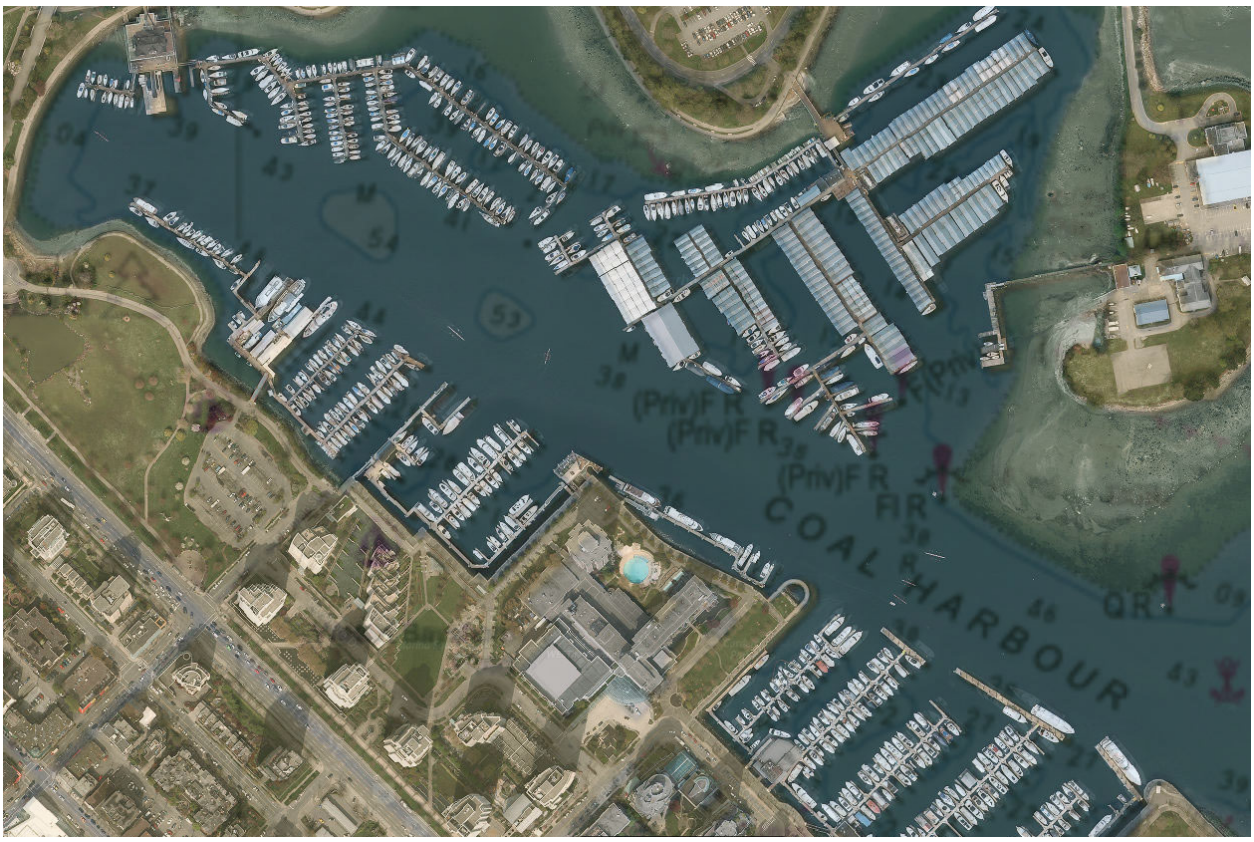
ROYAL VANCOUVER YACHT CLUB

PROPOSED EXPANSION PROJECT



NAVIGATION CHANNEL DESIGN

COAL HARBOUR

Prepared for: Royal Vancouver Yacht Club
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COAL HARBOUR

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1. Introduction

Coal Harbour, a portion of Burrard Inlet is home to hundreds of vessels, several marinas, a float plane base, a floating helicopter terminal and a rowing club. The Royal Vancouver Yacht Club (RVYC) has been located in Coal Harbour since 1903 and is currently the largest marina in the immediate area. RVYC currently has 326 berths and is proposing to expand its marina towards the navigable water in Coal Harbour.

