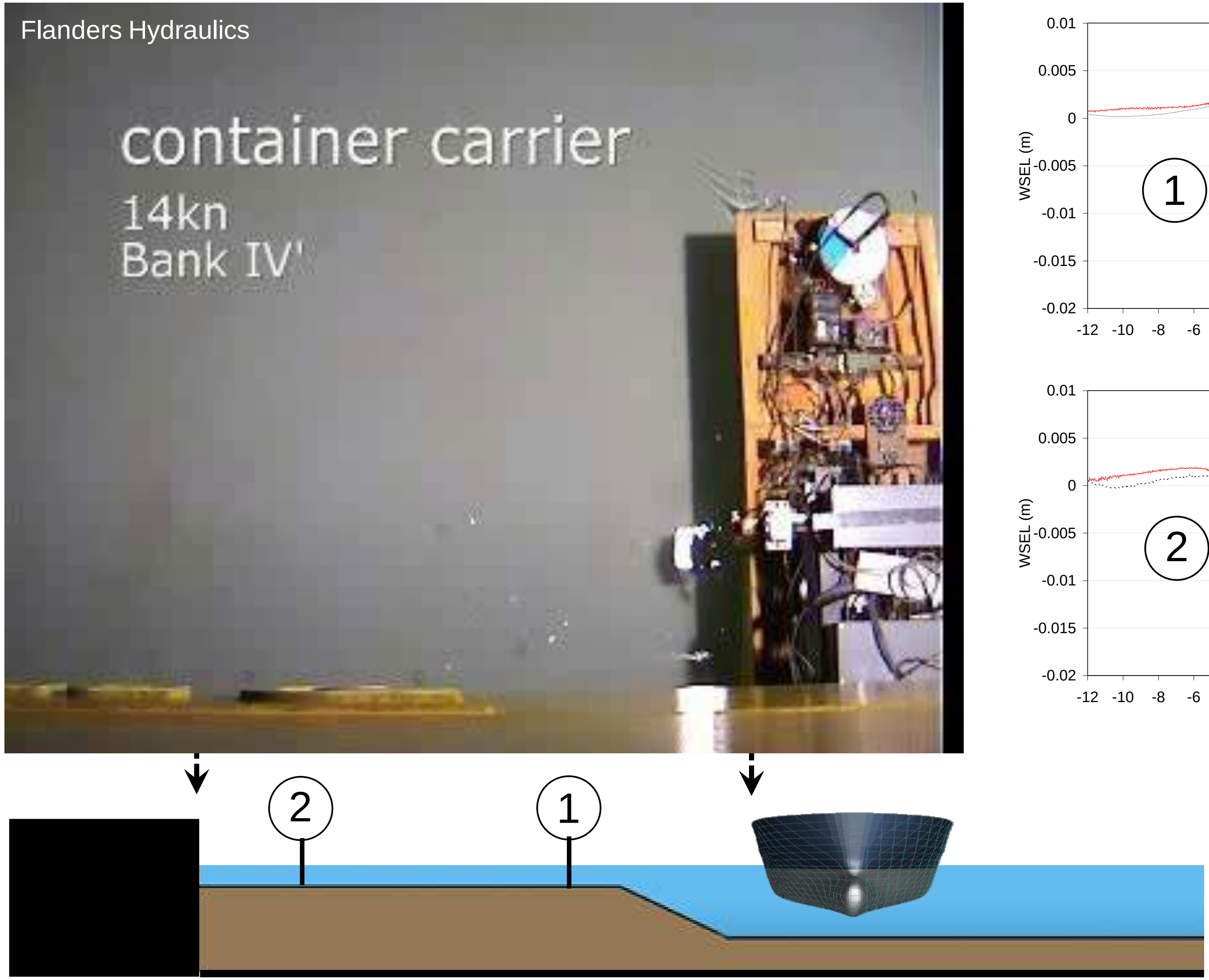


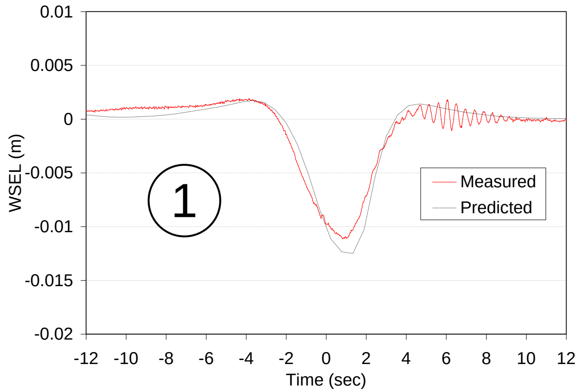



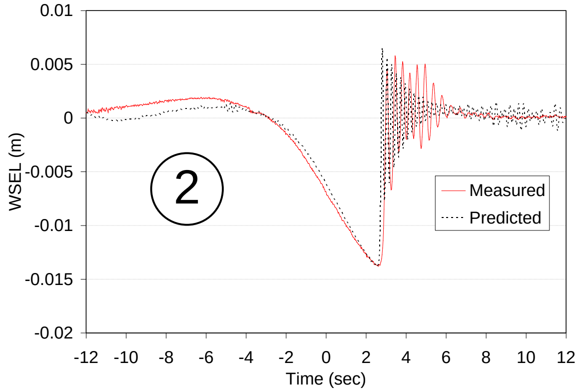

- 38:1 scale containerships
- Vertical quay
- Parallel-passing only
- Passing Ship Speed: 5.5 knots
- Passing Ship Distances: 75 m

# Development and Validation of Predictive Tools

Lataire et al. 2009
Lab Tests at Flanders Hydraulics

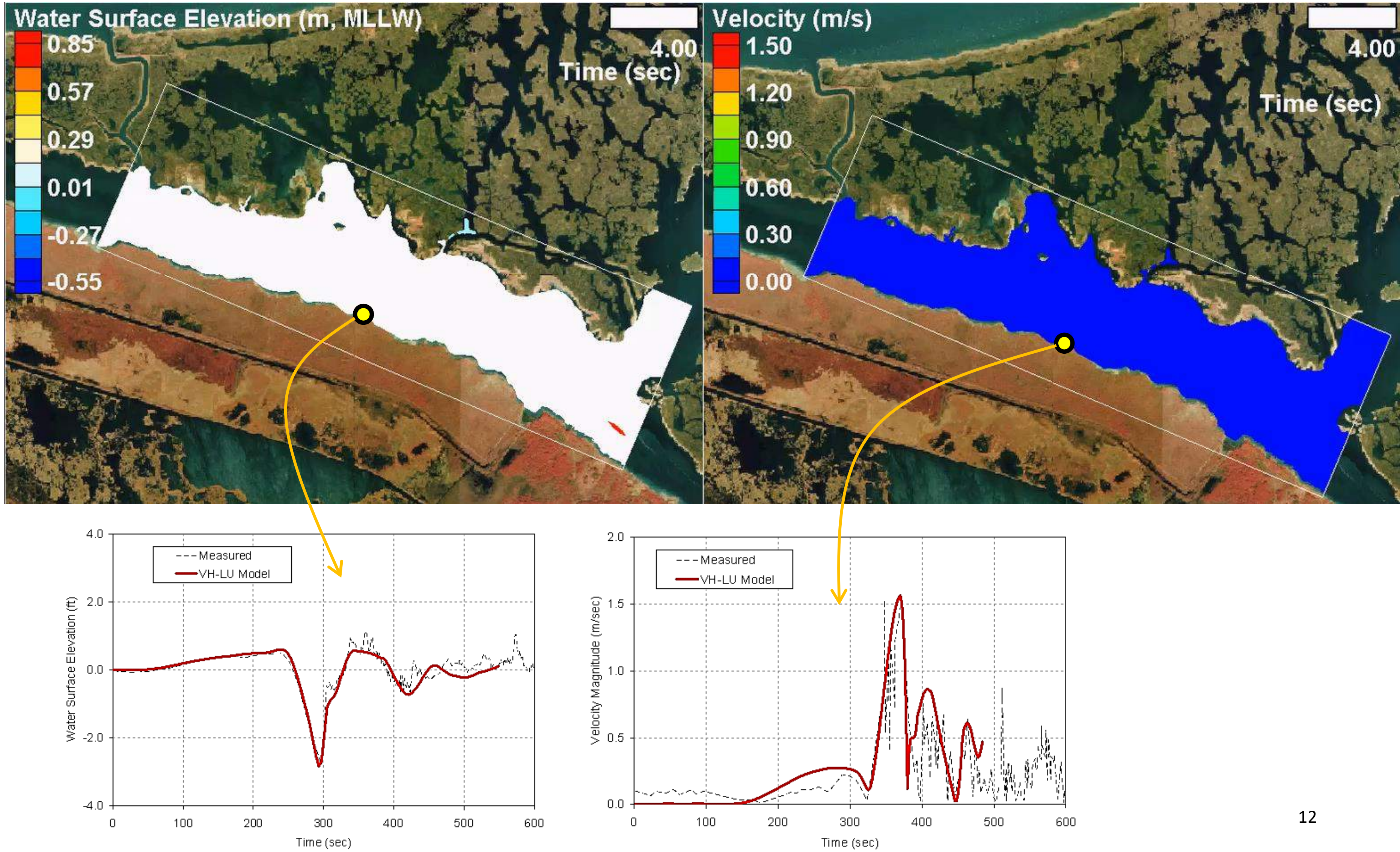


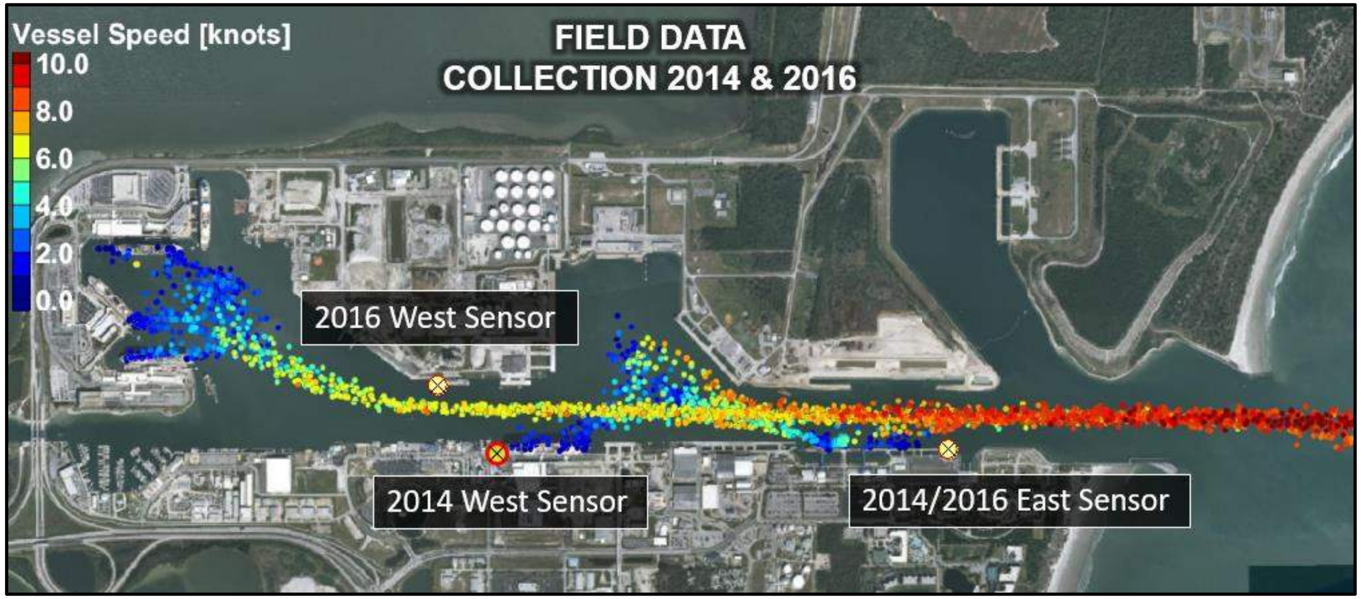
# Development and Validation of Predictive Tools

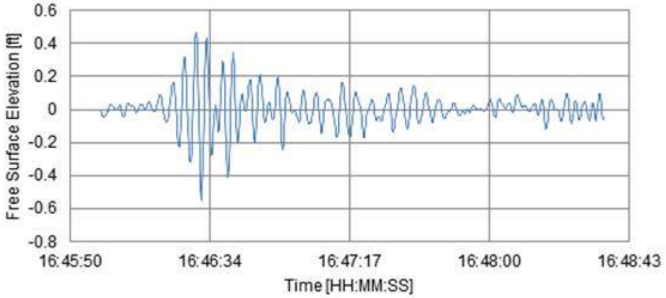
USACE
Measured Water Levels and Velocities
MS River Gulf Outlet

