APPLICATION OF SHIP SIMULATIONS ON THE TEXAS COAST TO UPDATE DESIGN GUIDANCE FOR CONCEPTUAL NAVIGATION CHANNEL DESIGN

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INTRODUCTION

This presentation describes design lessons from application of ship simulations on the Texas Coast over the last 30 years. The most recent US Army Corps of Engineers (USACE) design guidance (USACE 2006) for determining channel dimensions was compared to results of ship simulations to evaluate the effectiveness of both the simulations and existing guidance. That comparison revealed general lessons to be applied by engineers when planning ship simulations for navigation channel design and specifically updates design vessel beam multipliers for channel width on the Texas Coast or similar locations for some design conditions.

NAVIGATION CHANNEL EXPANSION IN TEXAS

Intense development on the Texas Coast, improvements to the Panama Canal, and the global increase in trade have all driven major channel improvements in Texas. The USACE Galveston District, in collaboration with our Non-Federal Partners, manages eight deep draft navigation channels with a total length of over 270 miles and 750 miles of shallow draft navigation channels that serve to connect the deep draft ports. All deep draft channels are either in the process of being deepened and/or widened or have been improved over the last 30 years, most of them many times. Today, 2 of the 8 deep draft channels are on final construction contracts, 3 have already awarded construction contracts, 2 are in design, and the last completed construction about 10 years ago. In addition to deep draft channel expansion, improvements to coastal storm risk management systems and shallow draft navigation channels have both required continuous design and construction of modifications to the navigation system. Ship simulation techniques have been applied to each of these projects many times throughout the planning and design process.

EXISTING DESIGN GUIDANCE AND CRITERIA

Channel depth is based initially on the design vessel selected through economic analysis accounting for vessel squat and motion added to the vessel draft. Channel width and alignment are more complex, requiring ship simulations in most cases. Each of the many navigation channel improvements over the last 30 years has relied on ship simulations to help determine channel dimensions and alignment. Unfortunately, simulations remain expensive and time consuming, requiring careful scoping to optimize the use of both simulators and pilots to inform channel design most efficiently.

USACE scopes ship simulations through expert judgement in consultation with its Engineer Research and Development Center (ERDC) and by applying guidance documented in USACE (2006) to help identify critical channel reaches for simulation. USACE (2006) guidance is also frequently used to estimate concept level channel requirements. Although the nature of planning civil works projects requires successively more involved analyses to enable continuing commitment of funds, a significant risk with this approach is that early low fidelity analyses can result in inflated costs which can terminate the investigation before ship simulations are completed. Unfortunately, design vessel beam multipliers provided in USACE (2006) are reported to be conservative.

USACE (2006) provides design vessel beam multipliers to enable concept level estimation of channel width requirements. To estimate channel width, designers first determine the design vessel dimensions through economic analysis and engagement with partners and pilots. Then the multipliers are applied to the design vessel beam to estimate the required channel width; design vessel length is implicit in the calculation based on the limited data used to develop the multiplier table. Then the channel is aligned based on expert judgment, modification of any turns, integration into berthing areas, and estimation of required turning basins.

APPROACH TO RE-EVALUATING THE DESIGN CRITERIA

USACE is currently applying the limited criteria in USACE (2006) for concept design and scoping initial ship simulations. Fortunately, since its publication, we have nearly 20 years of additional simulation and channel construction on the Texas Coast. Those 20 years of additional simulations were analyzed to estimate new design vessel beam multipliers to determine how conservative the guidance in USACE (2006) is, how much ship simulations have saved the United States in construction cost on the Texas Coast, and to provide improved guidance to be applied in navigation channel concept design in the future.

Each of the ship simulation reports, USACE feasibility reports, and/or design reports for navigation projects reviewed have evaluated channel width using some combination of ship simulations, expert and pilot elicitation, and design guidance. Those reports that included ship simulation analysis of channel width were compiled to create a record of channel dimension recommendations and design vessels. Beam width from the design vessels was then applied using the multipliers from USACE (2006) to estimate channel width requirements. Those channel width requirements were compared to the recommendations from ship simulations and constructed channel conditions to assess the guidance contained in USACE (2006).