To ensure the proposed expansion plans do not interfere with navigation and/or use of the Coal Harbour waterway, RVYC contracted TyPlan Consulting Ltd. (TyPlan) to conduct a navigation review. The Vancouver Fraser Port Authority (port authority) has administration and navigation jurisdiction of Coal Harbour and has advised Typlan that part of the navigation review should include updating the Coal Harbour navigation channel design to reflect the most recent national and international channel design guidelines. In addition, the port authority recommends guidelines for rowing lanes be considered in concert with the navigation channel design to ensure continued rowing use within Coal Harbour.

As such, TyPlan and port authority worked together to re-design the Coal Harbour navigation channel. This report reflects this work and provides recommendations for the alignment and horizontal dimensions of a navigation channel based on the 2014 PIANC "Harbour Approach Channels - Design Guidelines" and the 2010 FISA "Guidelines for Rowing". Both guidelines represent industry standards.

The initial Coal Harbour navigation channel was developed using the 1997 PIANC "Harbour Approach Channels - Design Guidelines" by TyPlan. It is proposed the results of the channel design work undertaken as part of this assessment supersede the TyPlan channel design for Coal Harbour undertaken as part of the Coal Harbour Master Plan (2012), Appendix A of the application.

2. Channel Design General

As mentioned above, the Coal Harbour channel design is based on the following two international guidelines:

- PIANC – Harbour Approach Channels – Design Guidelines
- FISA – Rowing Lane Guidelines

The design comprises information for the following categories:

- Vessel Particulars
- Physical Aspects
- Environmental Factors
- Rowing Lanes

3. Vessel Particulars

3.1 Design Vessel

The required width of a navigation channel fairway is conveniently expressed as a multiple of the width of the beam of the design (control) vessel. The identification of a design vessel is critical and essential for detailed channel design. By definition, the design vessel represents:

> *"The largest vessel capable of navigating the channel today and in the near future taking into consideration the vessels vertical clearance, beam, length, weight, capacity and frequency of transits"*

TyPlan undertook a detailed site/field survey of Coal Harbour on September 4, 2011. The field study was augmented with discussions from representatives of RVYC in an effort to identify the largest vessel frequently operating in the harbour. Based on this work, it was determined that "Harbour Cruises and Events" operate three of the larger vessels which regularly transit the Coal Harbour waterway.

Further to the field study and discussions with RVYC, TyPlan via discussions with the Harbour Master from Harbour Cruises who confirmed the vessels operated by Harbour Cruises were indeed the largest vessels utilizing the navigation channel in Coal Harbour.

The three largest vessels operating in Coal Harbour have been identified as: "MPV Constitution", "MV Harbour Princess" and the "Britannia". All three vessels are operated by Harbour Cruises whose operations are located within the Bayshore Marina at the foot of Denman Street. The vessel characteristics are outlined below:

Table 1: Large Vessel Identification

Vessel Name	Length (m)	Beam (m)	Draft (m)
MPV Constitution	23.84	7.24	1.79
Harbour Princess	26.46	7.92	2.29
MV Britannia	38.50	9.66	2.50

The design of a two-way navigation channel for vessels operating in small recreational approach channels such as Coal Harbour, must account for two-way traffic of the 2nd largest vessel as it is impossible for the largest vessel to meet itself. However, the largest vessel must also be evaluated to ensure it is able to use the channel in a one lane situation. For Coal Harbour, the design vessels for both one-lane and two-lane channels are shown below:

Table 2: Design Vessel				
Channel Type	**Vessel Name**	**Length (m)**	**Beam (m)**	**Draft (m)**
One-Lane	MV Britannia	38.50	9.66	2.50
Two-Lane	Harbour Princess	26.46	7.92	2.29

3.2 Vessel Manoeuvrability

Canadian Coast Guard guidelines for design of navigation channels state:

> *"the manoeuvring lane is the width required to allow for the oscillating track produced by the combination of sway and yaw of the vessel. The oscillation is partly due to forces acting on a moving vessel, such as directional instability and response to rudder action, and the human response to course deviations."*

According to PIANC Guidelines, the basic manoeuvring lane (defined as W BM) is measured as a multiple of vessel beam (width) and varies depending on the manoeuvring characteristics of the design vessel. Rating options include poor, good or excellent manoeuvrability.

The rating associated with vessel manoeuvrability of the design vessel (Harbour Princess) for Coal Harbour navigational channel is deemed to be "excellent" due to the handling nature of this particular vessel and in part due to the nature of recreational vessels in general, which are designed with manoeuvrability in mind.

Given the design vessel is deemed to have "Excellent" manoeuvrability and that Coal Harbour is located within a "protected waterway", a factor of 2.6 times the beam of the control vessel is applied to the Vessel Manoeuvrability portion of the Coal Harbour design for a two-lane channel.

