US Army Corps of Engineers®
New York District

Storm Surge Barrier Sub-Appendix

Annex A – Conceptual Design Development, Minimum Gate Width and Maritime Traffic Analyses

DRAFT

New York – New Jersey Harbor and Tributaries Coastal Storm Risk Management Feasibility Study

Annex B2.A

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Table of Contents

List of Tables

List of Figures

1 Synopsis

The following analyses are summarized under this Annex A of the New York – New Jersey Harbor and Tributaries Coastal Storm Risk Management Feasibility Study (HAT Study) Storm Surge Barrier Sub-Appendix:

- Maritime traffic analyses and recommendations for design vessels for storm surge barriers with navigable passages under HATS. From this vessel evaluation, assessments were made for minimum feasible widths of the navigable passages through the storm surge barriers. The dimensions identified in this study are preliminary. There are numerous factors that would affect the final selection of gate widths for the navigable barriers that go well beyond the scope of this brief study.
- Conceptual design development and assessment of the minimum required dimensions for the navigable passages and auxiliary flow gates of the storm surge barriers under HATS. Descriptions and design that outline the basis for key geometric characteristics (e.g., height, width, and depth of openings) informed USACE-NAN Cost Engineering which enabled the USACE-NAN to use a parametric cost model to estimate the approximate cost of construction of the storm surge barriers associated with the study.

Conceptual design development and maritime traffic analyses and recommendations for design vessels are documented for the storm surge barriers listed under Table 1-1. It is assumed that the reader is familiar with the geographic extent of the HAT Study area and the location of the storm surge barriers. For location references, authorized channel dimensions and maps the reader is referred to Storm Surge Barrier Sub-Appendix for this study.

Table 1-1: Storm Surge Barriers under HAT Study discussed herein

Storm Surge Barrier Name under HAT Study	Abbreviation used throughout this document and other HAT Study documents
Outer Harbor (Also referred to as the Sandy Hook to Breezy Point storm surge barrier)	SHBP Storm Surge Barrier
Throgs Neck	TN Storm Surge Barrier
Arthur Kill	AK Storm Surge Barrier
Verrazano Narrows	VN Storm Surge Barrier
Jamaica Bay	JB Storm Surge Barrier
Kill van Kull	KVK Storm Surge Barrier
Gowanus Canal	GC Storm Surge Barrier
Hackensack River	HR Storm Surge Barrier
East Chester Creek	ECC Storm Surge Barrier
Flushing Creek	FC Storm Surge Barrier
Newtown Creek	NC Storm Surge Barrier
Sheepshead Bay	SHB Storm Surge Barrier
Gerritsen Creek	GRC Storm Surge Barrier
Port Washington	PW Storm Surge Barrier

Storm Surge Barrier Name under HAT Study	Abbreviation used throughout this document and other HAT Study documents
Hempstead Harbor (also Referred to as Glen Cove)	HH Storm Surge Barrier
Hammond Creek	HC Storm Surge Barrier
Highlands	HL Storm Surge Barrier
Raritan River	RR Storm Surge Barrier

2 Maritime Traffic Analyses and Recommendations for Design Vessels for Storm Surge Barriers with Navigable Passages

This section documents maritime traffic analyses and recommendations for design vessels for the storm surge barriers with navigable passages under the HAT Study (Table 1-1). An assessment of the minimum required dimensions for the navigable passages of eight proposed storm surge barriers is summarized in the following sub-sections. This list includes two of the reference storm surge barriers (VN and JB) and six (6) other storm surge barriers for which sufficient AIS data or maritime use data was readily available at the time of analysis. The dimensions identified in this study are preliminary. There are numerous factors that would affect the final selection of gate widths for the navigable barriers that go well beyond the scope of the study summarized in this annex. The study was performed under the following list of broad assumptions:

- No future channel widening projects are considered. At the time of this analysis there were no future plans identified that had a scope to widen the federally authorized navigation channels under consideration. Recommended gate widths do not make any allowance for future, wider channels.
- No future channel deepening projects are considered. M&N is not aware of any future plans to deepen the federally authorized navigation channels under consideration. Recommended sill elevations do not make any allowance for future, deeper channels.
- A very limited forecast of future vessel sizes was performed, providing a design vessel of a 400m long container ship for the main shipping channel for this study. For other channels (e.g., Arthur Kill), no evaluation of future vessels was performed. A future phase of study for this project should include much more detailed evaluation of potential future vessels.
- Both one-way and two-way traffic widths are computed for barriers in locations where the existing channel allows for two-way traffic. It is beyond the scope of this study to provide a conclusion regarding whether it would be acceptable to restrict passage to one-way traffic, for certain vessel sizes, in an existing two-way channel (e.g., Ambrose Channel). A large majority of the deep draft harbor traffic passes through Kill van Kull, which currently already is a one-way channel for larger vessels. The feasibility of adding an additional one-way traffic area is only discussed at a very high level in this study and must be confirmed by further study, in coordination with the port and the harbor pilots.
- For navigable gate width calculations, guidance on channel widths is taken from both EM 1110-2-1613 *Hydraulic Design of Deep-Draft Navigation Projects* and PIANC Working Group 121 report *Harbour Approach Channels Design Guidelines*. Neither of these reports provide methodology specifically for sizing navigable storm surge barrier gates. With regard to this topic, EM states that "the width and depth of the navigation gap should be designed to allow adequate clearance by normal size ships with due regard for safety of ship transits inside the barrier." The PIANC guidance includes a factor in the channel width calculation for "hard structures" along the banks but does not provide any discussion for storm surge barriers specifically. A more detailed study is required, in coordination with the harbor pilots, to firmly establish navigable opening widths that would be acceptable for these locations. The estimates provided here are very preliminary and are subject to change upon a more detailed analysis.

- A detailed analysis of current velocity magnitudes and increases in currents through the navigable passages of the storm surge barriers has been omitted at this point and will need to be completed at a later date.
- In addition, an analysis of the vessel-flow interactions through the navigable passes has been omitted at this point. I.e., during transit the vessel partially blocks the navigable passage and the reduction in cross-sectional area can result in increases of current flow velocities thereby. A more detailed study of vessel-flow interactions is recommended after a feasible alternative has been selected.
- It is recognized that there are additional storm surge barriers that are part of the HAT Study Alternatives beyond the ones listed in sections 2.2 through 2.9. Those storm surge barriers are the Hackensack River, East Chester Creek, Flushing Creek, Sheepshead Bay, Gerritsen Creek, Port Washington, Hempstead Harbor, Hammond Creek, Highlands, and Raritan River storm surge barriers and they are not discussed in detail in this report. For this set of storm surge barriers there is insufficient reliable AIS data. This provides the basis for the assumption that deep draft maritime traffic is not expected to traverse those smaller barriers. Navigable passage dimensions for those barriers will instead be based on existing federal channel dimensions or on other known channel restrictions.

2.1 AIS DATA

Both the International Maritime Organization (IMO, SOLAS, Chapter V, Regulation 19, Paragraph 2.4) and the United States Government (33 CFR 164.46) require that most commercial vessels[1] maintain an operational Automatic Identification System (AIS). The shipborne AIS provides regular (every 10 seconds, or more frequent) very high frequency (VHF) radio signals containing basic information regarding the ship's identity, location, speed, etc. This system was originally outlined by the IMO in Resolution A.917(22) in 2002 and was implemented progressively over the following years.

AIS data is broadcast over two specific VHF channels and is not encrypted, making the data easily accessible to any other shipborne or shore-based receiver. AIS data is collected, stored, and shared by a variety of organizations for different purposes. Moffatt & Nichol maintains a large in-house database of AIS data collected from in-house receivers, as well as global data from participation in real-time data-sharing co-ops.

Taken as spatial data, AIS signals are individual points. However, by grouping points from individual vessels, the track of each vessel can be drawn (Figure 2-1, for Verrazano Narrows). Vessel track data provides a straightforward way of generating statistics for how many vessels pass certain locations. While vessel tracks are helpful for statistics, they are difficult to visualize when numerous tracks are present. Traffic intensity maps (Figure 2-2, for Verrazano Narrows) are often more helpful for visualizing what areas see higher traffic than others. As Figure 2-2 shows, traffic maps can be prepared for an entire dataset or for only a portion (e.g., a specific vessel type).

[1] All vessels over 500 gross tonnage, and smaller vessels under certain conditions.

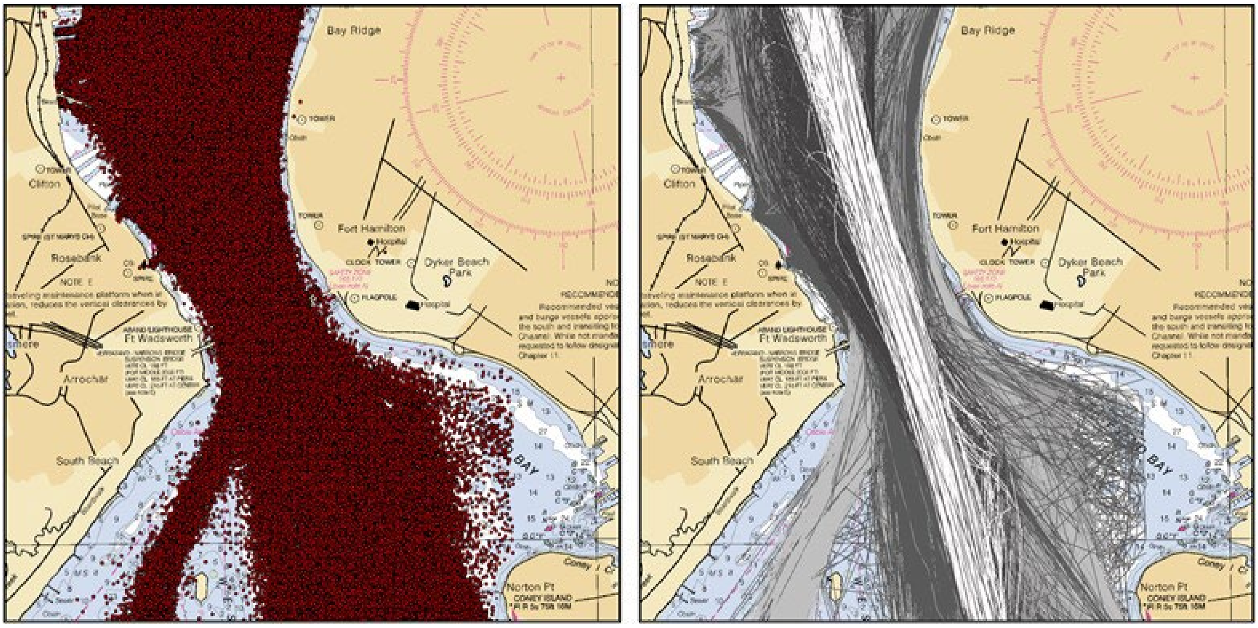


Figure 2-1: AIS Data Signals (left) and Tracks (right)

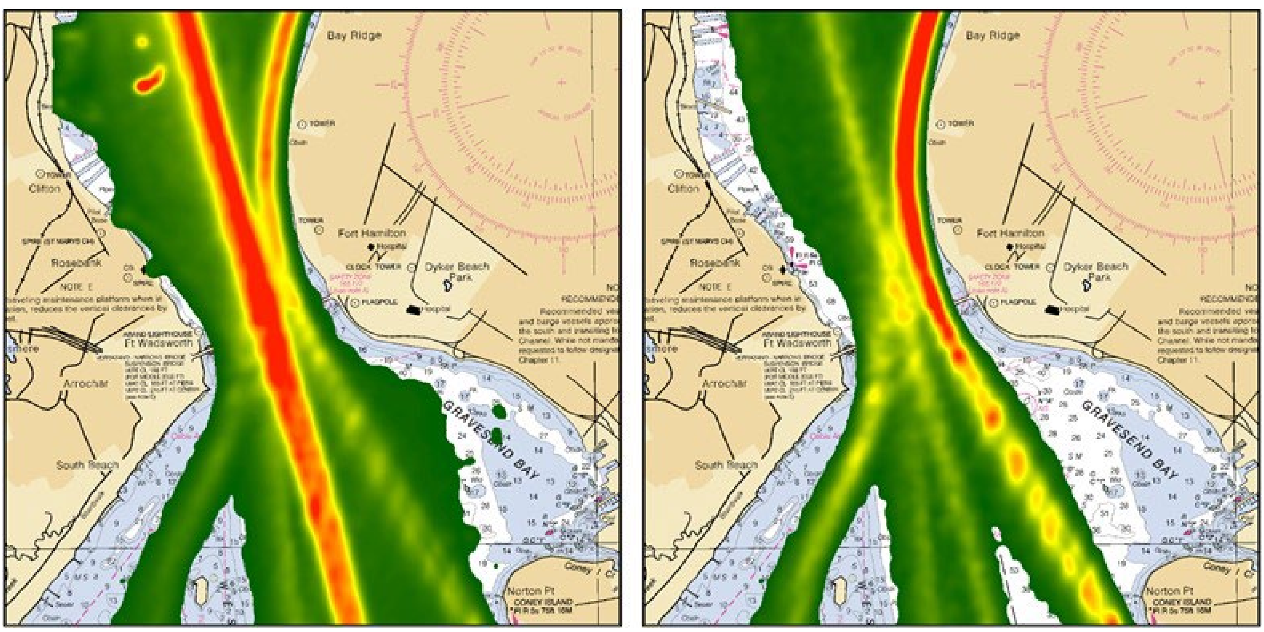


Figure 2-2: Vessel Traffic Intensity Maps – All Traffic (left) – Passenger Vessels (right)

For this study, AIS data was queried for five of the storm surge barrier locations under consideration. AIS data was not used to develop traffic statistics for the other barrier locations, because the vessels transiting those locations are smaller and do not reliably report AIS data. Other sources are more appropriate for those locations. AIS data is presented for the following five barrier locations:

- Verrazano Narrows – Section 2.2.
- Sandy Hook to Breezy Point – Section 2.3.
- Throgs Neck – Section 2.4.

- Arthur Kill – Section 2.5.
- Kill van Kull – Section 2.6.

2.2 Verrazano Narrows

2.2.1 Traffic Summary

Traffic statistics were prepared for Verrazano Narrows based on part-year data from 2017 and 2018, representing a total of 310 days of data. The purpose of this study is not to develop absolute/precise numbers for vessel passes, so the gaps present in the dataset were not of concern for this analysis. Table 2-1, Table 2-2, Figure 2-3, and Figure 2-4, present summaries of the vessel traffic passing through the Verrazano Narrows. Table 2-1 and Figure 2-3 present the data categorized by vessel length. Table 2-2 and Figure 2-4 present the data categorized by vessel beam (width).

Table 2-1: Vessel Length Statistics - Verrazano Narrows

LOA [ft]	Bulker	Container	General Cargo	Other	Passenger	Ro-Ro	Tanker	Tug	Total
0-100				5771	10330		15	2580	18696
100-200				3495	3597		2	3346	10440
200-300				102	7		37	25	171
300-400		87	53	16	13		14	1	184
400-500	4	8	38	9	3		119	42	223
500-600	70	199	34	1	16	52	340		712
600-700	218	244	61	2	14	582	842	3	1966
700-800	53	82	4	1	22	108	220		490
800-900		493	1	1	45	4	185	1	730
900-1000		938	83	7	143		5		1176
1000-1100		739			91				830
1100-1200		344			93				437
1200-1300		85							85
2000-2100				1					1
2200-2300				2					2
2400-2500				2					2
Unspecified				148				1	149
Total	345	3219	274	9558	14374	746	1779	5999	36294

Table 2-2: Vessel Beam Statistics - Verrazano Narrows

Beam [ft]	Bulker	Container	General Cargo	Other	Passenger	Ro-Ro	Tanker	Tug	Total
0-20				3251	57			197	3505
20-40				6010	13869		15	5649	25543
40-60		1	49	98	8		14	75	245
60-80	4	97	54	32	15		182	71	455
80-100	73	434	39	12	41	2	233	2	836
100-120	268	766	53	16	166	725	1054	3	3051
120-140		770	79	1	111	19	116		1096
140-160		1129			34		165	1	1329
160-180		22			73				95
Unspecified				138				1	139
Total	345	3219	274	9558	14374	746	1779	5999	36294

