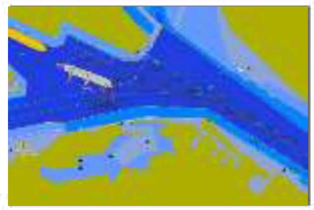
Appendix K

Ship Simulation Report

Note: The Section 508 amendment of the Rehabilitation Act of 1973 requires that the information in Federal documents be accessible to individuals with disabilities. The USACE has made every effort to ensure that the information in this appendix is accessible. However, this appendix is not fully compliant with Section 508, and readers with disabilities are encouraged to contact Mr. Jayson Hudson at the USACE at (409) 766-3108 or at SWG201900067@usace.army.mil if they would like access to the information.

Environmental Impact Statement – Feasibility Study


THE SEAMEN'S CHURCH INSTITUTE

RIBEN
MARINE

Contents

Introduction

Study Name	Environmental Impact Statement – Feasibility Study
Project Location	Corpus Christi Ship Channel – Harbor Island, TX
Purpose	To assist Riben Marine and Freese and Nichols with simulation studies for completion of an Environmental Impact Statement (EIS).
Customer	Riben Marine, Inc. and Freese and Nichols
Vendor	Seamen's Church Institute of NY and NJ 50 Broadway Floor 26 New York, NY 10004
CME Contact	Center for Maritime Education 9650 High Level Road Houston, TX 77029 Stephen Polk T: (713) 674-1236 F: (713) 674-1239 spolk@seamenschurch.org
Release Date	March 1, 2022
Project Lead(s)	Capt. Stephen Polk, Director, Center for Maritime Education
Authorized Signature	Capt. Jay Rivera, Riben Marine

Legal Disclaimer

With respect to the Seamen's Church Institute (SCI) simulator, databases, and models used for this study, the inspection, review, accuracy, and acceptance is validated by the customer and the participants prior to the study. SCI cannot accept liability for the findings, conclusions, or recommendations provided by the participants in this simulation study, nor can SCI be responsible for errors within data provided by the clients, or third parties used for programming of the simulator, hydrodynamic models, and databases. Key to any successful simulation is the accuracy of the data programmed into the simulator. SCI creates its simulations based upon information provided and approved by the client. The quality of this data has an impact on the accuracy of these test results.

The 6DOF hydrodynamic-vessel VLCC models used in these simulations are based upon data supplied by the ship builder to Kongsberg Maritime, and validated to 'Pilot Grade' standards, the highest quality available. These models have been vetted by experienced pilots, mooring masters, subject matter experts, SCI staff members, and additional customers. These models provide an idealized approximation of the classes and types of vessels which would be used in real world conditions. Specific vessels in the real world could handle differently from the simulator vessels utilized based on varying specifications and equipment on board. While a set of worst-case environmental factors were tested based on supplied data, the model behaviors can vary based on the dynamics introduced by real world changes in current and wind forces.

While SCI's simulator system provides a close approximation of vessel squat in shallow water, additional safety margin needs to be used to consider channel depths, tidal action, vessel speed and other continuously changing environmental factors. Water currents were modelled by engineering firm, Baird for the Harbor Island area simulated. Current models were constructed using 3D bathymetric meshes to represent future with permit (FWP) profiles for the channel.

The ship models used for the study and model information can be found within Appendix F. The VLCC models selected for this study was VLCC18, an existing pilot grade model in which the draft of the hull was tuned to meet the project specifications for the following configurations:VLCC18Q – 52' even keel, VLCC18R – 68' even keel, and VLCC18L – fully loaded 73' 9" draft.

The tug used for the study was Tug60 which was recently validated by Kotug, Riben Marine, and SCI staff. The tug was designed by Robert Allan, Ltd. for Riben Marine, and built by the STAR Center in Dania Beach, FL modeled hydrodynamically by their hydrodynamicist on staff using the Kongsberg modelling tool (HDMT) licensed and supplied by Kongsberg Digital.

Due to the tug requirements and available ownship bridges we also used one simulated tug for the study. The simulated tug features of the simulator provide a realistic simulation of an assist tug but is not as accurate as a captain in a tug bridge on the full-mission simulator. A simulated tug controlled by the simulator operators were used to control the robot tug during the study.

The results assume that experienced pilots will be manning the seaworthy vessels during real world maneuvers, and all vessels will meet the minimum safety standards and practices.

Operational limits should consider the actual tug and ship capabilities, and the need for all local pilots and mariners to have experience. Limitations can be gradually reduced as pilots and tug masters gain experience.

Process

In February 2021, Riben Marine contracted the Seamen's Church Institute (SCI) for the performance of a port study and environmental impact statement to assist with feasibility for updated channel configurations and dredge profiles, current flow models, and validate tug requirements for safe transit, and determining operational environmental limits for fully loaded VLCCs.

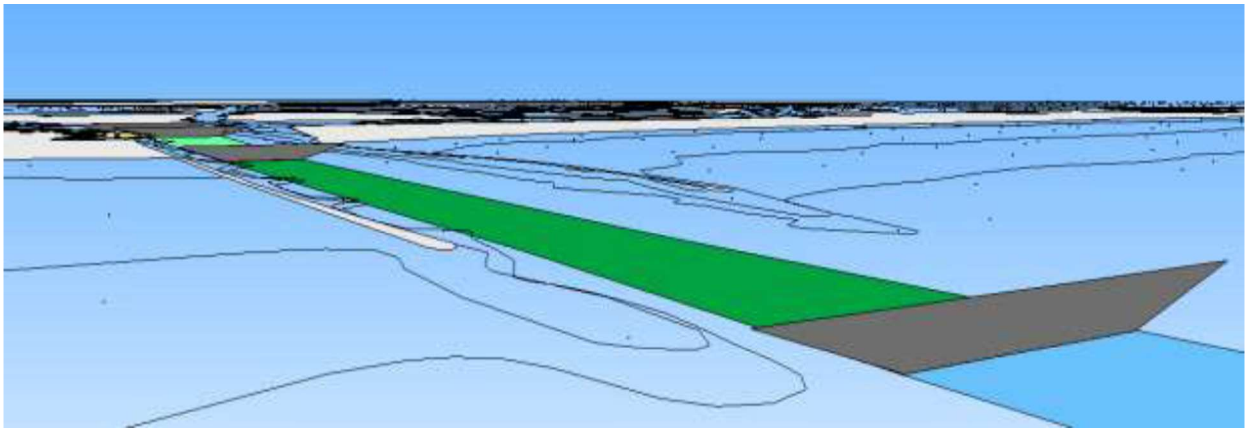
Database Development

Accuracy of existing database area

This visual database of the Corpus Christi/Harbor Island area was produced and maintained by SCI in Houston. Matt Hyner serves as SCI's Visual Database and Development Manager at the Center for Maritime Education. Matt developed the Corpus Christi database in a Flat Earth projection and WGS84 datum based upon a 2019 NOAA ENC Chart, and SRTM Elevation data. Upon commencement of this project, SCI was sent CAD files curated by Freese and Nichols for the dredge profile of the Corpus Christi Ship Channel, including Harbor Island Crude Terminal (HICT) as well as the Axis Terminal.

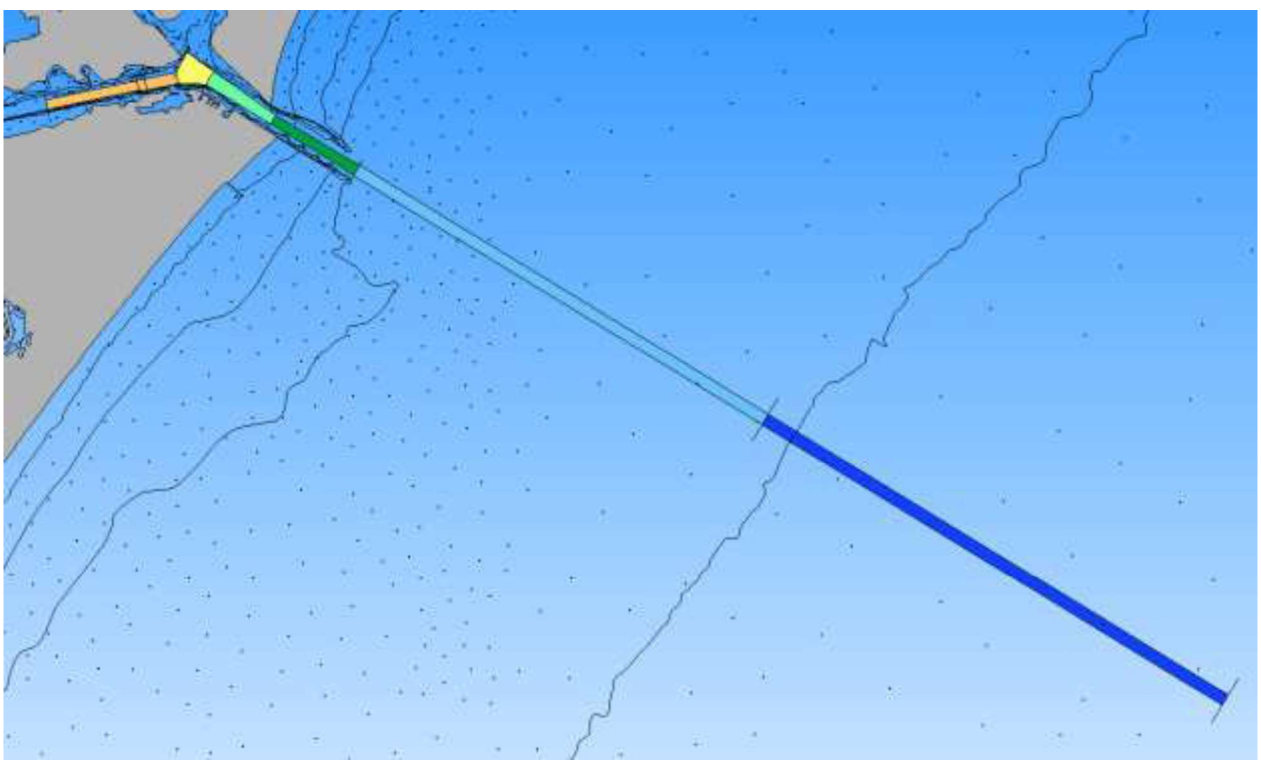
Area of the project

The source data for the database files were converted into WGS84/Flat Earth Projection to properly align them with Presagis and Kongsberg's database building tools. Upon inspection of the final CAD files, no issues were found with the alignment to SCI's existing visual database.