The Vessel Manoeuvrability rating of "Excellent" results in additional channel width of 20.6 m.

Table 3: Vessel Manoeuvrability			
Item	**Rating**	**Factor**	**Width (m)**
Vessel Manoeuvrability	Excellent	2.6	20.6

According to PIANC, vessel manoeuvrability is also impacted by other factors such as vessel, speed, wind, currents, waves and other site-specific attributes which are explored in the following sections.

3.3 Vessel Speed

The speed of vessel transits utilizing the Coal Harbour channel is deemed to be "Slow", ranging from 5 to 8 knots. This is based primarily on conversations with users, general observations made from TyPlan's field survey and AIS recordings.

According to PIANC Guidelines, vessels transiting 8 knots or less are considered “Slow” and therefore a factor of 0.0 is applied to the Vessel Speed portion of the Coal Harbour design for a two-lane channel.

The Vessel Speed rating of “Low” results in additional channel width of 0.0 m.

Table 4: Vessel Speed			
Item	**Rating**	**Factor**	**Width (m)**
Vessel Speed	Slow	0.0	0.0

3.4 Cargo Hazard

From an environmental perspective, the channel design process should consider the vessel cargo as part of the evaluation with the final design providing a channel width that makes the likelihood of a grounding or interaction a rare event.

There are no known cargo vessels utilizing the Coal Harbour channel on a regular basis and as such a rating of "Low" is applied to the Cargo hazard portion of the Coal Harbour design for a two-lane channel.

The Cargo Hazard rating of “Low” results in additional channel width of 0.0 m.

Table 5: Cargo Hazard			
Item	**Rating**	**Factor**	**Width (m)**
Cargo Hazard	Low	0.0	0.0

3.5 Traffic Density

Although there can be several vessels navigating simultaneously within the Coal Harbour channel, there is very little chance of 2 or more design vessels operating within the channel at the same time.

Channel design considers total usage and not just simultaneous uses. As such, this portion of the channel design incorporates the nature of harbour cruise vessels in Burrard Inlet where there is a very high chance that the design vessel will utilize the Coal Harbour channel several times throughout the day. Based on this, a rating of “Moderate” has been applied.

A Traffic Density rating of “Moderate” results in additional channel width of 0.0 m.

Table 5: Traffic Density			
Item	**Rating**	**Factor**	**Width (m)**
Traffic Density	Moderate	0.0	0.0

4. Physical Aspects

4.1 Depth / Draft Effects

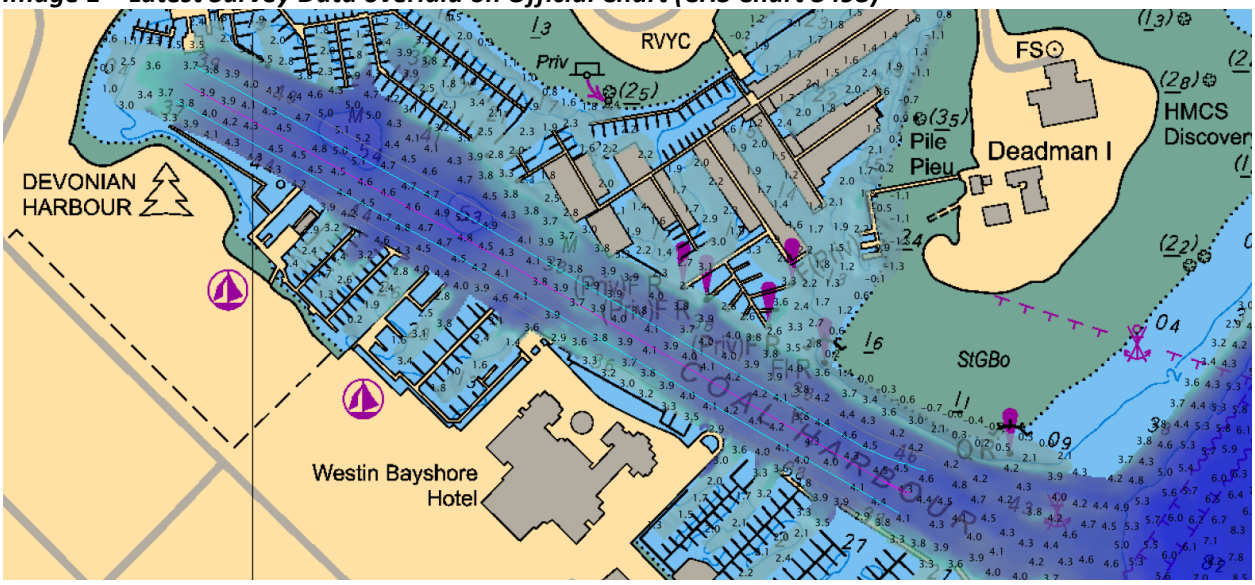
As part of the channel design process, the channel depth needs to be compared to the vessel draft in order to determine the under-keel clearance.