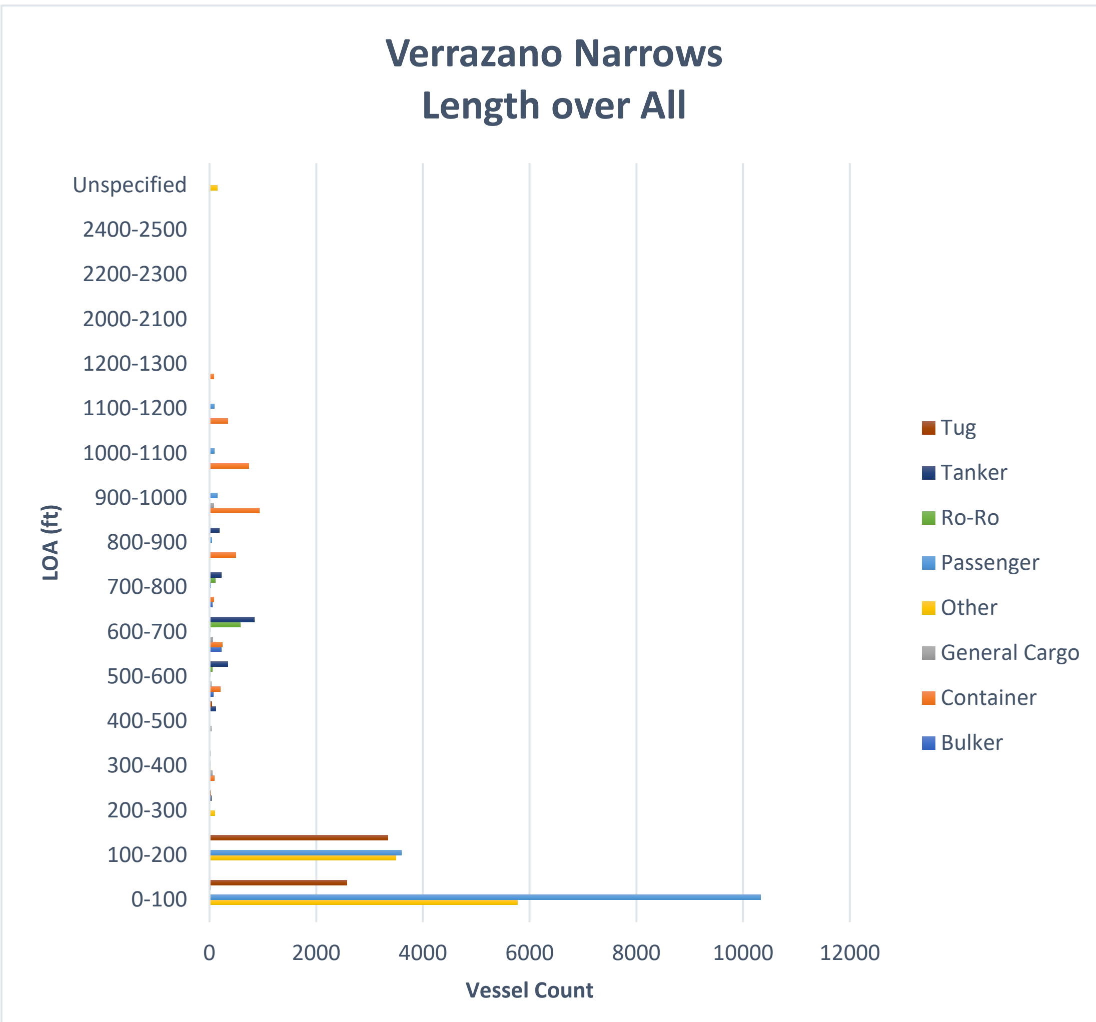


Figure 2-3: Vessel Length Statistics - Verrazano Narrows

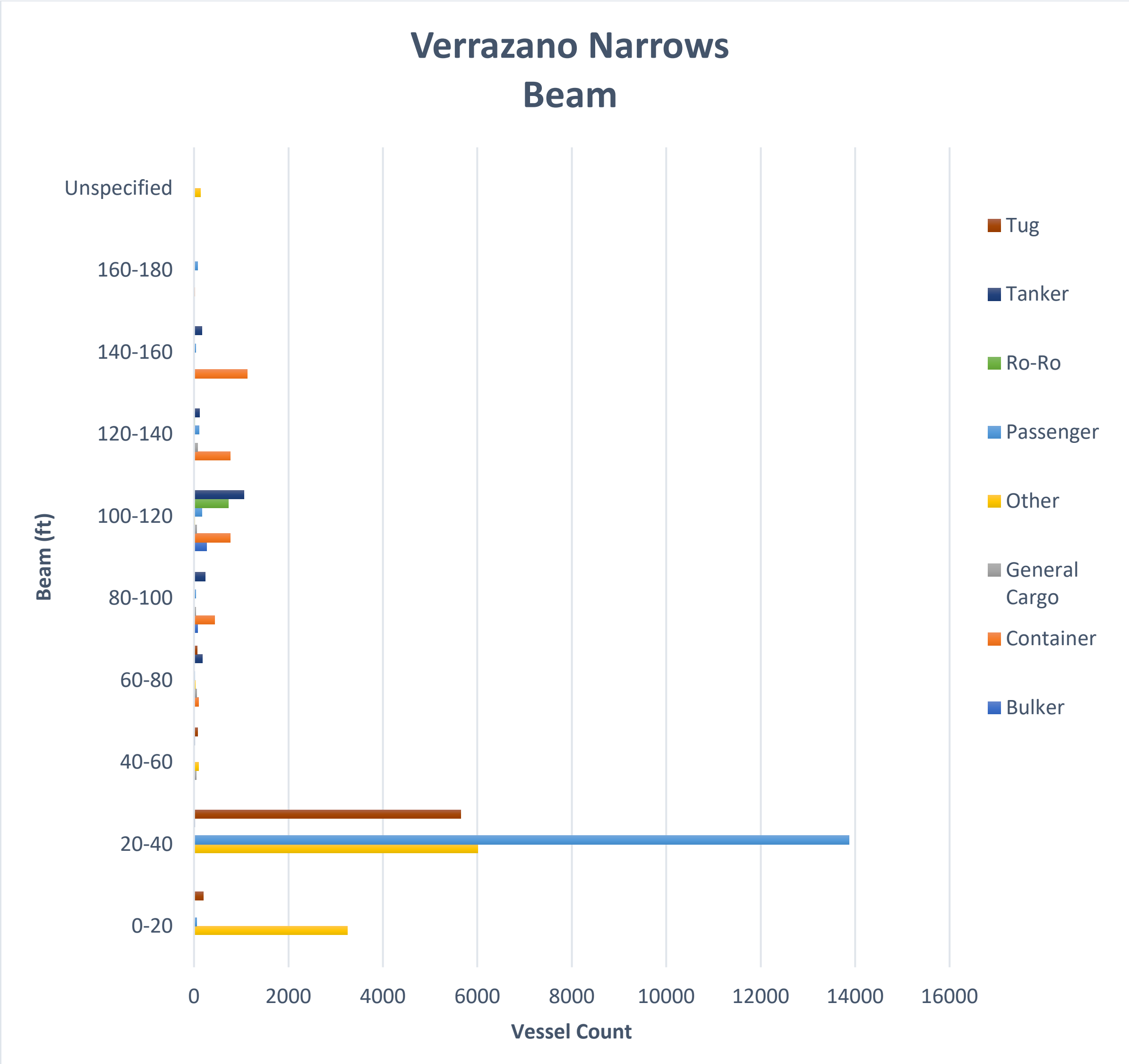


Figure 2-4: Vessel Beam Statistics - Verrazano Narrows

2.2.2 Minimum Practical Channel Width (Main Navigable Passage) – Verrazano Narrows

The vessel data presented above provides a perspective of the current traffic. However, future traffic may involve larger vessels, and either greater or lesser vessel count. For this study a larger vessel was used for sizing the gate opening and based on a cursory review of vessel size trends. It is beyond the scope of this study to address the question of whether or not larger vessels could safely navigate the NY harbor channels, particularly the Kill van Kull. The design vessel for the main gate opening was taken to be the OOCL Hong Kong, an Ultra Large Container Vessel (ULCV), with summary specifications as follows:

- Container Capacity: 21,413 TEU,
- Length over Axis (LOA): 400m (approx. 1310ft),
- Beam: 58.8m (193ft)

Using this design vessel, the USACE Engineering manual EM 1110-2-1613 *Hydraulic Design of Deep-Draft Navigation Projects* was consulted first for insight into appropriate one and two-way channel widths. The channel width beam multipliers, for three channel cross-section categories, provided in the EM are summarized in Table 2-3 and Table 2-4 for one-way and two-way channels, respectively. Unfortunately, none of the three channel cross-section categories presented in the EM apply very well to the Verrazano Narrows channel, which is naturally deep in the areas currently under consideration for the barrier.

Table 2-3: One-Way Ship Traffic Channel Width Design Criteria (EM 1110-2-1613, Table 8-2)

Channel Cross Section	Design Ship Beam Multipliers for Maximum Current, 0.0 to 0.5 knots	Design Ship Beam Multipliers for Maximum Current, 0.5 to 1.5 knots	Design Ship Beam Multipliers for Maximum Current, 1.5 to 3.0 knots
Constant Cross Section, Best Aids to Navigation			
Shallow	3.0	4.0	5.0
Canal	2.5	3.0	3.5
Trench	2.75	3.25	4.0
Variable Cross Section, Average Aids to Navigation			
Shallow	3.5	4.5	5.5
Canal	3.0	3.5	4.0
Trench	3.5	4.0	5.0

Table 2-4: Two-Way Ship Traffic Channel Width Design Criteria (EM 1110-2-1613, Table 8-3)

Channel Cross Section	Design Ship Beam Multipliers for Maximum Current, 0.0 to 0.5 knots	Design Ship Beam Multipliers for Maximum Current, 0.5 to 1.5 knots	Design Ship Beam Multipliers for Maximum Current, 1.5 to 3.0 knots
Constant Cross Section, Best Aids to Navigation			
Shallow	5.0	6.0	8.0
Canal	4.0	4.5	5.5
Trench	4.5	5.5	6.5

As far as geometry is concerned, the channel cross section, upstream and downstream of the navigable passage, would be most similar to the “Shallow” type section (EM 1110-2-1613, page 8-2), which would lead to a channel width of 5.0 to 5.5 times the vessel beam, inclusive of the assumption that one would experience high currents through the navigable passage (depending on aids to navigation, etc., however for a world-class port like the port of New York and New Jersey, *best aids* to navigation may be assumed). However, the reason "Shallow" type channels are specified as wider is that they are often subject to cross currents. Cross currents are expected to be minor to merit consideration in the Verrazano Narrows. Thus, it seems reasonable to state that the channel width requirements would be less than required for the "Shallow" designation. The geometry of Verrazano Narrows does not fit the Canal or Trench designations well. It does, however, seem reasonable to use the width multiplier specified for the Trench category as a lower bound because the naturally deep waters in the Verrazano narrows would be less restricting (e.g., no bank effects) than a Trench channel.

Given the discussion above, a first estimate of a one-way channel width for Verrazano Narrows is expected to be between 4.0 and 5.0 times the design vessel beam (772 to 965 ft). This width range assumes "best" aids to navigation but allows for relatively high currents (1.5 to 3.0 knots), which can reasonably be expected in Verrazano Narrows. By similar logic, we would expect a first estimate for a two-way channel width to be between 6.5 and 8.0 times the design vessel beam (1,254 ft to 1,543 ft, assuming passing of two 21,000 TEU vessels, which is conservative). Further study would be required to identify the appropriate design vessels for the design of a two-way passing width if the navigable passage is to be designed to accommodate two-way traffic.

These widths do not explicitly account for the effects of the barrier itself. Even in the absences of a hard barrier, setting the width of navigable waterways is a complex question. Further study is necessary to determine the actual required barrier opening width, with consideration for numerous factors, including, but not limited to:

- Design ship beam, length, and draft.
- Local piloted ship control.
- Channel cross section and alignment.
- River and tidal currents.
- Navigation traffic pattern (one- or two-way).
- Vessel traffic intensity and congestion.
- Wind and wave effects.
- Visibility.
- Quality and spacing of navigation aids.
- Composition of channel bed and banks.
- Variability of channel and currents.
- Speed of design ship.

Because the USACE manual does not provide any discussion of how hard structures on each bank would affect the required channel width, a separate calculation was performed following the approach outlined by the World Association for Waterborne Transport Infrastructure (PIANC) in the Working Group 121 report Harbour Approach Channels Design Guidelines. This calculation is summarized in Table 2-5 for the Verrazano Narrows main navigation gate. Based on this method, a minimum channel width for one-way traffic in Verrazano Narrows would be 968 ft. According to PIANC, the two-way channel width can be estimated by doubling all of the factors in Table 2-5 except the Bank Allowance factors. This results in a two-way width of 7.4 times the vessel beam (1,428 ft).

Based on both USACE and PIANC channel width analyses, it seems appropriate to recommend 1,000 ft as a preliminary gate width for one-way and 1,400 ft as a preliminary gate width for two-way traffic. It is highly likely that two-way traffic is required; hence, a gate width of 1,400ft is appropriate for use as preliminary estimate in the overall storm surge barrier feasibility study.

Table 2-5: PIANC Channel Width Calculation for Verrazano Narrows Main Channel (Navigable Passage)

Parameter	Specification	Factor [x Beam] One-way traffic	Factor [x Beam] Two-way traffic
Basic Maneuvering Lane	Good	1.3	2.6
Location	Inner Channel (Protected Water)	0	0
Vessel Speed	Fast (>= 12 kts)	0.1	0.2
Prevailing Crosswind	Moderate (<33 kts)	0.3	0.6
Additional Factor for High Wind Area	(Based on vessel type)	0	0
Prevailing Cross-current	Negligible (<0.2 kts)	0	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.1	0.2
Wave Effects	Mild (Hs<=1m)	0	0
AtoN	Excellent	0	0
Bottom Surface	Rough and Hard	0.2	0.4
Depth of Waterway, h	h < 1.25T	0.4	0.8
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	1.3	1.3
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	1.3	1.3
Total Channel Width [x Beam]		5.0	7.4
Total Channel Width [ft]		968	1428

2.2.3 Minimum Practical Channel Width (Additional Passage for Smaller Vessels)

In addition to the main navigation channel, the AIS data (Section 2.2.1) suggests that there is a high volume of smaller traffic. It would be advisable to include at least one smaller, navigable gate in the barrier to pass smaller vessels, keeping the smaller vessels out of the main navigation channel. For this purpose, a ferry was identified as the design vessel. The particulars for this design vessel are as follows:

- Design Vessel Name: Seastreak,
- Length: 42.9m (LOA),
- Beam: 10.45m.

Using this design vessel, a design channel width of 178ft was computed using the PIANC method (Table 2-6) for a one-way channel. Given the space available in the main navigable passage, it was deemed appropriate to size the additional passage for one-way traffic only. Further study would be needed to confirm this assumption. Based on this estimate, it seems reasonable to recommend a 200 ft wide opening for the supplementary / smaller vessel navigable passage for this feasibility study. From the AIS data and traffic patterns it is recommended to place the secondary navigable passage on the east side of the main passage.

Table 2-6: PIANC Channel Width Calculation for Verrazano Narrows (Additional Navigable Passage)

Parameter	Specification	Factor [x Beam] One-way traffic
Basic Maneuvering Lane	Good	1.3
Location	Inner Channel (Protected Water)	0
Vessel Speed	Fast (>= 12 kts)	0.1
Prevailing Crosswind	Moderate (<33 kts)	0.3
Additional Factor for High Wind Area	(Based on vessel type)	0.2
Prevailing Cross-current	Negligible (<0.2 kts)	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.1
Wave Effects	Mild (Hs<=1m)	0
Aids to Navigation	Excellent	0
Bottom Surface	Rough and Hard	0.2
Depth of Waterway, h	h < 1.25T	0.4
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	1.3
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	1.3
Total Channel Width [x Beam]		5.2
Total Channel Width [ft]		178

2.3 Sandy Hook to Breezy Point

Traffic and gate widths are presented for three different locations along the Sandy Hook to Breezy Point Barrier, corresponding to the three federally maintained navigation channels that cross the barrier alignment:

- Sandy Hook Channel – Section 2.3.1.
- Ambrose Channel – Section 2.3.2.
- Rockaway Inlet – Section 2.3.3.

In each case, the same approach is applied as for Verrazano Narrows (Section 2.2). Traffic statistics were prepared based on part-year data from 2017 and 2018, representing a total of 329 days of data.

2.3.1 Sandy Hook Channel

2.3.1.1 Traffic Summary

Table 2-7, Table 2-8, Figure 2-5 and Figure 2-6 present summaries of the vessel traffic passing through Sandy Hook. Table 2-7 and Figure 2-5 present the data categorized by vessel length and Table 2-8 and Figure 2-6 present the data categorized by vessel length.

Table 2-7: Vessel Length Statistics - Sandy Hook Channel

LOA [ft]	Other	Passenger	Tanker	Tug	Total
0-100	174	33	1	329	537
100-200	55	2	1	273	331
200-300	39	1			40
300-400	1				1
400-500			16	4	20
500-600			92		92
600-700	8		305	3	316
700-800	8		65		73
800-900			78		78
900-1000			1		1
Unspecified	102			1	103
Total	387	36	559	610	1592

Table 2-8: Vessel Beam Statistics - Sandy Hook Channel

Beam [ft]	Other	Passenger	Tanker	Tug	Total
0-20	145			1	146
20-40	86	4	1	589	680
40-60	36	31	1	11	79
60-80	1		29	5	35
80-100	1	1	53		55
100-120	16		366	3	385
120-140			37		37
140-160			72		72
Unspecified	102			1	103
Total	387	36	559	610	1592

