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December 20, 2017

TECHNICAL MEMORANDUM

TO: K. Ned Mitchell, Ph.D.
U.S. Army Engineer Research and Development Center Coastal and Hydraulics Laboratory

FROM: Jim Kruse, Director, Center for Ports and Waterways, TTI

RE: Task 4 – Effect of Pilot Restrictions

This technical memorandum provides a summary of the analysis of pilot transit restrictions, which is part of Task 4. These restrictions are imposed by the pilots based on vessel dimensions and the channel design. We examine two of the restrictions in detail. Given the time constraints contractual issues, we opted to limit our detailed analysis to these first two. The methodology employed for these two restrictions can be applied to the other two restrictions in similar fashion.

A snapshot in time is probably not of much value in this type of analysis. However, following the trends over time may indicated that the vessels calling at the port have "outgrown the channel" if the effects of the restrictions continue to increase. We do not attempt to establish an index in this analysis. This may require more investigation and collaboration with ERDC project team members to develop a tracking method that is most effective and meaningful.

We believe the methodology employed at Mobile is transferable to other port complexes, although the level of complexity may vary with the differences in the layout of the ports.

Please contact me at j-kruse@tti.tamu.edu or (713) 613-9210 if you have any questions about this technical memorandum or the underlying methodology employed.

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ANALYSIS OF EFFECTS OF PILOT RESTRICTIONS

Background

The Mobile Bar Pilots have several safety guidelines they follow when handling larger vessels (referred to as restrictions in this document). The restrictions related to channel size are:

1. The channel shall be limited to one-way traffic when a vessel whose beam exceeds 115 feet is transiting the ship channel (Restriction 1).
2. The maximum combined length of any two vessels that will be allowed to meet in the ship channel will be 1775 feet, regardless of draft (Restriction 2).
3. Any two vessels with a combined length overall (LOA) of 1650 feet or greater will not be allowed to meet in the channel if the combined draft is greater than 75 feet (**Restriction 3**).
4. Maximum combined draft of two meeting vessels shall not exceed 85 feet (**Restriction 4**).

There are other restrictions regarding daylight transits and the number of pilots. This analysis provides a detailed analysis of the first two restrictions and provides a methodology for analyzing the last two.

Restriction 1: One-way traffic when a vessel whose beam exceeds 115 feet is transiting the ship channel

In this analysis, vessels whose beam exceeds 115 feet are referred to as wide vessels or wide ships.

The vessel list was updated with the recent vessel dimension data. It contains 1,210 cargo vessels with unique IMO numbers and MMSI numbers. In this analysis, the IMO number is used as the unique identifier. There are 2,199 trips included in this analysis (trips with incomplete data were removed).

- There are 151 vessels with a beam > 115 ft. They made 494 trips during the two years.
- They have very different compositions compared to the non-wide vessels in terms of vessel type groups. There are virtually no wide trips made by chemical ships and general cargo ships.

Table 1 shows the distribution of wide and non-wide ships across ship types. Figure 1 displays the same data in graphical form.

Table 1. Distribution of Trips by Ship Type Group and Beam Size.

Ship Type Group	Trips by Non-Wide Ships (≤ 115 ft.)	Trips by Wide Ships (>115ft)
Bulk	703 (41.2%)	96 (19.4%)
Chemical	182 (10.7%)	2 (0.4%)
Container Ship-Fully Cellular	254 (14.9%)	97 (19.6%)
Crude Oil Tanker	5 (0.3%)	135 (27.3%)
General Cargo Ship	269 (15.8%)	0 (0.0%)
Other	292 (17.1%)	164 (33.2%)
Total	**1,705 (100.0%)**	**494 (100.0%)**

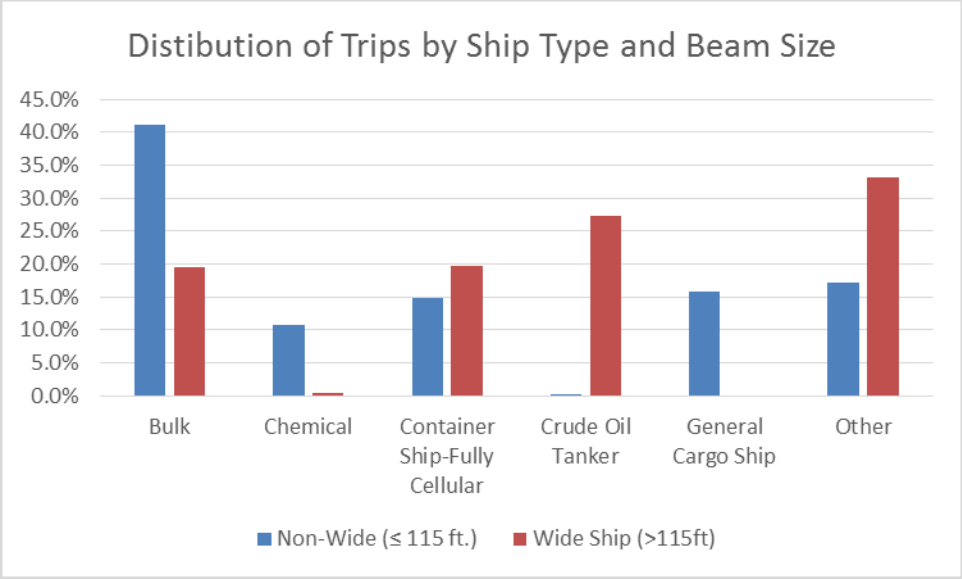


Figure 1. Distribution of Trips by Ship Type Group and Beam Size

Table 2 shows the percentage of trips within each ship type that were made by wide vessels.

Table 2. Percentage of Trips That are Wide Vessels.

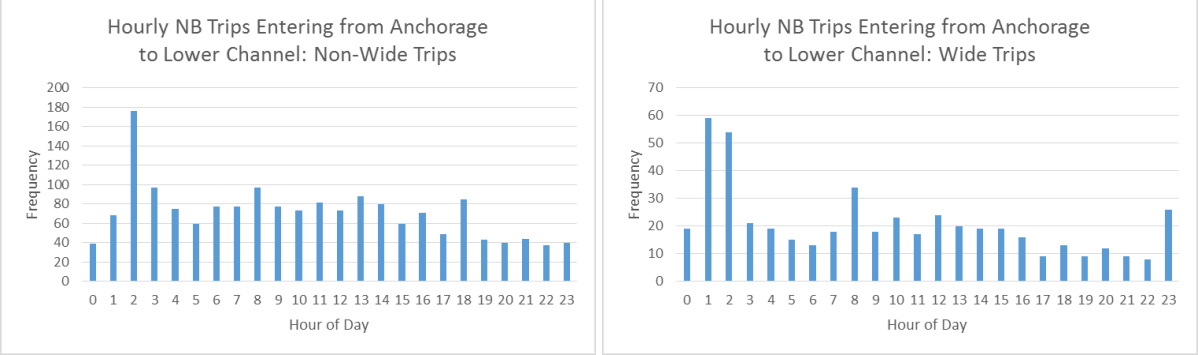
Ship Type Group	Percent of Trips with Wide Beam
Bulk	12%
Chemical	1%
Container Ship-Fully Cellular	28%
Crude Oil Tanker	96%
General Cargo Ship	0%
Other	56%

In Table 3, we compare the channel transit times for wide ships to transit times for all others. Table 3 also shows the degree to which vessel dimensions vary between the two groups on average.