RESULTS

The simple analysis described above resulted in three tables: two for one-way vessel traffic and another for two-way vessel traffic following the same approach as USACE (2006). The results were summarized into maximum, average, and minimum values for each of 3 sets of current conditions between 0, 0.5, 1.5, and 3.0 knots. USACE (2006) further breaks these criteria down into three typical cross sections; however, on the Texas Coast for these simulations, most channels were classified as trench or canal. USACE (2006) also further breaks down the multipliers for one-way traffic by constant or variable cross section and quality of the aids to navigation.

Table 1 lists the range of design vessel dimensions evaluated in the simulation data. Tables 2-4 list the final calculated maximum, average, and minimum design vessel beam multipliers from twelve different simulations for one-way traffic and ten different simulations for two-way traffic. In cases where only one simulation was available for a specific scenario, only one value is provided. No data indicates that no scenarios were simulated for those criteria.

Table 1. Range of design vessel characteristics in recent ship simulation studies.

	Maximum	Minimum
Draft, FT	52.0	32.0
Length, FT	1,200.0	329.0
Beam Width, FT	226.0	105.6

Table 2. Design vessel beam multipliers for one-way traffic with constant cross section and best aids to navigation for various maximum current in knots.

	Max currents, Kts	Max.	Min.	Avg.
Canal	0.0 to 0.5	1.59	1.52	1.56
Canal	0.5 to 1.5	No Data		
Canal	1.5 to 3.0	No Data		
Trench	0.0 to 0.5	2.36		
Trench	0.5 to 1.5	2.17		
Trench	1.5 to 3.0	No Data		

Table 3. Design vessel beam multipliers for one-way traffic with variable cross section and average aids to navigation for various maximum current in knots.

	Max currents, Kts	Max.	Min.	Avg.
Canal	0.0 to 0.5	2.44	1.83	2.13
Canal	0.5 to 1.5	No Data		
Canal	1.5 to 3.0	No Data		
Trench	0.0 to 0.5	3.34	2.71	3.03
Trench	0.5 to 1.5	2.56	1.11	1.86
Trench	1.5 to 3.0	3.99		

Table 4. Design vessel beam multipliers for two-way traffic for various maximum current in knots.

	Max currents, Kts	Max.	Min.	Avg.
Canal	0.0 to 0.5	No Data		
Canal	0.5 to 1.5	No Data		
Canal	1.5 to 3.0	2.44	2.44	2.44
Trench	0.0 to 0.5	No Data		
Trench	0.5 to 1.5	4.88	3.05	4.03
Trench	1.5 to 3.0	No Data		

Comparing Tables 2-4 against the criteria in USACE (2006) resulted in a range of design vessel beam multipliers from 4% to 72% greater than the results achieved through simulation. The average reduction was 32% for one-way traffic and 33% for two-way traffic. Ship simulations resulted in reduced channel width in each channel design simulation.

CONCLUSIONS AND RECOMMENDATIONS

Evaluation of twenty-two ship simulation analyses across eight deep draft channels on the Texas Coast revealed substantial conservatism in USACE navigation channel design guidance. This analysis helped to quantify the conservatism built into the simplified methods in USACE (2006). The data also show that application of ship simulations in Texas has resulted in an average of 32%-33% narrower channels. Since the dredged depth is much greater in the widened sections of channel than the existing channel, this translates to a far greater percentage of cost reduction, details of which will be presented at the conference. Finally, the data included in Tables 2-4 can be applied directly to help better inform conceptual channel design for future channel development in Texas and similar locations worldwide. However, refer to the original ship simulation data when adapting the design beam multipliers for future work to ensure that design conditions are comparable.

The application of design vessel beam multipliers (or rules of thumb) is a good way to initially size proposed navigation channel improvements. They can also be applied to help scope ship simulations to use precious simulator and pilot resources most efficiently. However, engineers should continue to rely on ship simulations to account for the complex physical processes and pilot requirements for all navigation channel improvement projects.

REFERENCES

USACE (2006): Hydraulic Design of Deep-Draft Navigation Projects, EM 1110-2-1613, USACE.