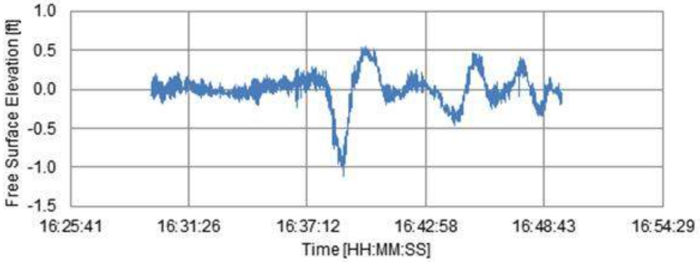


# Development and Validation of Predictive Tools

Measured Water Levels
Port Canaveral, FL

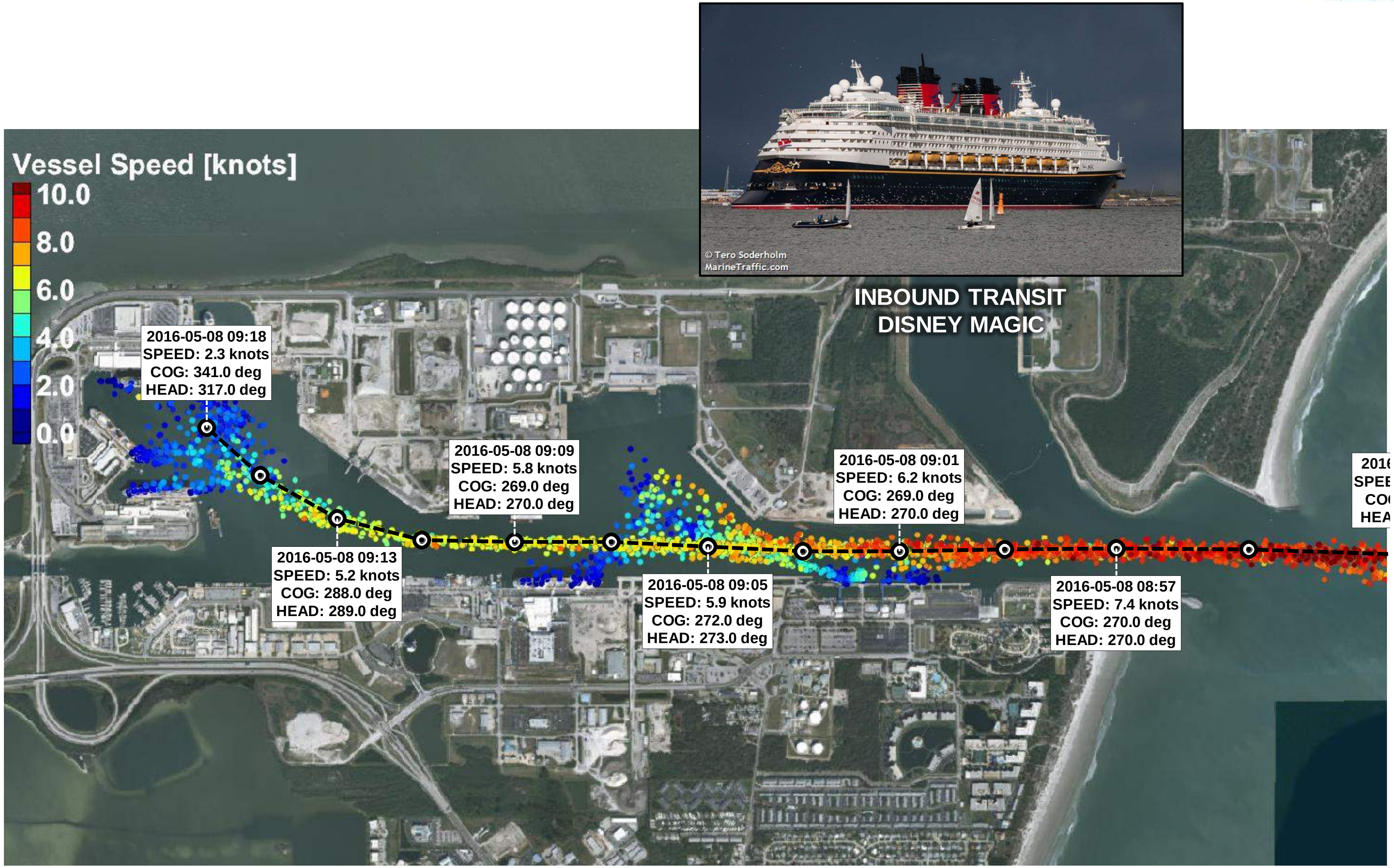


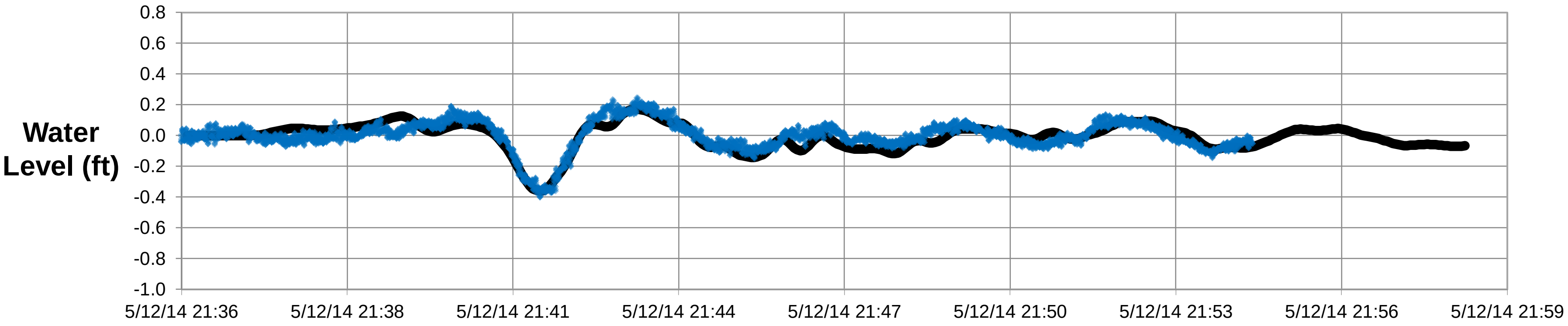

# Development and Validation of Predictive Tools

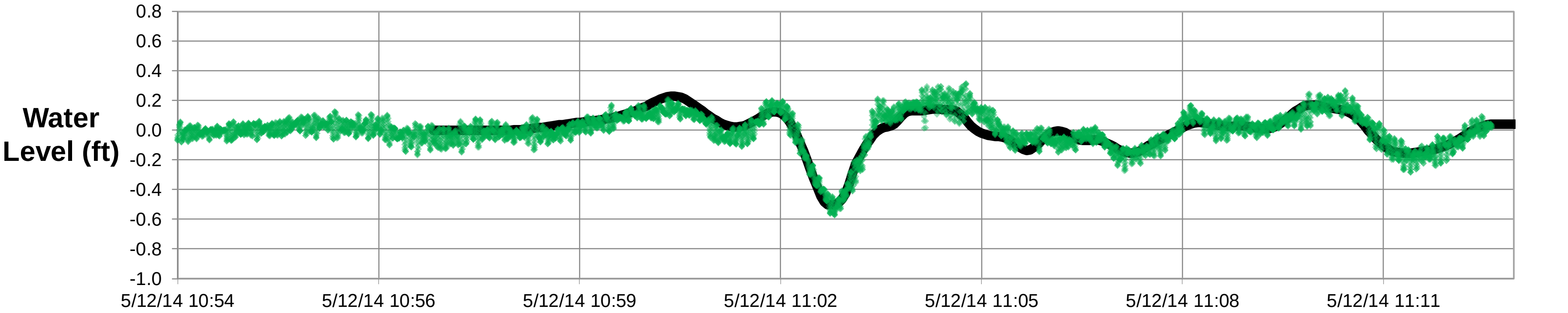
Measured Water Levels
Port Canaveral, FL



# Development and Validation of Predictive Tools

Measured Water Levels
Port Canaveral, FL



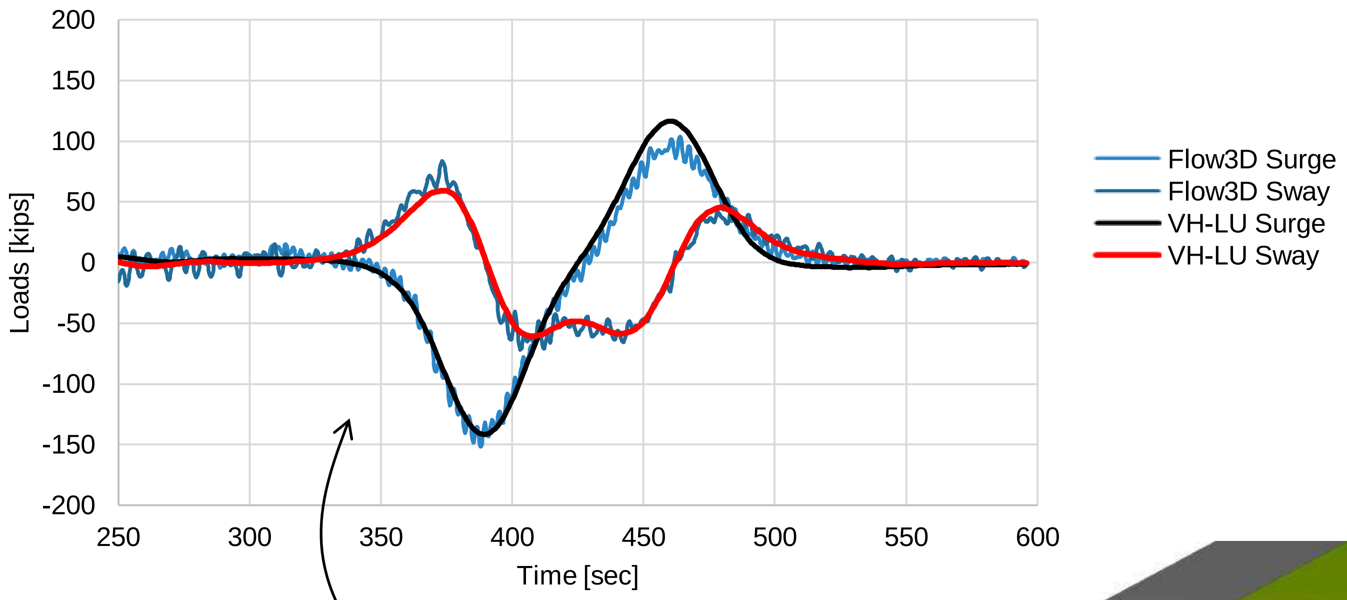



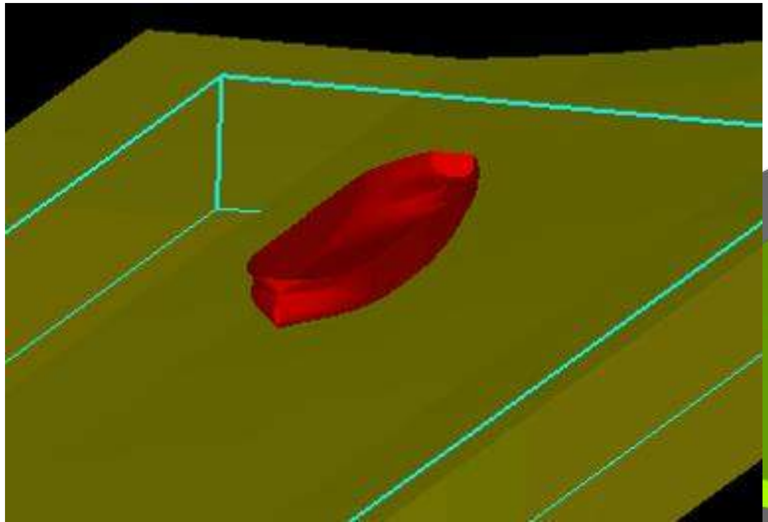

# Development and Validation of Predictive Tools

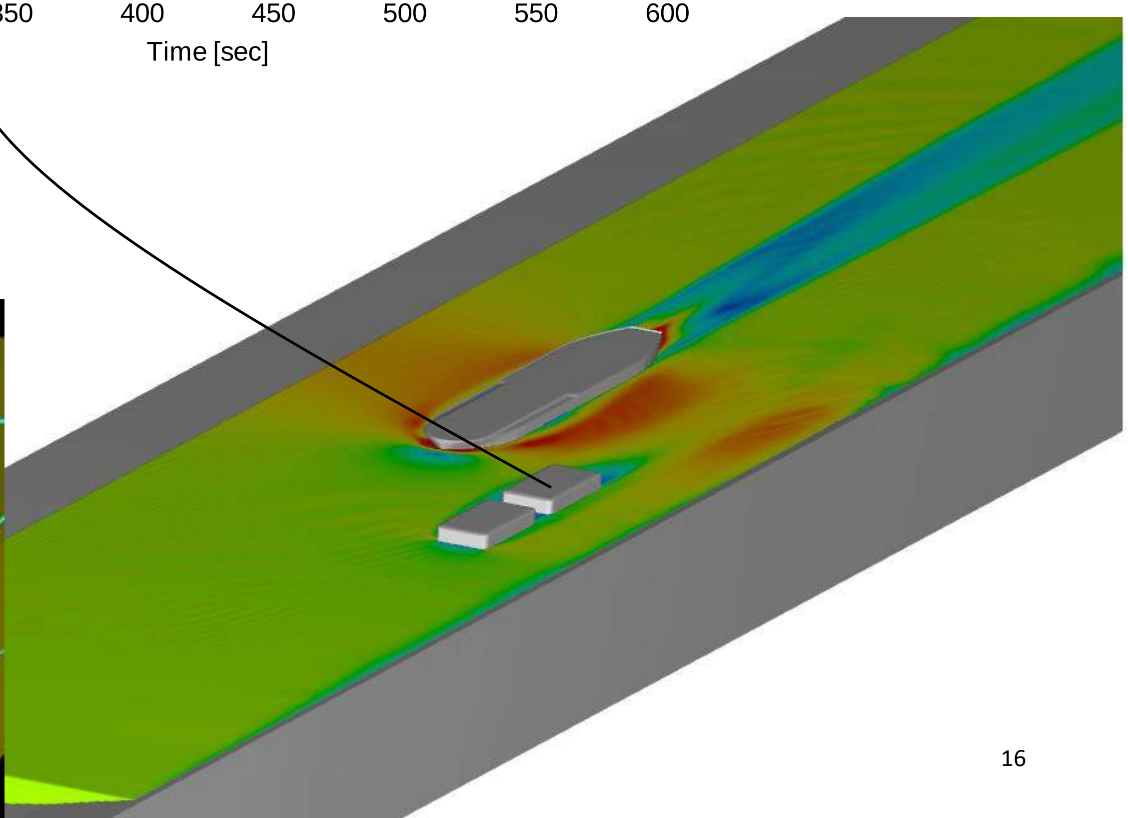
Comparison between VH-LU model and Commercial CFD Programs

*Moored floating caissons over a slope with passing tanker*

*Results are the same for practical purposes, effort/cost is much different.*

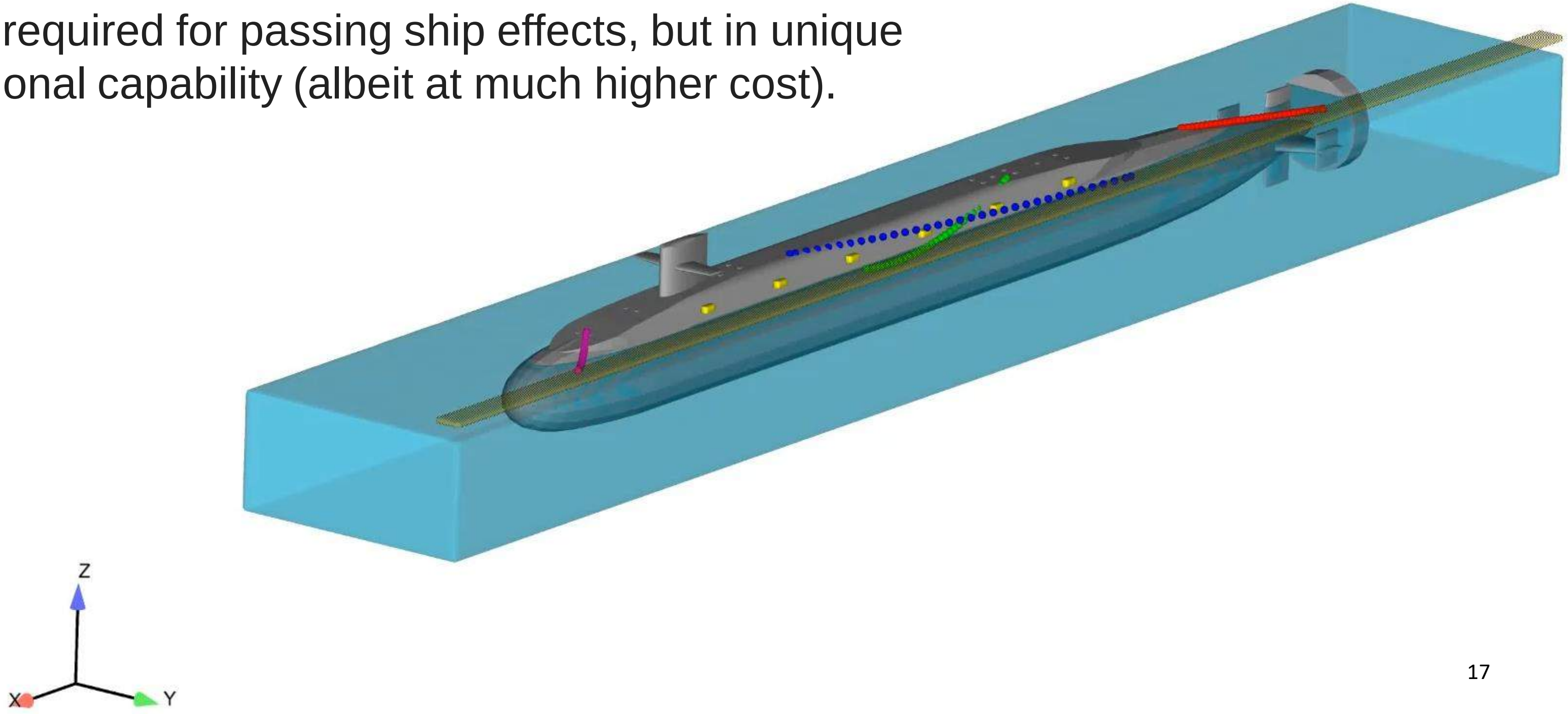




# Development and Validation of Predictive Tools

- Many predictive tools now in use, with varying capability.  Validations are critical to ensure tools are being applied to appropriate conditions.
- Developments slowing, as vast majority of real-world cases now accurately addressed in cost-effective manner.
- Commercial CFD rarely required for passing ship effects, but in unique cases can provide additional capability (albeit at much higher cost).