Table 3. Size and Channel Transit Time Comparison Between Wide and Non-Wide Trips.

		Trips by Non-Wide Ships (≤ 115 ft.)	Trips by Wide Ships (>115ft)	All Trips
Channel Transit Time	Avg. TTIB	142 minutes	161 minutes	146 minutes
	Avg. TTOB	142 minutes	156 minutes	145 minutes
Vessel Dimension	Avg. Beam	93 ft.	132 ft.	102 ft.
	Avg. Length	634 ft.	783 ft.	669 ft.

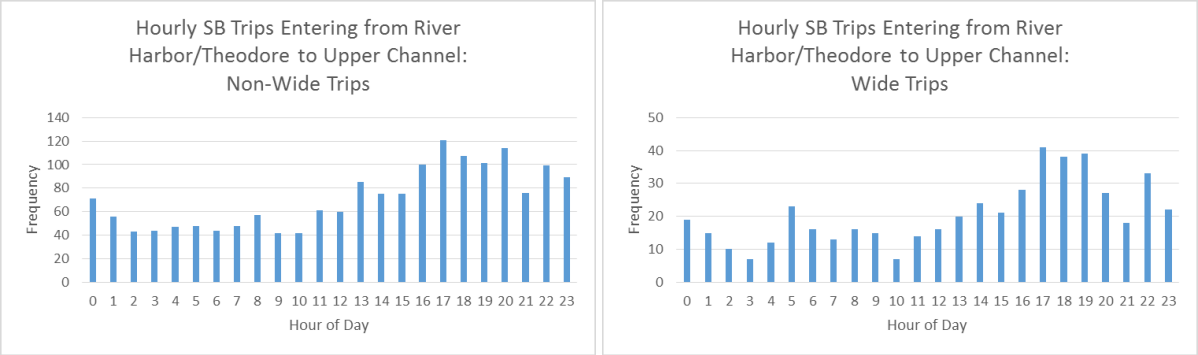
Figure 2 charts the hourly distribution of northbound trips based on the time they enter the lower channel (leave the anchorage area). (Appendix A has more plots by ship types.) There is an interesting spike in activity in the 2:00 am to 3:00 am range. This may reflect an attempt to be at the dock and ready to commence loading/unloading at first light.



(a) Non-wide Trips (b) Wide Trips

Figure 2. NB Hourly Distributions of Non-Wide and Wide Trips

Figure 3 does the same for southbound trips leaving either the river harbor or Theodore. (Appendix B has more plots by ship types). Departures tend to rise in late afternoon and early evening as vessel operations for the day are concluded and a vessel that has completed its call can depart.



(a) Non-wide Trips (b) Wide Trips

Figure 3. SB Hourly Distributions of Non-Wide and Wide Trips

The potential effects of transits by wide ships is conducted in two separate analyses—one for situations in which the wide ship is northbound and one for when wide ships are southbound.

Case 1: Southbound trips are blocked by a wide northbound vessel entering the lower channel

Figure 4 illustrates this situation.

Figure 4. Illustration of Case 1: SB Trips are Blocked by Wide NB Vessels

Figure 5 shows the average segment transit times used in the analysis.

Figure 5. Average Channel Transit Times Used in the Analysis.

Because there are two harbors (river harbor and Theodore) that join at mid-bay to use a common lower channel, there are actually four separate scenarios that must be analyzed.

- SB trips from the river harbor blocked by a NB trip for the river harbor
- SB trips from the Theodore blocked by a NB trip for the river harbor
- SB trips from the river harbor blocked by a NB trip for the Theodore
- SB trips from the Theodore blocked by a NB trip for the Theodore

We analyze the pattern of southbound trips that immediately precede or follow a northbound trip of a wide vessel. Time Zero is the point at which the wide ship leaves the channel and the restriction is removed (channel is freed). When a northbound wide ship enters the river harbor/Theodore dock area the channel is freed for southbound trips originating in the river harbor.

Figure 6 show the number of southbound trips by hour starting at the time the upper channel is freed. There is an obvious spike in the number of trips occurring in the first 3 hours after the channel is freed. The average number of trips for the time span of 3 hours to 12 hours is 67. The average during the first 3 hours is 83. This would indicate that the timing of 48 trips was potentially altered (3 x (83-67)).

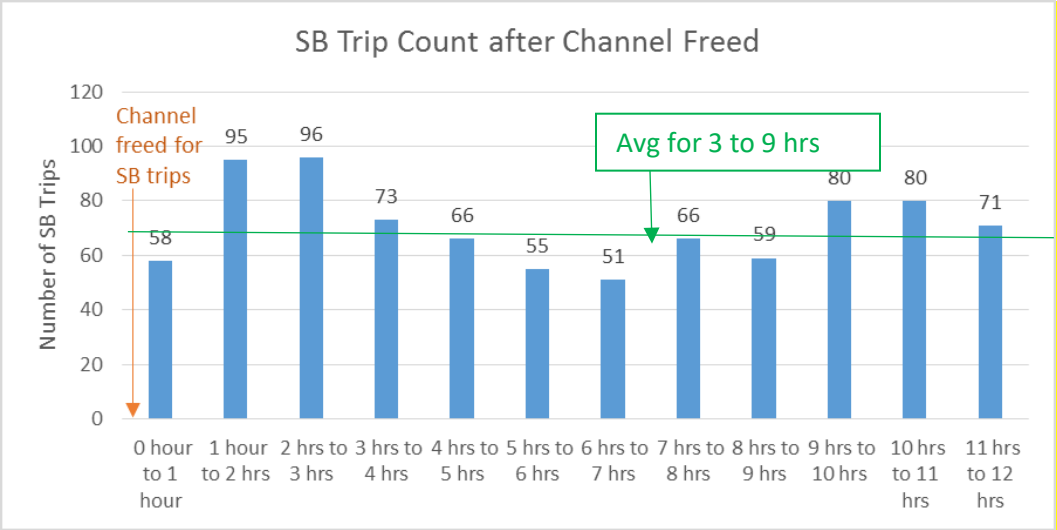


Figure 6. Hourly SB Trips after Channel is freed

We also look at what happens immediately preceding the entrance of a northbound wide vessel into the channel—at which time the channel is blocked or restricted. Figure 7 shows the number of southbound trips by hour that began in the river harbor or at Theodore in the 12 hours preceding the time at which the channel is blocked/restricted.