Depth Generation

This study involved the creation of a new depth file based upon the dredge profiles provided for this project in the source data, Appendix D, "PCCA_X-Sections_8.5x11 Final Channel Alignment for 75ft Ship.pdf". Measuring the base of the dredge slope, the widths were confirmed to match the CAD dimensions.



Dredge Profile Layout

New contours were traced along the 3D cutaway and integrated with NOAA's iENC chart data for the area. Additional contour modifications were next made to integrate the Harbor Island Crude Terminal (HICT) and Axis Terminal. The final dredge contours along with the charted depth contours were triangulated into a new mesh depth file using Kongsberg's area generation tools to create the final depth file for the area. These contours were then brought over to the Instructor Map to represent the new profile visually for the simulator operators during simulation runs. The visual 3D model of the area is based upon an existing SCI Training database as populated with trees and cultural features based on photographic reference material from a 2015 site survey when they database was initially created. Additions to the database for terminals at AXIS, HICT, South Texas Gateway and MODA were incorporated and based upon earlier updates to the original area.

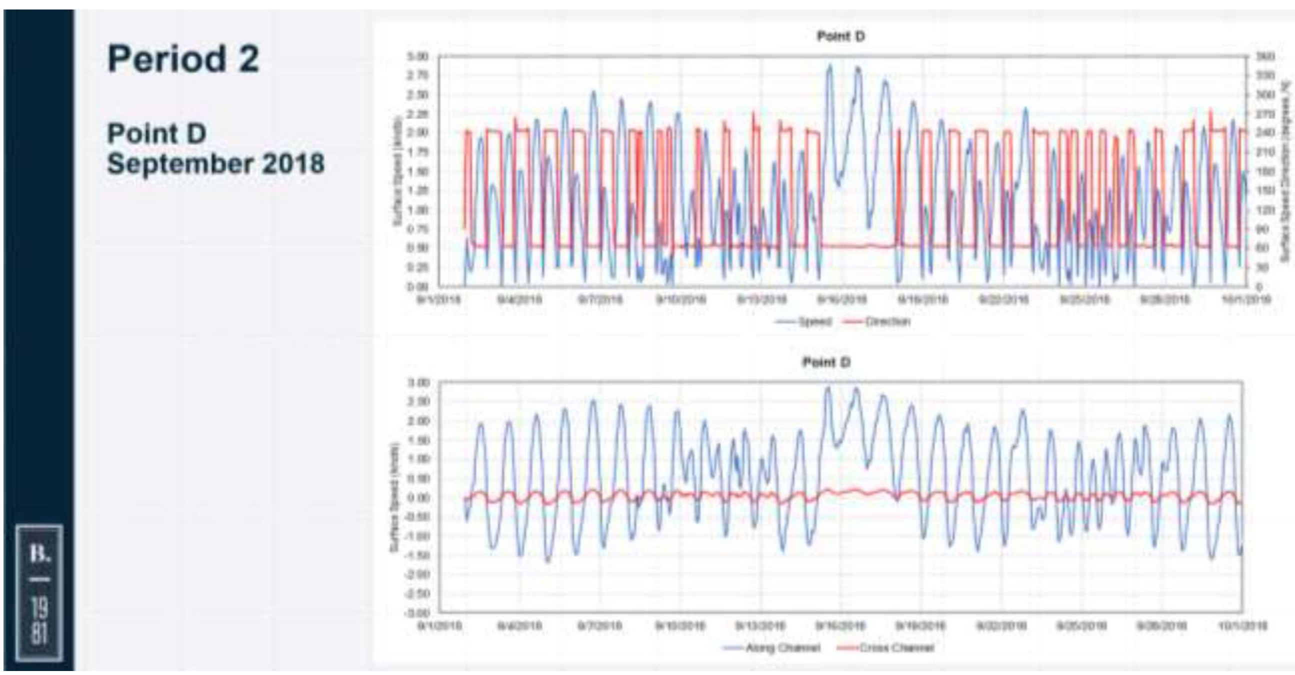
Hydrographic Model

A MIKE3 Flexible Mesh Hydrodynamic Model (HD Model) was developed to simulate the hydrodynamic conditions in the Corpus Christi area by Baird for the Corpus Christi Ship Channel, the approaches, and Harbor Island area. The current model provides currents at each cell node within the domain and vertically at approximately 2m intervals. The currents within and adjacent to the channel were extracted for direct input to the ship simulation model. Additionally, Baird provided snapshots of modeled currents along the water column depth every two meters at five various data points A – F (shown below).

Current meter data points A through F

Data from the model was exported from MIKE into an ETD file, with velocity and heading updated every 15 minutes. Current models were constructed using 3D bathymetric meshes to represent a future with project – FWP dredge profile for a 75' MLLW maintained depth. The Baird current model was based on maintained channel depth, not including advanced maintenance or allowable over dredge. The current data provided by Baird was kept in the original .ETD format and loaded for each corresponding run matrix parameters. Below illustrates the information for the current models provided.

Flow model showing data points and water strata (in red) 3D layered current



Corresponding data of the information from the flow model Sept 2018

Riben Marine and SCI staff reviewed three months of hydro analysis provided by Baird and found the best snapshots of six possible current profiles, Ebb – low, medium, and high, and

Flood – low, medium, and high; for the FWP profile. The information below are the snap shots chosen to simulate and validate the current flow models.

Offshore Currents			Inland Currents		
Flow	File & Time Stamp	Velocity	Flow	File & Time Stamp	Velocity
North high	P03 - 9/22/2020 @ 1000	0.9 knots	Ebb high	P03 - 09/22/2020 @ 1000	2.5 - 3.0 knots
North medium	P06 - 11/25/2018 @ 0400	0.5 knots	Ebb medium	P02 - 09/15/2018 @ 1300	2.0 - 2.4 knots
North low	P01 - 07/25/2020 @ 0800	N/A	Ebb low	P09 - 09/06/2018 @ 1600	1.3 - 1.6 knots
South high	P01 - 07/25/2020 @ 0300	1.5 knots	Flood high	P01 - 07/25/2020 @ 1500	2.5 - 3.1 knots
South medium	P10 - 09/13/2018 @ 1900	0.9 knots	Flood medium	P01 - 07/25/2020 @ 0800	2.0 - 2.4 knots
South low	P10 - 09/13/2018 @ 2100	0.6 knots	Flood low	P08 - 09/06/2018 @ 0400	0.9 - 1.3 knots

Development of Simulator Exercise Matrix and Study Objectives

A matrix of the exercises to be run, was carefully crafted, reviewed and refined to include those exercise conditions that would best cover the simulation study objectives, which include:

1. Validate channel configuration, approaches to any future terminal developments at Harbor Island;
2. Validate current models and their effects on vessels in the proposed channel. The current models will be created and provided by Baird. The model current's effect on the vessels transiting the channel will then be validated to ensure its realism and accuracy;
3. Develop and validate number and size of tugboats/assist vessels necessary for transit and stand by;
4. Determine operational environmental limitations (wind speed, current flow, current direction, visibility) for vessels approaching and departing facility, if any; and
5. Identify necessary vessel traffic control and vessel monitoring procedures to protect any future terminal developments on Harbor Island, monitor passing vessel traffic, and vessels engaged in cargo transfer operations at the facility.

The variables considered in the development of the run matrix included:

Vessel Types – Three versions of VLCC18 were used. The model VLCC18 was modelled after the "Elizabeth I. Angelicoussi" developed using source documents provided by Daewoo Shipbuilding & Marine Engineering Company, LTD, Project *Kristen 306,000 TDW Cruse Oil Tanker*, Project no. 5194. VLCC18Q was used to simulate the model in a 52' draft even-keel partially-loaded condition, VLCC18R was used to simulate the model in a 68' draft even-keel condition, and VLCC18L was used to simulate a 73' 9" draft fully-loaded condition.

Pilot cards for the vessels used in the study are in Appendix F. The "pilot grade" models were used for the simulations – which are described as having *high-hydrodynamic quality* and additionally have been validated by numerous pilot associations, mooring masters, ship owners, and research firms.

Ship models	Vessel Class & Type	DWT (m3)	Deepest Draft	Year Built	LOA	Beam	Engine & Propeller Type	Max Power (hp)	Rudder Type & Max Angle
VLCC18Q "Elizabeth I. Angelicoussi" (52' even keel draft)	VLCC Tanker	237,859	15.8m	2004	332m	58m	Diesel, FPP	40,015	Semi, 35°
VLCC18R "Elizabeth I. Angelicoussi" (68' even keel draft)	VLCC Tanker	306,229	20.73m	2004	332m	58m	Diesel, FPP	40,015	Semi, 35°
VLCC18L "Elizabeth I. Angelicoussi" (Loaded)	VLCC Tanker	340,488	22.49m	2004	332m	58m	Diesel, FPP	40,015	Semi, 35°
TUG60 "ART120-35W" Rotor Tug	Harbor Assist Tug Boat	1,172	6.08	2021	36.25m	14.55m	Diesel, CPP	10,441	Azipod, 180°

Models used for the study

Tug size, horsepower, placement, and numbers used – Custom designed tugs by Robert Allan, LTD were used (Tug 60) based on customer requests. The decision to utilize 120 MT bollard pull rotor tug was based on project needs and pilot requests, and the decisions to utilize five tugs during the simulations was strictly based on pilot recommendations, procedures, precautionary measures, and local ordinary practice for the ACC Pilots. The target (tug 60) *simulator-tug* used with an understood max rating of 120-metric ton bollard pull instructor-controlled tug. With SCI's simulator configuration of 5-full mission bridges, one simulator as the ship bridge, and the other four bridges as ship-assist tug bridges, so that the simulations could maintain a minimum of five harbor tugs which were needed to perform this study. Additionally, hydraulic winch controls installed in the tug bridges provided tug captains the ability to easily heave in or payout hawsers as needed or required for ship assist work.