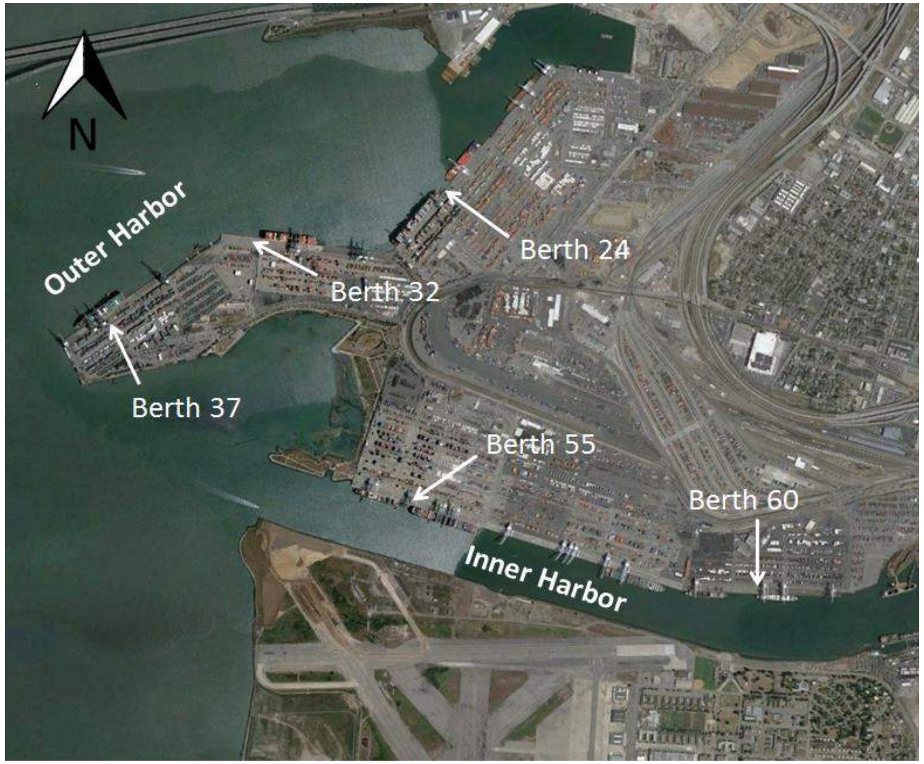


# Harbor Development and Improvement

Larger Vessel Accommodation:
CMA CGM Ben Franklin
Port of Oakland, CA

*Comprehensive vessel accommodation study, included maneuvering, surge effects, berthing and mooring.*

| Particular | CMA CGM Ben Franklin |
|---|---|
| Length Overall (ft) | 1309 |
| Breadth (ft) | 177 |
| Moulded Depth (ft) | 99 |
| Draft (ft) | 52.5 |



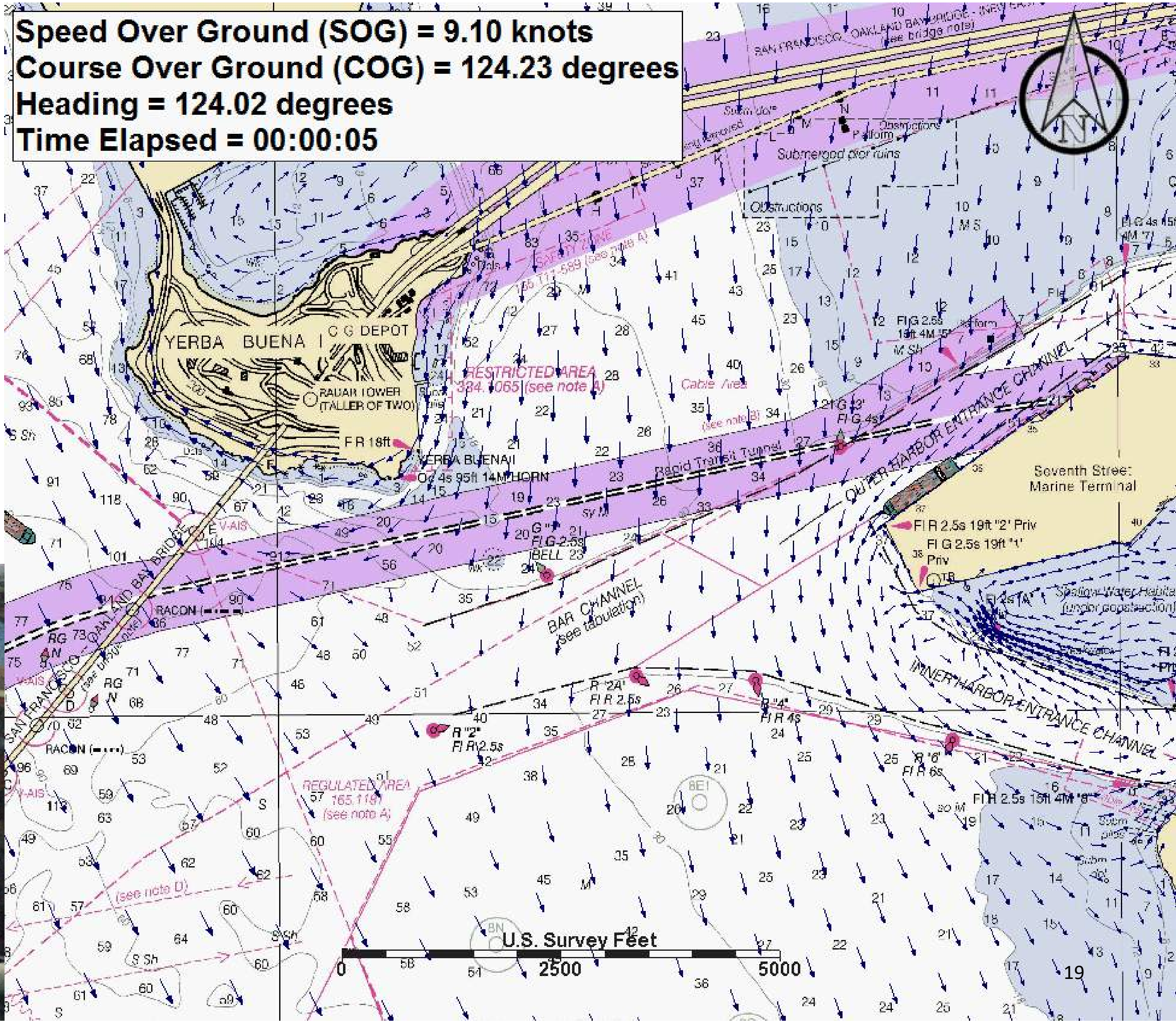
# Harbor Development and Improvement

PORT OF OAKLAND

Larger Vessel Accommodation:
CMA CGM Ben Franklin
Port of Oakland, CA

*Maneuvering simulations help define suitable environmental conditions, and generate input data for surge analysis.*


Simulations performed at CA Maritime Academy

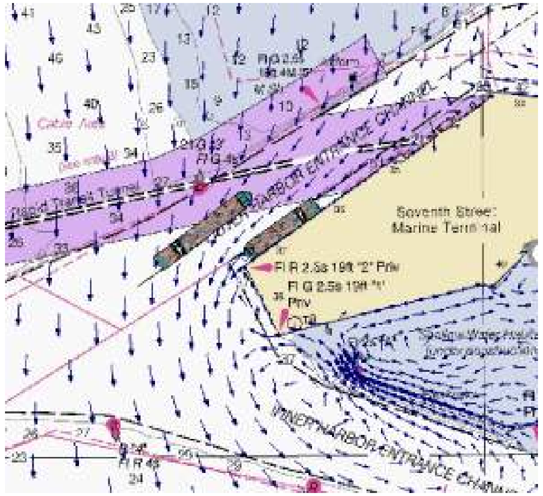


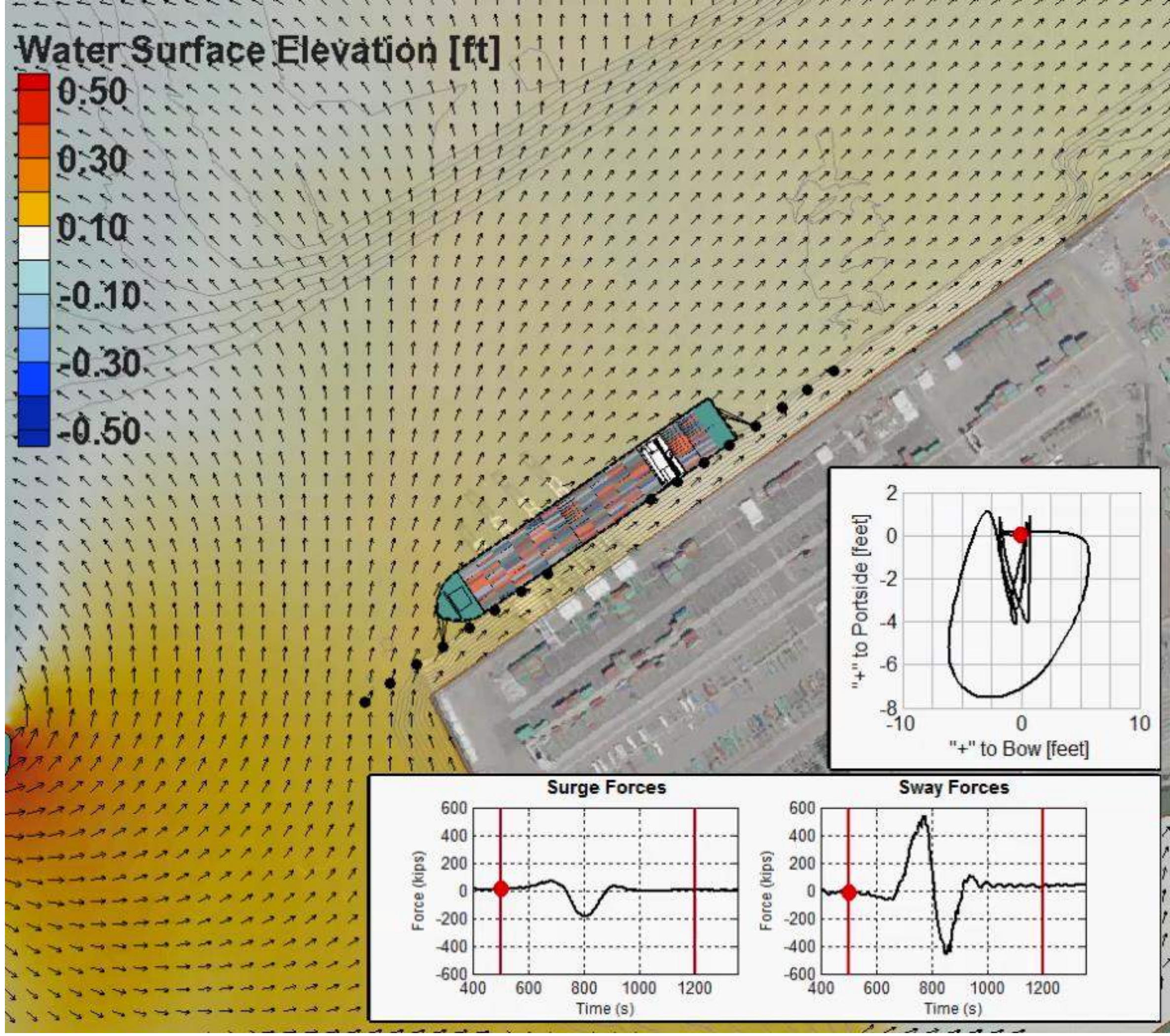
# Harbor Development and Improvement

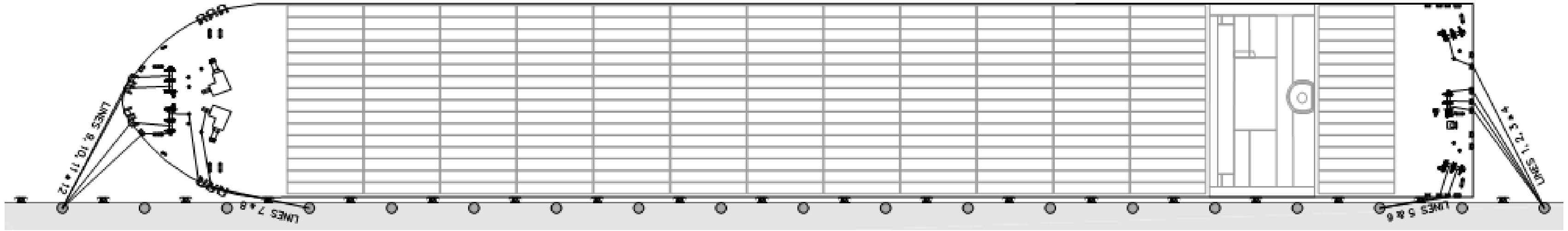
Larger Vessel Accommodation:
CMA CGM Ben Franklin
Port of Oakland, CA