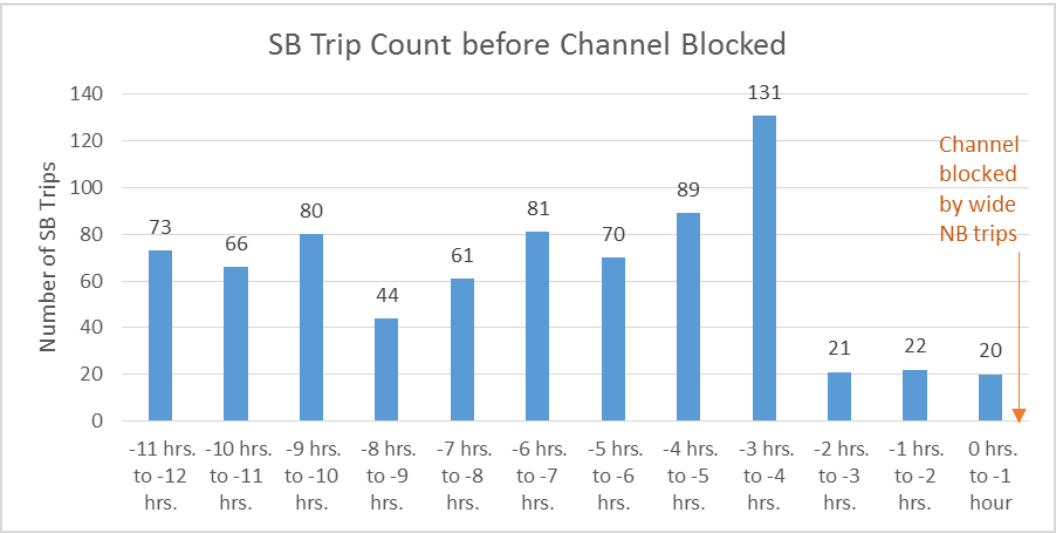


Figure 7. Hourly SB Trips before Channel is blocked

Figure 7 shows a peak at 3 to 4 hours before the channel is blocked. It is interesting that there are very few southbound trips between 0 to 3 hours before the channel is blocked. It may be that the channel is effectively (if not physically) restricted to avoid possible conflicts in the middle for an incoming wide vessel well before the wide vessel enters the lower channel.

The interesting point here is that it is not possible for a vessel to transit the entire channel leave the channel in two hours. This would indicate that at least the 42 trips immediately preceding the restriction (and possibly 63) may represent vessels that left Theodore and were timed to arrive at the junction with the main channel after the northbound wide vessel passed the junction. Further analysis of these trips is needed to determine their characteristics.

The trips in Figure 7 do not reflect delay and therefore do not reflect additional operating costs.

Case 2: Northbound trips are blocked by a wide southbound vessel leaving either the river harbor or Theodore

Figure 8 illustrates this situation.

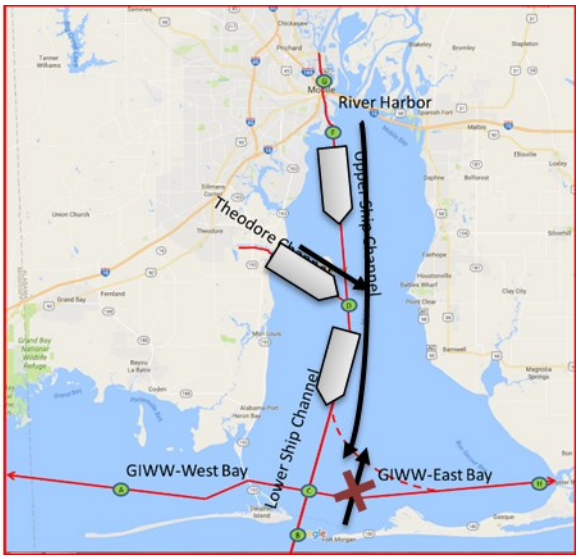


Figure 8. Illustration of Case 2: NB Trips are blocked by Wide SB Vessels.

Figure 9 show the number of southbound trips by hour starting at the time the upper channel is freed. There is a severe spike in the number of trips occurring in the first 2 hours after the channel is freed. Even though it drops significantly, the third hour is much higher than the average in later hours. The average number of trips for the time span of 3 hours to 12 hours is 60. The average during the first 3 hours is after the channel is freed is 115. This would indicate that the timing of 165 trips was potentially altered (3 x (115-60)). This is over 3 times higher than the potentially affected vessels in the opposite case.

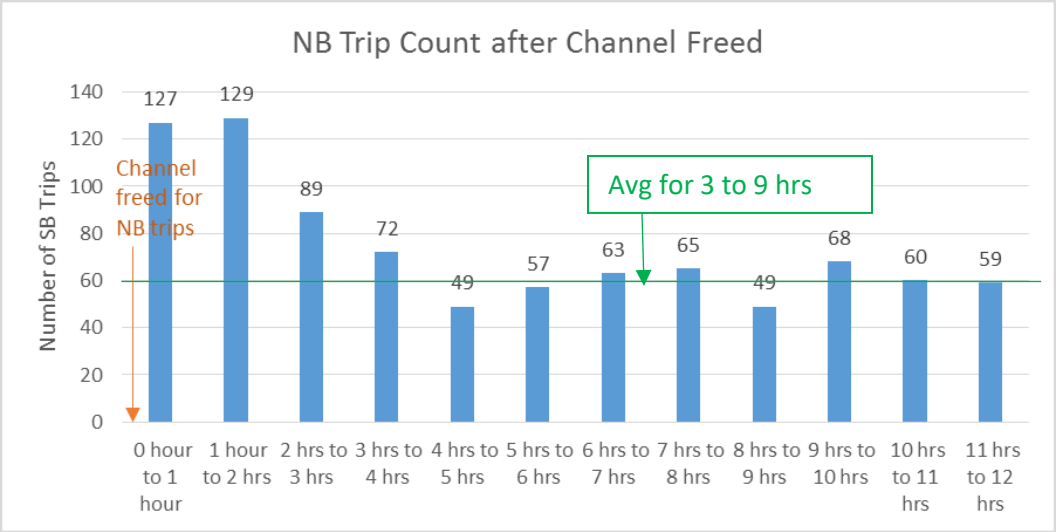


Figure 9. Hourly NB Trips after Channel is freed

The AIS data indicate that a large number of northbound vessels were waiting at the anchorage area until the channel became available (see Figure 10 showing the high density of traffic around the anchorage area). In other words, these vessels are physically detained in the anchorage area until the channel is freed.

Figure 10. GIS Map of AIS Vessel Movement Data

We also look at what happens immediately preceding the entrance of a southbound wide vessel into the channel—at which time the channel is blocked or restricted. Figure 11 shows the number of

northbound trips by hour that began at the entrance to the lower channel In the 12 hours preceding the time at which the channel is blocked/restricted.