Tug 60

Outbound ship maneuvering with ship assist tugs

Wind Condition – Wind was a variable used within the matrix, North wind of 25 knots was used and SSE winds of 25 knots was loaded to either enhance the flood or ebb tidal current. The idea was to simulate the most challenging circumstances to help identify operational limits, safety margins, and what control measures may be needed to minimize risks.

Current condition – Current models used were provided by Baird for the simulations and loaded according to run matrix parameters.

Waves and swell condition – The Kongsberg system uses wind speed to model wave height according to the Beaufort scale. Using the UKC report provided by Baird, in appendix E, SCI programed two wave files in the simulator. The SSE wave file simulated 2m swell at 7.3s between the end of the jetties and the pilot boarding area. With a 1m wave at the end of the jetties, and minimal wave once inside the jetties. The N wave file simulated a 2m swell at 7.3s between the end of the jetties and the pilot boarding area, and a 1m wave at the end of the jetties. This information closely approximates the data provided by Baird for the same areas.

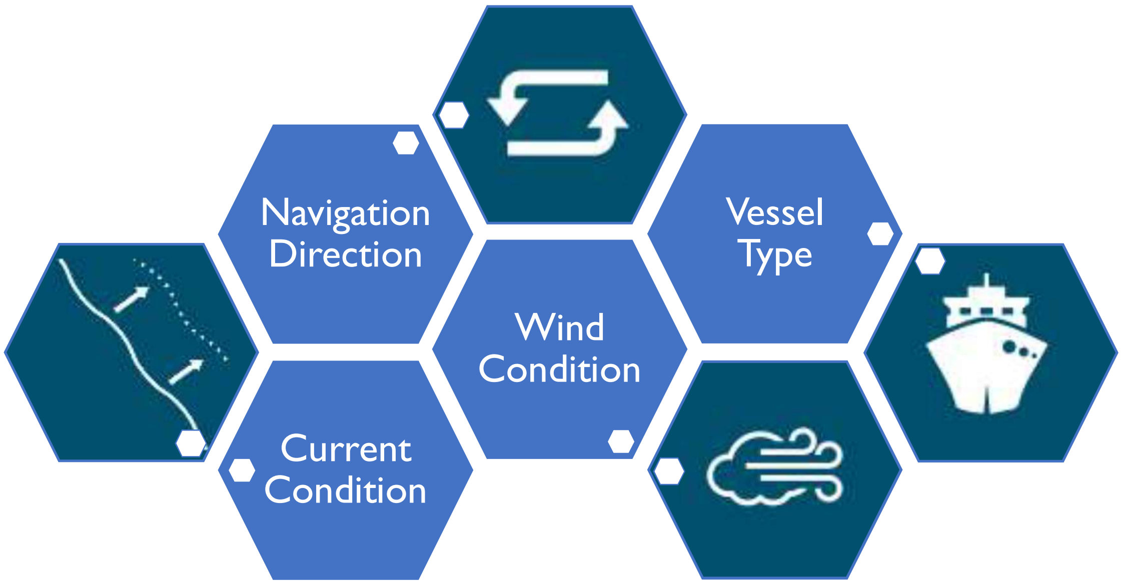
Navigation Direction – Vessels were run inbound and outbound, simulating typical arrivals and departures, for HICT, including VLCCs at various drafts.

Dredge profile configurations and channel dimensions – The depth and fairway files SCI used were built for future with permit (FWP) and that corresponding dredge profile.

We then loaded the VLCC models with the proper drafts according to the dredge profile needed and run parameters.

Simulation Run Matrix

To document the precise conditions encountered during each simulation exercise the team designed a matrix of run parameters (see Appendix C for all matrixes developed). This matrix outlines the various conditions tested, vessel types, sizes, wind, and tidal flows. The run matrix was designed to capture and test each variable to best capture and understand the various navigational safety requirements.



The plan is always to conduct each simulation run once, with the possibility of some runs being performed multiple times either due to complexity, challenge, or simply providing multiple pilots an opportunity to conduct it for themselves.

Simulation Preparation, External Testing, and Validation

Each simulator exercise was configured in accordance with the run matrix parameters agreed upon during preliminary phases. SCI expected each departure simulation to last approximately 12 to 15 minutes, with the approach simulations running about 20 to 40 minutes. Immediately following the simulation, participants would be given standard questions (run survey) which we updated in preparation for the actual study.

During the external testing and validation which occurred on January 10-14, 2022 with participation from Riben Marine, and various tug captains with operational knowledge of the harbor, the validation stage tested the conditions for in bound VLCCs with a 52’ draft inbound and loaded VLCCs with a 68’ draft outbound using the FWP current channel dredge profile and Baird’s current files using tug60.

Run Matrix – planned

The run matrix planned (shown below) illustrates the final plan for the week. We eliminated the Axis runs and most "head-in" scenarios, due to the emphasis on running simulations which are most likely to occur.

run #	location	destination	Depth	Draft			Inshore Current				Offshore Wind Current					Tug	comments
			81'	52'	68'	74'	25 N Ebb Med	25 N Ebb High	25 SE Flood Med	25 SE Flood High	N Med	N High	S Low	S Med	S High	120	
1	Sea	Jetties	x	x							x					x	familiarization
2	Sea	Jetties	x	x								x				x	familiarization
3	Sea	Jetties	x	x										x		x	familiarization
4	Sea	Jetties	x	x											x	x	familiarization
5	Jetties	HI W	x	x			x									x	max tug power
6	Jetties	HI W	x	x				x								x	low score
7	Jetties	HI W	x	x					x							x	max tug power
8	Jetties	HI W	x	x						x						x	max tug power
9	Jetties	HI E	x	x			x									x	max tug power
10	Jetties	HI E	x	x				x								x	low score
11	Jetties	HI E	x	x					x							x	max tug power
12	Jetties	HI E	x	x						x						x	max tug power
13	Ferries	Jetties	x	x			x									x	passing vessel speed
14	Ferries	Jetties	x	x				x								x	passing vessel speed
15	Ferries	Jetties	x	x					x							x	passing vessel speed
16	Ferries	Jetties	x	x						x						x	passing vessel speed
17	Ferries	Jetties	x		x		x									x	passing vessel speed
18	Ferries	Jetties	x		x			x								x	passing vessel speed
19	Ferries	Jetties	x		x				x							x	passing vessel speed
20	Ferries	Jetties	x		x					x						x	passing vessel speed
21	HI W	Jetties	x		x		x									x	max tug power
22	HI W	Jetties	x		x			x								x	low score
23	HI W	Jetties	x		x				x							x	max tug power
24	HI W	Jetties	x		x					x						x	failure
25	HI E	Jetties	x		x		x									x	low score
26	HI E	Jetties	x		x			x								x	low score
27	HI E	Jetties	x		x				x							x	max tug power
28	HI E	Jetties	x		x					x						x	max tug power
29	Jetties	Sea	x		x						x					x	not run
30	Jetties	Sea	x		x							x				x	not run
31	Jetties	Sea	x		x									x		x	max tug power
32	Ingleside	HI W	x	x			x									x	max tug power
33	Ingleside	HI W	x	x				x								x	max tug power
34	Ingleside	HI W	x	x					x							x	max tug power
35	Ingleside	HI W	x	x						x						x	max tug power
36	Ingleside	HI E	x	x			x									x	max tug power
37	Ingleside	HI E	x	x				x								x	max tug power
38	Ingleside	HI E	x	x					x							x	max tug power
39	Ingleside	HI E	x	x						x						x	max tug power
40	HI W	Jetties	x			x	x									x	failure
41	HI W	Jetties	x			x				x						x	failure
42	HI E	Jetties	x			x		x								x	not run
43	HI E	Jetties	x			x			x							x	not run

PCCA TUG STUDY run survey - Pilots

1. Pilot Name: ________________________________

2. The CHANNEL CONFIGURATION (slope, width, depth profile, and layout) was sufficient and adequate. *1 being the channel is inadequate and 5 being the channel is adequate.*
   ◯1 ◯2 ◯3 ◯4 ◯5

3. If the channel configuration was inadequate in any way, please explain why.

4. Did the ENVIRONMENTAL FORCES (current, wind, wave) exceed the operational limitations of your vessel?
   ◯Yes ◯No

5. If any of the environmental forces (wind, wave, current) exceeded operational limitations, please explain what could be changed to safely execute the maneuver.

6. The TUG CONFIGURATION (number of tugs, tug bollard-pull rating, and tug type) was sufficient and adequate. *Please rate based on number of tugs used, bollard pull rating, and tug type used vs. what is needed to do the job safely – 1 being the Tug Configuration is inadequate and 5 being the Tug Configuration is adequate.*
   ◯1 ◯2 ◯3 ◯4 ◯5

7. If the tug configuration was not adequate, please explain why.

8. The overall safety, stress and difficulty level of this run was: *Please rate the based on – 1 being extremely unsafe, stressful, and very difficult and 5 being safest, low stress, and not challenging, and.*
   ◯1 ◯2 ◯3 ◯4 ◯5

9. If not safe, please explain why.

10. Run was ________________________________ based on run parameters
    ◯Successful ◯Unsuccessful

11. If the run was not successful, please explain why.

PCCA TUG STUDY run survey – Tug Captains

ART 120-35W Validation – Tug Survey

1. Tug Captain Designator: ______________________

2. Tug Type: ◯ Robot Tug ◯ Rotor 90 MT ◯ Rotor 120 MT ◯ Rastar 80 MT

3. Tug Test – ***[drop drown]***

   Free running speed fwd
   Free running speed aft
   Free running speed athrwartship
   Bollard pull ahead
   Bollard pull astern
   Escort performance C/L aft
   Acceleration assist C/L fwd
   Acceleration assist/Escort performance off fwd winch P/S shoulder

4. Tug Location – Beginning: ***[drop down]***

   Center lead aft
   Port B1
   Port B2
   Port B3
   Port midship
   Port quarter
   Port transom
   Center lead front
   Starboard B1
   Starboard B2
   Starboard B3
   Starboard midship
   Starboard quarter
   Starboard transom