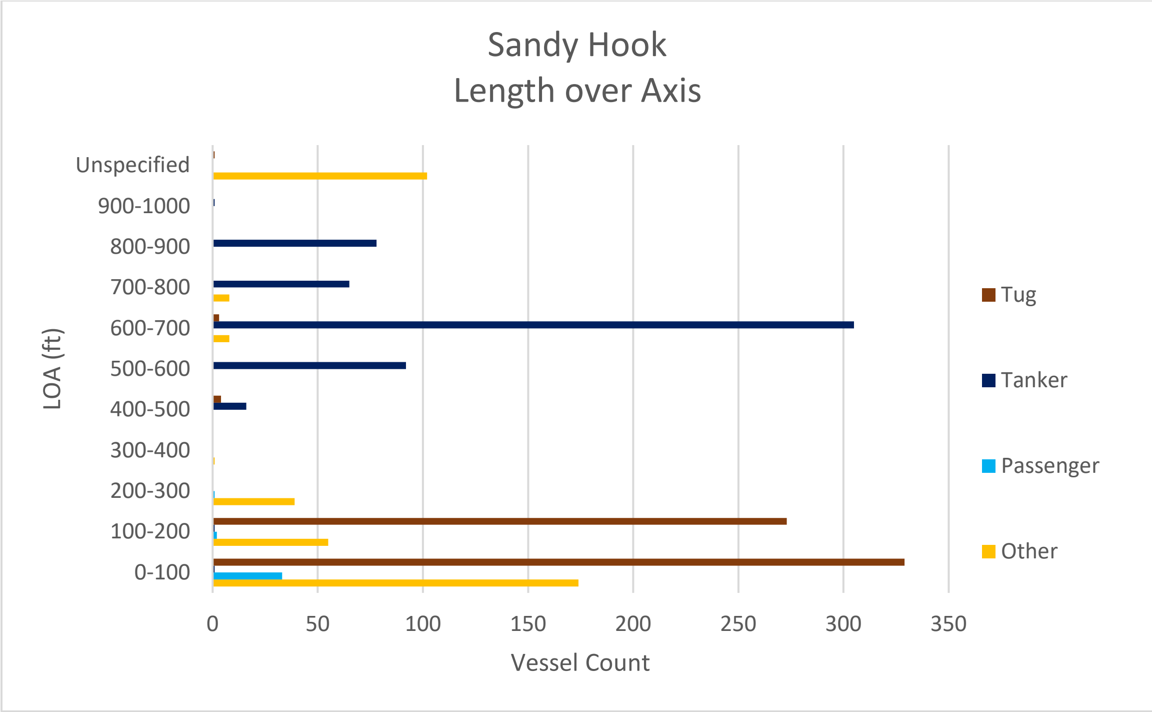


Figure 2-5: Vessel Length Statistics - Sandy Hook Channel

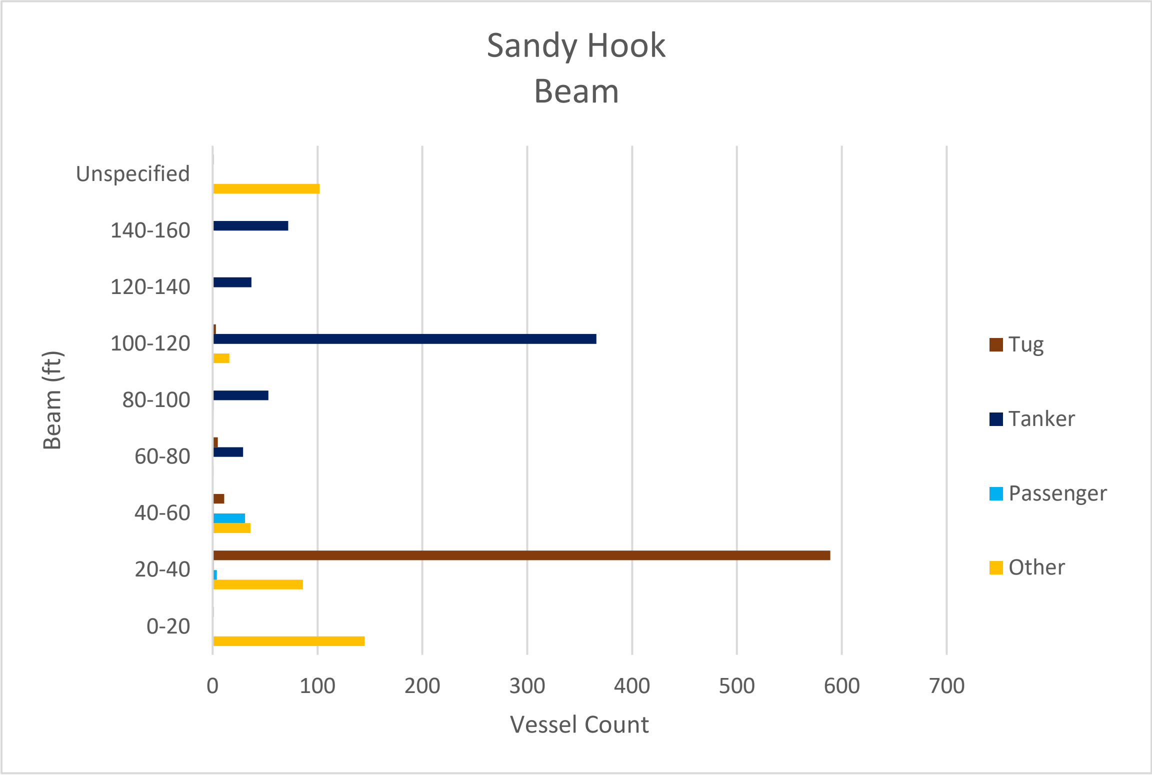


Figure 2-6: Vessel Beam Statistics - Sandy Hook Channel

2.3.1.2 Minimum Practical Channel Width – Sandy Hook

Based on the vessel data presented above, the largest vessel expected to transit the Sandy Hook Channel is a tanker. The design vessel for the Sandy Hook Channel gate is taken to be the following:

- Design Vessel Name: Cape Bonny,
- Length: 274.5m (LOA),
- Beam of 48m.

Using this design vessel, the channel width estimates were obtained as 630-866 feet based on the USACE manual and 835ft based on PIANC guidance for one-way traffic. These estimates confirm that the current authorized channel width of 800 ft is appropriate to serve as the width of the corresponding storm surge barrier gate.

Table 2-9: PIANC Channel Width Calculation for Sandy Hook Channel (Navigable Passage)

Parameter	Specification	Factor [x Beam] One-way Traffic
Basic Maneuvering Lane	Good	1.3
Location	Outer Channel (Open Water)	0
Vessel Speed	Fast (>= 12 kts)	0.1
Prevailing Crosswind	Moderate (<33 kts)	0.3
Additional Factor for High Wind Area	(Based on vessel type)	0
Prevailing Cross-current	Negligible (<0.2 kts)	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.1
Wave Effects	Moderate (Hs>1m)	0.5
AtoN	Excellent	0
Bottom Surface	Rough and Hard	0.2
Depth of Waterway, h	h < 1.25T	0.2
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	1.3
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	1.3
Total Channel Width [x Beam]		5.3
Total Channel Width [ft]		835

2.3.2 Main Ambrose Channel

2.3.2.1 Traffic Summary

Similar to Verrazano Narrows, the Ambrose Channel is on the primary shipping route for deep draft vessels entering the harbor. As expected, the deep draft traffic statistics for larger vessels appear very similar to the statistics for Verrazano Narrows (Section 2.2.1). Table 2-10, Table 2-11, Figure 2-7, and Figure 2-8 summarize the vessel traffic passing through Ambrose Channel. Table 2-10 and Figure 2-7 present data categorized by vessel length. Table 2-11 and Figure 2-8 present the data categorized by vessel beam.

Table 2-10: Vessel Length Statistics - Ambrose Channel

LOA [ft]	Bulker	Container	General Cargo	Other	Passenger	Ro-Ro	Tanker	Tug	Total
0-100				162	11			284	457
100-200				237	2		2	1338	1579
200-300				48	3		1	17	69
300-400		90	54	8	9		4	2	167
400-500	4	8	41	8	3		116	12	192
500-600	76	190	33	1	17	52	310		679
600-700	222	249	56	2	14	610	800	1	1954
700-800	53	88	4		22	117	235		519
800-900		491	1		45	4	200		741
900-1000		956	88	6	150		4		1204
1000-1100		769			98				867
1100-1200		360			98				458
1200-1300		96							96
2200-2300				1					1
Unspecified				13					13
Total	355	3297	277	486	472	783	1672	1654	8996

Table 2-11: Vessel Beam Statistics - Ambrose Channel

Beam [ft]	Bulker	Container	General Cargo	Other	Passenger	Ro-Ro	Tanker	Tug	Total
0-20				146	1			5	152
20-40				258	10			1585	1853
40-60		1	48	45	9		4	44	151
60-80	4	97	59	7	8		141	18	334
80-100	79	434	37	10	41	2	223		826
100-120	272	753	48	6	173	759	1004	1	3016
120-140		802	85	1	111	22	126		1147
140-160		1183			40		174	1	1398
160-180		27			79				106

Beam [ft]	Bulker	Container	General Cargo	Other	Passenger	Ro-Ro	Tanker	Tug	Total
Unspecified				13					13
Total	355	3297	277	486	472	783	1672	1654	8996

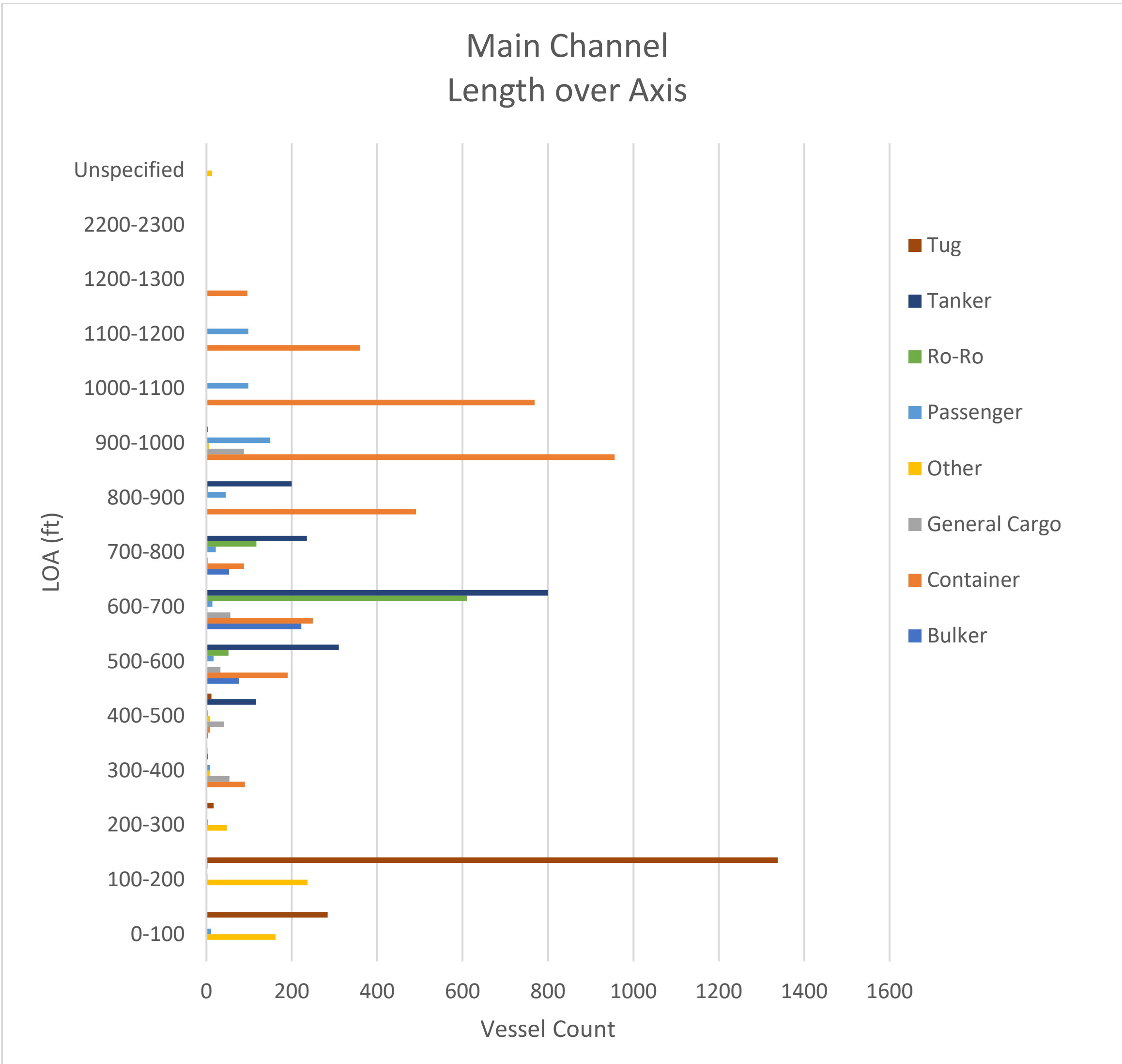


Figure 2-7: Vessel Length Statistics - Ambrose Channel (Tug statistics omitted for clarity)

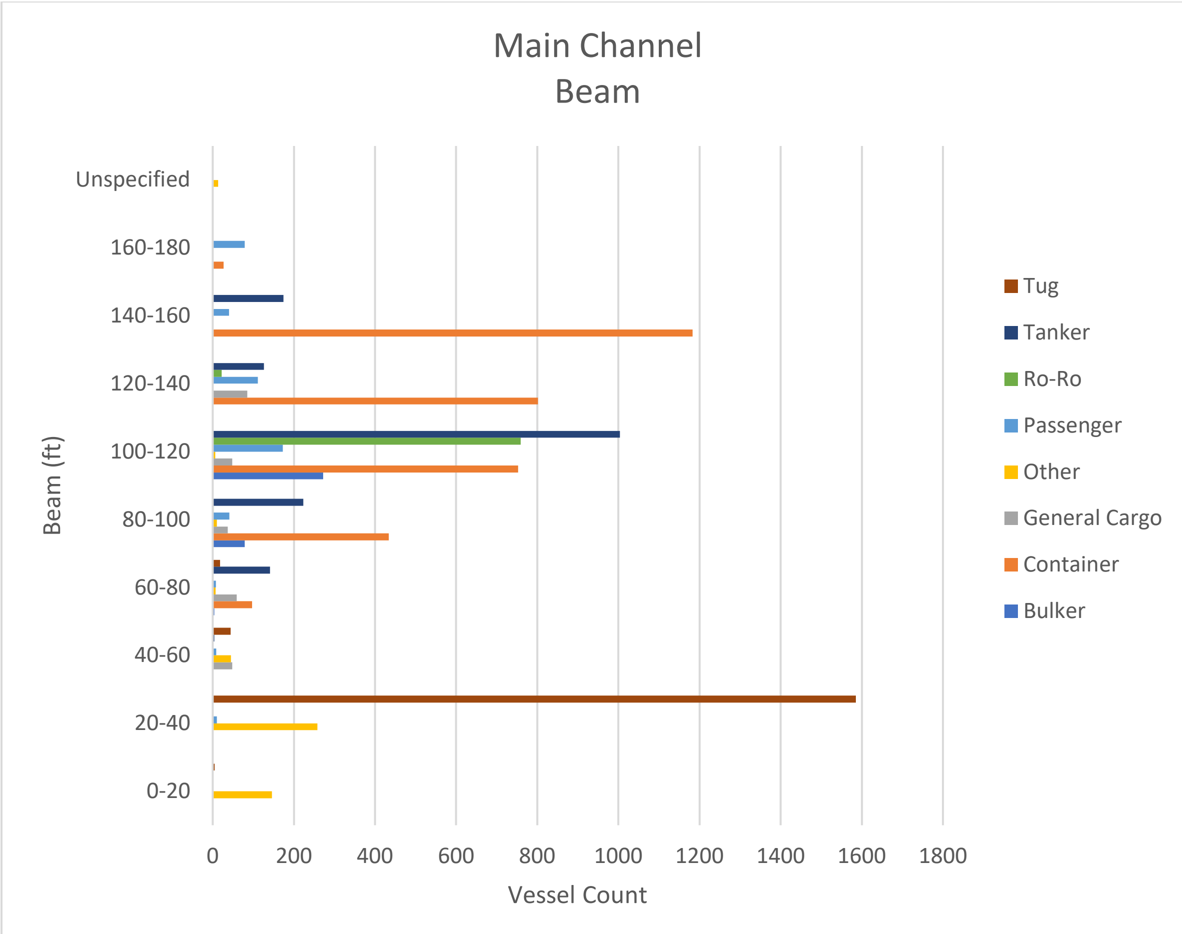


Figure 2-8: Vessel Beam Statistics - Ambrose Channel (Tug statistics omitted for clarity)

2.3.2.2 Minimum Practical Channel Width

As for Verrazano Narrows, the design vessel for the Ambrose Channel was identified as a large container ship, representing larger vessels that could potentially call in New York during the lifetime of the storm surge barrier project. The design vessel is summarized as follows:

- Design Vessel Name: OOCL Hong Kong,
- Container Capacity: 21,413 TEU,
- Length: 400m (LOA),
- Beam: 58.8m.

Using this design vessel, and in light of the discussion provided for the main passage for Verrazano Narrows, a channel width analysis was performed based on guidance from PIANC. The Channel width is very similar for both Ambrose Channel and Verrazano Narrows. Based on both USACE and PIANC channel width analyses, it seems appropriate to recommend 1,000 ft as a preliminary navigable passage width for one-way and 1,500 ft as a preliminary navigable passage width for two-way traffic. While it is not possible at this point to determine definitively whether two-way traffic is required (or what size vessels would be used for the design of a two-way gate width), a gate width of 1,500ft seems conservatively appropriate for use as preliminary estimate in the overall storm surge barrier feasibility study.

Table 2-12: PIANC Channel Width Calculation for Ambrose Channel (Main Navigable Passage)

Parameter	Specification	Factor [x Beam] One-way traffic	Factor [x Beam] Two-way traffic
Basic Maneuvering Lane	Good	1.3	2.6
Location	Outer Channel (Open Water)	0	0
Vessel Speed	Fast (>= 12 kts)	0.1	0.2
Prevailing Crosswind	Moderate (<33 kts)	0.3	0.6
Additional Factor for High Wind Area	(Based on vessel type)	0	0
Prevailing Cross-current	Negligible (<0.2 kts)	0	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.1	0.2
Wave Effects	Moderate (Hs>1m)	0.5	1
AtoN	Excellent	0	0
Bottom Surface	Rough and Hard	0.2	0.4
Depth of Waterway, h	h < 1.25T	0.2	0.4
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	1.3	1.3
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	1.3	1.3
Total Channel Width [x Beam]		5.3	8.0
Total Channel Width [ft]		1026	1543

2.3.3 Rockaway Inlet

2.3.3.1 Traffic Summary

Table 2-13, Table 2-14, Figure 2-9, and Figure 2-10 summarize the vessel traffic passing in and out of the harbor north of the Ambrose Channel. This includes traffic in and near Rockaway Inlet channel. Table 2-13 and Figure 2-9 present the data categorized by vessel length. Table 2-14 and Figure 2-10 present the data categorized by vessel beam.