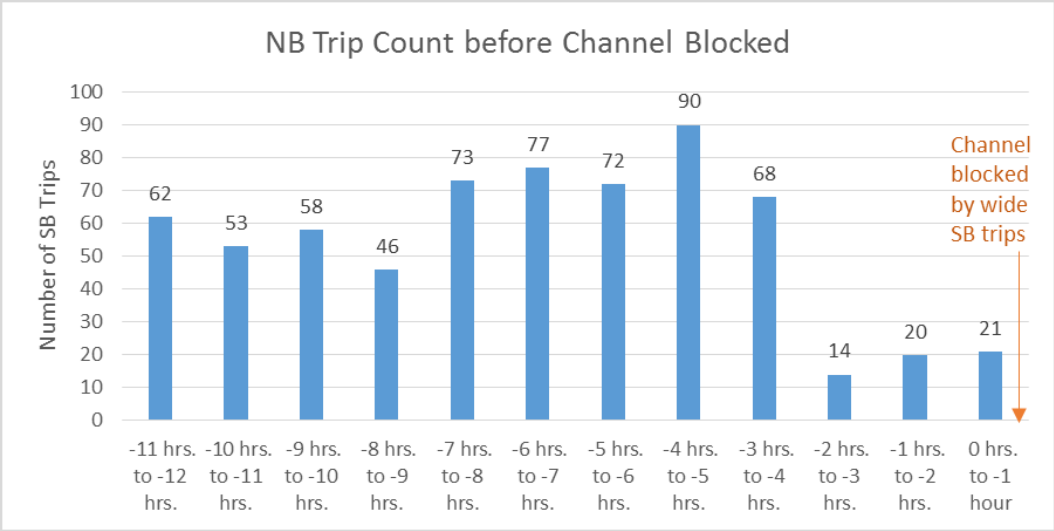


Figure 11. Hourly NB Trips before Channel is blocked

Similarly to the previous cases, Figure 11 shows a very low number of northbound trips between 0 to 3 hours before the channel is blocked. There seems to be a buildup of activity in the 3 to 6 hour range, although it is not as pronounced as in the first case. Again, it may be the channel is effectively (if not physically) restricted to avoid possible conflicts in the middle for an outbound wide vessel well before the wide vessel enters the channel.

As with the south bound trips further examination of the trips taking place in the 2-3 hour time span before the channel is blocked need to be examined in more detail. It is most likely related to trips that can turn off to Theodore and be out of the channel before a wide ship arrives at the junction.

The trips in Figure 11 do not reflect delay and therefore does not reflect additional cost.

Restriction 2: Maximum combined length of any two vessels that will be allowed to meet in the ship channel will be 1775 feet

Preparation of Data Set for the Current Restriction: LOA(A)+LOA(B)≤1775ft

- When we sort the ships by length overall (LOA), the shortest one is 191 feet and the longest one is 1,066 feet. The frequency distribution of the trips by ship length is shown in Figure 12

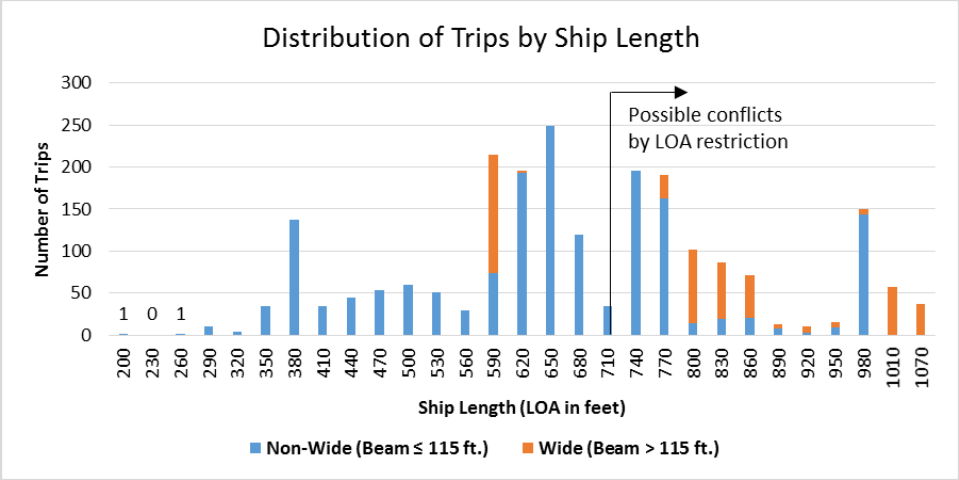


Figure 12. Distribution of Trips by Ship Length (LOA)

- Given that the sum of two meeting vessels' LOAs should be less than or equal to 1,775 feet and the longest vessel has a LOA of 1,066 feet, if a ship is shorter than or equal to 709 feet, it is not constrained by the restriction. The trips with LOA>709 feet would have possible conflicts when the sum of the two meeting vessels' LOAs exceeds 1,775. For example, a vessel with a length of 730 feet cannot meet with a vessel with a length of 1,045 feet or longer in the channel.
- As shown in Table 4, 927 trips were made by vessels that have LOAs longer than 709 feet. Among the 927 trips, trips with a wide beam as defined in Restriction 1 (> 115 feet) are subject to Restriction 1, which is analyzed above; they are therefore excluded from the current analysis. The resulting number of 576 trips (with LOA > 709 feet and beam ≤ 115 feet) are investigated for possible cases of conflicts by Restriction 2.

Table 4. Number of Trips by LOA and Beam Size.

	Beam ≤ 115	**Beam > 115**	**Total**
LOA ≤ 709	1,129	143	1,272
LOA > 709	**576**	351	927
Total	1,705	494	2,199

The set of 576 trips in Table 4 is further analyzed by ship type group. Table 5 shows Bulk and Container Ship-Fully Cellular groups make up more than 90 percent of the trips that are affected by the Restriction 2.

Table 5. Distribution of Ship Type Groups that are constrained by Restriction 2

Ship Type Group	# Trips with LOA > 709 & Beam ≤ 115	Percentage
Bulk	296	51.4%
Chemical	1	0.2%
Container Ship-Fully Cellular	232	40.3%
Crude Oil Tanker	4	0.7%
General Cargo Ship	0	0.0%
Other	43	7.5%
Total	576	100%

The two major ship type groups in Table 5 are further analyzed for channel transit time. Table 6 shows Bulk trips take more time than Container Ship trips to pass through the channel. It is interesting to see Bulk trips take more time for outbound trips while Container Ship trips take more time for inbound trips, though the differences are relatively small.