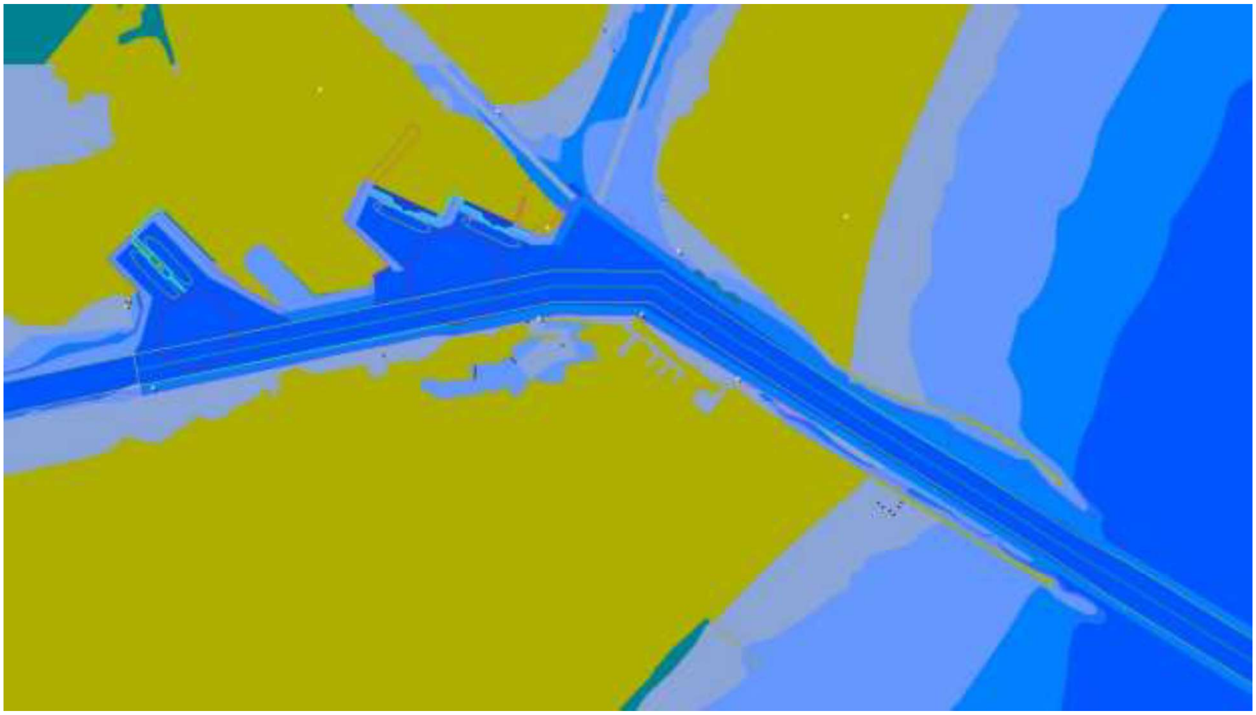
5. Tug Location – End: ***[drop down]***

   Center lead aft
   Port B1
   Port B2
   Port B3
   Port midship
   Port quarter
   Port transom
   Center lead front
   Starboard B1
   Starboard B2
   Starboard B3
   Starboard midship

Starboard quarter
Starboard transom

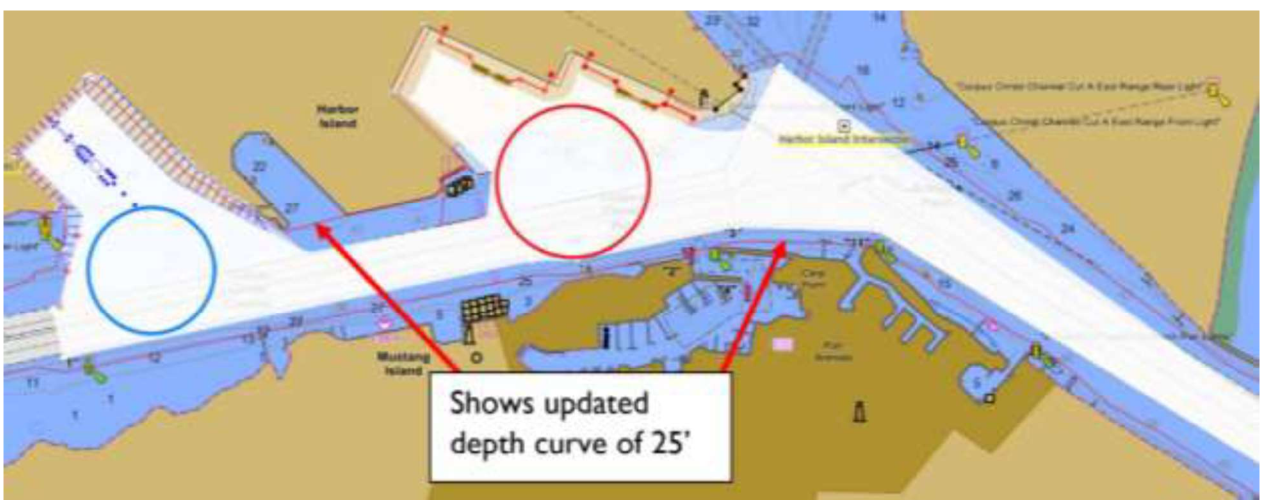
6. The tug perfomed/reacted as expected (COMPARISON TO DATA SET) to include (maneuverability, Z drive speed, thrust, vessel motions). *Please rate this statement based on – 1 being not as described and 5 equal to description and provided data).*
   ◯1 ◯2 ◯3 ◯4 ◯5
7. If the tug performance/beahvior were not as expected, please explain why.
8. Did the ENVIRONMENTAL FORCES (current, wind, waves) cause operational limits to be exceeded?
   ◯Yes ◯No
9. If any of the environmental forces caused vessel operational limits to be exceeded, please explain why, and if the forces prevented you from performing any specific maneuver, what occurred.
10. The tug configuration and performance were adequate. *Please rate based on - 1 being unsatisfied with the tug configuration and 5 being satisfied with the tug configuration.*
    ◯1 ◯2 ◯3 ◯4 ◯5
11. If the tug configuration and performance was not adequate, please explain why.
12. The overall safety, stress and difficulty level of this run was: *Please rate the based on –1 being extremely unsafe, stressful, and very difficult and 5 being safest, low stress, and not challenging.*
    ◯1 ◯2 ◯3 ◯4 ◯5
13. If not safe, please explain why.
14. Were any of the maneuvers or commands given by the pilots difficult relative to the time provided or the environmental conditions simulated? Did you have any trouble getting into position, or staying in shape due to the current, ship's speed, or environmental conditions?
    ◯Yes ◯No
15. If Yes, please explain why.
16. Did you feel that you were asked to operate at max power for an extended period of time?
    ◯Yes ◯No
17. Run was ______________________________ based on run parameters
    ◯Successful ◯Unsuccessful
18. If the run was not successful, please explain why.

Pictured below is the base area we used for external testing and validation.



Instructor Station Area Map

The modified navigation chart below shows the updated dock facility and channel limits which was provided in each pilothouse to reflect changes not yet visible on a navigational chart. SCI staff generated a GPX file to be displayed onto Rosepoint ECS so that operators could tell when they were getting close to the edge of the channel to avoid running aground.



Base ECS chart view – with dock and database changes showing channel limits

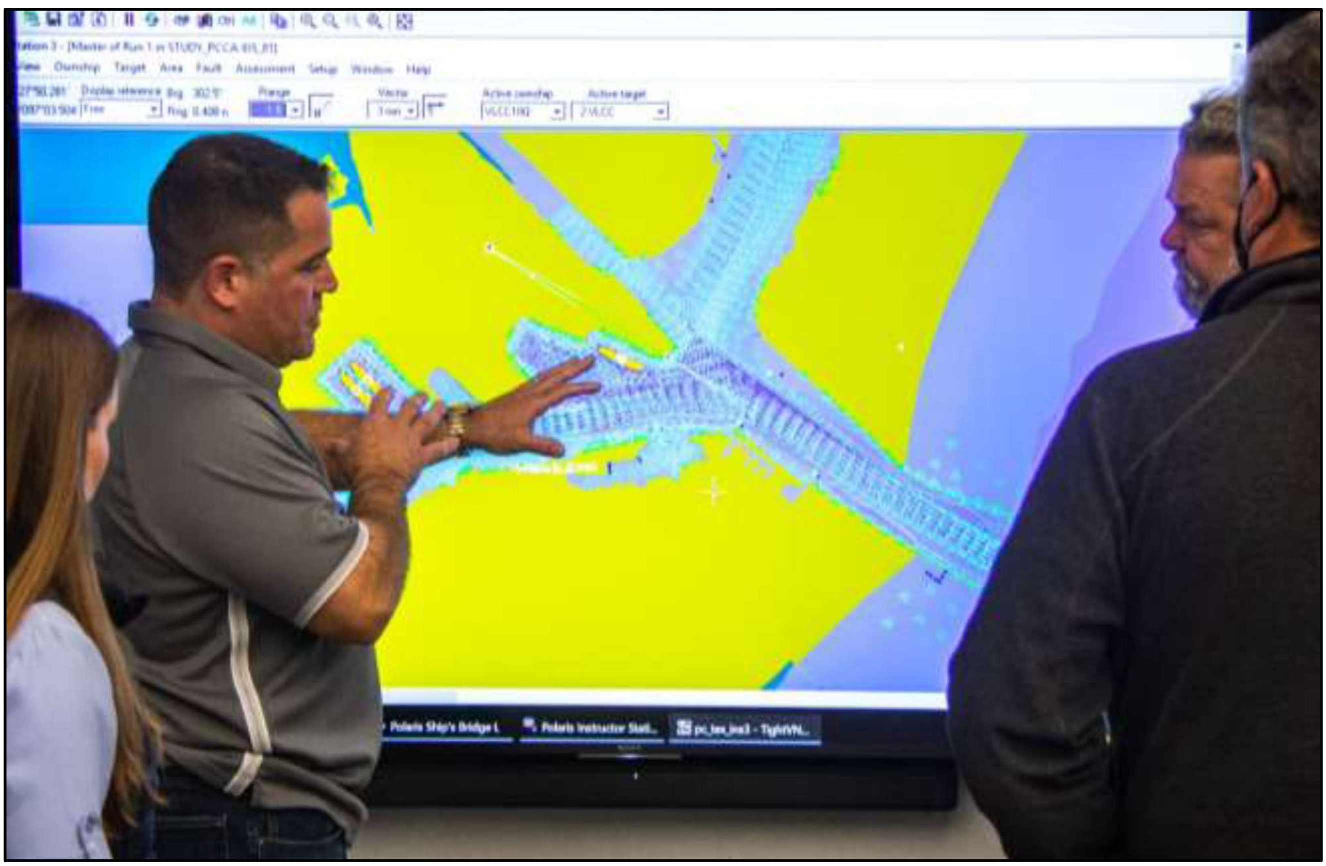
Adding this was helpful for the participants to do a comparison between the navigation chart and the database used at SCI showing the improved channel. The depth file (.DCS) used was provided by data supplied by Freese and Nichols.