*Surge modeling showed variability in loading due to drift, speed and location.*

*Surge modeling results used as input to dynamic mooring analysis.*



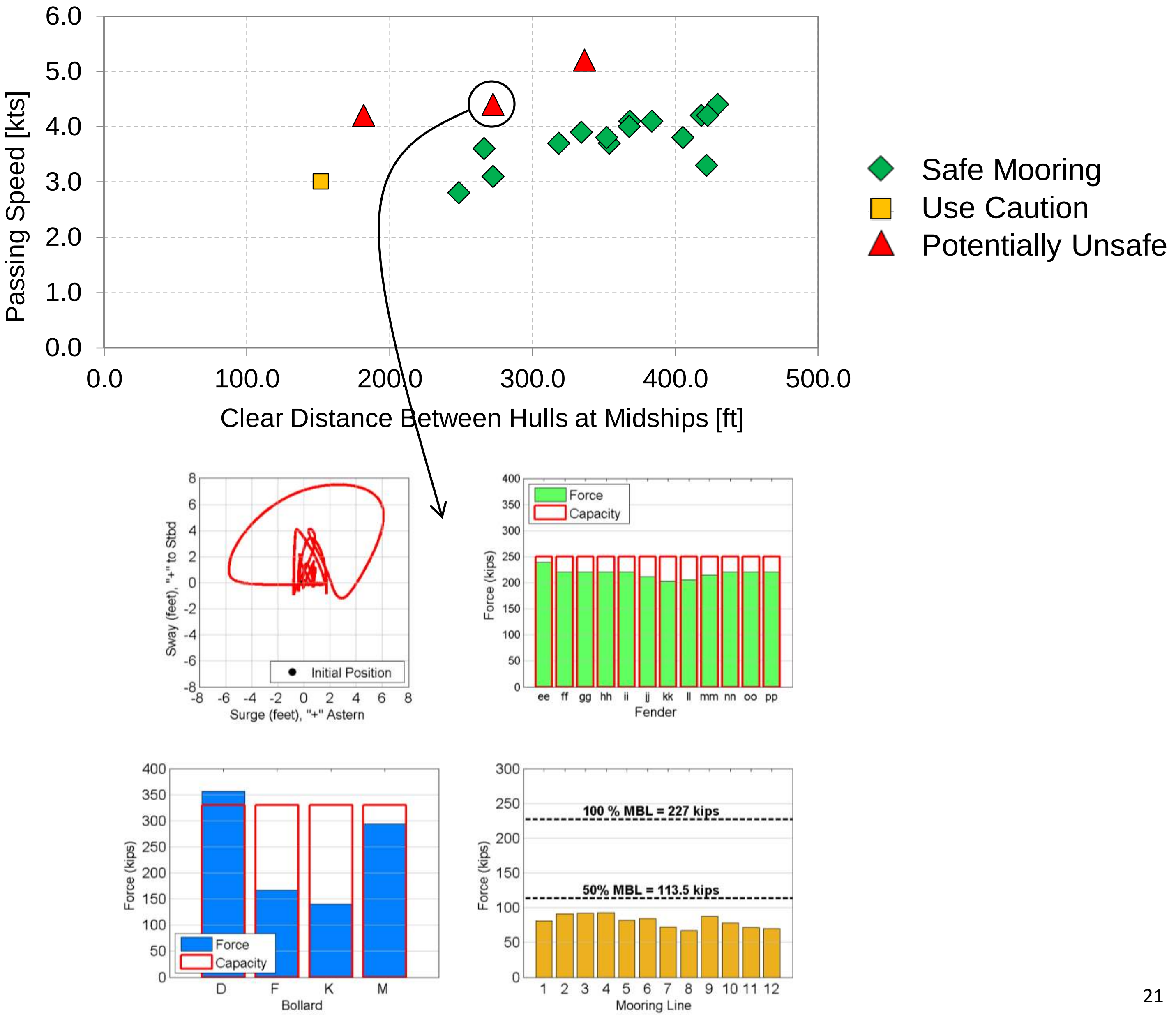

PORT OF OAKLAND

# Harbor Development and Improvement

Larger Vessel Accommodation:
CMA CGM Ben Franklin
Port of Oakland, CA

*Simulations helped define safe navigation practice from a surge perspective*

*Limiting surge effects is a critical element of safe navigation.*



# Harbor Development and Improvement

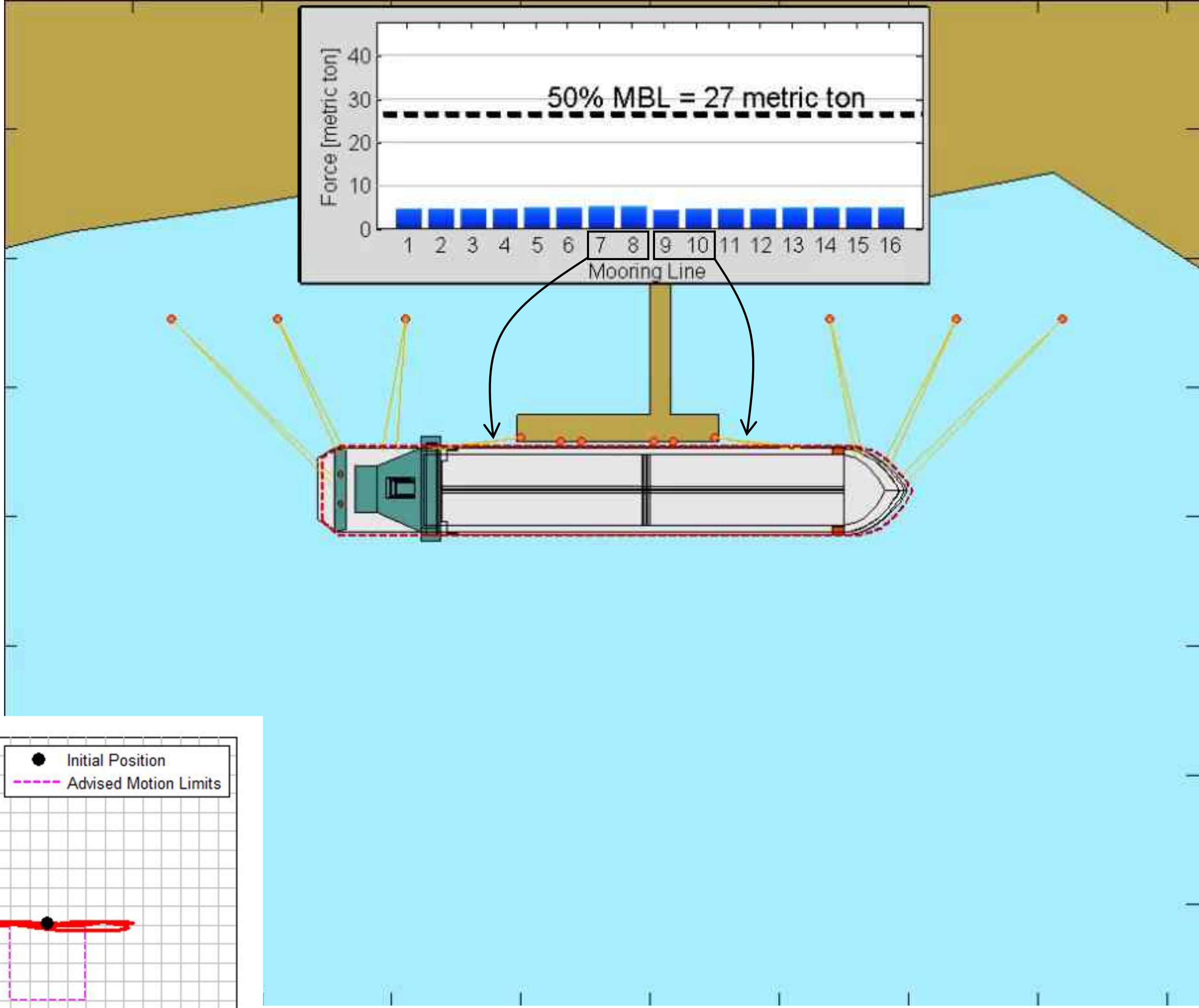
Tanker Dock Mooring Studies: Frequent Findings in Confined Channels

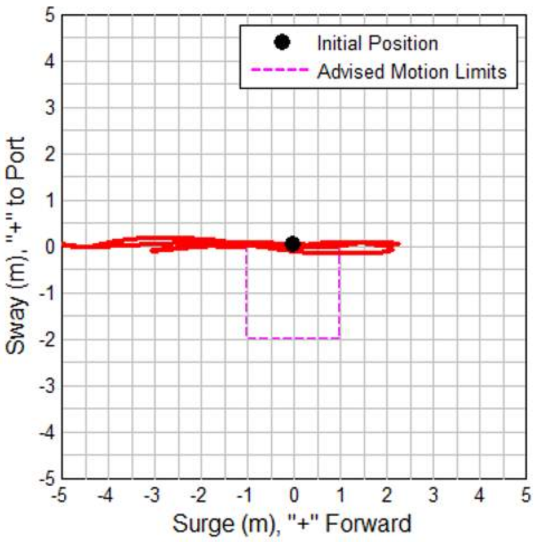
*Terminals and vessels are designed to resist wind forces (OCIMF, etc.)*

*In confined channels, forward/aft (surge) loads are most important.*

*Most vessels have insufficient surge (forward/aft) restraint.*

*Passing ships are often more important than winds.*



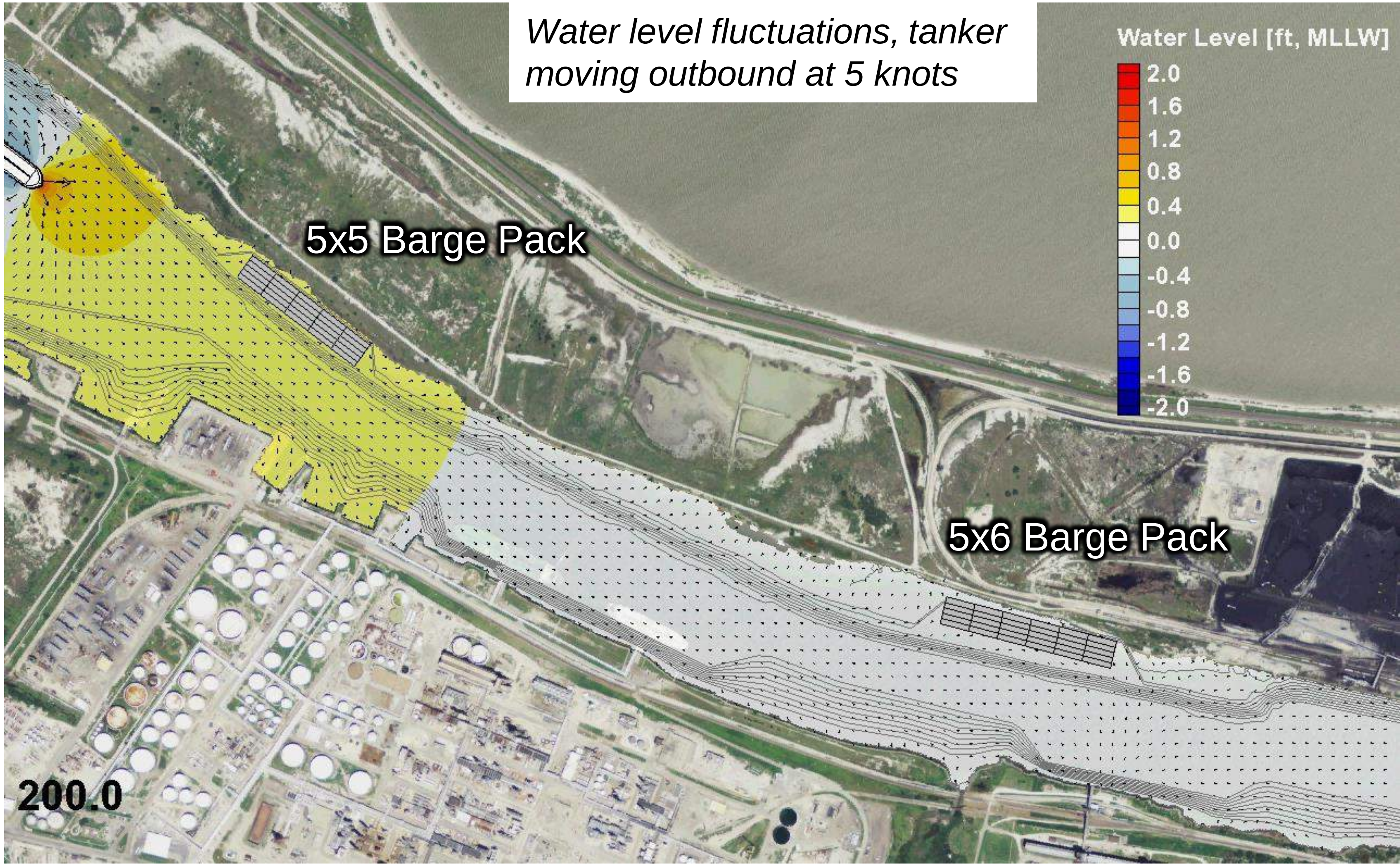



# Harbor Development and Improvement

Barge Fleet Mooring Studies:
Port of Corpus Christi, TX

*Analysis performed to evaluate forces, define dredging schemes, and design mooring systems.*

*Loads are individual barges are very small, however loads on the fleet can quickly grow with fleet size.*