Table 2-13: Vessel Length Statistics – Rockaway Inlet

LOA [m]	Container	Other	Passenger	Tanker	Tug	Total
0-50		690	3		67	760
50-100		3		1		4
100-150		1	1			2
Unspecified		7				7
Total		700	4	1	67	772

Table 2-14: Vessel Beam Statistics – Rockaway Inlet

Beam [m]	Container	Other	Passenger	Tanker	Tug	Total
0-10		663	2		66	731
10-20		30	2		1	33
20-30				1		1
Unspecified		7				7
Total		700	4	1	67	772

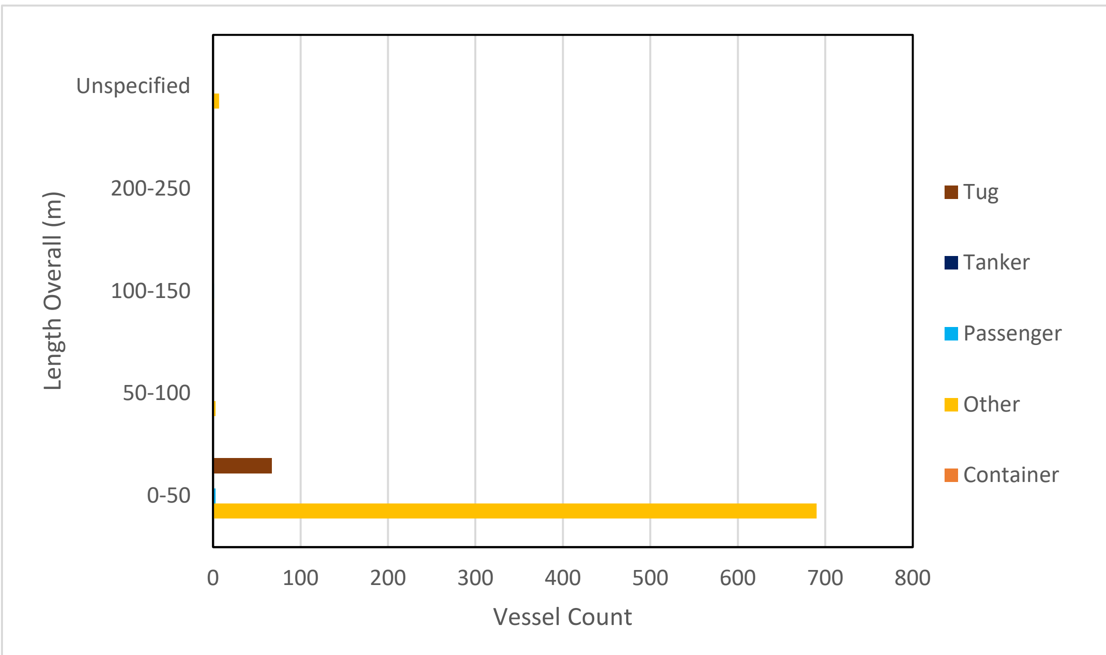


Figure 2-9: Vessel Length Statistics – Rockaway Inlet

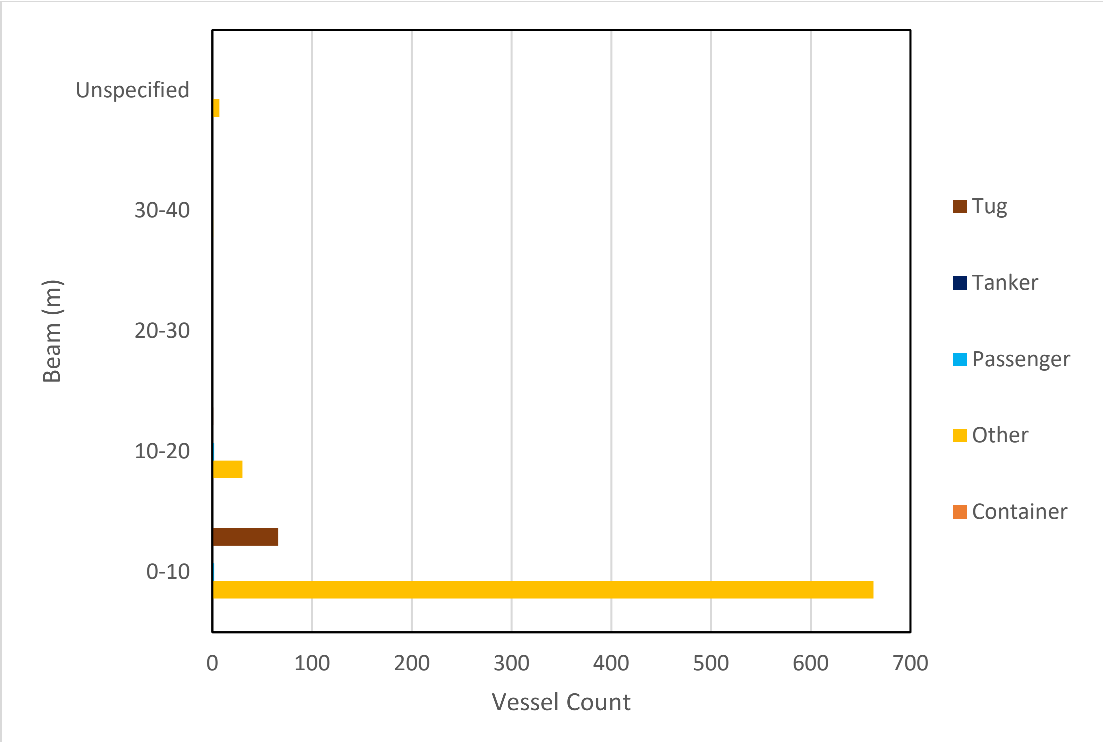


Figure 2-10: Vessel Beam Statistics – Rockaway Inlet

2.3.3.2 Minimum Practical Channel Width

Based on the traffic data presented above, a representative design vessel was identified for the Rockaway Channel storm surge barrier gate. The design vessel is as follows:

- Design Vessel Name: American Princess,
- Length: 45m (LOA),
- Beam: 11m.

Using this vessel, the PIANC method indicates a channel width of 198 ft (Table 2-15). Based on this, it seems reasonable to suggest a minimum practical navigable passage width of 200 ft for this location.

Table 2-15: PIANC Channel Width Calculation for Rockaway Inlet Channel (Navigable Passage)

Parameter	Specification	Factor [x Beam] One-way Traffic
Basic Maneuvering Lane	Good	1.3
Location	Outer Channel (Open Water)	0
Vessel Speed	Fast (>= 12 kts)	0.1
Prevailing Crosswind	Moderate (<33 kts)	0.3

Parameter	Specification	Factor [x Beam] One-way Traffic
Additional Factor for High Wind Area	(Based on vessel type)	0.2
Prevailing Cross-current	Negligible (<0.2 kts)	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.1
Wave Effects	Moderate (Hs>1m)	0.5
AtoN	Excellent	0
Bottom Surface	Rough and Hard	0.2
Depth of Waterway, h	h < 1.25T	0.2
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	1.3
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	1.3
Total Channel Width [x Beam]		5.5
Total Channel Width [ft]		198

2.4 Throgs Neck

2.4.1 Traffic Summary

Traffic statistics were prepared for Throgs Neck based on part-year data from 2017 and 2018, representing a total of 329 days of data. Table 2-16, Table 2-17, Figure 2-11, and Figure 2-12 summarize the vessel traffic passing Throgs Neck. Table 2-16 and Figure 2-11 present the data categorized by vessel length. Table 2-17 and Figure 2-12 present the data categorized by vessel beam.

Table 2-16: Vessel Length Statistics - Throgs Neck

LOA [ft]	Bulker	General Cargo	Other	Passenger	Tanker	Tug	Total
0-100			259	18		1449	1726
100-200			66	13	1	2380	2460
200-300			10	62		8	80
300-400			1	5		53	59
400-500						24	24
500-600	1	1			1		3
Unspecified			29	29		2	60
Total	1	1	365	127	2	3916	4412

Table 2-17: Vessel Beam Statistics - Throgs Neck

Beam [ft]	Bulker	General Cargo	Other	Passenger	Tanker	Tug	Total
0-20			99	1		145	245
20-40			173	28		3688	3889
40-60			63	6	1	3	73
60-80		1	1	3		78	83
80-100	1			60			61
100-120					1		1
Unspecified			29	29		2	60
Total	1	1	365	127	2	3916	4412

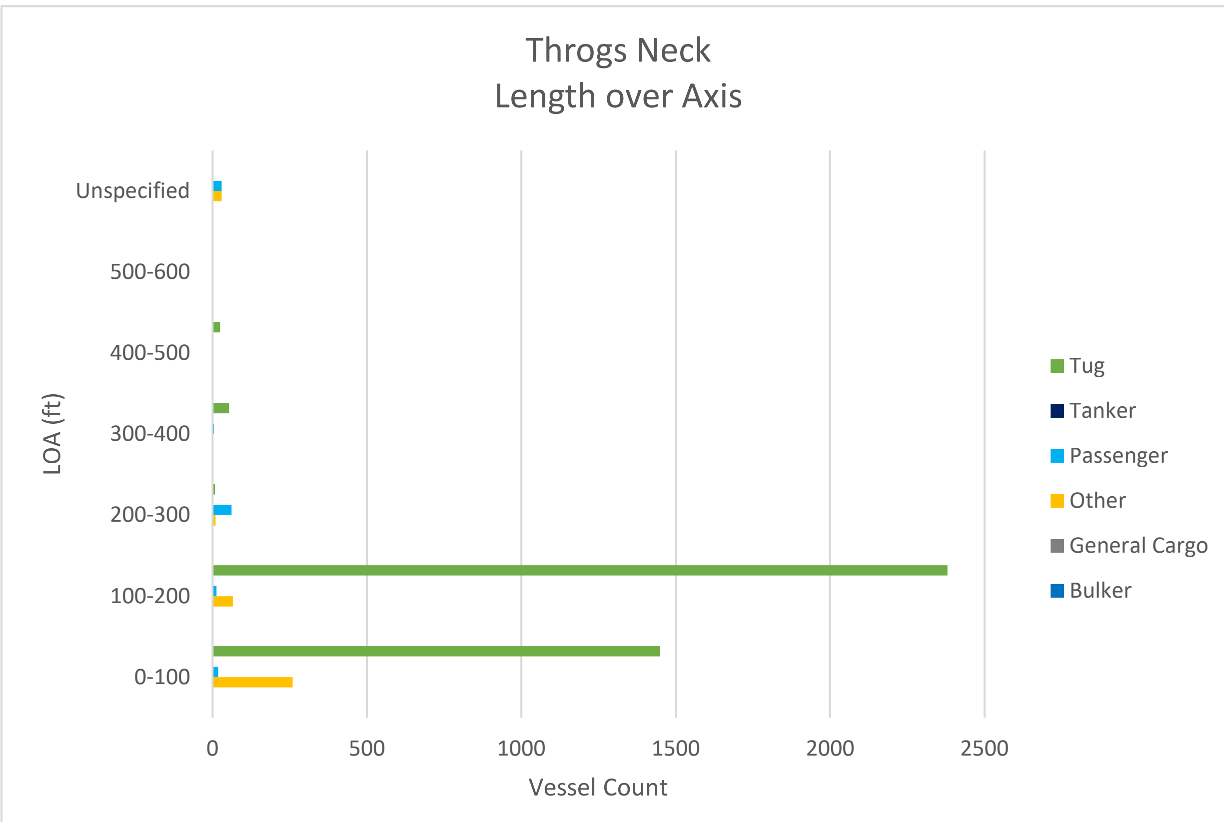


Figure 2-11: Vessel Length Statistics - Throgs Neck (Tug statistics omitted for clarity)

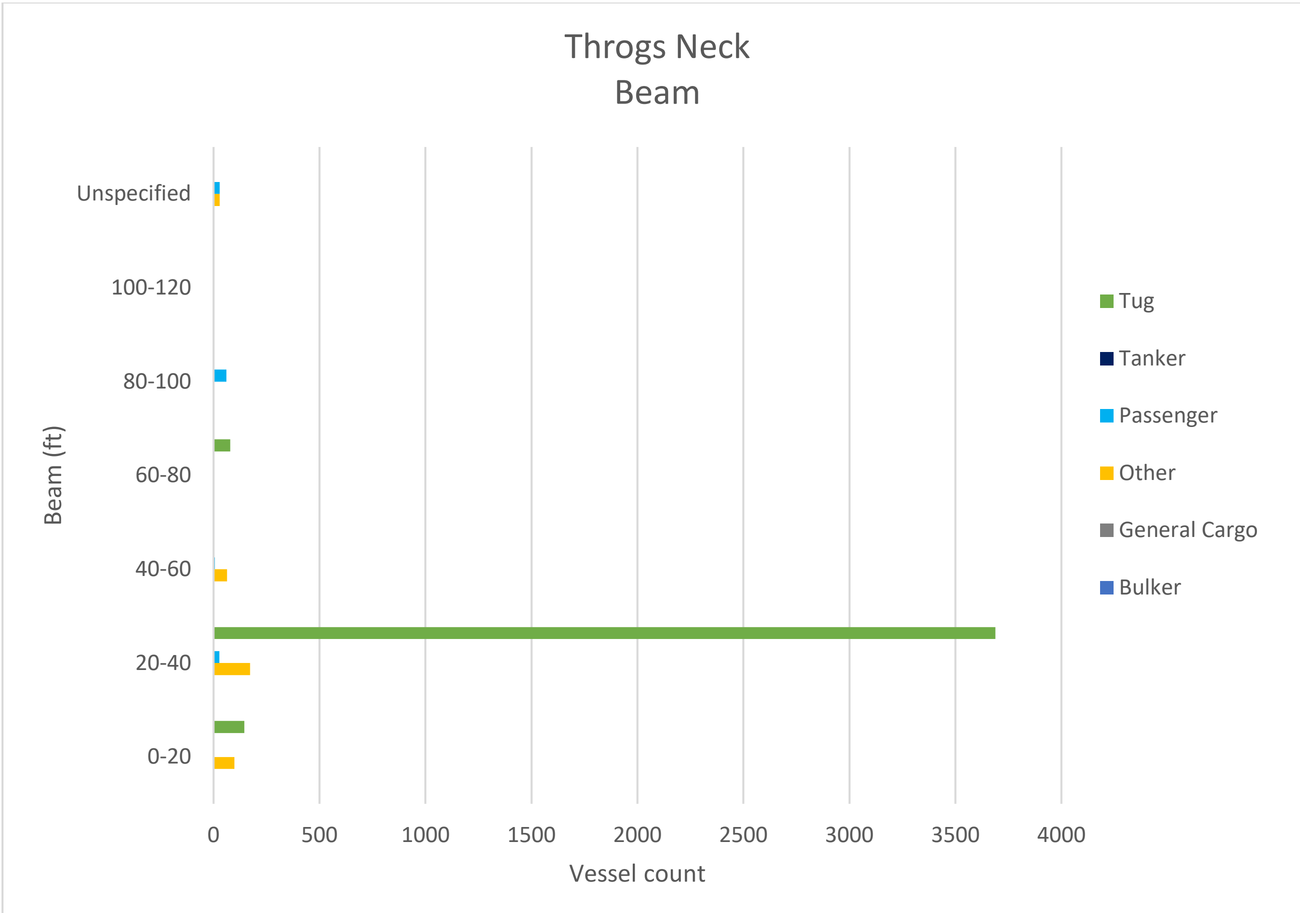


Figure 2-12: Vessel Beam Statistics - Throgs Neck (Tug statistics omitted for clarity)

2.4.2 Minimum Practical Channel Width

Based on the traffic data, the majority of the traffic that is reporting AIS data is tugboats. AIS data does not record information about what size barges each tug is towing, which makes it difficult to use AIS data to evaluate barge traffic. There was one larger tanker (beam of 30.6m) that passed during the period of AIS data collection. This tanker was used for the initial channel width estimate, but with the understanding that this particular vessel size infrequently navigates this waterway, and most traffic would be classified by narrower beams. The design vessel is as follows:

- Design Vessel Name: Asphalt Splendor
- Length: 179.9m (LOA), (590ft)
- Beam 30.6m. (100ft)

Based on this vessel and its frequency the PIANC method for one-way traffic is used and indicates a design channel width of 478 ft. It is assumed that this represents a conservative estimate of the required navigable width, since vessels of this size do not pass frequently. If the gate width was slightly more restricting, this vessel could still pass, but perhaps would require a slower speed or greater tug assistance. In addition, majority of the vessels have a beam width of less than 16m (52ft). If passing of vessels of such dimensions is assumed to be maintained within the navigable passage of the storm surge barrier, then a width of 447ft is suggested based on PIANC calculations.

Based on the traffic data and typical PIANC channel widths, it seems reasonable to recommend a navigable passage width of 450 ft for the Throgs Neck storm surge barrier.

Table 2-18: PIANC Channel Width Calculation for Throgs Neck (Navigable Passage)

Parameter	Specification	Factor [x Beam] One-way Traffic	Factor [x Beam] Two-way Traffic
Basic Maneuvering Lane	Good	1.3	2.6
Location	Inner Channel (Protected Water)	0	0
Vessel Speed	Slow (>=5 kts)	0	0
Prevailing Crosswind	Moderate (<33 kts)	0.6	1.2
Additional Factor for High Wind Area	(Based on vessel type)	0	0
Prevailing Cross-current	Negligible (<0.2 kts)	0	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.4	0.8
Wave Effects	Mild (Hs<=1m)	0	0
AtoN	Good	0.2	0.4
Bottom Surface	Rough and Hard	0.2	0.4
Depth of Waterway, h	h < 1.25T	0.4	0.8
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	0.5	0.5
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	0.5	0.5

Parameter	Specification	Factor [x Beam] One-way Traffic	Factor [x Beam] Two-way Traffic
Additional Width Due to Response Time in Turning	Turning	0.4	0.8
Additional Width Due to Drift Angle	(Based on vessel type & characteristics)	0.3	0.6
Total Channel Width [x Beam]		4.8	8.6
Total Channel Width [ft] (Design Beam 100ft)		480	
Total Channel Width [ft] (Design Beam 52ft)			447

2.5 Arthur Kill

2.5.1 Traffic Summary

Traffic statistics were prepared for Arthur Kill based on part-year data from 2017 and 2018, representing a total of 329 days of data. Table 2-19, Table 2-20, Figure 2-13, and Figure 2-14 summarize the vessel traffic through Arthur Kill. Table 2-19 and Figure 2-13 present the data categorized by vessel length. Table 2-20 and Figure 2-14 present the data categorized by vessel beam.