Simulation process & sequence of events

Participants

For the simulation phase the project team assembled in Houston, Texas at SCI's facility on January 31 – February 3, 2022. Over the course of the 4-day session the following entities were represented:

- Capt. Mike Kershaw
- Riben Marine
- Aransas-Corpus Christi Pilots Association (ACC Pilots)
- Freese and Nichols
- Seamen's Church Institute (SCI)



Riben Marine debriefing the simulations with representatives from the ACC Pilots

Sequence of events

On commencement of the simulation phase of the project the participants of the study arrived at SCI where they filled out pilot questionnaires, SCI staff explained the run matrix, as well as the expected timeline of events. The team assembled in the briefing room, conducted a facility safety brief, everyone introduced themselves, and a project briefing was provided for the mariners participating in the study who were not present during the testing phase. SCI explained the process of how the study was to be conducted, the study objectives, vessel models used, tug configurations, and environmental conditions. SCI staff advised the group that the Kongsberg simulator can easily determine when *any* vessel runs aground, experiences a collision, or an allision during a simulation, and due to the close tolerances and the operational limits of the VLCC we can easily determine a PASS vs. FAIL. Therefore, if any vessel in a simulation harbor tug or VLCC experienced a problem it would be recorded as a "FAIL" and marked on the survey accordingly.

The sequence of simulation order was decided by pilot preference. Once SCI had the order of simulations to be performed, a pilothouse orientation was conducted. SCI performed a familiarization simulation allowing the participants to become familiar with operational aspects of the simulator. During the study if an exercise was needed to run multiple times, the numbering system was used: 1, 1.2, 1.3, 1.4, and so on. The actual runs performed, and their corresponding score (averaged) are shown below:

				Depth	Draft			Inshore Current				Offshore Wind Current					Tug				
run #	day	location	destination	43'	52'	68'	74'	25 N Ebb Med	25 N Ebb High	25 SE Flood Med	25 SE Flood High	N Med	N High	S Low	S Med	S High	120	Current file	comments	Pilot Average	Tug Average
2	1	Sea	Jetties	x	x								x				x	9/22/2020 @ 1000	familiarization	4.5	5.0
3	1	Sea	Jetties	x	x										x		x	9/13/2018 @ 1900	familiarization	4.0	4.3
7	1	Jetties	HI W	x	x					x							x	7/25/20 @ 0800	max tug power	4.5	5.0
9	1	Jetties	HI E	x	x			x									x	9/15/2018 @ 1300	max tug power	4.8	4.9
12	1	Jetties	HI E	x	x						x						x	7/25/2020 @ 1000	max tug power	5.0	4.8
13	1	Ferries	Jetties	x	x			x									x	9/15/2018 @ 1300	passing vessel speed	3.5	5.0
16	1	Ferries	Jetties	x	x						x						x	7/25/2020 @ 1000	passing vessel speed	5.0	5.0
17	1	Ferries	Jetties	x		x		x									x	9/15/2018 @ 1300	passing vessel speed		5.0
27	1	HI E	Jetties	x		x				x							x	7/25/20 @ 0800	max tug power	4.3	4.7
32	1	Ingleside	HI W	x	x			x									x	9/15/2018 @ 1300	max tug power	5.0	5.0
34	1	Ingleside	HI W	x	x					x							x	7/25/20 @ 0800	max tug power	4.5	5.0
15	2	Ferries	Jetties	x	x					x							x	7/25/20 @ 0800	passing vessel speed	4.8	5.0
20	2	Ferries	Jetties	x		x					x						x	7/25/2020 @ 1000	passing vessel speed		3.9
21	2	HI W	Jetties	x		x		x									x	9/15/2018 @ 1300	max tug power	4.8	4.3
24	2	HI W	Jetties	x		x					x						x	7/25/2020 @ 1000	failure	4.5	4.7
26	2	HI E	Jetties	x		x			x								x	9/22/2020 @ 1000	low score	5.0	5.0
30	2	Jetties	Sea	x		x							x				x	9/22/2020 @ 1000	not run	5.0	5.0
31	2	Jetties	Sea	x		x									x		x	9/13/2018 @ 1900	max tug power	4.5	5.0
37	2	Ingleside	HI E	x	x				x								x	9/22/2020 @ 1000	max tug power	4.5	4.8
38	2	Ingleside	HI E	x	x					x							x	7/25/20 @ 0800	max tug power	5.0	4.9
40	2	HI W	Jetties	x			x	x									x	9/15/2018 @ 1300	failure	4.8	5.0
41	2	HI W	Jetties	x			x				x						x	7/25/2020 @ 1000	failure	4.5	4.7
42	2	HI E	Jetties	x			x		x								x	9/22/2020 @ 1000	not run	5.0	4.6
1	3	Sea	Jetties	x	x							x					x	11/25/2018 @ 0400	familiarization	5.0	5.0
4	3	Sea	Jetties	x	x											x	x	7/25/20 @ 0800	familiarization	4.8	5.0
5	3	Jetties	HI W	x	x			x									x	9/15/2018 @ 1300	max tug power	4.5	5.0
6	3	Jetties	HI W	x	x				x								x	9/22/2020 @ 1000	low score	4.8	5.0
8	3	Jetties	HI W	x	x						x						x	7/25/2020 @ 1000	max tug power	4.5	5.0
10	3	Jetties	HI E	x	x				x								x	9/22/2020 @ 1000	low score	2.3	4.3
11	3	Jetties	HI E	x	x					x							x	7/25/20 @ 0800	max tug power	4.0	5.0
14	3	Ferries	Jetties	x	x				x								x	9/22/2020 @ 1000	passing vessel speed	4.8	4.9
18	3	Ferries	Jetties	x		x			x								x	9/22/2020 @ 1000	passing vessel speed	4.8	5.0
22	3	HI W	Jetties	x		x			x								x	9/22/2020 @ 1000	low score	3.8	4.8
28	3	HI E	Jetties	x		x					x						x	7/25/2020 @ 1000	max tug power	2.8	3.0
28.2	3	HI E	Jetties	x		x					x						x	7/25/2020 @ 1000	max tug power	4.0	5.0
29	3	Jetties	Sea	x		x						x					x	11/25/2018 @ 0400	not run		5.0
36	3	Ingleside	HI E	x	x			x									x	9/15/2018 @ 1300	max tug power	5.0	5.0
19	4	Ferries	Jetties	x		x				x							x	7/25/20 @ 0800	passing vessel speed	4.3	5.0
23	4	HI W	Jetties	x		x				x							x	7/25/20 @ 0800	max tug power	4.8	5.0
25	4	HI E	Jetties	x		x		x									x	9/15/2018 @ 1300	low score	4.8	5.0
33	4	Ingleside	HI W	x	x				x								x	9/22/2020 @ 1000	max tug power	4.3	5.0
35	4	Ingleside	HI W	x	x						x						x	7/25/2020 @ 1000	max tug power	5.0	5.0
39	4	Ingleside	HI E	x	x						x						x	7/25/2020 @ 1000	max tug power	4.8	5.0
43	4	HI E	Jetties	x			x			x							x	7/25/20 @ 0800	not run	4.8	5.0
44	4	Jetties	Sea	x			x									x	x			4.8	5.0

Averaged matrices for the week

Data collection Process

After each simulator run attempt from the matrix listed above the participants document their findings on detailed surveys. This process for data collection occurs after each simulation and is uploaded in real-time after each simulator run. Copies of the original and completed survey data can be found in Appendix H.

SCI needed to perform 44 runs over 4 days, therefore, we would need to conduct roughly 11-12 simulation runs per day, to allow for multiple attempts, if requested because of a fail or due to participant requests.

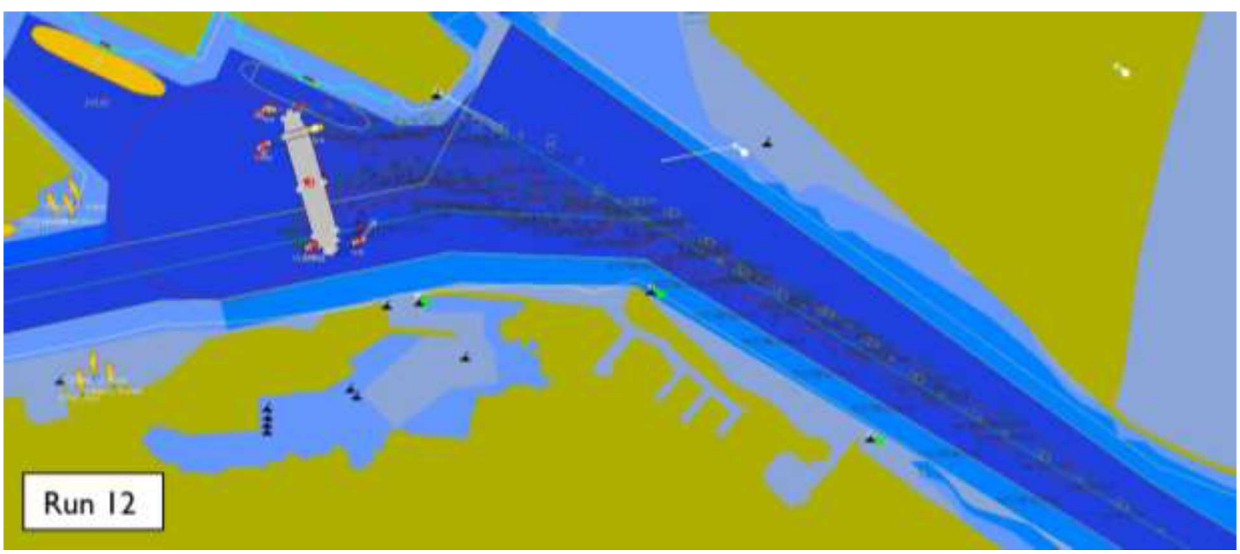
SCI staff reminded participants to exercise caution when working near the stern of a ballasted VLCC (pictured to the right), because of the difficulties operating in push mode near a due to the curvature of the hull. Tugs working at these problematic locations aft of the bridge wing were only operated in "pull" mode to account for this real-life limitation.