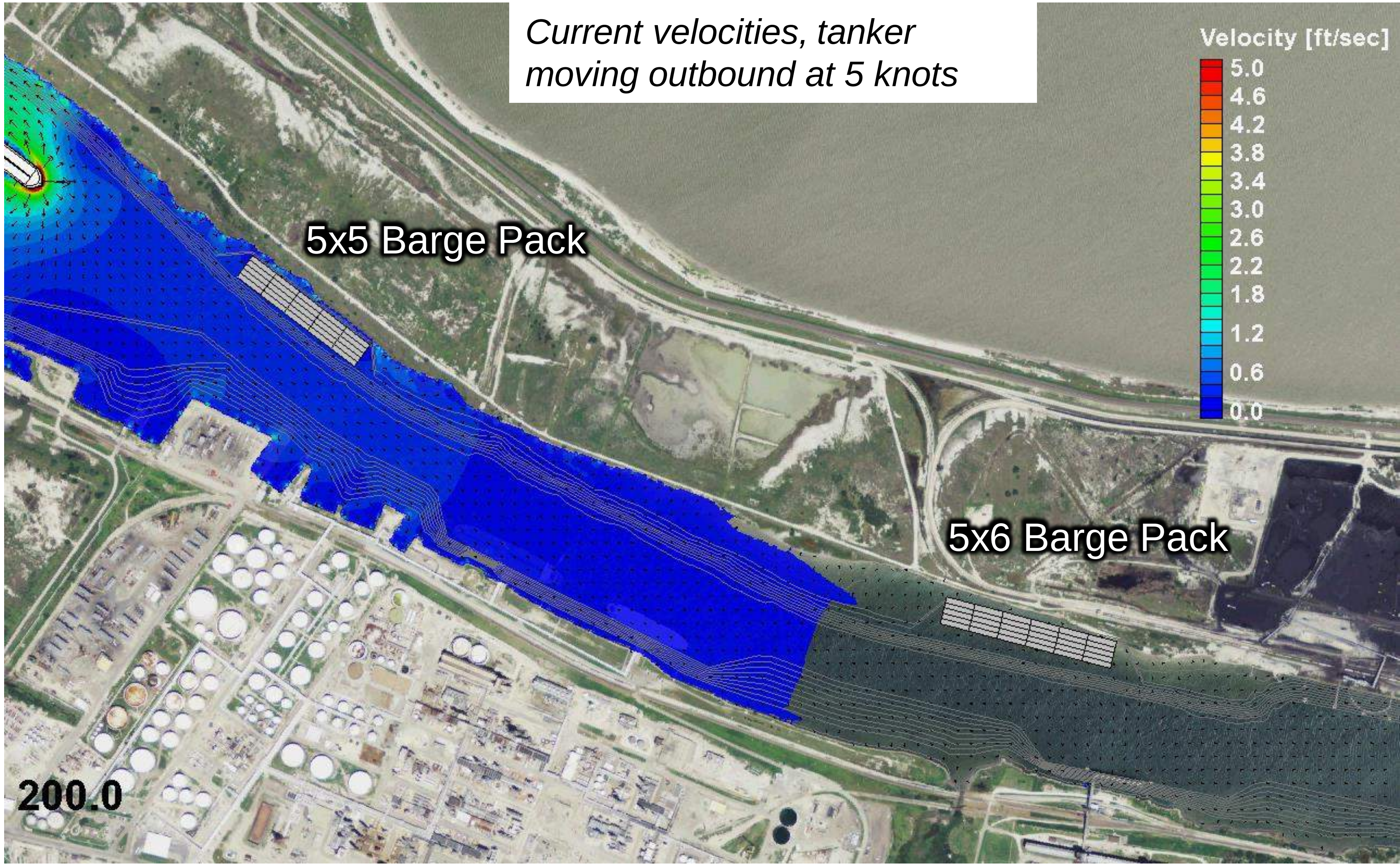
# Harbor Development and Improvement

Barge Fleet Mooring Studies: Port of Corpus Christi, TX

*Both spud barge and shoreside mooring systems evaluated.*

*Surge forces larger than sway forces.*

*Eastern site selected and developed, successfully in operation.*

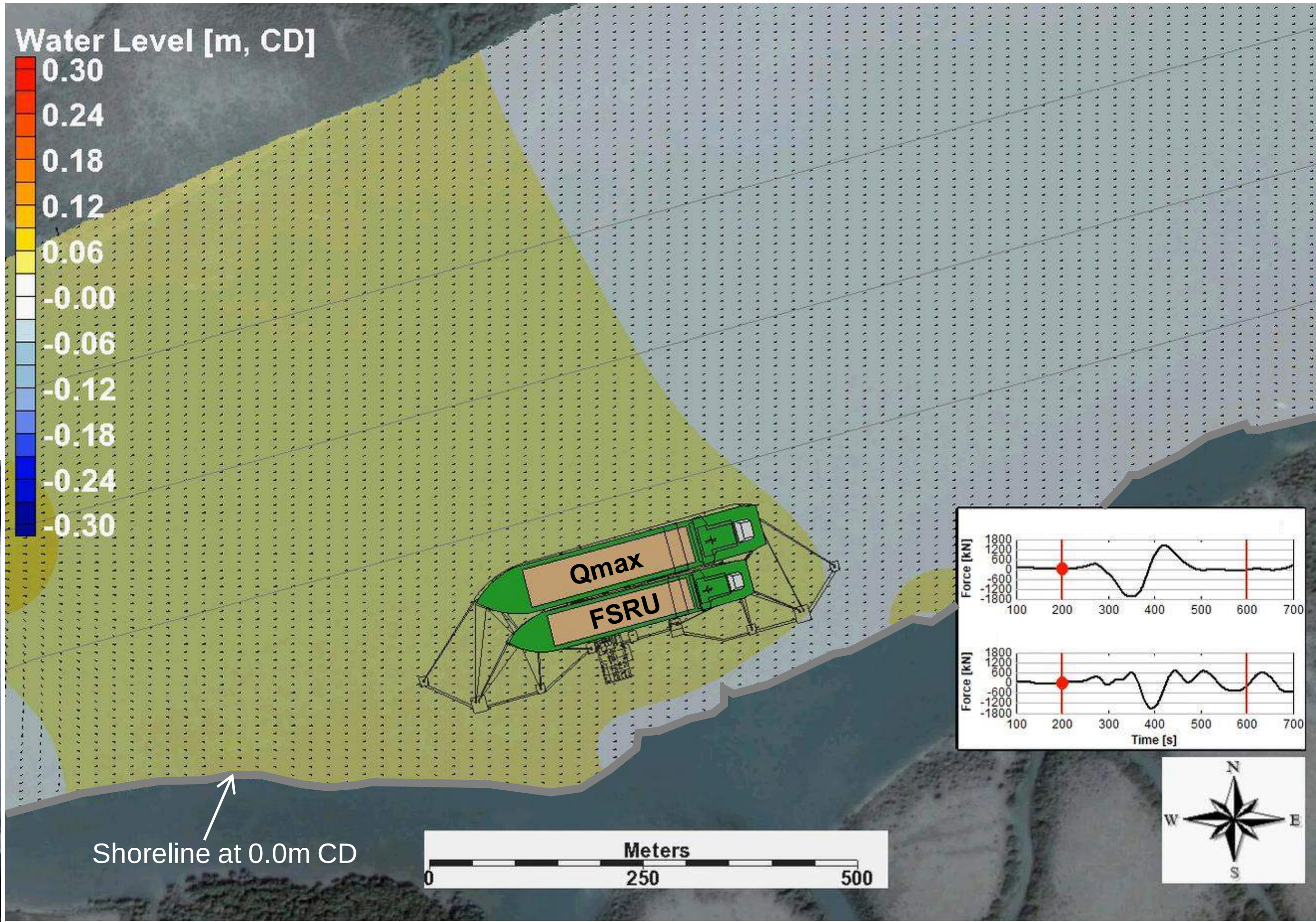


# Harbor Development and Improvement

FSRU Mooring Studies: Confidential

*Analysis includes loading on both vessels, and STS dynamic mooring simulations*

*FSRU lines control mooring safety in most instances.*

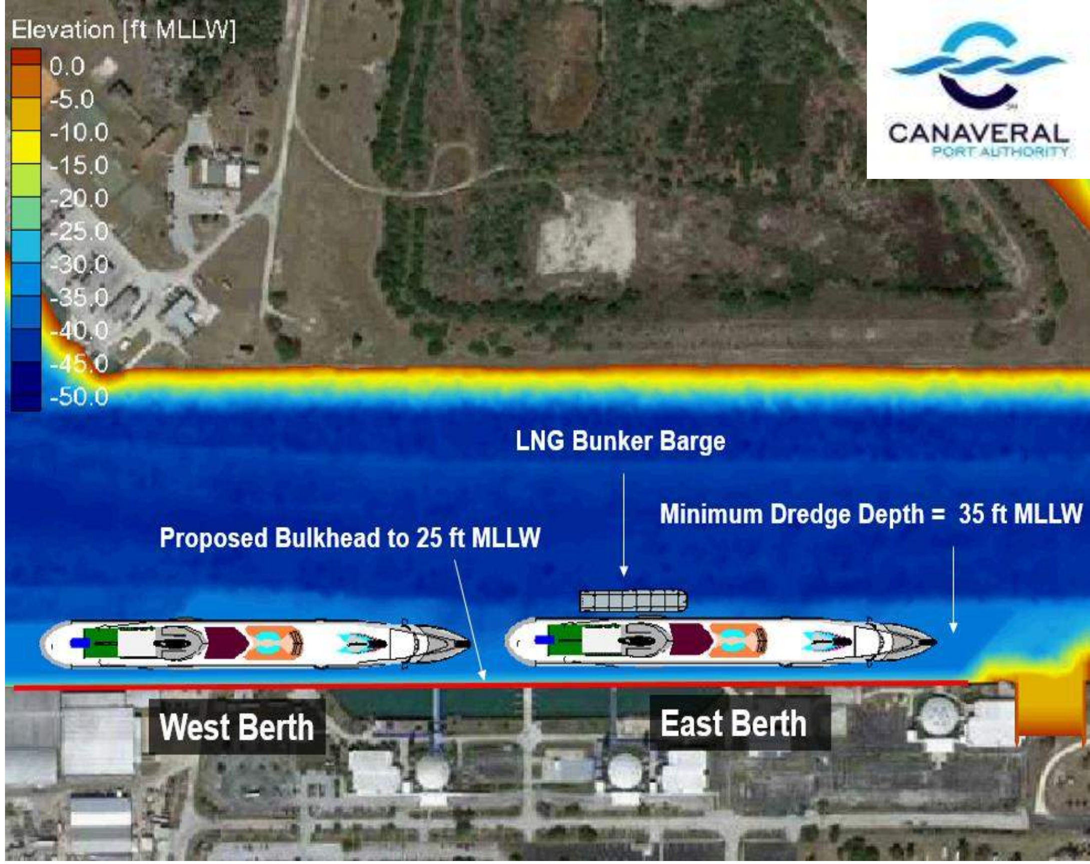
# Harbor Development and Improvement

LNG Bunker Barge Mooring Studies:
Cruise Terminal 3, others

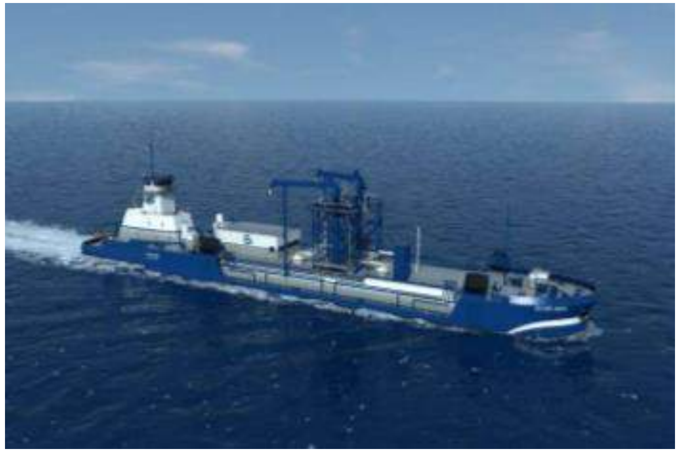
*LNG bunker barges are relatively small, hence passing ship surge forces are typically manageable*

*Largest surge-related challenges seem to be spatial conflicts, and development of geometrically suitable mooring arrangements.*

https://www.portcanaveral.com/getattachment/About/LNG-at-Port-Canaveral/LNG-Bunkering-Info.pdf.aspx?lang=en-US