Table 2-19: Vessel Length Statistics - Arthur Kill

LOA [ft]	Other	Passenger	Tanker	Tug	Total
0-100	1	1		18	20
100-200		1		63	64
200-300	2				2
400-500			5		5
500-600			34		34
600-700			122		122
700-800			26		26
800-900			10		10
Total	3	2	197	81	283

Table 2-20: Vessel Beam Statistics - Arthur Kill

Beam [ft]	Other	Passenger	Tanker	Tug	Total
0-20	1			1	2
20-40		2		79	81
40-60	2			1	3
60-80			6		6
80-100			19		19
100-120			158		158
120-140			5		5

Beam [ft]	Other	Passenger	Tanker	Tug	Total
140-160			9		9
Total	3	2	197	81	283

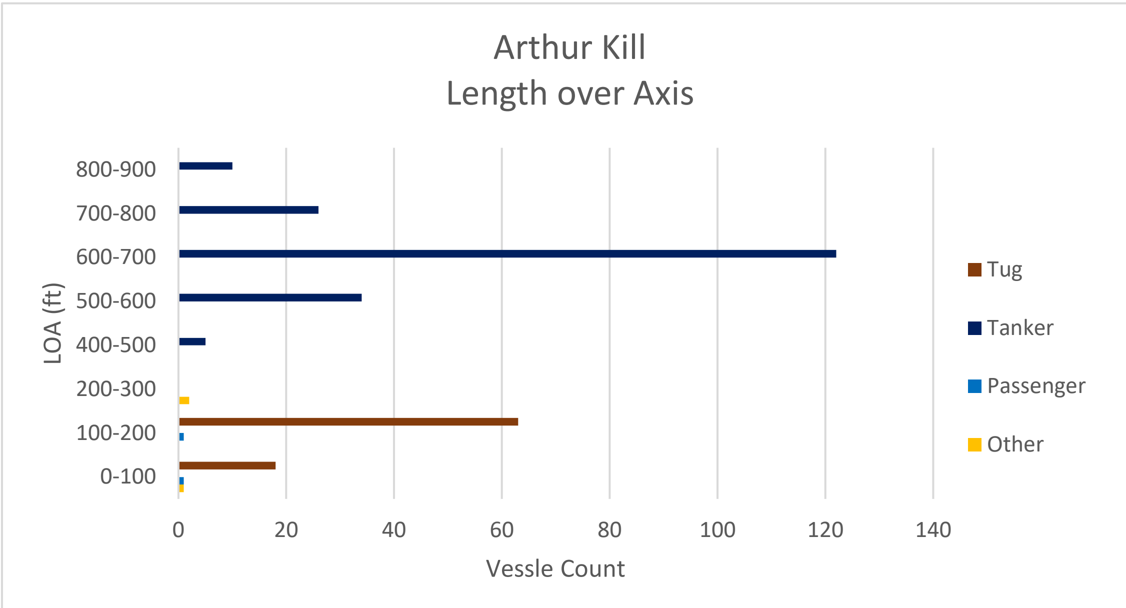


Figure 2-13: Vessel Length Statistics - Arthur Kill

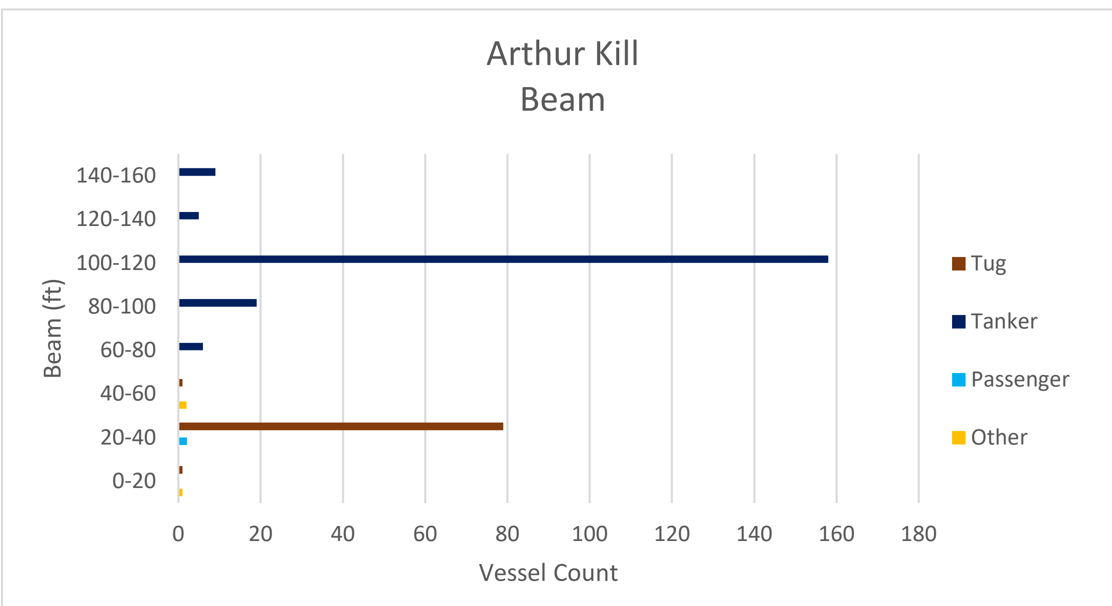


Figure 2-14: Vessel Beam Statistics - Arthur Kill

2.5.2 Minimum Practical Channel Width

Based on the traffic data presented above, a design vessel was identified for evaluating an appropriate width for the Arthur Kill storm surge barrier navigable passage. The design vessel identified is summarized as follows:

- Design Vessel Name: Australian Spirit (Tanker),
- Length: 256m (LOA),
- Beam: 44.8m.

Using this design vessel, the USACE channel width calculation would suggest a width of approximately 4 times the vessel beam (or 587 ft). Using the PIANC method a navigable passage width of 661 ft was computed.

Noting that the Arthur Kill channel varies in width along its length, with a typical width of 600 ft at the location of the proposed storm surge barrier, it seems appropriate to recommend the following:

- The Arthur Kill barrier gate should not be narrower than the width of the channel at the location selected for the barrier. Simulations studies at a further design phase would indicate whether there would be value in making the gate wider than the channel to provide additional maneuvering area for assisting tugs.
- The Arthur Kill barrier gate should not be less than 600 ft wide.

For the purposes of the feasibility study, a navigable passage width of 600 ft is suggested

Table 2-21: PIANC Channel Width Calculation for Arthur Kill (Navigable Passage)

Parameter	Specification	Factor [x Beam]
Basic Maneuvering Lane	Good	1.3
Location	Inner Channel (Protected Water)	0
Vessel Speed	Moderate (>=8 kts)	0
Prevailing Crosswind	Moderate (<33 kts)	0.4
Additional Factor for High Wind Area	(Based on vessel type)	0
Prevailing Cross-current	Negligible (<0.2 kts)	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.2
Wave Effects	Mild (Hs<=1m)	0
AtoN	Excellent	0
Bottom Surface	Rough and Hard	0.2
Depth of Waterway, h	h < 1.25T	0.4
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	1
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	1
Total Channel Width [x Beam]		4.5
Total Channel Width [ft]		661

2.6 Kill van Kull

2.6.1 Traffic Summary

Traffic statistics were prepared for Kill van Kull based on part-year data from 2017 and 2018, representing a total of 332 days of data. Table 2-22, Table 2-23, Figure 2-15, and Figure 2-16 summarize the vessel traffic through Kill van Kull. Table 2-22 and Figure 2-15 present the data categorized by vessel length. Table 2-23 and Figure 2-16 present the data categorized by vessel beam.

Table 2-22: Vessel Length Statistics - Kill Van Kull

LOA [ft]	Bulker	Container	General Cargo	Other	Passenger	Ro-Ro	Tanker	Tug	Total
0-100				1671	20		473	21646	23810
100-200				403	11		1	22056	22471
200-300				344			341	305	990
300-400		94	4	4	8		183	390	683
400-500			7	3			93	155	258
500-600	23	148	16			51	217		455
600-700	145	226	50			542	471	2	1436
700-800	44	69	4			123	106		346
800-900		515	2			4	122		643
900-1000		939	90				1		1030
1000-1100		687							687
1100-1200		282							282
1200-1300		92							92
Unspecified				691				359	1050
Total	212	3052	173	3116	39	720	2008	44913	54233

Table 2-23: Vessel Beam Statistics - Kill Van Kull

Beam [ft]	Bulker	Container	General Cargo	Other	Passenger	Ro-Ro	Tanker	Tug	Total
0-20				742	9			1248	1999
20-40				939	13		473	42338	43763
40-60		2	1	870	9		184	418	1484
60-80		96	12	173	8		441	546	1276
80-100	23	352	25	4		2	162	1	569
100-120	189	810	47	2		700	572	2	2322
120-140		741	88			18	64		911
140-160		1029					112	1	1142
160-180		22							22
Unspecified				386				359	745
Total	212	3052	173	3116	39	720	2008	44913	54233

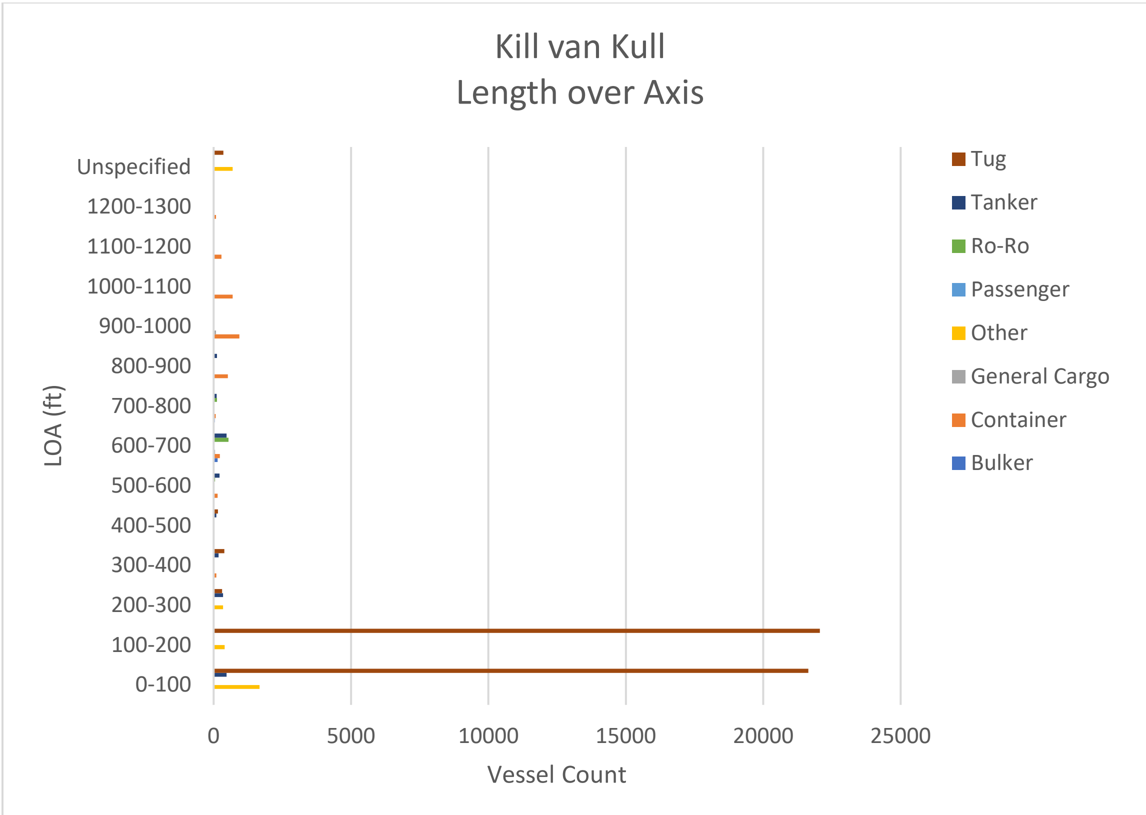


Figure 2-15: Vessel Length Statistics - Kill Van Kull (Tug statistics omitted for clarity)

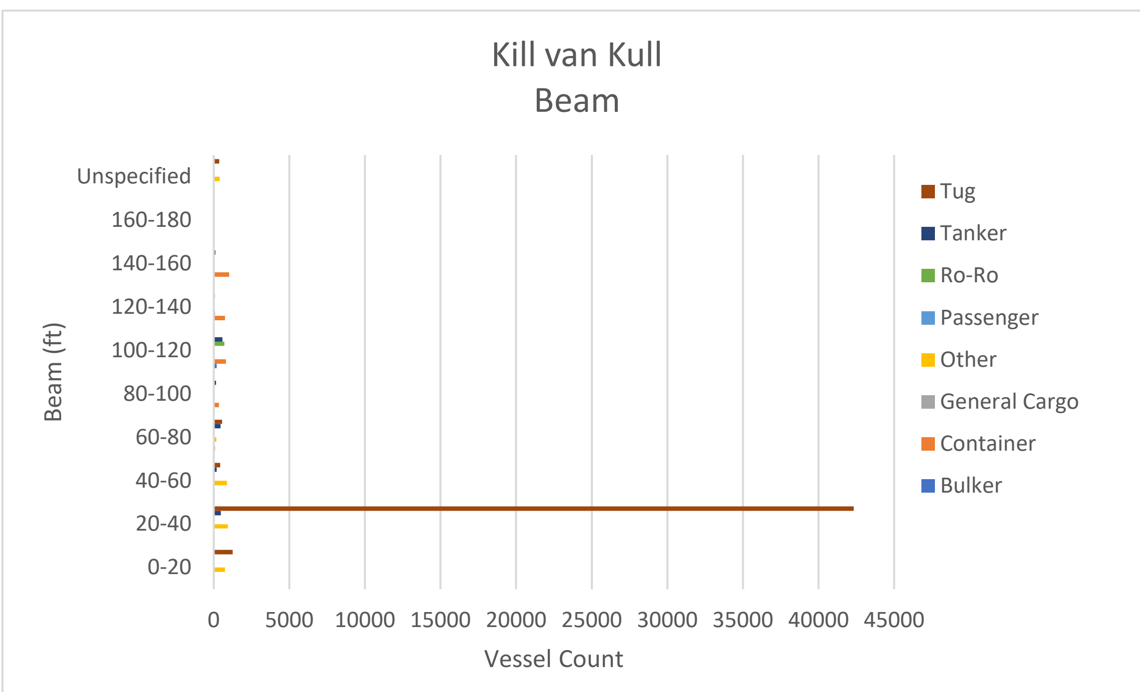


Figure 2-16: Vessel Beam Statistics - Kill Van Kull (Tug statistics omitted for clarity)

2.6.2 Minimum Practical Channel Width (Navigable Passage)

Similar to Verrazano Narrows and the Ambrose Channel, Kill van Kull is on the main navigation channel used by the largest container vessels entering the harbor. As such, the vessel statistics presented above present a partial perspective, but the design vessel used for the channel width calculation is representative of larger vessels that may call sometime in the future. The design vessel for Kill van Kull is as follows:

- Design Vessel Name: OOCL Hong Kong,
- Container Capacity: 21,413 TEU,
- Length: 400m (LOA), (1312ft)
- Beam: 58.8m. (193ft)

Using this vessel and the fact that this reach currently is used as a one-way traffic lane for the largest vessels, both the USACE and PIANC methods were applied to estimate an appropriate minimum channel width. The USACE method does not provide different estimate for this location as compared to the estimates for Verrazano Narrows and Ambrose Channel (771-1,061 ft). However, the PIANC method is able to account for the slower speed of the vessel in this reach, reducing the required width to 856 ft.

These channel width calculations confirm that the current Authorized channel width of 800 ft is appropriate for the minimum practical navigable passage through the storm surge barrier for Kill van Kull.

Table 2-24: PIANC Channel Width Calculation for Kill van Kull (Navigable Passage)

Parameter	Specification	Factor [x Beam] One-Way Traffic
Basic Maneuvering Lane	Good	1.3
Location	Inner Channel (Protected Water)	0
Vessel Speed	Slow (>=5 kts)	0
Prevailing Crosswind	Moderate (<33 kts)	0.6
Additional Factor for High Wind Area	(Based on vessel type)	0
Prevailing Cross-current	Negligible (<0.2 kts)	0
Prevailing Longitudinal Current	Strong (>=3 kts)	0.4
Wave Effects	Mild (Hs<=1m)	0
AtoN	Excellent	0
Bottom Surface	Rough and Hard	0.2
Depth of Waterway, h	h < 1.25T	0.4
Bank Allowance, Red Side (left)	Steep and Hard Embankments/ Structures	0.5
Bank Allowance, Green Side (right)	Steep and Hard Embankments/ Structures	0.5
Additional Width Due to Response Time in Turning	Not Turning	0.4

Parameter	Specification	Factor [x Beam] One-Way Traffic
Additional Width Due to Drift Angle	(Based on vessel type & characteristics)	0.1
Total Channel Width [x Beam]		4.4
Total Channel Width [ft]		856

2.7 Jamaica Bay

2.7.1 Traffic Summary

For Jamaica Bay no AIS data analysis was completed, but instead it was assumed that the traffic as presented for the Rockaway Inlet (see section 2.3.3) would be representative and that a navigable opening within the Jamaica Bay Barrier would at a minimum need to be equal to the Rockaway Inlet opening.

2.7.2 Minimum Practical Channel Width

Using the data provided and based on USACE 2016, it is assumed that the majority of commercial traffic is barge traffic with a vessel beam of 50ft. It is noted that there is a significant portion of recreational traffic within this area (there are over 50 private marinas located around the Bay providing boat slips and launch ramps – DEP Jamaica Bay Watershed protection plan). The estimate for the navigable passage width is set 200ft for this location. This estimate is based on the preliminary design provided in USACE 2016. Typically, the design vessel would be used to define the minimum practical width. However, for Jamaica Bay, it is further assumed that a 200ft navigable opening will be able to accommodate safe passage of vessels and is equal to the width of the Rockaway Inlet navigable passage and would thereby accommodate all traffic coming through that reach.