DAY ONE

On day one of the study, we performed 12 runs, specifically runs 2, 3, 3.2, 7, 7.2, 9, 12, 14, 15, 27, 32, and 34. The focus of day one is to target inbound runs to HICT with a VLCC loaded to 52' with medium current flows for pilot group one. The second objective was to slowly increase environmental conditions with a lighter loaded ship, prior to increasing to max flood and ebb flows with a fully loaded ship, which was scheduled for day two and day four for the respective pilot groups.

We experienced one failure on day one (run 3) pictured below, where the ship ran aground during a familiarization run, the rest of the simulations were successful runs for day 1.

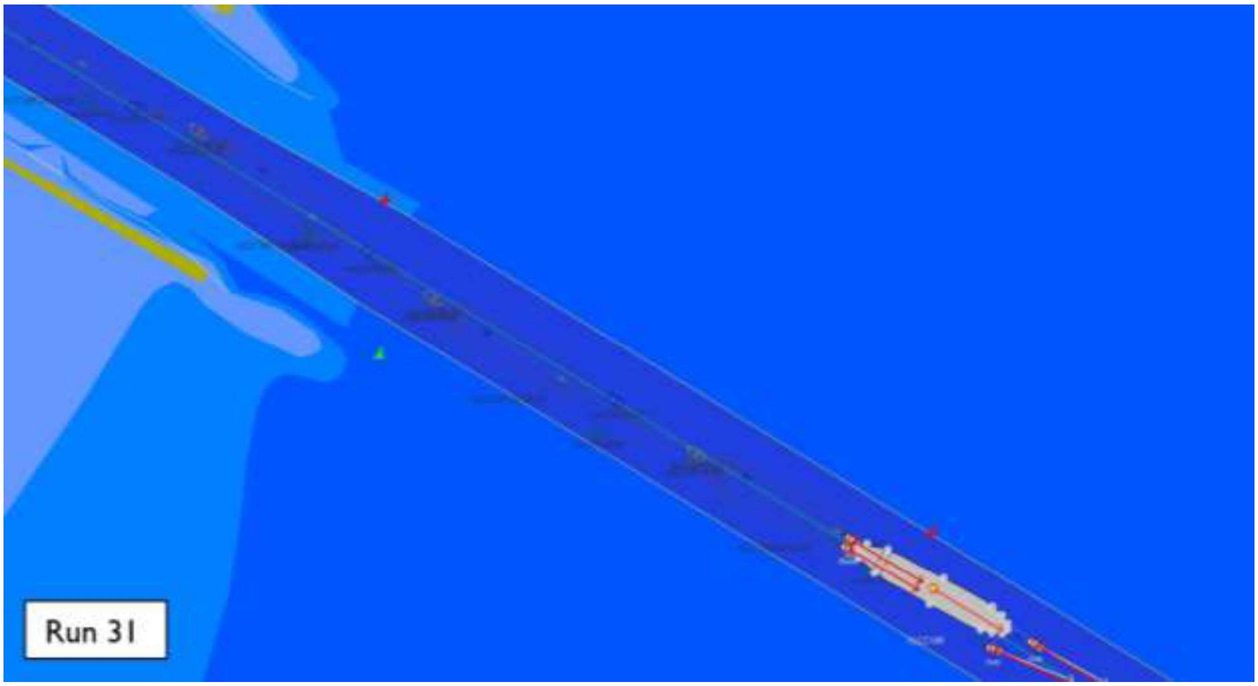
Shows stern of VLCC aground with medium flood velocity at the intersection



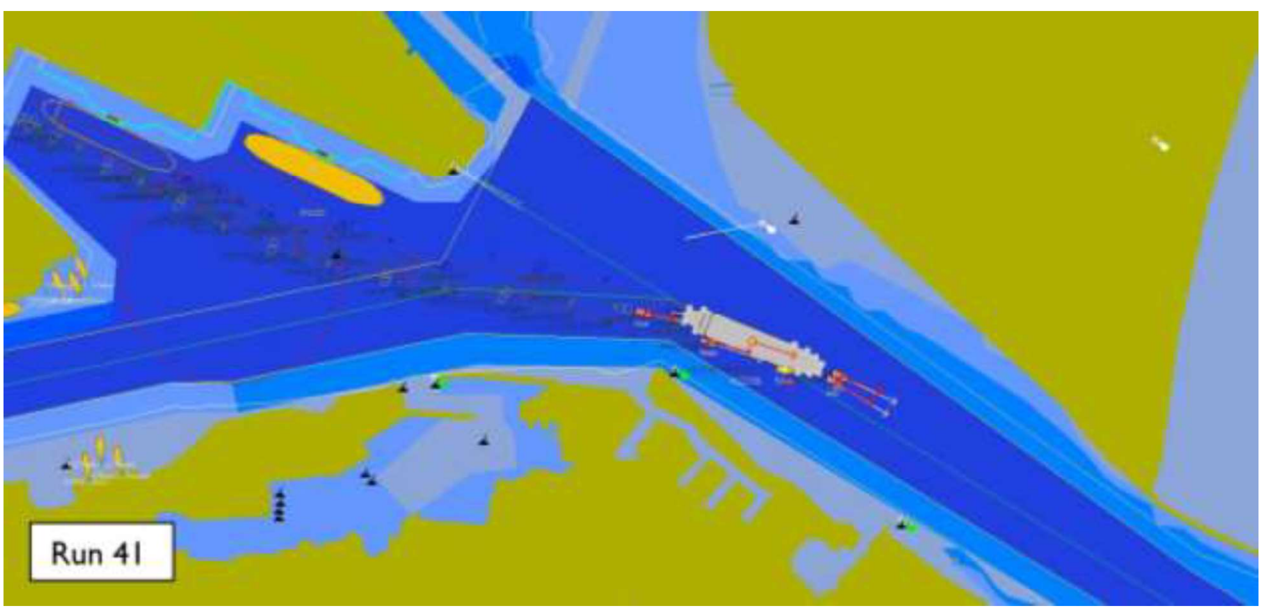
Showing a 52' VLCC maneuvering in a high flood tide to HI East Berth

DAY TWO

On day two of the study, we performed 12 runs, specifically runs 17, 20, 21, 24, 26, 30, 31, 37, 38, 40, 41, and 42. For day two scenarios we focused on running exercises with the fully loaded VLCC with a 68’ draft and high flood and ebb tide environmentals. There were no failures on day 2 with pilot group one.



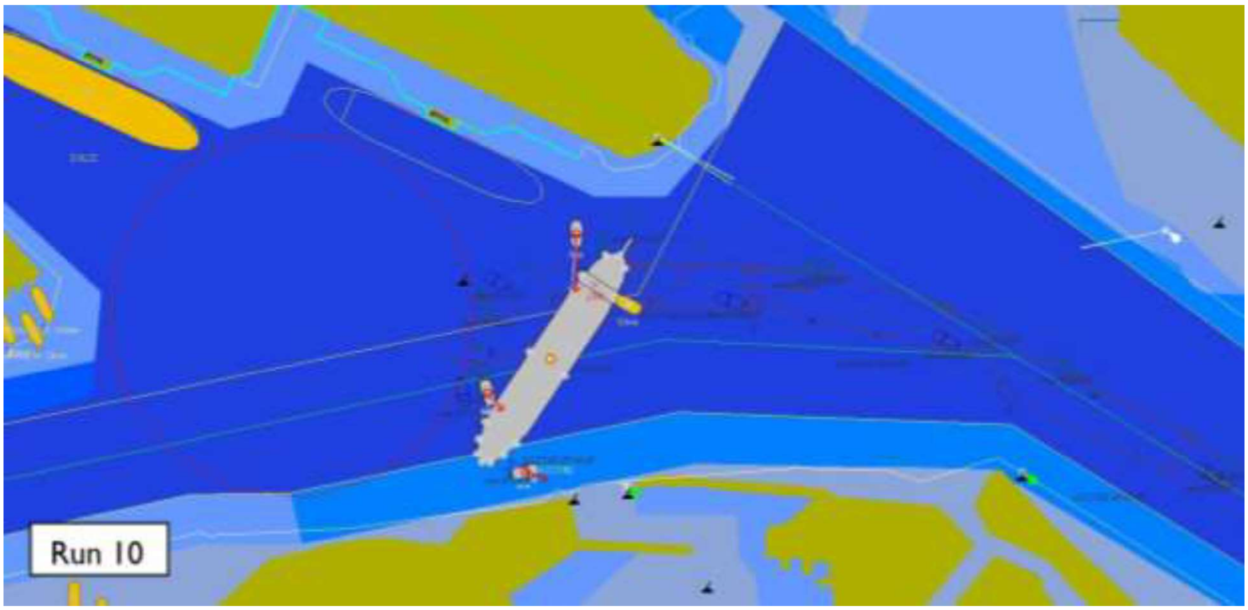
Fully loaded VLCC maneuvering with a 0.9 knot Southerly set near the end of the jetties