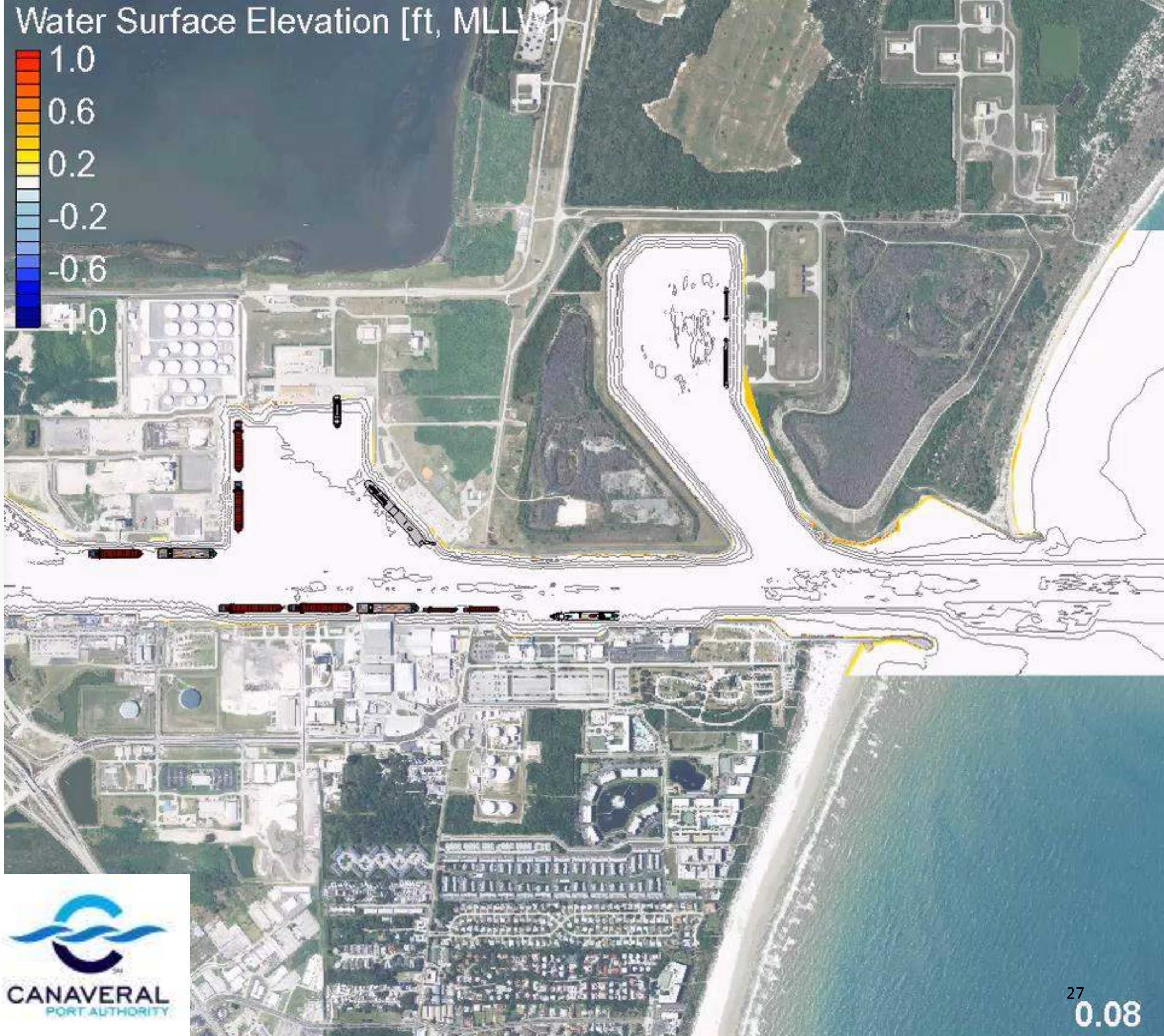



CANAVERAL PORT AUTHORITY



# Harbor Development and Improvement

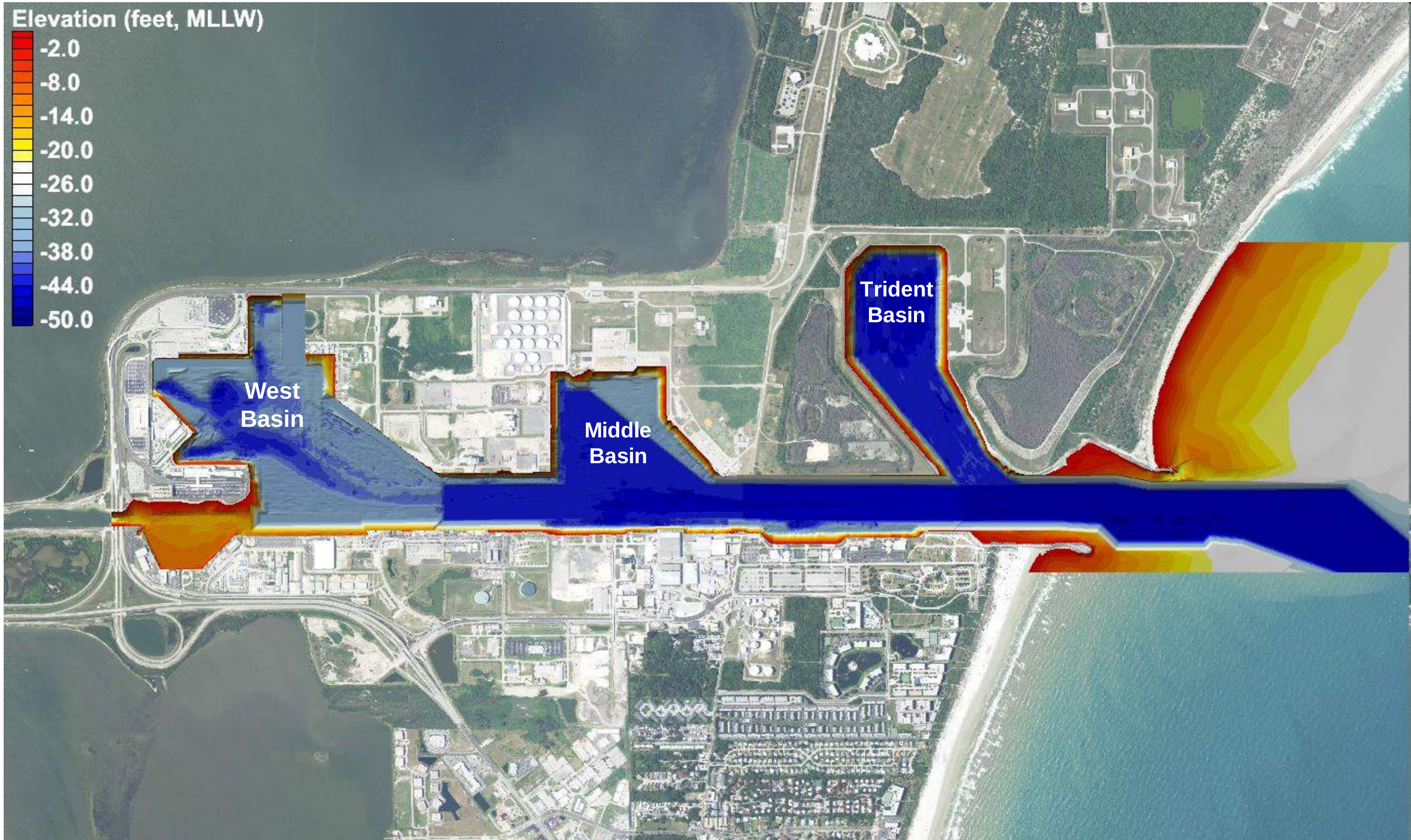
Harbor Improvements:
Canaveral Harbor
Deepening/Widening


CANAVERAL
PORT AUTHORITY

# Harbor Development and Improvement

Harbor Improvements:
Canaveral Harbor
Deepening/Widening
Completed 2016

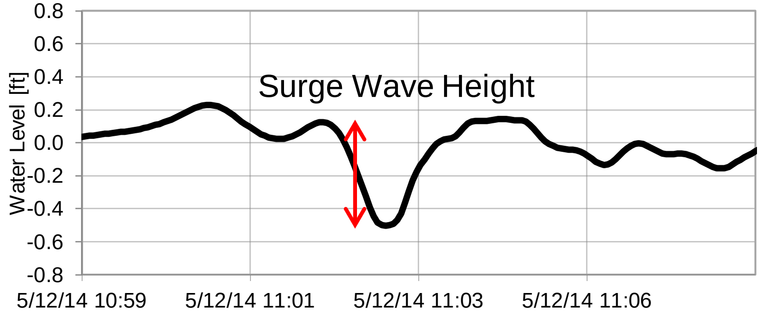


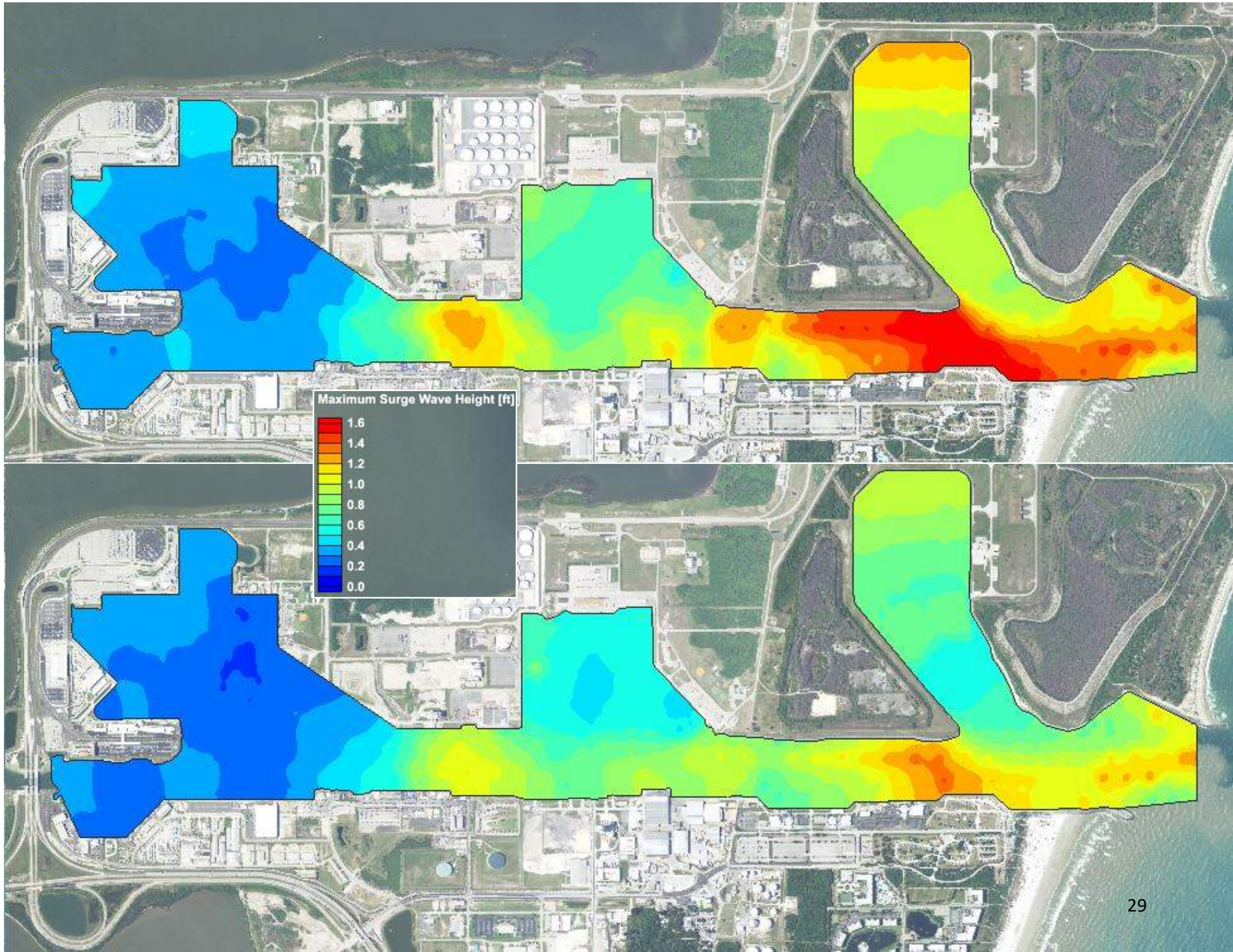
# Harbor Development and Improvement

Harbor Improvements:
Canaveral Harbor
Deepening/Widening
Completed 2016

*Surge effects significantly reduced harbor-wide*

*Loads on berthed vessels reduced, reductions depend on location.*



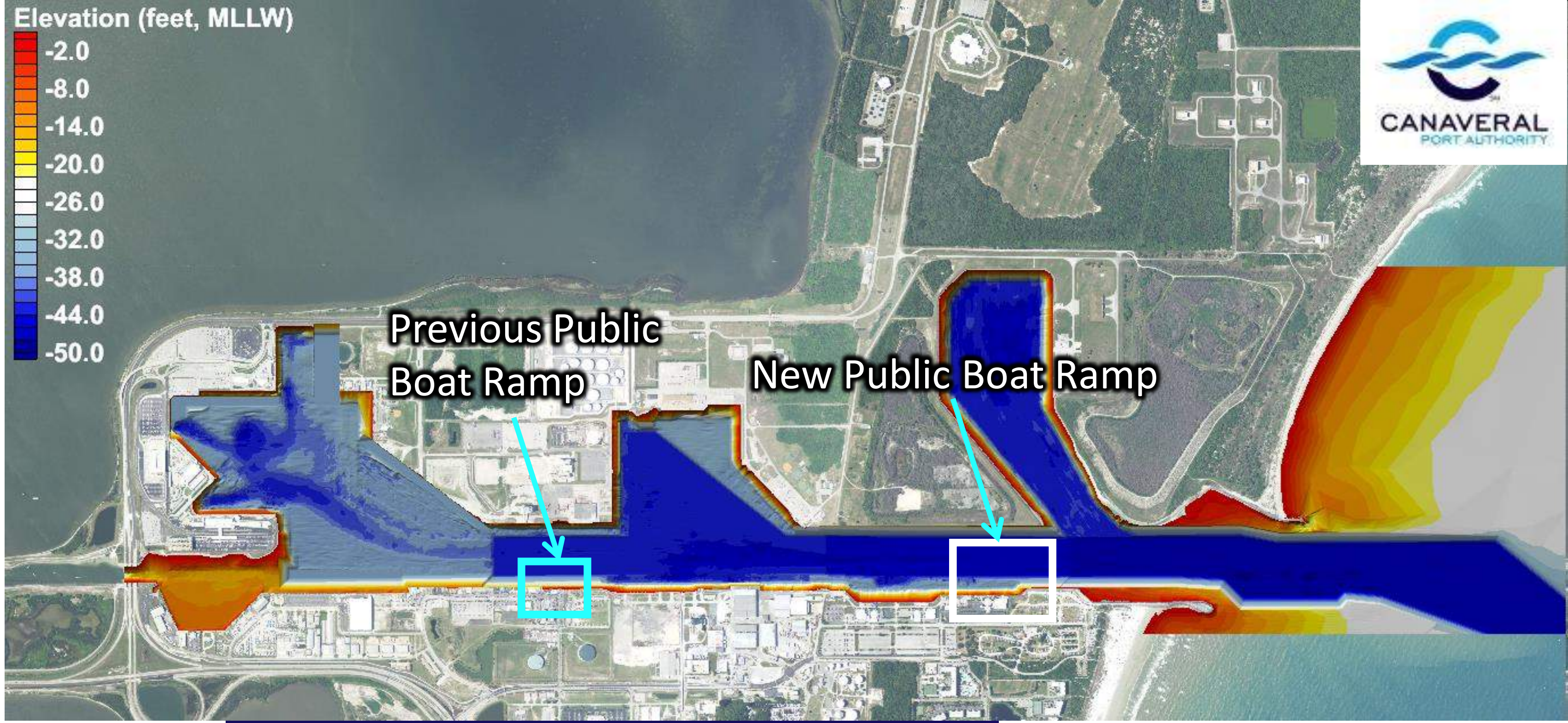
# Recreational and Mixed-Use Development