2.8 Newtown Creek

2.8.1 Traffic Summary

For Newtown Creek no extensive AIS data record was available. For the location where the navigable storm surge barrier is considered the authorized channel is authorized as a channel 23ft deep (MLLW datum) and 130ft wide. Maritime traffic was studied for a site-specific study under the direction of New York City Economic and Development Corporation (EDC) and Mayor's Office of Recovery and Resiliency (ORR). A portion of the study report "Newtown Creek Storm Surge Barrier Study" is included here verbatim.

> Newtown Creek is an active component of New York Harbor that has maintained a high level of commercial activity throughout the history of the port. The Creek is a narrow tidal extension of the East River and, in some locations, also serves as a boundary between the boroughs of Brooklyn and Queens. The surrounding area is high industrialized, and the tributary offers reliable marine transportation access to the various commercial and industrial firms, which line its banks.

The existing federal navigation project provides for a channel 23 feet deep and 130 feet wide from East River to 150 feet north of Maspeth Avenue, with a triangular area at the north side of the entrance. A turning basin 23 feet deep at Mussel Island becomes shallower and narrower approaching Metropolitan Avenue. A survey conducted on behalf of the USACE in 2009 reveals that while the federal channel depth of 23 feet has been identified, shoaling, and sedimentation has reduced the controlling depth to approximately 17 feet on the western portion and approach channels of the Creek.

The cargo passing through the tributary is predominantly via tug and barge, however, most businesses operate barges on seasonal rather than weekly schedules as a way to supplement regular truck and pipeline shipments. In 2005, the Federal Highway Administration conducted a navigation analysis of Newtown Creek as part of the Kosciuszko Bridge Project. The report includes a review of current vessel traffic through the channel as well as an overview of vessel sizes and types. Based on a review of the report, typical vessel types and sizes are given below.

TABLE 3-5
Newtown Creek Vessel Characteristics

	Air Draft (feet)	Water Draft (feet)	Length (feet)	Beam (feet)
Barge	10 to 35	5 to 15	50 to 300	25 to 60
Tugboat	15 to 50	6 to 13	35 to 100	15 to 35

Source: FHA, 2005.

In addition to frequent commercial barge use, the NYCDEP operates a fleet of sludge vessels that call at the Newtown Creek WWTP. A fleet of three new vessels has recently come into operation. The vessels typically make one call at the WWTP per day, though in summer this can increase to twice daily as sludge production goes up. The WWTP does have 24 hours sludge holding capacity in the event that vessels are unable to call, such as in storm conditions. It is expected that longer term improvements at the plant will eventually lead to a higher percentage of solids in the sludge and, hence, a decrease in vessel frequency.

The new fleet of vessels is designed to navigate under the Pulaski Bridge, without the need for the bridge to open. The barges are self-propelled. Key characteristics are summarized in Table 3-6. Typically, the vessels operate in at least 17.5 to 18.5 feet of water for safe navigation. The new vessels have an increased beam to accommodate the air draft restrictions without reducing capacity. The wider beam means that vessels are marginally less maneuverable.

TABLE 3-6
NYCDEP Vessel HUNTS POINT Vessel Characteristics (newer vessel)

Air draft (feet)	43 (mast down)
Length (feet)	290
Beam (feet)	70
Draft (feet)	14.5

TABLE 3-7
NYCDEP Vessel RED HOOK Vessel Characteristics (older vessel—no longer in service on Newtown)

Air draft (feet)	63 (mast down)
Length (feet)	360
Beam (feet)	53
Draft (feet)	21

One-way traffic operations are in effect on Newtown Creek and vessels rely on AIS data to identify and communicate with other vessels.
The minimum preferred navigation channel width is 150 feet as defined by the width at Pulaski Bridge. The navigation channel narrows between 2nd Street and Vernon Boulevard. An additional restriction to navigation—such as a barrier—would preferably be located on a straight section of channel to allow vessel traffic to approach as perpendicular as possible, particularly given the reduced maneuverability of the wider barges, so as to allow adequate forward visibility of approaching vessels.

The Kosciuszko Bridge on the Brooklyn Queens Expressway has a fixed height clearance of 125 feet.

2.8.2 Minimum Practical Navigable Passage Dimensions

In the absence of more detailed information regarding the vessel sizes that transit this area, it seems reasonable to base the minimum dimension of the navigable passage based on previous studies. The minimum practical channel dimensions are based on the recommendations for the recommended barrier alternative “2nd Street” in CH2MHILL 2016:

- The sill level will be set at a depth of -20ft as to lie flush with the existing bed level
- Set the gate span conservatively equal to the span of the Pulaski Bridge (150ft to 170ft), however, to minimize impacts to water quality tidal exchange and flushing requirements could require a wider gate opening (or additional gates)

2.9 Gowanus Canal

2.9.1 Traffic Summary

For Gowanus Canal no extensive AIS data record was available. The authorized channel terminates at the Hamilton Avenue bridge and at this upper limit is authorized as a channel 18ft deep (MLLW datum) and 100ft wide. Maritime traffic was studied for a site-specific study under the direction of New York City Economic and Development Corporation (EDC) and Mayor's Office of Recovery and Resiliency (ORR). A portion of the study report "Gowanus Canal Storm Surge Barrier Study" (CH2MHill 2016) is included here verbatim.

The Gowanus Canal begins at Butler Street and extends southward approximately 8,500 feet to its mouth with depths ranging from 4 feet to approximately 15 feet at Hamilton Avenue, then rapidly increasing in depth to approximately 30 feet for the rest of the canal heading out to Gowanus Bay. The canal is approximately 100 feet wide up to Hamilton Avenue where it widens and flows into Gowanus Bay and Upper New York Bay. Present land uses along the Canal consist primarily of manufacturing, industrial, and commercial uses. The canal shorelines are entirely altered consisting almost exclusively of bulkheads with some areas of riprap and piers. Traffic is primarily barges with tug escort. Vessel traffic through the canal is limited with only the federal navigational channel maintained south of Hamilton Avenue. There are four turning basins located north of Hamilton Avenue at 4th Street, 6th Street, 7th Street, and 11th Street. These basins experience limited marine traffic as they are not part of the main navigational channel and are primarily used as a means for vessels to reverse direction during transit.

Due to the relatively shallow water depth, narrow channel width, and numerous air draft restrictions (with moveable bridges closed), vessel traffic is restricted primarily to tugboats and barges. This is especially true for the traffic traveling further inland. Based on a review of waterfront land use, typical vessel characteristics are likely within the ranges shown below.

TABLE 3-5
Indicative Vessel Characteristics

	Air Draft (feet)	Water Draft (feet)	Length (feet)	Beam (feet)
Barge	10-35	3-12	25-150	20-45
Tugboat	20-50	8-20	50-120	20-40

2.9.2 Minimum Practical Channel Dimension

In the absence of more detailed information regarding the vessel sizes that transit this area, it seems reasonable to base the minimum dimension of the navigable passage based on previous studies. The minimum practical channel dimensions are based on the recommendations for the recommended barrier alternative "Hamilton Avenue" in CH2MHILL 2016:

- The sill level will be set at a depth of -22ft as to lie flush with the post-remediation bed level,
- The width of the navigation opening is to be approximately 90ft so as to provide the same channel cross-sectional area as he Hamilton Avenue bridge immediately upstream, and
- The gate would be aligned with the existing navigation channel and opening through the bridge structure.

3 Conceptual Design Development of the Storm Surge Barriers for the HAT Study

The rationale and the development of the conceptual design and assessment of the minimum required dimensions for the navigable passages and auxiliary flow gates of the storm surge barriers considered under the HAT Study are documented in this section. Design vessel specifications and channel dimensions were established following PIANC guidance and presented in the previous section.

3.1 Storm Surge Barriers – Basic Elements

Based on the functional requirements presented in Storm Surge Barrier Sub-Appendix, it is assumed that each conceptual design for the storm surge barrier will aim to maximize the flow gate openings and the portion of "dam section" of the storm surge barrier will be minimized. The auxiliary flow gates serve to maximize the water exchange through the opening and minimize impacts on the inner basin environmental conditions during normal hydrodynamic and meteorological conditions.

At the tie-in locations of the storm surge barrier to the shore-based system, i.e., shallow waters, a dam section on the order of 100 ft to 500 ft long, depending on the location, would be needed. This dam section will be the transition between the operable storm surge barrier gate structure and land-based flood risk reduction measures.

The locations of the storm surge barriers discussed herein are, for the most part, determined by the extent and location of the perimeter risk reduction systems that are part of the HAT Study Alternatives. Site location maps are provided in Annex G. Once a location has been set, the overall geometry was then dictated by the existing bathymetry, geometry of the navigable passage(s) and the auxiliary flow gates given the existing bathymetric profile and the design criteria.

3.2 Navigable Passage

Development of the dimensions of the navigable passages and gate dimensions are provided in this section.

3.2.1 Navigable Passage Dimensions Verrazano Narrows

The storm surge barrier from Staten Island to Brooklyn would require at least two navigable passages:

1. Ambrose Channel Navigable Passage Opening: minimum <u>1400ft</u> wide

   - PIANC guidance to set navigational opening: to a minimum of 968ft and 1428ft for one-way and two-way traffic respectively. Rounded to the nearest hundred, 1400ft is considered a conservatively appropriate value for use as preliminary estimate in the overall storm surge barrier feasibility study.

- Set sill of Navigable Passage at -55ft MLLW (Authorized Channel Depth equals -53ft MLLW and additional 2ft clearance below design channel is included to account for the hard bottom structure). -55ft MLLW equals -58ft NAVD88,

- Air Draft is controlled by the Verrazano Bridge at 228ft. This clearance is adopted as a conservative assumption which in practicality for the design of moveable gates translates to unrestricted air clearance.

In addition to the main navigation channel, the AIS data suggests that there is a high volume of smaller traffic. It would be advisable to include at least one smaller, navigable gate in the storm surge barrier to pass smaller vessels, to keep the smaller vessels out of the main navigation channel. Enclosure 1 details the selection of the design vessel and analyses to establish the minimum practical width for the secondary navigable passage.

2. Secondary Navigable Passage on East Side of Main Channel: <u>200ft</u> wide (one-way vessel traffic)

    - PIANC guidance to set navigational opening: minimum 178ft

    - Set sill of Navigable Passage at -42ft MLLW. Authorized Channel Depth is -40ft MLLW and additional 2ft clearance below the design channel is included to account for the hard bottom structure. -42ft MLLW equals -45ft NAVD88,

    - Air Draft: 50ft

It should be noted that the dimensions of the navigable passage for the Ambrose Channel is larger than any gated opening in constructed storm surge barriers (Maeslant Barrier in The Netherlands spans 1200ft). The findings presented herein are a preliminary assessment and further refinement of the gate dimensions and gate configurations (including layout, number, and width) will need to occur during later stages in the design.

3.2.2 Navigable Passage Dimensions Throgs Neck

The storm surge barrier which would span from Westchester, NY to Queens, NY would at least require one navigable passage:

1. Throgs Neck navigable passage opening: <u>450ft</u> wide (two-way vessel traffic)

    - PIANC guidance to set navigational opening for one-way traffic to a minimum of 447ft.

    - Set sill at -37ft M.LLW (2ft clearance below the authorized channel depth of -35ft MLLW). -37ft MLLW equals -40ft NAVD88,

    - Air Draft is controlled by the Throgs Neck Bridge at 142ft. This clearance is adopted as a conservative assumption which in practicality for the design of moveable gates translates to unrestricted air clearance.

3.2.3 Navigable Passage Dimensions Arthur Kill

The Arthur Kill storm surge barrier from Woodbridge, NJ to Staten Island, NY would at least require one navigable passage:

1. Arthur Kill Navigable Passage Opening: 600ft wide (width of existing channel).

    - PIANC guidance to set navigational opening for one-way traffic to a minimum of 661ft, yet the Authorized Channel Width is 600ft.

    - Set sill at -37ft MLLW. Authorized Channel Depth is -35ft MLLW and additional 2ft clearance below the design channel is included to account for the hard bottom structure. -37 ft MLLW equals -40ft NAVD88

    - Unrestricted air draft to the Outerbridge Crossing, after that it is controlled by the Outerbridge Crossing at 143ft. This clearance is adopted as a conservative assumption which in practicality for the design of storm surge barriers translates to unrestricted air clearance.

3.2.4 Navigable Passage Dimensions Outer Harbor

The storm surge barrier from Sandy Hook to Breezy Point would at least require three navigable passages:

1. Sandy Hook Navigable Passage Opening: 800ft wide.

    - PIANC guidance to set the navigational opening for one-way traffic to a minimum of 835ft, but the Authorized Channel Width is 800 ft as such the width of the existing channel is used to set the opening width

    - Set sill at -37ft MLLW. Authorized Channel Depth is -35ft MLLW and additional 2ft clearance below the design channel is included to account for the hard bottom structure. -37 ft MLLW equals -40ft NAVD88,

    - Air draft: 143ft (assume up to 43.6m for this vessel size class). This clearance is adopted as a conservative assumption which in practicality for the design of storm surge barriers translates to unrestricted air clearance.

2. Ambrose Channel Navigable Passage Opening: 1500ft wide

    - PIANC guidance to set Navigational Opening: to a minimum of 1026ft and 1543ft for one-way and two-way traffic respectively. Rounded to the nearest hundred, 1500ft is considered appropriate for use as preliminary estimate in the overall storm surge barrier feasibility study.

    - Set sill of Navigable Passage at -55ft MLLW. Authorized Channel Depth is -53ft MLLW and an additional 2ft is included to account for hard bottom structure. -55ft MLLW equals -58ft NAVD88.

- Air Draft is controlled by the Verrazano Bridge at 228ft. This clearance is adopted as a conservative assumption which in practicality for the design of storm surge barriers translates to unrestricted air clearance.

3. Rockaway Inlet Navigable Passage Opening: 200ft wide

   - PIANC guidance to set navigational opening: minimum 198ft (one-way vessel traffic)
   - Set sill at a minimum at -22ft MLLW. Authorized Channel Depth is -20ft MLLW and an additional 2ft is included to account for hard bottom structure. -22ft MLLW equals -25ft NAVD88,
   - Air Draft: 50ft

The difference in navigable passage opening for the Ambrose Channel in the Verrazano Narrows and Outer Harbor storm surge barrier is a resulted of the more exposed conditions of the Ambrose Channel (see Enclosure 1 for more details). Again, it can be noted that the dimensions of the navigable passage at the Ambrose Channel as part of the Outer Harbor storm surge barrier is larger than any gated opening in constructed storm surge barriers (Maeslant Barrier in The Netherlands spans 1200ft).

3.2.5 Navigable Passage Dimensions Kill van Kull

The storm surge barrier from Bayonne, NJ to Staten Island, NY will require one navigable passage:

1. Kill Van Kull Navigable Passage Opening: 800ft wide (width of existing channel).

   - PIANC guidance to set navigational opening for one-way traffic to a minimum of 856ft, yet the Authorized Channel Width is 800ft.
   - Set sill at -52ft MLLW. Authorized Channel Depth is -50ft MLLW and an additional 2ft is included to account for hard bottom structure. -52 ft MLLW equals -55ft NAVD88,
   - Air Draft is controlled by the Verrazano Bridge at 228ft. This clearance is adopted as a conservative assumption which in practicality for the design of storm surge barriers translates to unrestricted air clearance.

3.2.6 Navigable Passage Dimensions Jamaica Bay

The siting of the storm surge barrier is discussed in section 2 and is based on the analysis completed in 2016 (USACE, 2016) and equal to the concept proposed in that study, the storm surge barrier from Barren Island, NY, to Rockaway, NY will have two openings to allow for maritime traffic to traverse:

1. Rockaway Inlet Navigable Passages Openings: 200ft wide

   - PIANC guidance to set navigational opening: minimum 198ft

- Set sill at a minimum at -22ft MLLW. The Authorized Channel Depth is -18ft MLLW and a 2ft clearance is included to account for the hard bottom structure and an additional 2ft is included to increase flow conveyance. -22ft MLLW equals -25ft NAVD88

- Air Draft is controlled by the Gil Hodges Bridge at 152ft. This clearance is adopted as a conservative assumption which in practicality for the design of storm surge barriers translates to unrestricted air clearance.

3.2.7 Navigable Passage Dimensions Hackensack

The storm surge barrier is located just upstream of the terminus of the constructed federal channel (also discussed in the Storm Surge Barrier Sub-Appendix). However, the river is still navigable beyond that point. The storm surge barrier on the Hackensack River would at least require one navigable passage to accommodate vessel traffic. The most restricting horizontal dimension on the waterway is the swing bride upstream of the storm surge barrier, which has a horizontal clearance of 100 ft. The existing channel thalweg depths upstream of the Marion Reach, where the storm surge barrier is proposed, vary between -20ft and -25ft NAVD88 (-17ft MLLW and -22ft MLLW). At this stage of design, a sill elevation of -20ft is proposed.

1. Hackensack River Navigable Passage Opening: <u>100ft</u> wide. (one-way vessel passage)

- Navigation opening is based on upstream bridge restriction

- Set sill at -20ft MLLW (equal to -23ft NAVD88)

- Air draft is controlled by the upstream bridge at 103 ft. This clearance is adopted as a conservative assumption which in practicality for the design of moveable gates translates to unrestricted air clearance.

3.2.8 Navigable Passage Dimensions Raritan River

The storm surge barrier is located across the Raritan River just east of the Highway 35 (Convery Blvd) bridge. The storm surge barrier would require one navigable passage to accommodate vessel traffic. The most restricting horizontal dimension on the waterway is the swing bride located to the East (south of Perth Amboy), which has a horizontal clearance of 100 ft. The existing channel thalweg depths in the Raritan River, where the storm surge barrier is proposed, vary between -28ft and -33ft NAVD88 (-25ft MLLW and -30ft MLLW). At this stage of design, a sill elevation of -27ft MLLW is proposed which includes an additional 2ft of under keel clearance.