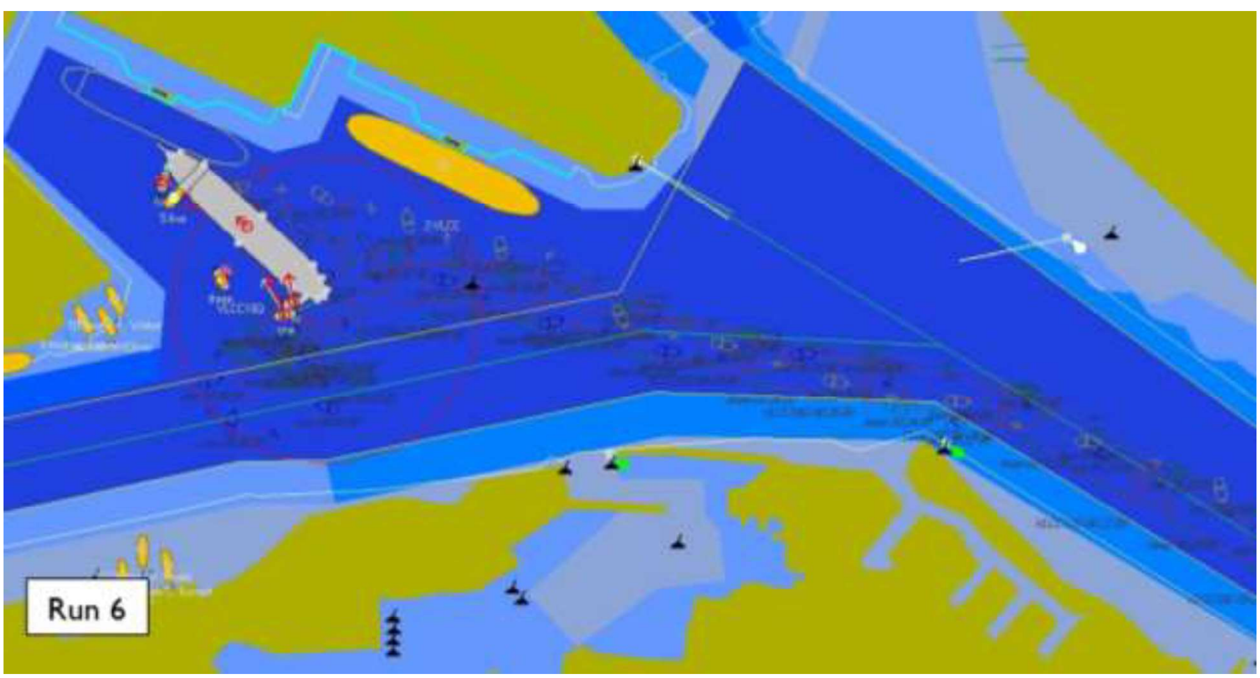
74’ loaded VLCC outbound from HI-West with a high flood

DAY THREE

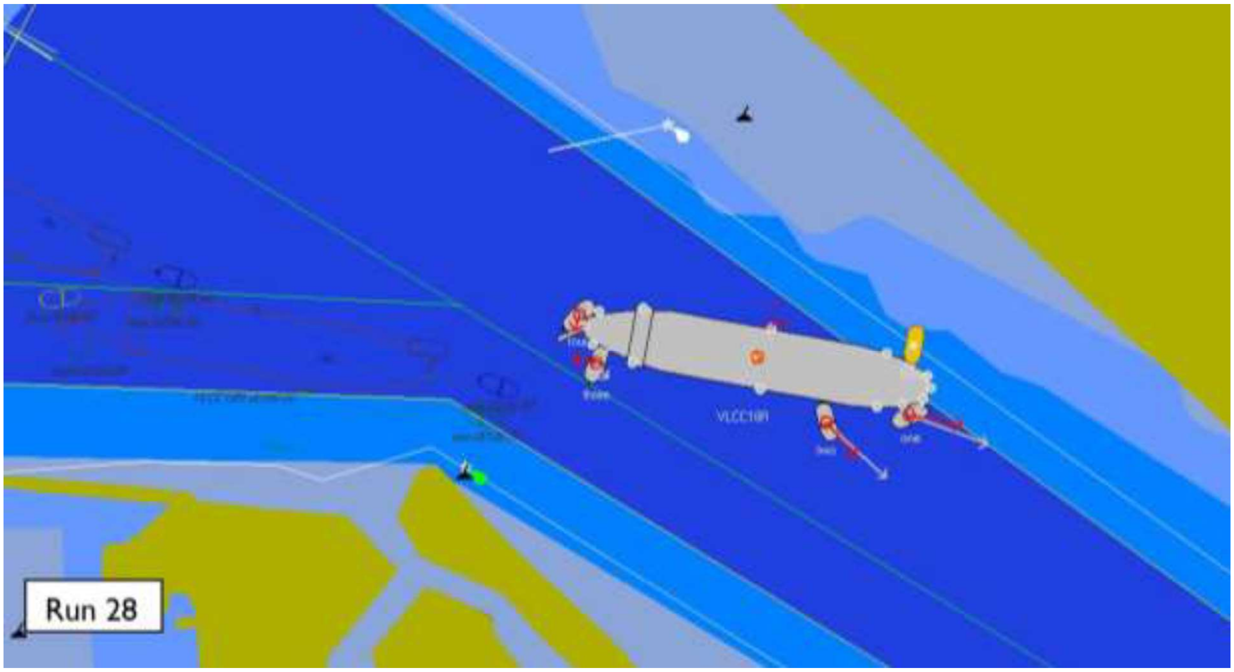
On day three of the study, we performed 16 runs, specifically runs 1, 1.2, 4, 4.2, 5, 6, 6.2, 8, 8.2, 10, 11, 13, 16, 18, 22, 28, 28.2, 28.3, 29, and 36. The focus of day three is to target inbound runs with a 52' loaded VLCC and medium current flows with the second pilot group. The other goal was to slowly ramp up the environmental conditions prior to increasing to max flood and ebb flows with a fully loaded ship, which is scheduled for day four.



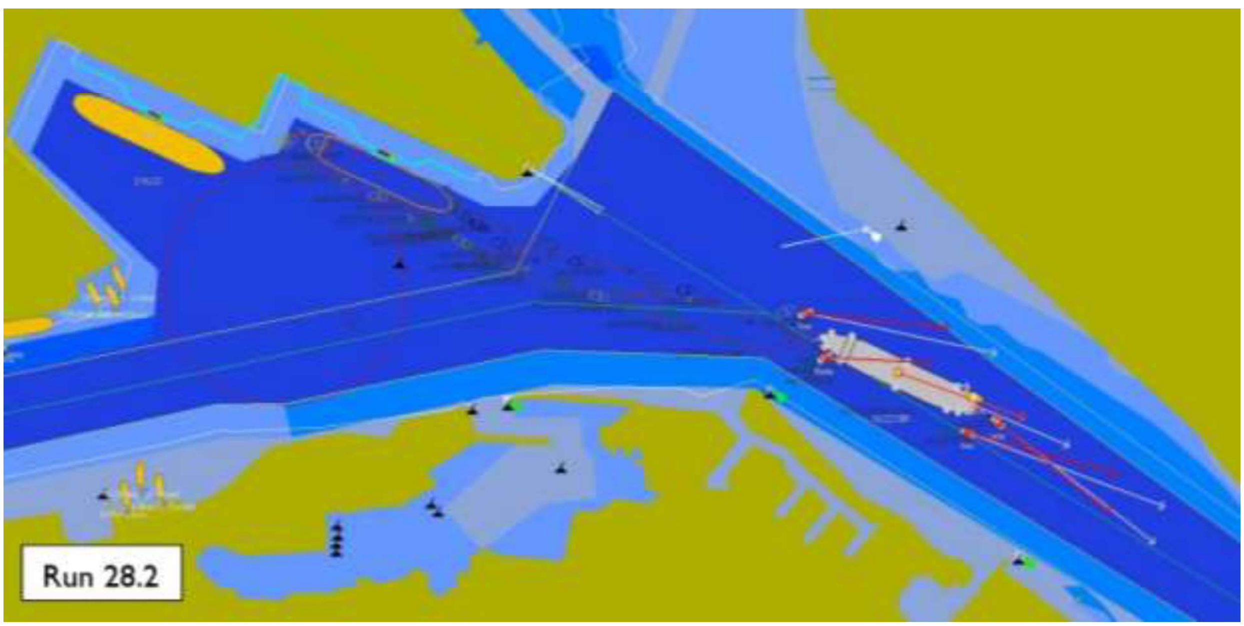
Bow aground while turning with an ebb high current (emergency run)



Successful run inbound with an ebb high current



Fully loaded VLCC ran aground at St. Joe Island on a high flood

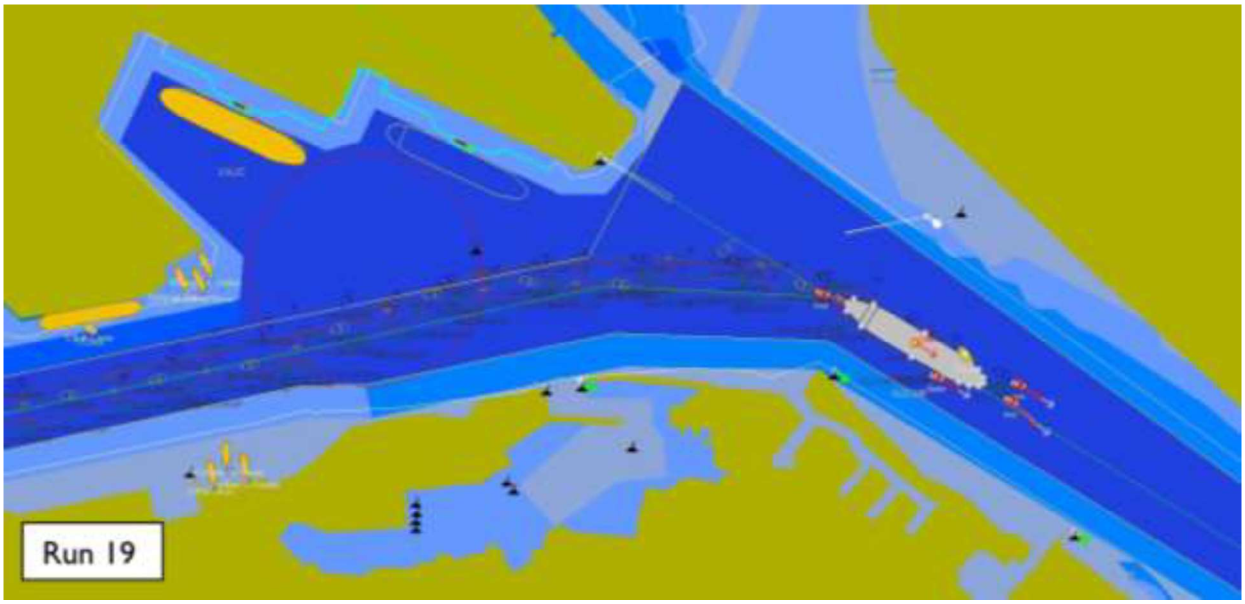


Second attempt of Run 28 with a high flood

During the second attempt of run 28 the fully loaded VLCC was able to overcome the max flood tidal conditions and complete the turn at Harbor Island outbound. Then they were able to hold up on the high side of the channel as the ship transited out to prepare for the southerly set just past the jetties. The picture above shows the ship under control with the max flood and the tugs which helped make the maneuver be successful and avoid grounding on the south side of the channel.