Recreational Facilities:
CT4 Boat Ramp
Port Canaveral, FL

*Public boat ramp removed due to construction of Cruise Terminal 1*

*CPA developed a new public boat ramp near former CT4*

*Initial concept consisted of a long basin offset from the main channel.*



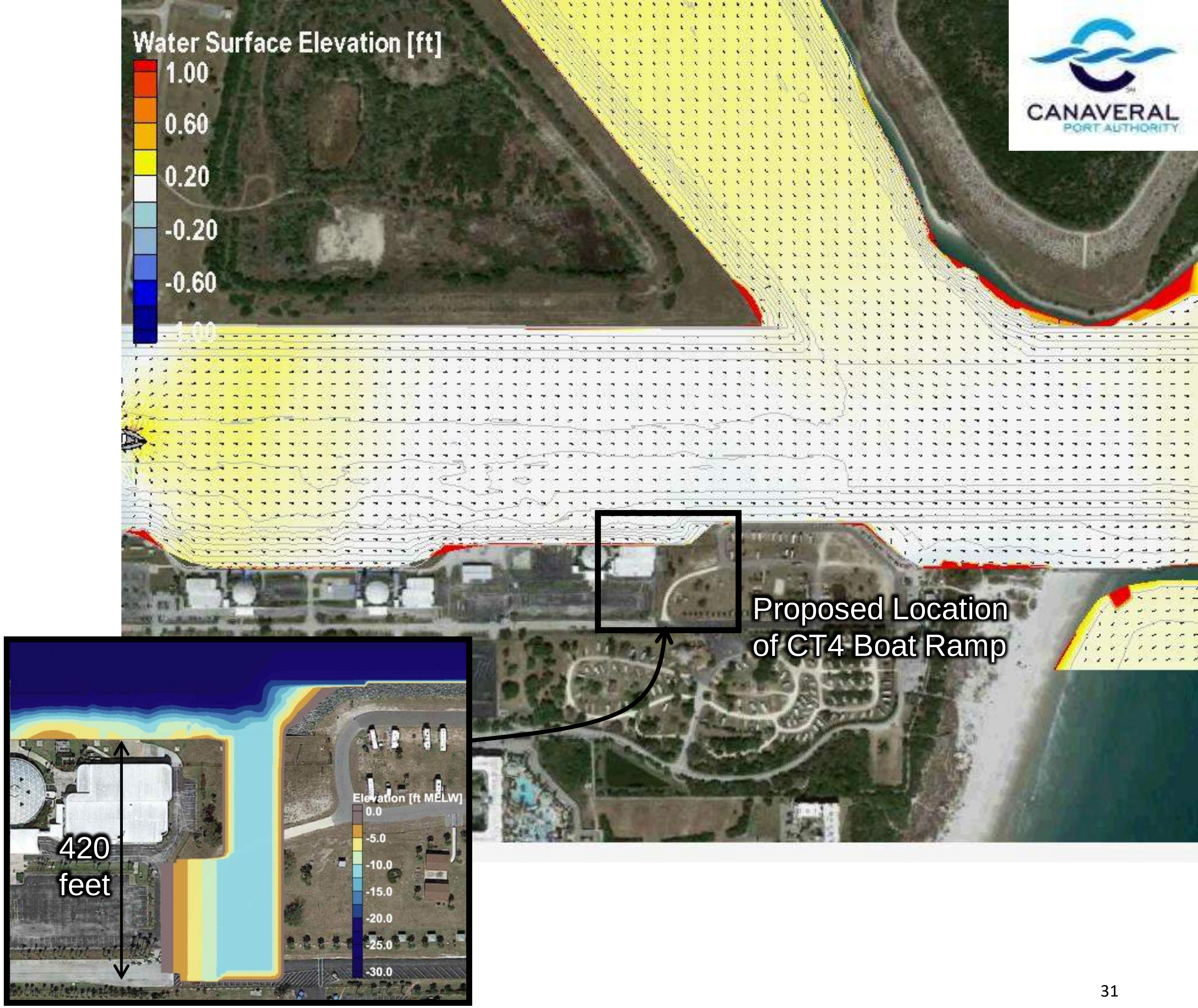


Initial Concept

# Recreational and Mixed-Use Development

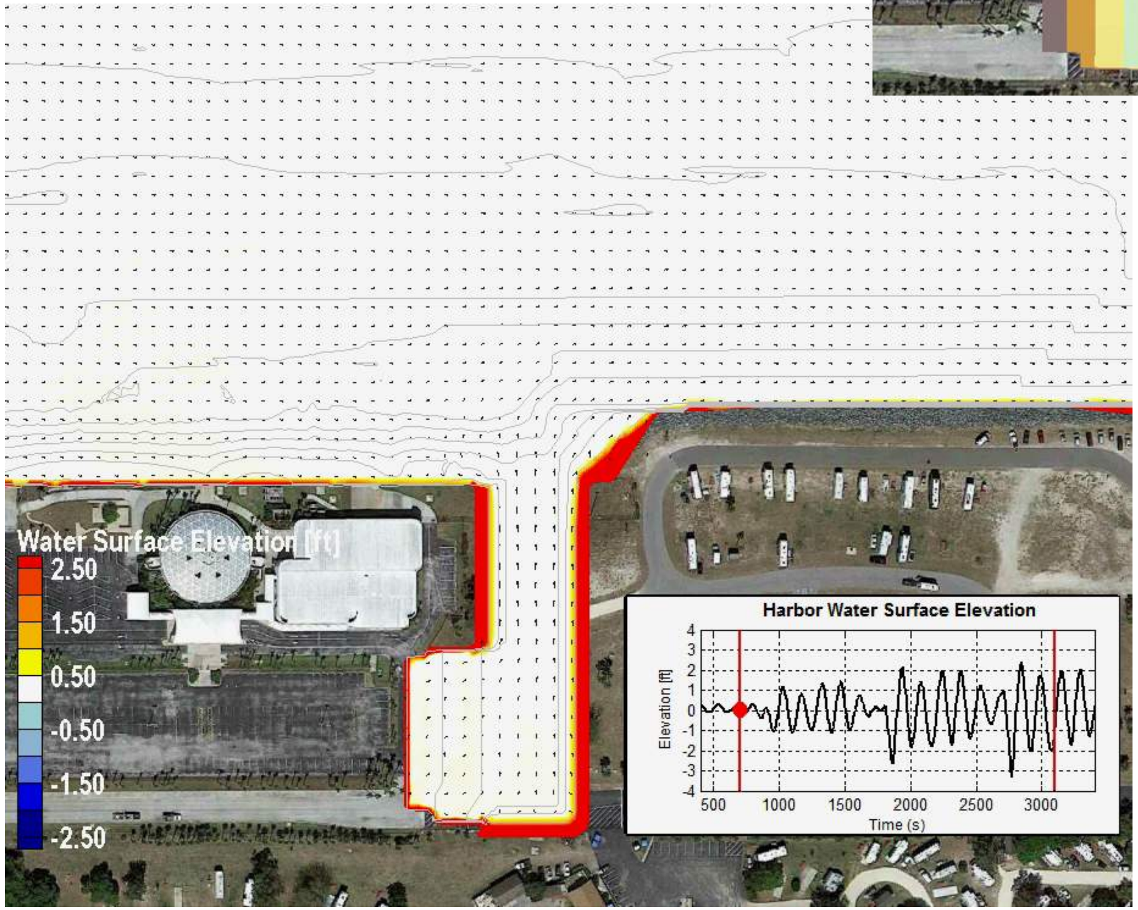
Recreational Facilities:
CT4 Boat Ramp
Port Canaveral, FL

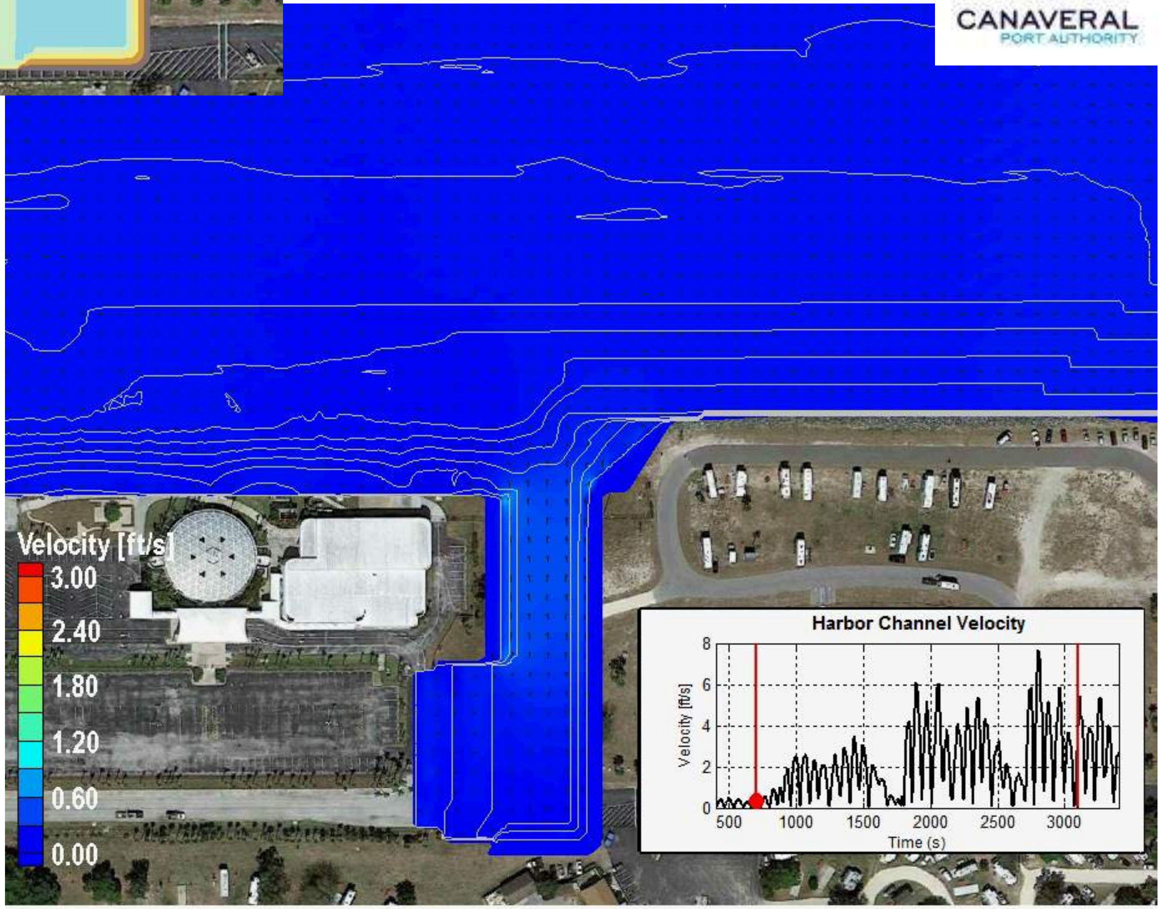
*Location of the new boat ramp is energetic in terms of surge, due to higher speeds and basin interactions.*



# Recreational and Mixed-Use Development

Recreational Facilities:
CT4 Boat Ramp
Port Canaveral, FL


CANAVERAL
PORT AUTHORITY

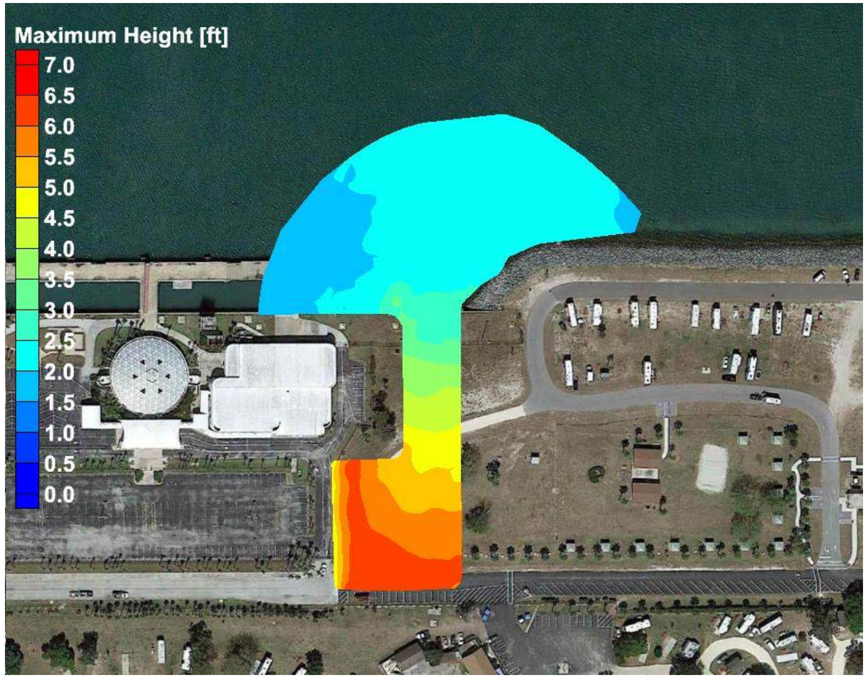
# Recreational and Mixed-Use Development

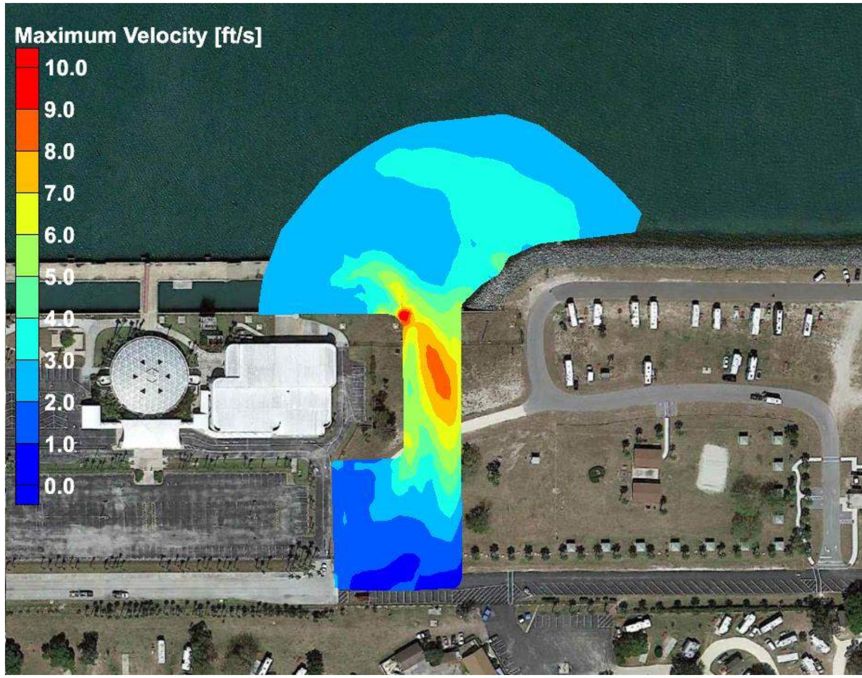
Recreational Facilities:
CT4 Boat Ramp
Port Canaveral, FL

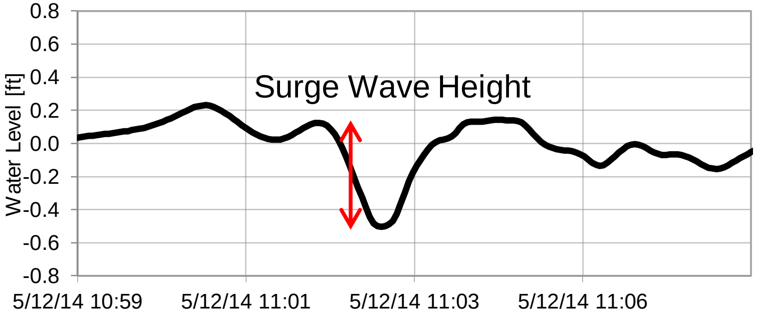
*Water level oscillations greater than 6 feet, entrance velocities ~ 8 ft/sec*

*Surge effects would have been significant and likely hazardous to users*

*Design changes recommended.*



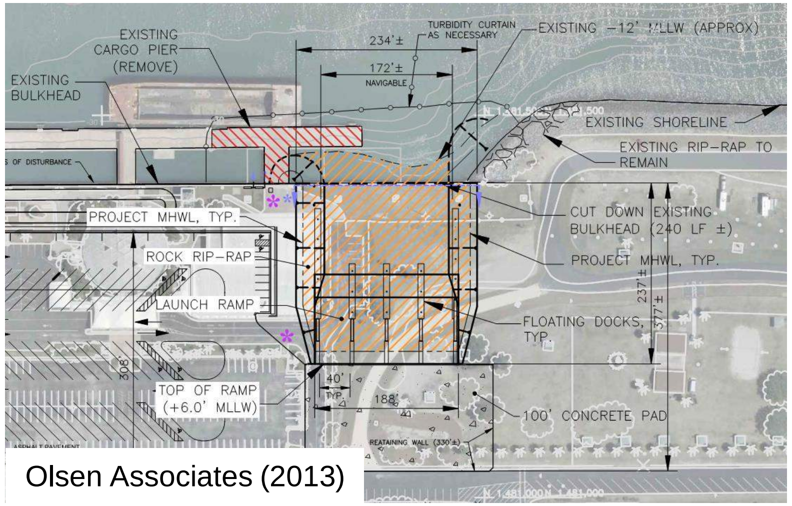
# Recreational and Mixed-Use Development

Recreational Facilities:
CT4 Boat Ramp
Port Canaveral, FL

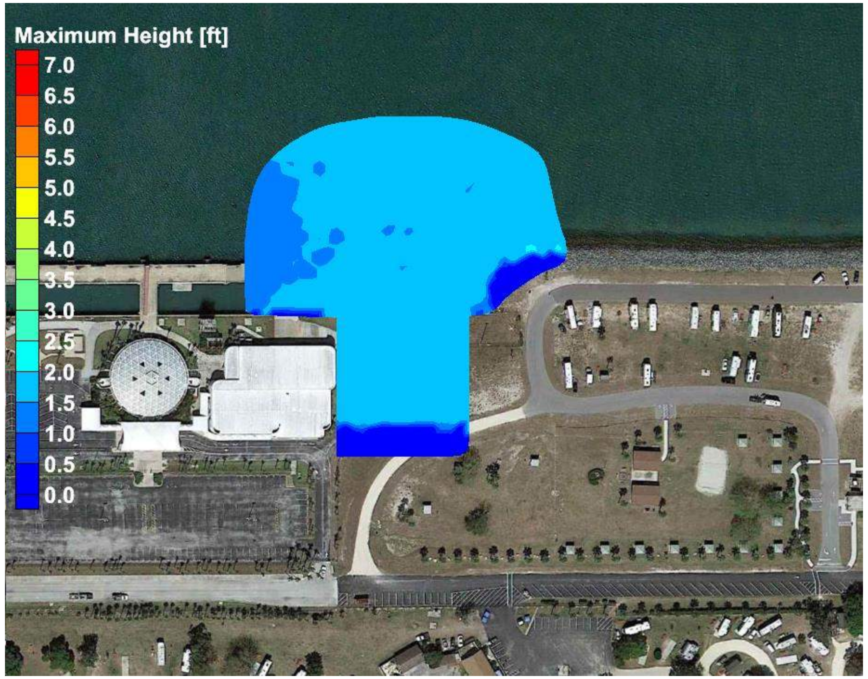
*Recommended design immediately adjacent to deep water*