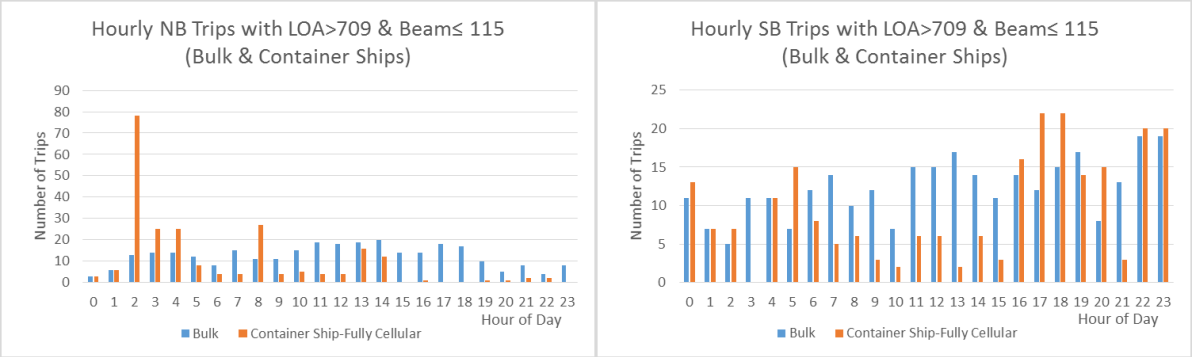
Table 6. Transit Time Comparison between Bulk and Container Ship Groups shown in Table 5

Ship Type Group	Avg. TTIB	Avg. TTOB	TTIB + TTOB
Bulk	152 minutes	167 minutes	319 minutes
Container Ship-Fully Cellular	144 minutes	137 minutes	281 minutes

Figure 13 charts the hourly distributions of Bulk and Container Ships from the Table 5 for (a) northbound trips based on the time they enter the lower channel (leave the anchorage area) and (b) southbound trips leaving either the river harbor or Theodore (Appendices C and D have plots for more LOA and beam size combinations).

For NB container trips, there is a spike in activity in the 2:00 AM to 3:00 AM range (Figure 13 (a)). Specifically, 34 percent of NB container ship trips are entering the lower channel during this one-hour period. This may reflect at an attempt to be at the dock and ready to commence loading/unloading at first light. Bulk ships have relatively steady frequency of hourly NB trips.

For SB trips departures tend to rise in late afternoon through midnight for both of the ship types while container ships have much fewer trips between 7:00 AM and 4:00 PM (Figure 13 (b)). Generally, container ships tend to use specific time periods of a day while bulk trips have less variabilities over a day for both directions.



(a) NB Trips (b) SB Trips

Figure 13. Hourly Distributions of Trips with LOA > 709 ft. & Beam ≤ 115 ft.

Analysis of Trips with the Restriction: $LOA_{TripA}+LOA_{TripB}\leq 1775$ft

The potential effects of transits subject to the combined LOA restriction are conducted in two separate analyses—one for situations in which the ship is northbound and one for when large LOA ships are southbound.

Case 1: Some Southbound trips are blocked by a northbound vessel with large LOA entering the lower channel

Figure 14 illustrates this situation where a NB ship with large LOA (e.g. L1) is moving along the channel. Some SB ships with large LOA (e.g. L2 or L3) are blocked because the sum of the two LOAs is more than 1,775 feet (e.g. LOA_{L1} + LOA_{L2} (or LOA_{L3}) > 1,775) while the other SB ships (S1 – S5) are free to travel along the channel because their LOAs are not large enough to exceed 1,775 feet when summed with L1's LOA. In the following analysis, only the conflicting trips such as L2 and L3 are counted to see the effect of Restriction 2.

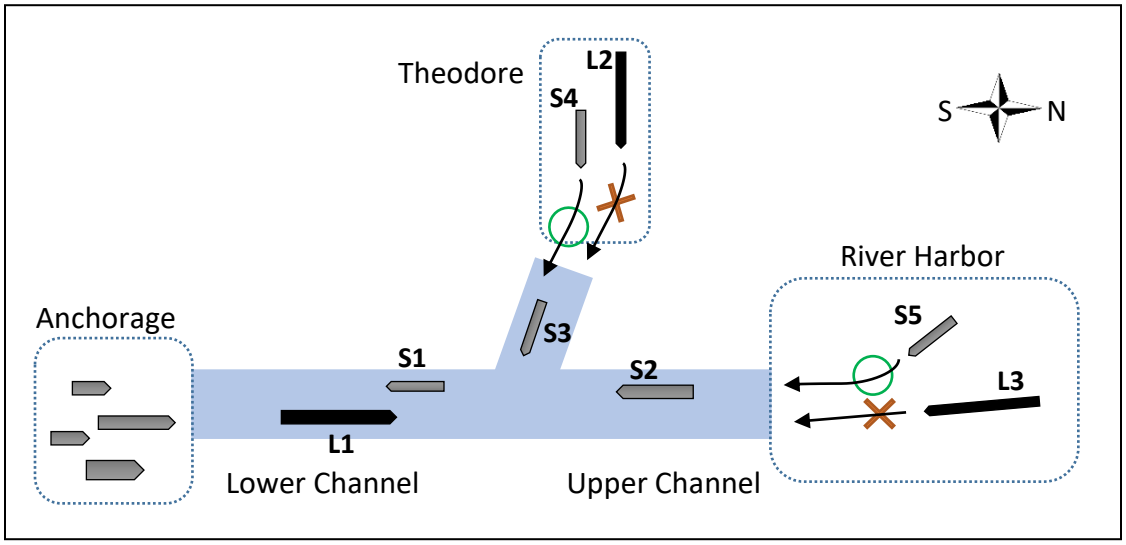


Figure 14. Illustration of Case 1: Some SB Trips are blocked by NB Vessels with Large LOA

We analyze the pattern of southbound trips with possible conflicts that immediately precede or follow a northbound trip of a wide vessel. Time Zero is the point at which the large LOA ship leaves the channel

and the restriction is removed (channel is freed). When a northbound large LOA ship enters the river harbor/Theodore dock area the channel is freed for southbound trips originating in the river harbor.

Figure 15 shows the number of southbound trips by hour starting at the time the upper channel is freed. There is an obvious spike in the number of trips occurring in the first hour after the channel is freed. It is noticeable that 17 out of 20 SB trips in the first hour period were taken by container ships. Most of them were blocked by inbound container ships.