1. Hackensack River Navigable Passage Opening: <u>100ft</u> wide. (one-way vessel passage)

- Navigation opening is based on the bridge restriction located to the east

- Set sill at -27ft MLLW (equal to -30ft NAVD88)

- Air draft is controlled by the upstream bridge at 109 ft. This clearance is adopted as a conservative assumption which in practicality for the design of moveable gates translates to unrestricted air clearance.

3.2.9 Navigable Passage Dimensions Highlands SSB

The storm surge barrier is located in the lower Sandy Hook Bay in the approach to the Shrewsbury River, just north of Highlands, NJ. The storm surge barrier would require one navigable passage to accommodate vessel traffic. The existing channel is authorized at 12 ft MLW, and the Reach A (Bay to Highlands) is authorized at a minimum width of 300ft, while Reach B (starting at the Sandy Hook Bridge) is authorized at 150ft width. At this stage in the feasibility study, it is assumed that a navigable opening of 100 ft is sufficient to provide a narrowing of the navigation lane and accommodate vessel passage.

1. Highlands Navigable Passage Opening: 100ft wide. (one-way vessel passage)

    - Navigation opening is based on dimensions in Reach B
    - Set sill at -18ft MLLW (equal to -20ft NAVD88) to increase flow conveyance
    - Air draft is assumed to be unrestricted.

3.2.10 Summary of Navigable Passage Dimensions

The navigable passage dimensions and findings from the previous sections are summarized in Table 3-1 below. Note that the width of the navigable passage for the same federal channel can differ amongst storm surge barriers due to a difference in exposure to environmental conditions. Furthermore, based on the above selected dimensions, similar dimensions were selected for the storm surge barriers associated with the induced flooding mitigation feature alignment such as the Port Washington or Hammond Creek.

Table 3-1: Minimum Practical Dimensions for the Navigable Passages

Storm Surge Barrier Location	Federal Channel	Existing Depth (ft)	Minimum Practical Width of Opening [ft]	Authorized Channel Depth [ft, NAVD88]	Minimum Depth of Opening [ft NAVD88]	Air Clearance [ft NAVD88]
Verrazano Narrows	Ambrose Channel	70-75	1400[2]	-56	-58	Un-restricted
Verrazano Narrows	Secondary Navigation Channel	20-25	200[1]	-43	-45	50 ft
Throgs Neck	Throgs Neck	40-55	450[2]	-38	-40	Un-restricted
Arthur Kill	Arthur Kill Channel	35	600[1,3]	-38	-40	Un-restricted
Outer Harbor	Ambrose Channel	75-80	1500[2]	-56	-58	Un-restricted
Outer Harbor	Sandy Hook	60-70	800[1,3]	-38	-40	Un-restricted
Outer Harbor	Rockaway Inlet	20-30	200[1]	-23	-25	50 ft
Kill Van Kull	Kill Van Kull	50-55	800[1,3]	-53	-55	Un-restricted
Jamaica Bay	Rockaway Inlet	20-30	200[1]	-21	-25	Un-restricted
Hackensack River	Hackensack River	20-25	100[1,3]	-18	-23	Un-restricted
East Chester Creek	East Chester Creek	10-20	200	-8	-12	N/A
Flushing Creek	Flushing Bay and Creek	10-20	135	-15	-19	30 ft
Newtown Creek	Newton Creek	20-25	130	-23	-20[4]	Un-restricted
Gowanus Canal	Gowanus Creek	10-15	100	-18	-21	Un-restricted

Storm Surge Barrier Location	Federal Channel	Existing Depth (ft)	Minimum Practical Width of Opening [ft]	Authorized Channel Depth [ft, NAVD88]	Minimum Depth of Opening [ft NAVD88]	Air Clearance [ft NAVD88]
Sheepshead Bay	Sheepshead Bay	30-35	100	-6	-9	N/A
Gerritsen Creek	N/A	20-25	115	N/A	-19	35
Port Washington	N/A	10-20	60	N/A	-16	Un-restricted
Hempstead Harbor (Glen Cove)	Glen Cove Creek	10	60	-10	-11	Un-restricted
Hammond Creek	N/A	5-15	60	N/A	-15	Un-restricted
Highlands	Shrewsbury River	20-25	100	-15	-20	Un-restricted
Raritan River	Raritan River	15-20	100	-28	-30	Un-restricted

Notes:

1. *Practical width of navigable passage based on one-way traffic*
2. *Practical width of navigable passage based on two-way traffic*
3. *Practical width of navigable passage limited based on existing authorized channel dimensions*
4. *Sill set based on assumption of post remediation bed levels*

3.2.11 Navigable Gate Type Selection

Following the minimum design dimensions outlined in Table 3-1, a suitable gate type will have to be preliminarily selected. The HAT Study interim report (USACE, 2019) includes an overview of the supplemental data from Mooyaart and Jonkman (2017) and provides an overview of characteristics of constructed storm surge barriers. In addition, the interim report includes an overview of hydraulic gate types used in navigable storm surge barriers and lists general advantages and disadvantages of each gate type. Using the data set and the listed advantages and disadvantages, this annex provides a cursory review of the suitability of each gate type for the navigable passage. Based on the evaluation that is provided in Attachment 1, the sector gate (vertical axis) and floating sector gate are preliminarily selected for the conceptual design of the navigable passages. All gate types and a generalized overview of the evaluation in Attachment 1 is summarized in Table 3-2 below.

Table 3-2: Summary of Gate Type Selection for the Navigable Passage (from Attachment 1)

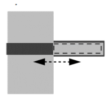
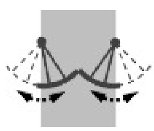
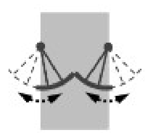
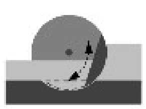
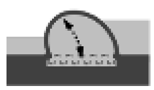
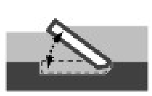
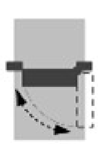
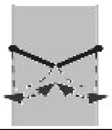
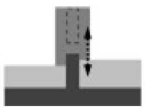
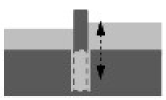
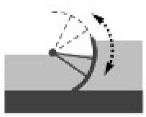
Image	Gate Type	Generalization of Notes and Evaluation from Section 4 (Attachment 1)	Navigable Passage where Gate Type is Selected
	Horizontal Rolling Gate	Impractical due to area needed to dock the gate	
	Sector Gate (Vertical Axis)	Suitable, proven concept for similar spans (spans up to 200 ft in these instances) and sill elevations.	- Verrazano Secondary Navigation Gate - Outer Harbor Rockaway Inlet Gate - Jamaica Bay Navigation Gates - Hackensack River Navigation Gate - East Chester Creek Navigation Gate - Newtown Creek Navigation Gate - Sheepshead Bay Navigation Gate - Port Washington Navigation Gate - Hempstead Harbor Navigation Gate - Hammond Creek Navigation Gate - Highlands Navigation Gate - Raritan River Navigation Gate
	Floating Sector Gate	Suitable, proven concept for wide and deep navigable opening.	- Verrazano Main Navigation Gate - Throgs Neck Main Navigation Gate - Outer Harbor Ambrose Channel Gate - Outer Harbor Sandy Hook Gate - Arthur Kill Main Navigation Gate - Kill van Kull Main Navigation Gate
	Rotating Segment Gate	Possible for some locations, but generally deemed relatively expensive and complex system and not suitable for deep and wide spans	
	Inflatable Gate or Dam	Generally, no proven concepts for large deep spans	
	Flap Gate	Not suitable for reverse head conditions and generally considered too challenging from a maintenance perspective	
	Barge Gate	Generally, not suitable, too complex and challenging to operate under wave and current conditions	

Image	Gate Type	Generalization of Notes and Evaluation from Section 4 (Attachment 1)	Navigable Passage where Gate Type is Selected
	Miter Gate	Not suitable for large spans or large reverse head conditions.	- Gowanus Canal Navigation Gate
	Vertical Lift Gate	Generally, not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs	- Flushing Creek Navigation Gate - Gerritsen Creek Navigation Gate
	Vertical Rising Gate	Generally assumed to be not suitable, related to the challenges from a maintenance perspective. In addition, no proven concept for large gate spans	
	Tainter Gate	Not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs	

3.3 Auxiliary Flow Gates

Design development of the dimensions of the auxiliary flow gates and gate type selections are provided in this section.

3.3.1 Auxiliary Flow Gate Dimensions

For the auxiliary flow gates, a standard gate span of 150ft is preliminarily selected based on the review of gate characteristics as presented in Mooyaart and Jonkman, 2017 and in the HAT Study interim report (USACE, 2019). 150ft is considered to be a reasonable assumption, where this width falls within the gate spans for constructed storm surge barriers. Some storm surge barrier locations have spatial constraints and smaller gate spans may be needed. Exceptions and special considerations for each location are provided in Attachment 2. Due to the variations in depth along the storm surge barrier alignment it is expected that varying gate sizes will be needed. Varying gate sizes will allow the design to follow the natural bathymetric contours of the area while maintaining a large open cross-section for flow. To minimize construction complexity and allow for optimization through the economies of scale the gate sill elevations are preliminarily assumed to vary in increments of 5ft. The sill elevation of the auxiliary flow gates is to be above the existing bed elevation such that the potential for sedimentation or siltation at the bottom of the sill is minimized.

When the gates are in the open position during normal day-to-day conditions, the bottom of the gates shall provide 3ft of clearance above MHHW at the end of the project service life. Positioning the bottom of the gate, when open, above this elevation will ensure that the gate will not be inundated more than needed and that flow will not be impeded by sluicing action under the gate for typical water level and operating conditions. The additional 3ft is used to account for potential wave action during normal conditions and allow for clear sight lines underneath the gate which may be needed during visual inspections. This elevation varies per storm surge barrier location. An example is provided here for the Verrazano Narrows storm surge barrier where this elevation is equal to +8ft NAVD88 which is the rounded sum of +2.41ft (MHHW), Sea level Change (1.82ft) and the additional 3ft clearance. Headwall elevations are set according to the values as summarized in Table 3-3 below.

Table 3-3: Headwall Elevations

Location	MHHW (ft, NAVD88)	Sea Level Rise[1] (ft)	Clearance (ft)	Headwall Elevation (ft, NAVD88)[1]
Verrazano Narrows Auxiliary Flow Gates	2.28	1.93	3	+8[3]
Throgs Neck Auxiliary Flow Gates	3.64	1.74	3	+8
Arthur Kill Auxiliary Flow Gates	2.41	2.29	3	+8
Outer Harbor Auxiliary Flow Gates	2.41	2.29	3	+8
Kill Van Kull Auxiliary Flow Gates	2.63	2.29	3	+8
Jamaica Bay Auxiliary Flow Gates	2.41	2.29	3	+8
Hackensack River Auxiliary Flow Gates	2.97	2.29	3	+8
East Chester Creek Flow Gates	3.64	1.74	3	+9
Flushing Creek Flow Gates	3.64	1.74	3	+8
Newtown Creek Flow Gates	2.28	1.93	3	+7
Gowanus Canal Flow Gates	2.28	1.93	3	+7
Sheepshead Bay Flow Gates	2.41	2.29	3	+8
Gerritsen Creek Flow Gates	2.41	2.29	3	+8
Port Washington Flow Gates	3.64	1.74	3	+9
Hempstead Harbor Flow Gates	3.64	1.74	3	+9
Hammond Creek Flow Gates	3.64	1.74	3	+9
Highlands Flow Gates	2.41	2.29	3	+8
Raritan River Flow Gates	2.41	2.29	3	+8

Notes:

1. *Sea level rise from 1992 to 2095.*
2. *Elevation = MHHW + SLR + Clearance, rounded to nearest foot.*
3. *VN headwall elevation was conservatively rounded up*

The auxiliary flow gate only passes flow and as such the gate does not need to be raised above the elevation stated above. The design elevation of the storm surge barriers is provided in the Storm Surge Barrier Sub-Appendix. To reduce the gate size, weight, and overall complexity of the hoisting mechanisms, it is proposed to include a solid, non-moveable, wall between the elevation +8ft and the top of the structure. For water control structures, this is commonly referred to as a headwall. While a headwall requires a fourth seal between structure and gate, since all four sides need to be sealed instead of three, the headwall reduces the overall height of the gates substantially[2]. For example, for the Verrazano Narrows storm surge barrier, a gate height of 52ft would be needed to close of an opening between a sill elevation of -30ft to a design elevation of +22ft, while with the use of a headwall the gate height would be 38ft (sill elevation at -30ft and top of gate at elevation +8ft). The dimensions for the Auxiliary flow gates discussed herein are summarized in Table 3-4.

Table 3-4: Design Dimensions for the Auxiliary Flow gates

Location	Existing Depth (ft)	Width of Flow Gate Opening (ft)	Depth of Flow Gate Opening (ft. NAVD88)	Required Bottom of the gate in raised position (ft, NAVD88)
Verrazano Narrows	Varying between 70ft to 30ft	150	-60, -25, and -20	+8
Throgs Neck	Varying between 55ft to 40ft	150	-45	+8
Arthur Kill	Varying between 20ft to 10ft	70[1]	-10	+8
Outer Harbor	Varying between 50ft to 20ft	150	varying	+8
Kill Van Kull	Varying between 40ft to 60ft	150	-28 to -30	+8
Jamaica Bay	Varying between 300ft to 20ft	150	varying	+8
Hackensack	Varying between 20ft to 25ft	50[2]	varying	+8
East Chester Creek Flow Gates	Varying between 10ft to 20ft	75	-15	+9
Flushing Creek Flow Gates	Varying between 10ft to 20ft	75	-21	+8
Sheepshead Bay Flow Gates	Varying between 20ft to 35ft	150	-20	+8
Gerritsen Creek Flow Gates	Varying between 20ft to 25ft	50	-19	+8
Port Washington Flow Gates	Varying between 10ft to 20ft	75	-16	+9
Highlands Flow Gates	Varying between 5ft to 25ft	50	-20	+8

[2] E.g., the Eastern Scheldt storm surge barrier (The Netherlands) includes a headwall type feature.

Location	Existing Depth (ft)	Width of Flow Gate Opening (ft)	Depth of Flow Gate Opening (ft. NAVD88)	Required Bottom of the gate in raised position (ft, NAVD88)
Raritan River Flow Gates	Varying between 15ft to 20ft	50	-22	+8

Notes:

1. *A gate span of 70ft is preliminarily selected based on the limited width and depth available between the navigable gate and gate housing and the shoreline*
2. *A gate span of 50ft is preliminarily selected based the previous USACE-NAN study (USACE, February 1989)*
3. *Newtown Creek, Gowanus Canal, Hempstead Harbor and Hammond Creek don't include auxiliary gates since flow is accommodated through the main navigable passage and are therefore excluded from this table.*

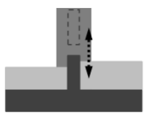
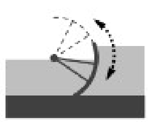
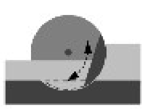
Finally, the sill elevation of the auxiliary flow gates is to be above the existing bed elevation such that the potential for sedimentation or siltation at the bottom of the sill is minimized. Future data collection will be needed to obtain bathymetric profiles and additional analyses are needed to evaluate the effect the storm surge barrier has on the hydrodynamics and morphology of the estuarine system.

3.3.2 Auxiliary Flow Gate Type Selection

Attachment 2 provides a cursory review of the suitability of gate types for the auxiliary flow gates. Based on the evaluation that is provided in Attachment 2, the vertical lift gate is preliminarily selected for the majority of the conceptual designs of the storm surge barrier discussed herein. For the Hackensack River storm surge barrier, the tainter gate type selection is informed by the previous USACE-NAN study (USACE, February 1989).

Gate types and a generalized overview of the evaluation in Attachment 2 is summarized in Table 3-5 below. The horizontal rolling gate, barge gate and miter gate are omitted from the table since these are the least suitable hydraulic gate options for auxiliary flow. Flap gates and vertical rising gates could potentially be utilized in some locations but are in general considered to be relatively expensive and complex systems to be used as auxiliary flow gate.

Table 3-5: Gate Type Selection Summary for the Auxiliary Flow gates (from Attachment 2)

Image	Gate Type	Generalization of Notes and Evaluation from Section 5 (Attachment 2)	Storm Surge Barrier where Conceptual Design Includes Gate Type
	Vertical Lift Gate	Suitable, proven concept	• Verrazano • Throgs Neck • Arthur Kill • Kill van Kull • Outer Harbor • Jamaica Bay • Flushing Creek • Sheepshead Bay • Gerritsen Creek • East Chester Creek • Port Washington • Highlands • Raritan River
	Tainter Gate	Suitable, proven concept, however reverse head conditions will need to be investigated	• Hackensack River (per previous study - USACE, February 1989)
	Inflatable Gate or Dam	Possible, but no proven concept for tidal inlet applications. Furthermore, deemed relatively complex system.	
	Rotating Segment Gate	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	

3.4 Piers and Gate Housing

To minimize the environmental impacts and maintain as much tidal exchange as possible, the concept will maximize the number of auxiliary flow gates to the extent considered reasonable. The storm surge barrier locations have been identified (more details to be found in the Storm Surge Barrier Sub-Appendix) and the dimensions of both the navigable opening and the flow gate openings have been established in the previous sections. In order to provide a conceptual geometry an assumption regarding the pier widths is to be made. The sector gate abutment is assumed to be, at a minimum, two-thirds of half of the gate opening. For the vertical lift gate, a pier width of 30ft was conservatively assumed based on the review of the characteristics of vertical lift gates constructed as part of storm surge barriers (Attachment 2).