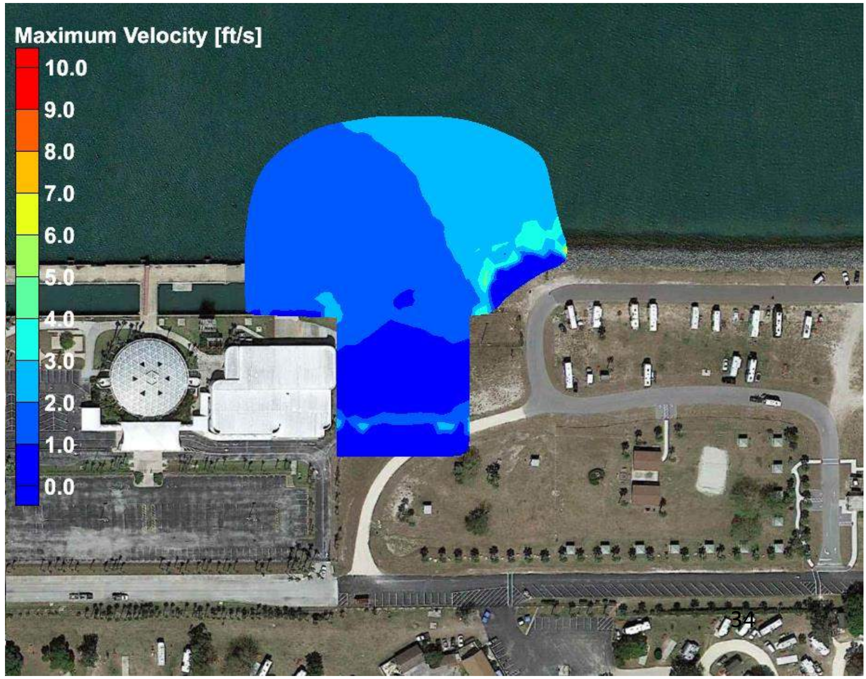
*New design concept showed negligible surge amplification, no significant nearshore currents.*

*Constructed 2014, and surge effects are minimal at the boat ramp as predicted.*



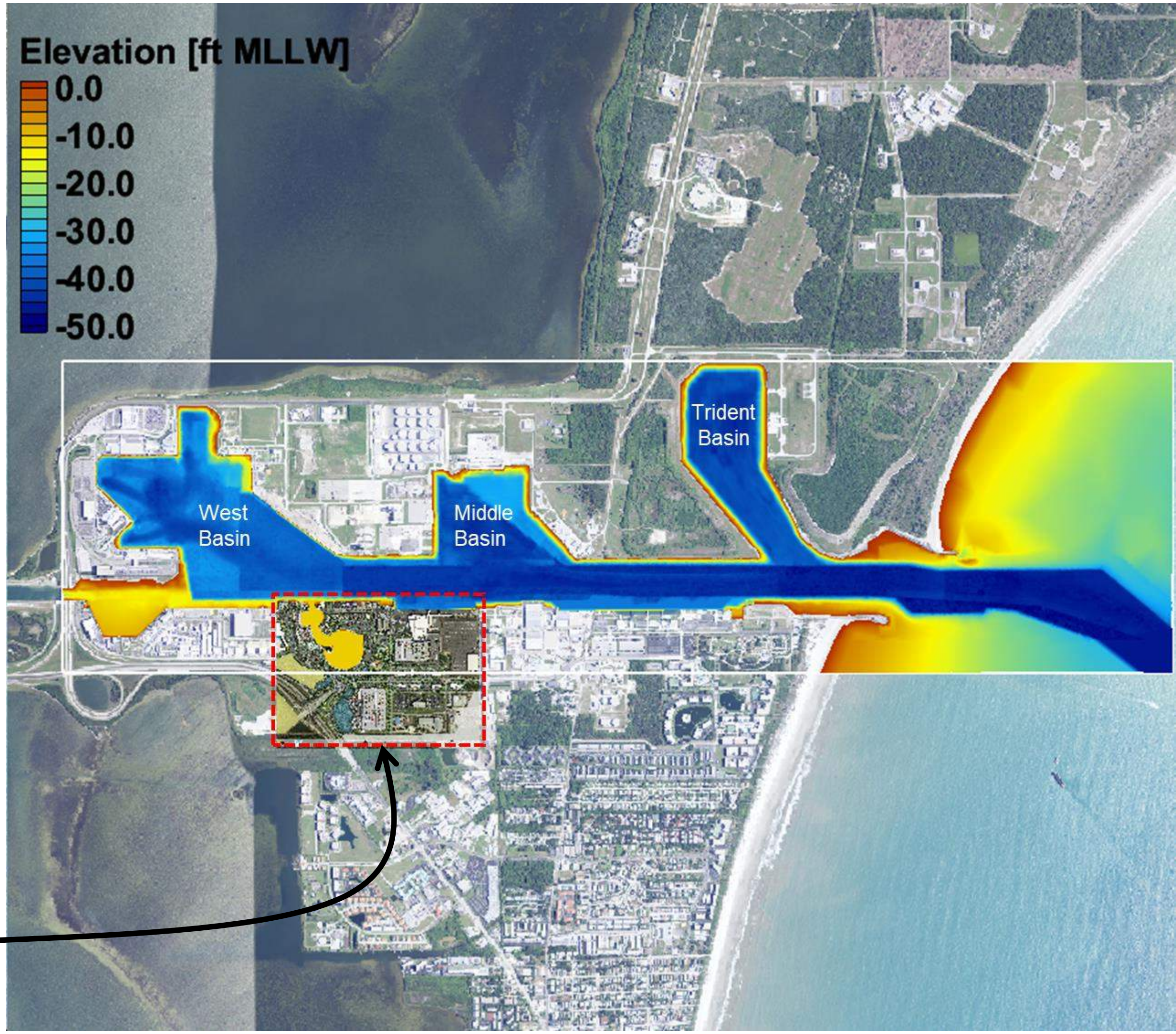
Olsen Associates (2013)



# Recreational and Mixed-Use Development

Mixed Use:
The Cove
Port Canaveral, FL

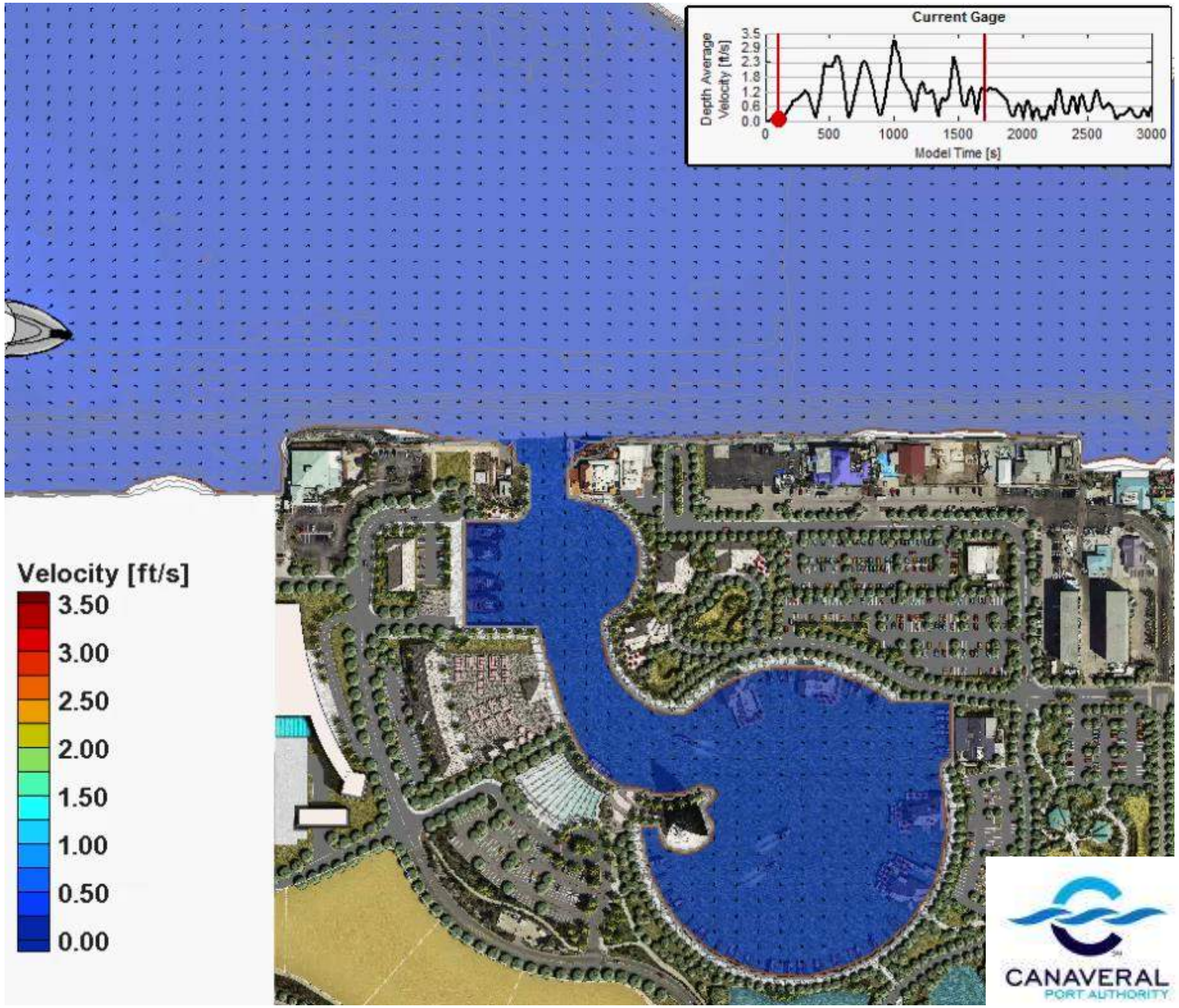

Bermello Ajamil & Partners

# Recreational and Mixed-Use Development

Mixed Use:
The Cove
Port Canaveral, FL

*Flows are generated in the entrance, but conditions are relatively mild due to low passing speeds.*

*Water level fluctuations were also relatively mild.*

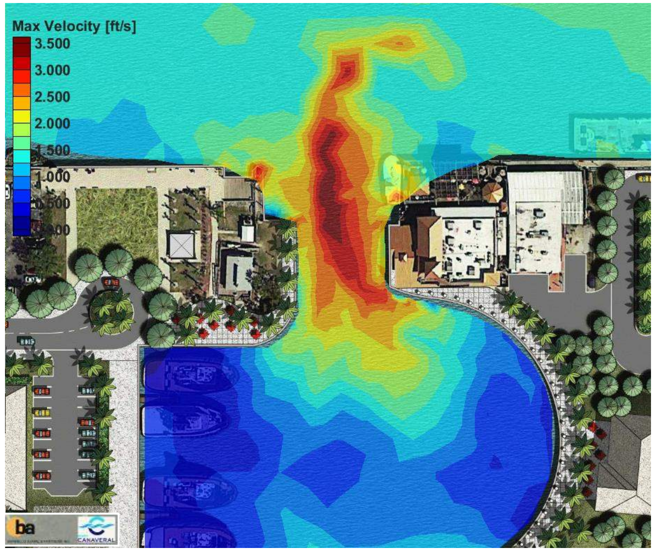



# Recreational and Mixed-Use Development

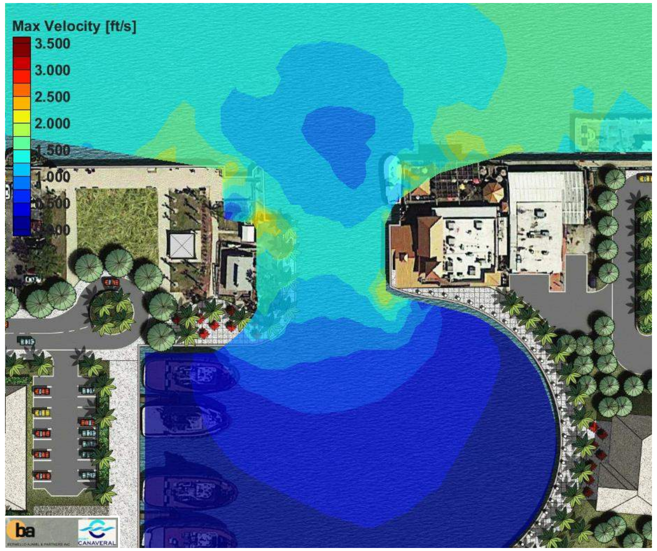
Mixed Use:
The Cove
Port Canaveral, FL

*Basin size/shape and entrance modifications were successful in minimizing the effects of surge.*

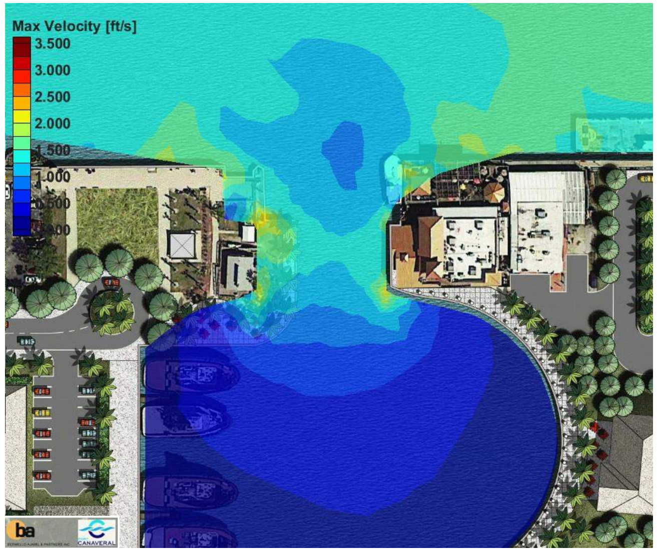
Original Scenario




Wider Entrance




Wider/Symmetrical Entrance



# Mitigations

- Simulation allows testing/development of surge effect mitigations such as:
  - Site modifications – over-dredging, setback, slope changes, structures
  - Targeted channel improvements – maneuverability reduces speed/surge
  - Terminal mooring system improvements
  - Vessel mooring equipment improvements
  - Operational guidelines – navigation, mooring procedures, draft at berth

# Conclusions

- Surge effects can disrupt many types of activities in active harbors/channels.
- Development activities in past 20 years have provided accurate modeling of most types of surge effects.
- Surge effect mitigation is site-specific, and depends on the source of the surge and character of the surge at the site of interest.
- Surge evaluations belong at feasibility-level design.

AAPA American Association of Port Authorities
Alliance of the Ports of Canada, the Caribbean, Latin America and the United States

# Predicting and Mitigating Passing Ship Surge Effects in Harbors

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## Questions?

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