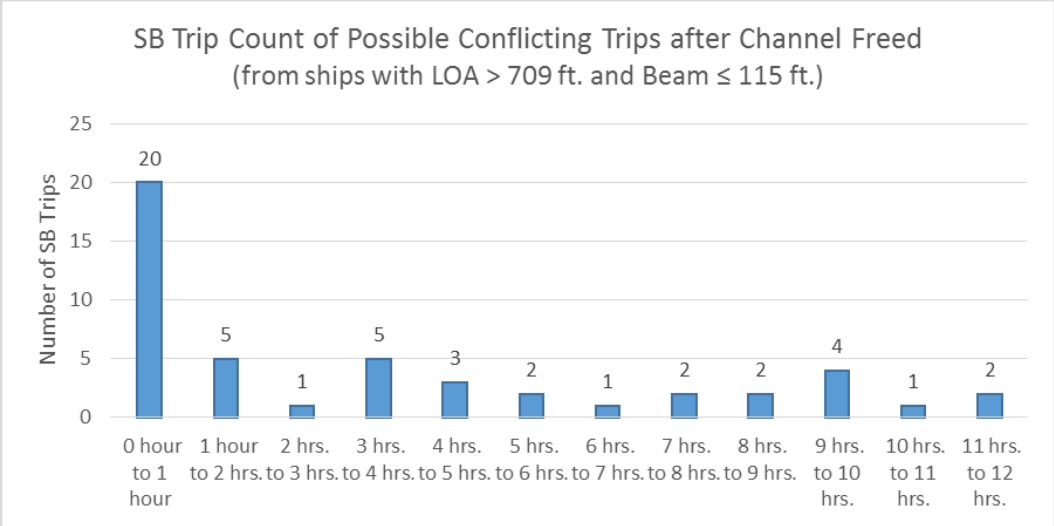


Figure 15. Hourly SB Trips after Channel is freed

We also look at what happens immediately preceding the entrance of a northbound vessel with a large LOA into the channel—at which time the channel is blocked or restricted for trips with conflicting LOAs. Figure 16 shows the number of possible conflicting southbound trips by hour that began in the river harbor or at Theodore in the 12 hours preceding the time at which the channel is blocked/restricted.

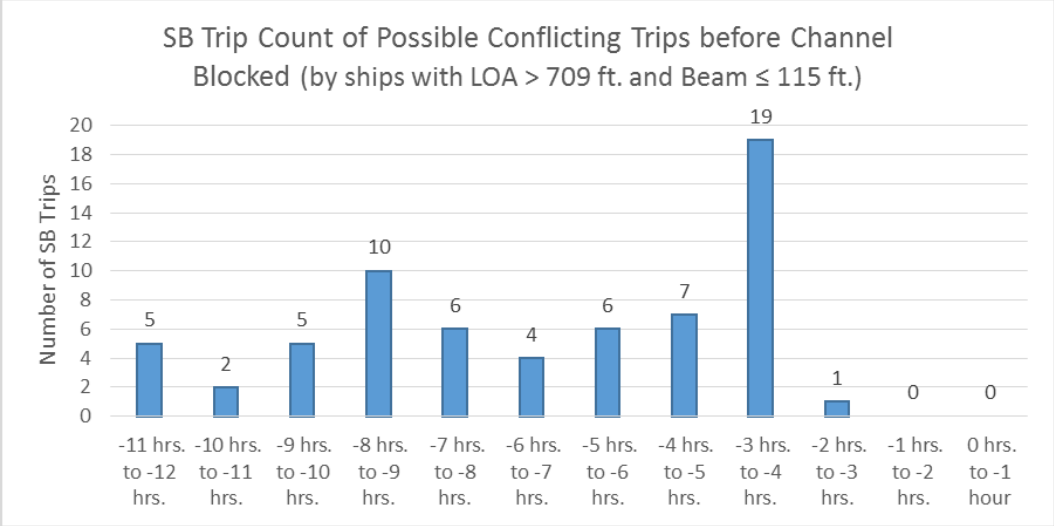


Figure 16. Hourly SB Trips before Channel is blocked

Figure 16 shows a peak at 3 to 4 hours before the channel is blocked. Among the 19 SB trips that entered the channel 17 trips were made by container ships. It is noticeable that there is only one

southbound trip between 0 to 3 hours before the channel is blocked. The SB ship entered the channel two and half hours before the channel is blocked and exited the channel 45 minutes before the long NB ship entered and blocked the lower channel. It may be that the channel is effectively (if not physically) restricted to avoid possible conflicts in the middle for an incoming long vessel well before the long vessel enters the lower channel.

Case 2: Northbound trips are blocked by a southbound vessel with a large LOA leaving either the river harbor or Theodore

Figure 17 illustrates this situation where a SB ship with large LOA (e.g. L1) is moving along the channel. Some NB ships with large LOA (e.g. L2 at anchorage) are blocked because the sum of the two LOAs is greater than 1,775 feet (e.g. $LOA_{L1} + LOA_{L2} > 1{,}775$) while the other SB ships (S1 – S4) are free to travel along the channel. In the following analysis only the conflicting trips like L2 are counted to see the effect of the restriction 2.

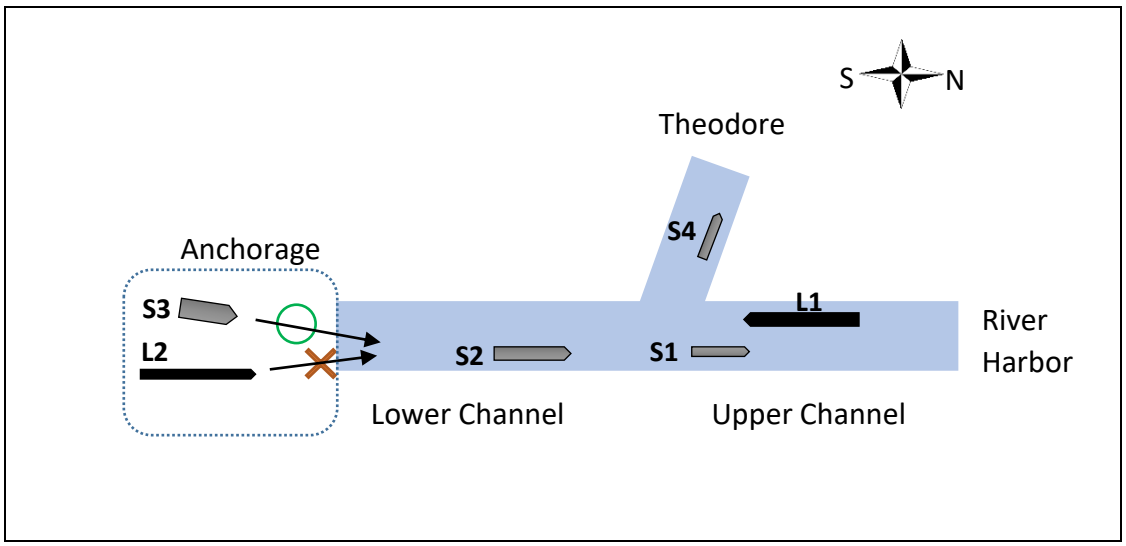


Figure 17. Illustration of Case 1: Some NB Trips are blocked by SB Vessels with Large LOA

Figure 18 shows the number of northbound trips by hour starting at the time the lower channel is freed. There is an obvious spike in the number of trips occurring in the second hour after the channel is freed. Like the SB trips, most of the conflicting trips were taken by container ships. For example, 15 out of 18 NB trips during the first 2 hours were container ships and the remaining 3 were bulk ships.