4 Attachment 1: Cursory Review of Hydraulic Gate Types for Application Within the Navigable Passages

Following the requirements above and the information provided in the Storm Surge Barrier Appendix, a cursory evaluation[3] of gate types and their suitability for the navigable passage has been completed for the Verrazano, Throgs Neck and Outer Harbor storm surge barriers in Table 4-1, for the Arthur Kill, Kill van Kull, Jamiaca Bay and Hackensack storm surge barriers in Table 4-2, for the East Chester Creek, Flushing Creek, Newtown Creek, Gowanus Canal, Sheepshead Bay, and Gerritsen Creek storm surge barriers in Table 4-3, and for the Port Washington, Hempstead Harbor, Hammond Creek, Highlands, and Raritan River Storm Surge Barriers in Table 4-4. Pictograms for the various gate types are modified after (Dijk, 2010).

[3] It should be noted that without a complete gate type study and evaluation of gate alternatives for the storm surge barriers (inclusive of preliminary cost estimates) this can only be regarded as a preliminary assumption which will have to be verified at a later stage. The evaluation of gate types is to establish a reasonable preliminary selection of gate types such that a preliminary geometry of the openings of the barrier can be established. The geometry and its performance can then be evaluated through hydrodynamic modeling and findings can be incorporated in the next round of refinements of the barrier designs.

Table 4-1: Cursory Review of Hydraulic Gate Types for Application Within the Navigable Passages of the Verrazano, Throgs Neck and Outer Harbor Storm Surge Barriers

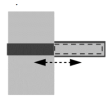
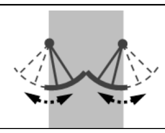
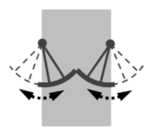
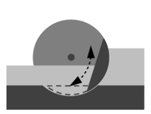
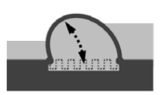
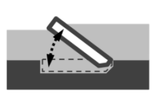
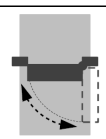
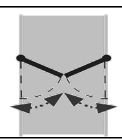
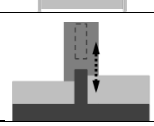
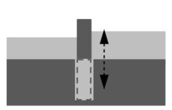
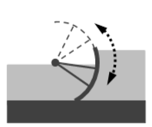
Image	GATE TYPE	Verrazano Suitability for Main Navigation Gate	Verrazano Suitability for Secondary Navigation Gate	Throgs Neck - Suitability for Main Navigation Gate	Outer Harbor - Suitability for Ambrose Channel Gate	Outer Harbor - Suitability for Sandy Hook Gate	Outer Harbor - Suitability for Rockaway Inlet Gate
	Horizontal Rolling Gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area need to dock the gate	Impractical due to area need to dock the gate	Impractical due to area need to dock the gate
	Sector Gate (Vertical Axis)	Not suitable for such a large span (no proven constructed concept)	Suitable, proven concept for similar span and sill elevation.	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept)	Suitable, proven concept for similar span and sill elevation.
	Floating Sector Gate	Suitable, proven concept for large navigable opening. Note that the 1400ft wide opening would be approx. 200 ft wider than existing largest built gate (Maeslant Barrier)	Not suitable, deemed relatively expensive and too complex system	Suitable, proven concept for large navigable opening.	Suitable, proven concept for large navigable opening. 300 ft wider than existing largest built gate (Maeslant Barrier)	Suitable, proven concept for large navigable opening	Not suitable, deemed relatively expensive and too complex system
	Rotating Segment Gate	Not suitable for such a large span (no proven constructed concept)	Possible, but deemed relatively expensive and complex system	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept)	Possible, but deemed relatively expensive and too complex system
	Inflatable Gate or Dam	Not suitable for such a large deep span (no proven constructed concept)	Possible, but no proven concept for the depths at this location	Not suitable for such a large deep span (no proven constructed concept)	Not suitable for such a large deep span (no proven constructed concept)	Not suitable for such a large deep span (no proven constructed concept)	Possible, but no proven concept for the depths at this location
	Flap Gate	Not suitable for reverse head conditions and deemed too challenging from a maintenance perspective. In addition, no proven concept for water depths exceeding 48ft.	Not suitable for reverse head conditions and deemed too challenging from a maintenance perspective	Possible, as a series of flap gates, but not suitable for reverse head conditions and deemed too challenging from a maintenance perspective	Not suitable for reverse head conditions and deemed to challenging from a maintenance perspective. In addition, no proven concept for water depths exceeding 48ft.	Not suitable for reverse head conditions and deemed to challenging from a maintenance perspective	Not suitable for reverse head conditions and deemed to challenging from a maintenance perspective
	Barge Gate	Not suitable for such a large span (no proven constructed concept)	Not suitable, deemed too challenging to operate under wave and current conditions	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept)	Not suitable, deemed too complex and challenging to operate under wave and current conditions
	Miter Gate	Not suitable for such a large span or reverse head conditions	Not suitable due to reverse head conditions	Not suitable for such a large span or reverse head conditions	Not suitable for such a large span or reverse head conditions	Not suitable for such a large span or reverse head conditions	Not suitable due to reverse head conditions
	Vertical Lift Gate	Not suitable since unrestricted air clearance is required	Not suitable since the required air clearance would prohibitively increase gate costs	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since the required air clearance would prohibitively increase gate costs
	Vertical Rising Gate	Deemed too challenging from a maintenance perspective and no proven concept for such a large gate span	Possible, but deemed to challenging from a maintenance perspective	Deemed too challenging from a maintenance perspective and no proven concept for such a large gate span	Deemed to challenging from a maintenance perspective and no proven concept for such a large gate span	Deemed to challenging from a maintenance perspective and no proven concept for such a large gate span	Possible, but deemed to challenging from a maintenance perspective
	Tainter Gate	Not suitable since unrestricted air clearance is required	Not suitable since the required air clearance would prohibitively increase gate costs	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since the required air clearance would prohibitively increase gate costs

Table 4-2: Cursory Review of Hydraulic Gate Types for Application Within the Navigable Passages of the Arthur Kill, Kill van Kull, Jamaica Bay and Hackensack Storm Surge Barriers

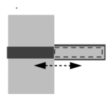
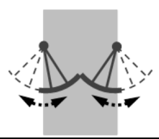
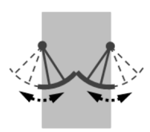
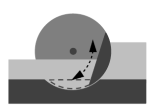
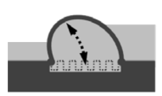
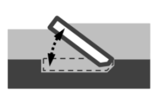
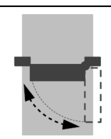
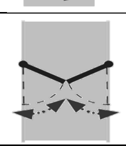
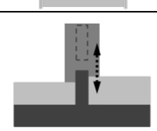
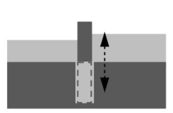
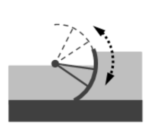
Image	GATE TYPE	Arthur Kill - Suitability for Main Navigation Gate	Kill van Kull - Suitability for Main Navigation Gate	Jamaica Bay - Suitability for Main Navigation Gates	Hackensack River - Suitability for Main Navigation Gate
	Horizontal Rolling Gate	Impractical due to area needed to dock the gate	Possible, the land area to the south could function as dock area. However difficult to operate under wave and current conditions.	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate
	Sector Gate (Vertical Axis)	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept)	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.
	Floating Sector Gate	Suitable, proven concept for large navigable opening.	Suitable, proven concept for large navigable opening.	Not suitable, deemed relatively expensive and too complex system	Not suitable, deemed relatively expensive and too complex system
	Rotating Segment Gate	Not suitable for such a large span (no proven constructed concept)	Not suitable for such a large span (no proven constructed concept) and too challenging to construct in rock substrate	Possible, but deemed relatively expensive and complex system. Potential for sediment built-up as a result of the sediment transport for the Jamaica Bay Inlet	Possible, but deemed relatively expensive and complex system.
	Inflatable Gate or Dam	Not suitable for such a large deep span (no proven constructed concept)	Not suitable for such a large deep span (no proven constructed concept)	Possible, but no proven concept for tidal inlet applications. In addition, considered a relatively complex system.	Suitable, proven concept at other similar location (Ramspol, NL).
	Flap Gate	Possible, as a series of flap gates, but not suitable for reverse head conditions and deemed too challenging from a maintenance perspective	Not suitable for reverse head conditions and deemed too challenging to construct in rock substrate.	Not suitable for reverse head conditions and deemed too challenging from a maintenance perspective	Possible, but deemed to challenging from a maintenance perspective as it relates to sediment built-up on the sill
	Barge Gate	Possible, however for such a large span there is no proven constructed concept	Not suitable for such a large span (no proven constructed concept)	Not suitable, deemed too challenging to operate under wave and current conditions	Suitable, proven concept.
	Miter Gate	Not suitable for such a large span or reverse head conditions	Not suitable for such a large span or reverse head conditions	Not suitable due to reverse head conditions	Not suitable for large reverse head conditions
	Vertical Lift Gate	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since the required air clearance would prohibitively increase gate costs	Not suitable since the required air clearance would prohibitively increase gate costs
	Vertical Rising Gate	Not suitable, deemed too challenging from a maintenance perspective and no proven concept for such a large gate span	Not suitable, deemed too challenging from a maintenance perspective and no proven concept for such a large gate span and too challenging to construct in rock substrate.	Possible, however deemed too challenging from a maintenance perspective Potential for sediment built-up as a result of the sediment transport for the Jamaica Bay Inlet	Possible, but deemed to challenging from a maintenance perspective as it relates to sediment built-up on the sill
	Tainter Gate	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since the required air clearance would prohibitively increase gate costs	Not suitable since the required air clearance would prohibitively increase gate costs

Table 4-3: Cursory Review of Hydraulic Gate Types for Application Within the Navigable Passages of the East Chester Creek, Flushing Creek, Newtown Creek, Gowanus Canal, Sheepshead Bay, and Gerritsen Creek Storm Surge Barriers

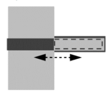
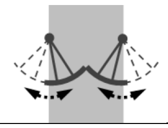
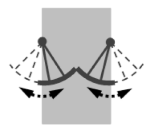
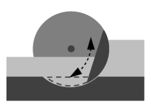
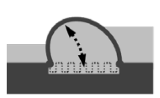
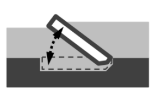
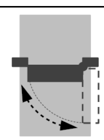
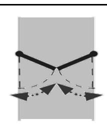
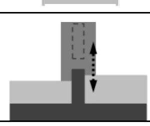
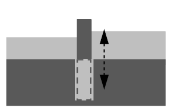
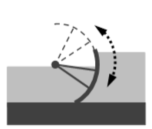
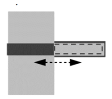
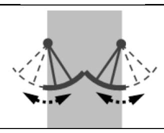
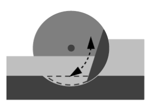
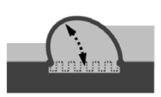
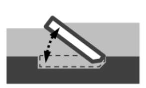
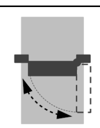
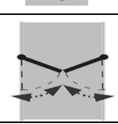
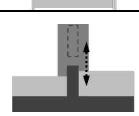
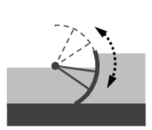
Image	GATE TYPE	East Chester Creek - Suitability for Main Navigation Gate	Flushing Creek - Suitability for Main Navigation Gate	Newtown Creek - Suitability for Main Navigation Gate	Gowanus Canal - Suitability for Main Navigation Gate	Sheepshead Bay - Suitability for Main Navigation Gate	Gerritsen Creek - Suitability for Main Navigation Gate
	Horizontal Rolling Gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate
	Sector Gate (Vertical Axis)	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.
	Floating Sector Gate	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.
	Rotating Segment Gate	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.
	Inflatable Gate or Dam	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.
	Flap Gate	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.
	Barge Gate	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.
	Miter Gate	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions
	Vertical Lift Gate	Not suitable since unrestricted air clearance is required.	suitable for those locations where the air clearance is restricted. Proven concept.	Not suitable since unrestricted air clearance is required.	Not suitable since unrestricted air clearance is required.	Not suitable since unrestricted air clearance is required.	suitable for those locations where the air clearance is restricted. Proven concept.
	Vertical Rising Gate	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.
	Tainter Gate	Not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs.	Not suitable since the required air clearance would prohibitively increase gate costs	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since unrestricted air clearance is required	Not suitable since the required air clearance would prohibitively increase gate costs

Table 4-4: Cursory Review of Hydraulic Gate Types for Application Within the Navigable Passages of the Port Washington, Hempstead Harbor, Hammond Creek, Highlands, and Raritan River Storm Surge Barriers

Image	GATE TYPE	Port Washington, Hempstead Harbor -, Hammond Creek, Suitability for Main Navigation Gate	Hempstead Harbor - Suitability for Main Navigation Gate	Hammond Creek - Suitability for Main Navigation Gate	Highlands - Suitability for Main Navigation Gate	Raritan River - Suitability for Main Navigation Gate
	Horizontal Rolling Gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate	Impractical due to area needed to dock the gate
	Sector Gate (Vertical Axis)	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.	Suitable, proven concept for similar span and sill elevation.
	Floating Sector Gate	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.
	Rotating Segment Gate	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.
	Inflatable Gate or Dam	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.	Possible, but generally deemed relatively expensive and complex system for a relatively small gate span.
	Flap Gate	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.	Not suitable, too complex, and likely cost prohibitive for relatively small gate spans.
	Barge Gate	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.	Generally, possible, but challenging to operate under wave and current conditions.
	Miter Gate	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions	Not suitable for large reverse head conditions
	Vertical Lift Gate	Not suitable since unrestricted air clearance is required.	Not suitable since unrestricted air clearance is required.	Not suitable since unrestricted air clearance is required.	Not suitable since unrestricted air clearance is required.	Not suitable since unrestricted air clearance is required.
	Vertical Rising Gate	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.	Generally assumed to be unsuitable, related to the challenges from a maintenance perspective.
	Tainter Gate	Not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs.	Not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs.	Not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs.	Not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs.	Not suitable since either unrestricted air clearance is required or the required air clearance would prohibitively increase gate costs.

5 Attachment 2: Cursory Review of Hydraulic Gate Types for Application Within the Auxiliary Flow Gate

The storm surge barriers will include auxiliary flow gates to minimize the impact on the water exchange through the opening in order to minimize impacts on the inner basin environmental conditions. Requirements for the dimensions for the auxiliary flow gates were established in and are summarized in the Storm Surge Barrier Appendix.

Following the requirements above and the information provided in the Storm Surge Barrier Appendix, a cursory evaluation of gate types and their suitability for both the navigable passage as well as the auxiliary flow gates has been completed for all storm surge barriers discussed herein.

A number of hydraulic gates are omitted from the table below as they are deemed unsuitable:

- The horizontal rolling gate and the sector gate (both floating and vertical axis) are impractical to function as auxiliary flow gate due to area needed to dock the gate,
- The barge gate is tot suitable and too complex of a system to operate and to be used for auxiliary flow,
- The miter gate is not suitable for reverse head conditions or operation during flow conditions,
- The flap gate, although potentially possible in some location, it is not suitable for reverse head conditions and in general is considered to be too challenging from a maintenance perspective and as such not selected for the conceptual design
- The vertical rising gate, similar to the flap gate, could potentially be utilized in some locations, but is in general considered to be relatively expensive and too complex a system to be used as auxiliary flow gate.

The evaluation of gate types for auxiliary flow is summarized in Table 5-1 and Table 5-2 below.

Table 5-1: Cursory Review of Hydraulic Gate Types for Use as Auxilary Flow Gates for all Storm Surge Barriers

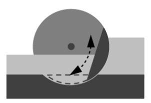
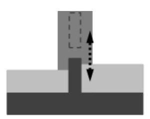
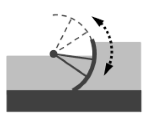
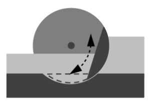
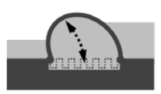
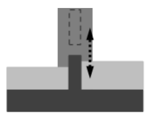
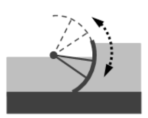
Image	GATE TYPE	Verrazano - Suitability for Auxiliary Flow Gates	Throgs Neck - Suitability for Auxiliary Flow Gates	Arthur Kill - Suitability for Auxiliary Flow Gates	Outer Harbor - Suitability for Auxiliary Flow Gates	Kill van Kull - Suitability for Auxiliary Flow Gates	Jamaica Bay - Suitability for Auxiliary Flow Gates	Hackensack - Suitability for Auxiliary Flow Gates
	Rotating Segment Gate	Not suitable, no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system. No proven concept for water depths exceeding of 30ft.	Not suitable, no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system. No proven concept for water depths exceeding of 30ft.	Possible, but deemed relatively expensive and complex system for relatively small auxiliary flow gate	Not suitable, deemed relatively expensive and too complex a system to operate in open ocean wave conditions	Not suitable, no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	Possible, but deemed relatively expensive and complex system	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system
	Inflatable Gate or Dam	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location	Possible, but deemed relative complex system for such a relatively small gate.	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for tidal inlet applications. Furthermore, deemed relatively complex system.	Suitable, proven concept for tidally influenced river application (albeit one constructed project).
	Vertical Lift Gate	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept
	Tainter Gate	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated

Table 5-2: Cursory Review of Hydraulic Gate Types for Use as Auxilary Flow Gates for all Storm Surge Barriers

Image	GATE TYPE	East Chester Creek - Suitability for Auxiliary Flow Gate	Flushing Creek - Suitability for Auxiliary Flow Gate	Sheepshead Bay - Suitability for Auxiliary Flow Gate	Gerritsen Creek - Suitability for Auxiliary Flow Gate	Port Washington - Suitability for Auxiliary Flow Gate	Highlands - Suitability for Auxiliary Flow Gate	Raritan River - Suitability for Auxiliary Flow Gate
	Rotating Segment Gate	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system	Possible, but no need for unrestricted air clearance, furthermore, deemed relatively expensive and too complex system
	Inflatable Gate or Dam	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location	Possible, but no proven concept for the depths at this location
	Vertical Lift Gate	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept	Suitable, proven concept
	Tainter Gate	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated	Suitable, proven concept, however reverse head conditions will need to be investigated