DAY FOUR

On day four of the study, we performed 9 runs, specifically runs 19, 23, 25, 33, 35, 39, 39.2, 43, and 44. The focus was on finishing up three of the inbound 52' VLCC runs from Ingleside to HI-W and E, with the high ebb and flood. After that, we planned to perform the rest of the 68' and 74' outbound runs. There were no failures on day 4.



68' VLCC outbound from the ferries with a medium flood tide

One of the objectives of the week was to better understand if a fully loaded VLCC could make the turn at harbor island at a slow rate of speed to accommodate ships berthed at HICT, which previous studies did not address. We ran at least eight simulations to evaluate if the turn could be made by slow steering, and understand at what tidal flow it was possible, and lastly if the tugs could overcome the tidal current forces on the ship's hull. The only failure was the first attempt of run 28, with a 68' loaded VLCC from HI East to the Jetties with a high flood current. Most of the runs were successful between 3-5 knots outbound and the tugs utilized were able to keep the ship under control the entire time.

Additionally, there was a need to perform more emergency runs with a fully loaded VLCC, which had not been adequately dealt with by previous studies. This was needed to better understand if operational risks were being addressed and proper safety margins were in place for common types of failures. During the week we incorporated nine emergencies ranging from jammed rudder on the ship, tug winch failure, broken tug hawser, tug sinking, tug experiencing black out conditions, and ship's loss of engine. All the emergencies experienced by participants occurred at the most stressful times during high-risk situations. It was important to note that there was only one failure (run 10) during the emergencies performed. During run 10 we simulated emergencies on two tugs at the same time, which resulted in a ship failure.

For all other emergencies performed when a tug experienced a casualty, the other tugs were adequate for maintaining control of the VLCC.

Over the course of the week, we were able to complete 44 runs. When study concluded, everyone was thanked for their time and dedication to the project. The simulation phase proved to be extremely useful in the development and transfer of understanding among participants. The range and number of simulations conducted adequately addressed the key parameters required to bring out the most important issues and objectives. The simulations conducted were challenging scenarios and any residual risks can be controlled by waiting on weather conditions to improve, adding additional pilots, requesting more tugs or more horsepower, and restricting traffic flow. Below are the project's recommendations and conclusions followed by a summary of each simulation from both sessions.

The remarks below are comments from the ACC Pilots participating in the study:

- Cross currents at the channel entrance offshore of the jetties and resulting leeway were manageable with minimal use of assist tugs.

- 120 MT rotor tugs provided adequate power for assisting fully loaded VLCCs in the currents within the ship channel and proposed Harbor Island terminal as represented in the simulation.

- Simulation models representing currents within the proposed Harbor Island Terminal Basin and Lydia Ann ebb currents not accurately represented. Pilots believe actual resulting currents in an as-built project will pose forces that will be more difficult to overcome. Current restrictions may be required.

- Overall, the pilots believe the project is feasible in terms of safe margins for maneuvering as represented in the simulations.

Recommendations and conclusions

Recommendations

1. The future with permit (FWP) channel dimensions, depth profile, and ship channel currents used were found to be acceptable for operating fully loaded VLCCs out of HICT. Run data and participant feedback recommended using 5–120-ton rotor tugs. Pilots and tug captains found the conditions tested to be highly accurate and provided acceptable margins of safety.

2. As dredging in the port continues, additional analysis of the currents will be needed. Pilot feedback currently supports this recommendation. During the study the pilots commented that tidal current velocities have increased as channel dredging progresses. Pilot feedback gathered varied regarding the strength of the currents and effect on VLCCs at the Harbor Island intersection. During the debriefs there was continued discussion of adding current meters at or near the Lydia Ann Channel for additional reference points. There were eight comments from participants about the fidelity of the current model. Comments for four of the runs (2, 3, 4, and 35) state the current was favorable, realistic, true to life, and that it felt correct. While comments on another four runs (11, 13, 23, and 28) state that the currents were extreme, weaker than expected, stronger than expected, or more than anticipated during the maneuvers. If the currents in the area are expected to be stronger in real life, then reducing the operational parameters of the terminal or VLCC when max flood or max ebb conditions exist may be required to offset the effect of the current flow.

3. Pilot comments recommend the use of 5-120T rotor tugs for the FWP runs and a 52' VLCC. The 120-ton bollard pull tugs were found to be necessary – based on participant feedback and tug power data gathered. The use of five rotor tugs rated at 120-ton bollard pull VLCCs with 52' draft runs for maneuvering in the FWP profile greatly enhances safety and allows for operating in more difficult environmental conditions.

4. During the FWP runs using a 68' VLCC, most pilots used five tugs. Tug power graphs for a majority of the runs show the 120T rotor tugs using short bursts of power, and not operating at maximum capacity for extended periods of time. Some of the inbound runs show maximum engine usage, during the inbound transit when the ship is at 12 knots or more. Additionally, 8 of 17 outbound runs with the 68' loaded VLCCs show tug power at or near maximum power, however 2 of the 8 simulations were emergency scenarios, and 4 of the 8 scenarios were evaluations of slow speed maneuvers outbound to better understand if the turn at harbor island can be made at reduced speeds, when a loaded ship is largely dependent on tugs and tug power. The tug power graphs are shown in appendix H.

5. The study revealed that all of the 74' runs were successful according to the data and the UKC was adequate. Tug performance data, scores, and participant feedback collected during those runs show the ship and tug operating parameters were pushed to the maximum. Pilot feedback call for operational restrictions for maneuvering ships at that draft at certain tidal flows to allow for acceptable margins of safety.
6. Regarding traffic management, when operating VLCC ships, it is recommended for the Corpus Christi Channel to employ one way traffic, with no meeting or overtaking of any vessels other than harbor-assist tugs when in transit.
7. Concerning simulations in which an emergency occurred, we performed 44 simulations total, and 7 runs included 9 emergencies such as ship rudder failure, ship engine failure, broken tug hawser, tug winch failure, tug experiencing a black out condition, and a tug sinking. Four runs were VLCCs with a 52' draft inbound for HICT. 1 out of the 7 emergency runs resulted in a failure when the ship ran aground (run 10) the lowest scoring simulation of the 44 conducted. This is a critical finding due to it being an emergency where two tugs experienced casualties, therefore, the ship was not able to maintain control with just three remaining tugs. For the 6 other emergencies conducted during runs the simulations were successful and scored well 4.5 out of 5 or better.
8. One of the study objectives was to better understand what the tug power needs are for a slow speed maneuver of an outbound partially or loaded VLCC shaping up for a turn at Harbor Island. We conducted 8 maneuvers where the objective was to make the turn at slower than normal speed to see if the tugs could overcome the environmental conditions. 3 of the 8 runs were with a 52' VLCC and 5 of the runs were with the 68' VLCC, the slowest speed transited safely was roughly 3 knots, and there were a few situations where the tugs towed the ship out with no engine and no rudder successfully. All slow speed maneuvers were successful using the 5-120T rotor tugs.

Conclusions

1. <u>Failures summarized:</u> 3 out of 44 simulations were *unsuccessful*, resulting in failure. Run 10 – 52' VLCC inbound from Jetties to HI-E with a high Ebb current, ship grounded after two tugs experienced failures. Run 3 – with a 52' VLCC from Sea to Jetties with a South Medium set, the ship ran aground when it could not overcome the environmental conditions. Run 28 – a 68' VLCC departing HI-E to the Jetties with a high flood current, got too close to Cline Point, ran across the channel and ran aground on the other side.
2. <u>Successful runs:</u> 41 of 44 *successful* runs were with environmental conditions described as very difficult and challenging, the use of 5 rotor tugs rated at 120 MT bollard pull are sufficient for handling up to fully loaded VLCCs. Out of 44 runs over the 4 days of simulation, we experienced 9 emergencies during 7 runs, of which 6 with successful outcomes.

3. The study concludes that the FWP channel dimensions are adequate, depth and currents were accurate in the channel areas, operating the VLCC with a 68' draft was possible, and the pilots could do it safely and reliably using the 5-120 MT Rotor Tugs. The simulations proved that the vessels could operate at maximum flood and ebb conditions. During the maneuvers data shows that the tugs used were not operating at maximum power for extended periods of time, and that there was power left in reserve to account for unforeseen risks. More training for tug masters with subject matter experts would be beneficial once the rotor tugs are in service, this would maximize tug use and operational output of the vessel.

4. It is a challenge to handle VLCCs in confined narrow waterways with shallow draft. In addition to the various forces affecting the vessel there is also high volume of commercial and recreational traffic. With more restrictive environmental fuel and engine regulations on the horizon success of these types of maneuvers will largely be dependent on the tugs available and the tug master's ability and skill. Having the 5-120T rotor tugs available combined with a competent operator will greatly increase safety and reliability of the maneuvers. In summary, we conclude the use of 5-120 MT Rotor Tugs was proven to be necessary and effective for safe navigation when fully loaded VLCCs are operating in the channel with the environmental conditions simulated.