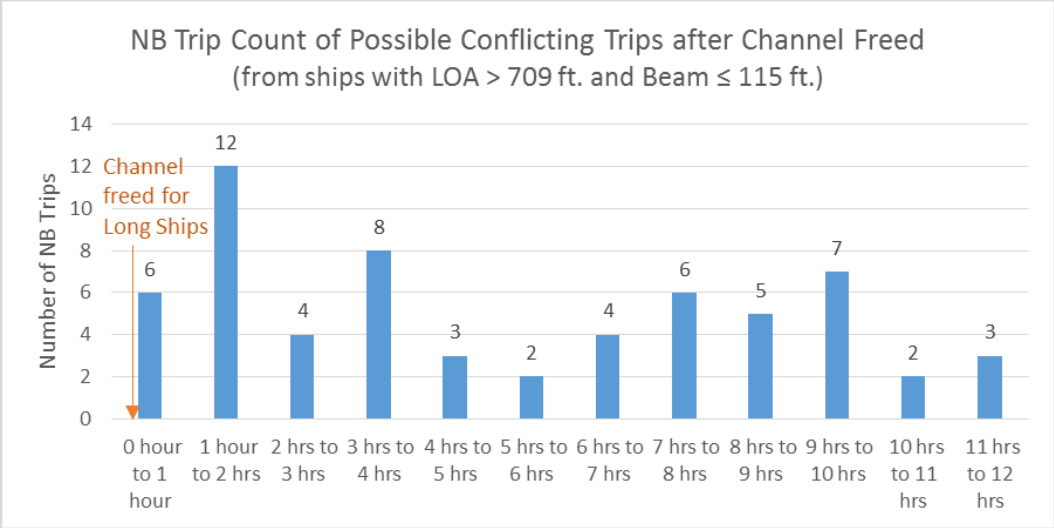


Figure 18. Hourly NB Trips after Channel is freed

We also look at what happens immediately preceding the entrance of a southbound vessel with a large LOA into the channel—at which time the channel is blocked or restricted for trips with conflicting LOAs. Figure 19 shows the number of possible conflicting northbound trips by hour that began at the entrance to the lower channel in the 12 hours preceding the time at which the channel is blocked/restricted.

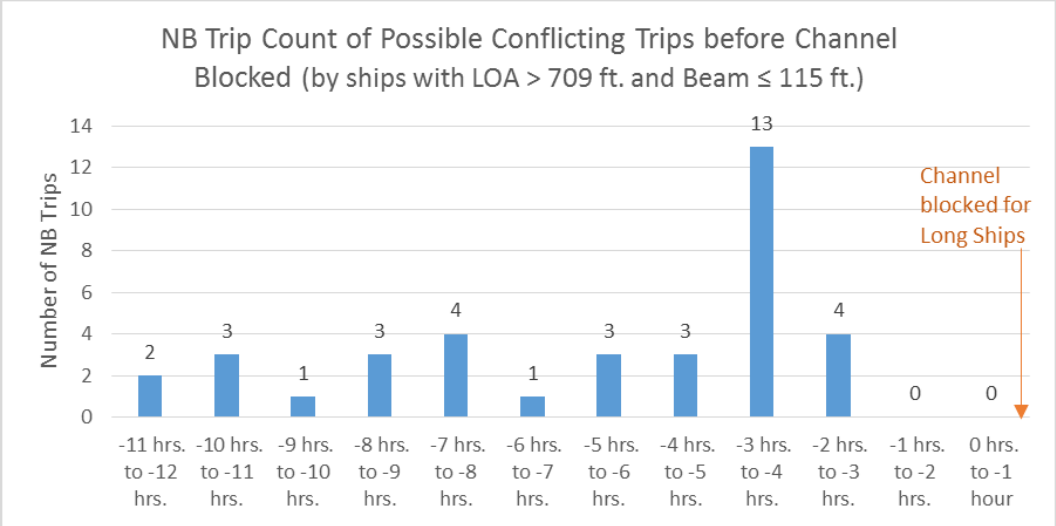


Figure 190 Hourly NB Trips before Channel is blocked

Similarly to the previous cases, Figure 19 shows a very low number of northbound trips between 0 to 3 hours before the channel is blocked. There are four northbound trips between 2 to 3 hours before the channel is blocked. We reviewed them one by one to confirm that they all exited the channel before the long SB ships entered the upper channel so that they would not have any conflict in the middle of the channel. It seems that the channel is effectively (if not physically) restricted to avoid possible conflicts for an incoming long vessel well before it enters the lower channel.

Restriction 3: Any two vessels with a combined length overall (LOA) of 1650 feet or greater will not be allowed to meet in the channel if the combined draft is greater than 75 feet

and

Restriction 4: Maximum combined draft of two meeting vessels shall not exceed 85 feet

These two restrictions require the availability of the sailing draft of each vessel transit. The U.S. Coast Guard publishes Entrances and Clearances files that have these drafts. Our initial examination of the Mobile files indicates that at least 95% (and we believe more than 98%) of the vessel drafts are available. A significant number of discrepancies between the Mobile data and the Coast Guard data occur because the two files have different IMO numbers for the same vessels. Resolving these discrepancies would require a manual review of the data, but that should not be a significant impediment.

Once the drafts are determined for each transit, the same analytical approach used for Restrictions 1 and 2 can be used here. The analysis of Restriction 4 would be the same as for Restriction 2, using draft as the key variable rather than LOA. Restriction 3 is a bit more complex; it requires a combination of restrictions similar to Restrictions 2 and 4.

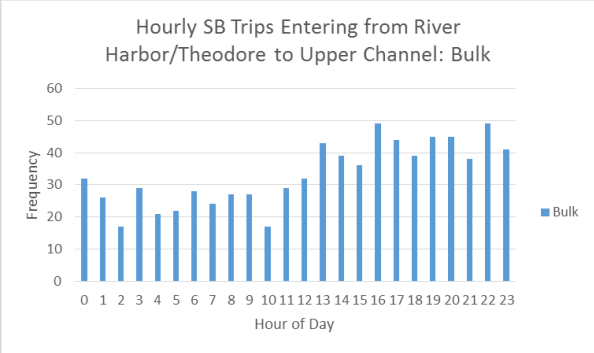
Concluding thoughts

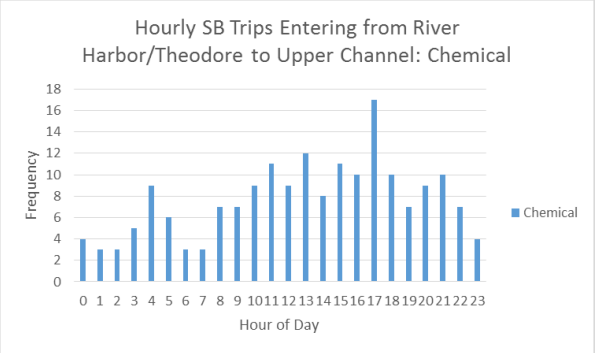
The number of potentially affected trips as a standalone number is probably not of much value. It would probably be of more value to develop an index or a trend based on these numbers and track what happens over time. A rise in the index or trend would indicate that the channel dimensions are becoming an increasing problem for the vessel sizes that are occurring at the port.

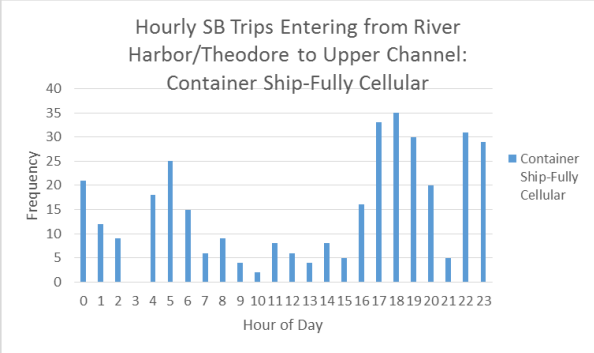
A number of vessels could potentially be affected by more than one restriction. In developing an index or trend analysis, we recommend prioritizing the restrictions. The restriction that could potentially affect the greatest number of trips should be highest priority. Any vessels potentially affected by this restriction should not be marked as potentially affected in subsequent restrictions. This approach would then be used for vessels identified in Restriction 2 and so on. In the case of Mobile, Restriction 1 was given the highest priority, followed by Restriction 2. We did not carry the analysis far enough to determine the order of Restrictions 3 and 4.

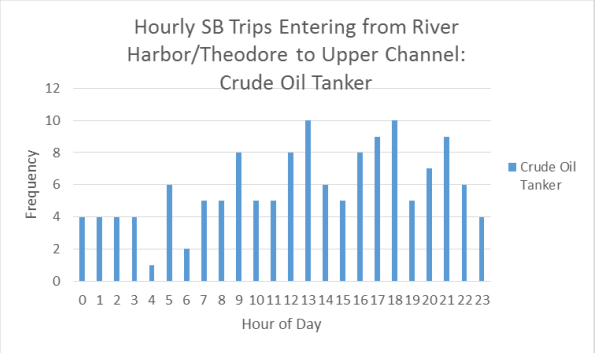
Appendix A. Hourly Distribution of NB Trips from Waiting Area to Lower Channel by Ship Type

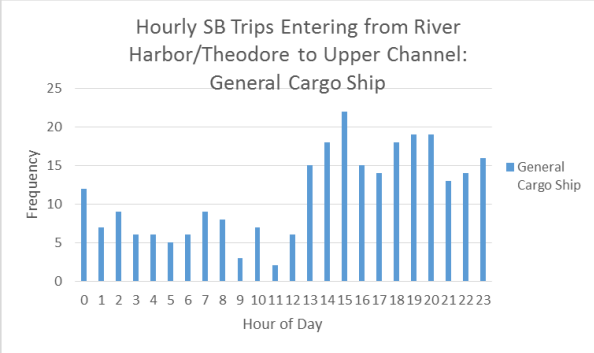
Appendix B. Hourly Distribution of SB Trips from River Harbor/Theodore to Upper Channel by Ship Type

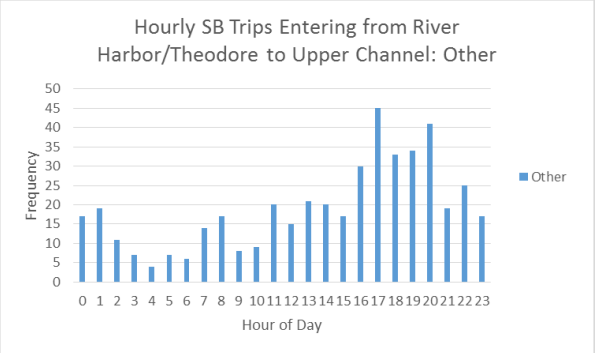




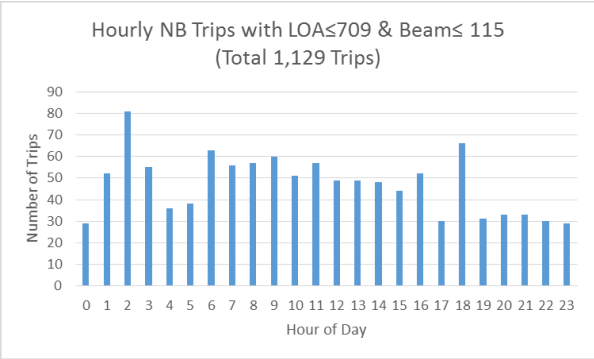


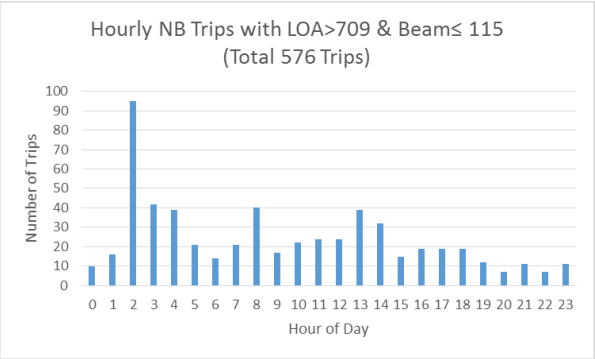


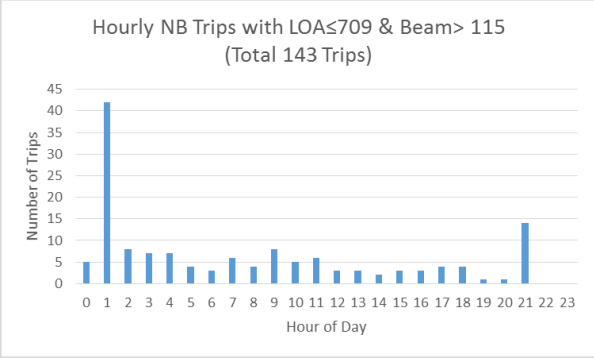


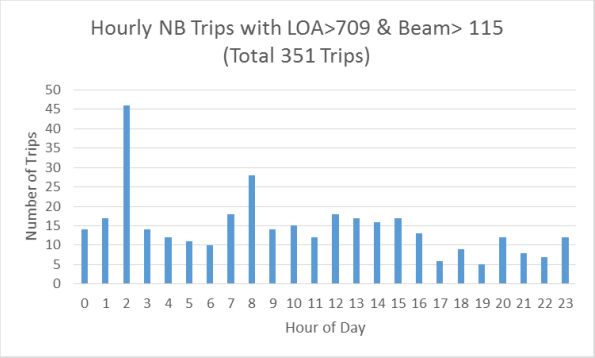


Appendix C. Hourly Distribution of NB Trips from Waiting Area to Lower Channel by LOA and Beam Size









Appendix D. Hourly Distribution of SB Trips from River Harbor/Theodore to Upper Channel by Ship Type