Sufficient channel depth is required to maintain vessel manoeuvrability. The closer the depth/draft ratio is to unity, the more directionally stable (difficult to alter course) the ship becomes. When minimum under-keel clearance is encountered, a vessel can be sluggish to respond. Therefore, the channel design accounts for this and the amount of under-keel clearance is directly related to vessel speed and current.

The channel depth is typically determined from official navigation charts or bathymetric information supplied from a competent authority. For the purposes of this report, the latest approved hydrographic survey data was overlaid on an official CHS chart and both data sets analyzed.

The bathymetric data and official navigation chart used for determining channel depth is shown in the image below:

Image 1 – Latest Survey Data overlaid on Official Chart (CHS Chart 3493)



The comprehensive depth analysis indicates a control depth of 3.7 m within the channel. The design vessel draft according to table 2 is 2.29 m. Therefore the depth is approximately 1.62 times the draft of the design vessel.

Given the depths within the Coal Harbour channel are greater than 1.5 times the draft of the design vessel, the Depth/Draft ratio is considered “Deep”. As such, a factor of 0.0 is applied to the Depth/Draft portion of the Coal Harbour design for a two-lane channel.

The Depth/Draft rating of “Deep” results in additional channel width of 0.0 m.

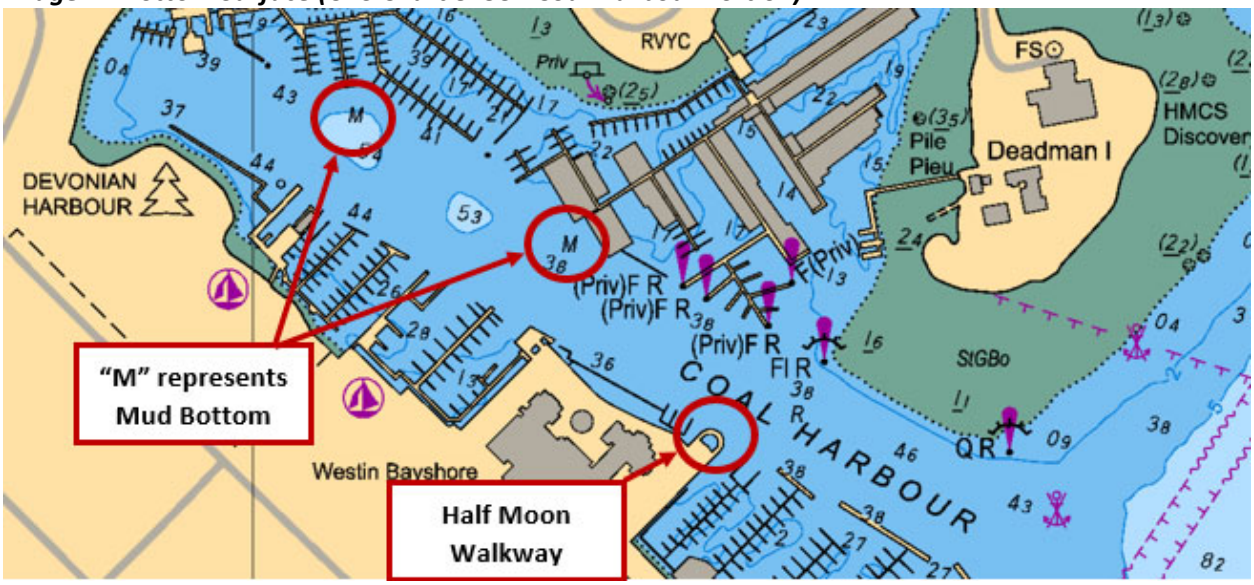
Table 6: Depth / Draught			
Item	**Rating**	**Factor**	**Width (m)**
Depth / Draft	Deep	0.0	0.0

4.2 Bottom Surface

The effect of bottom surface on channel width is really important in shallow waterways.

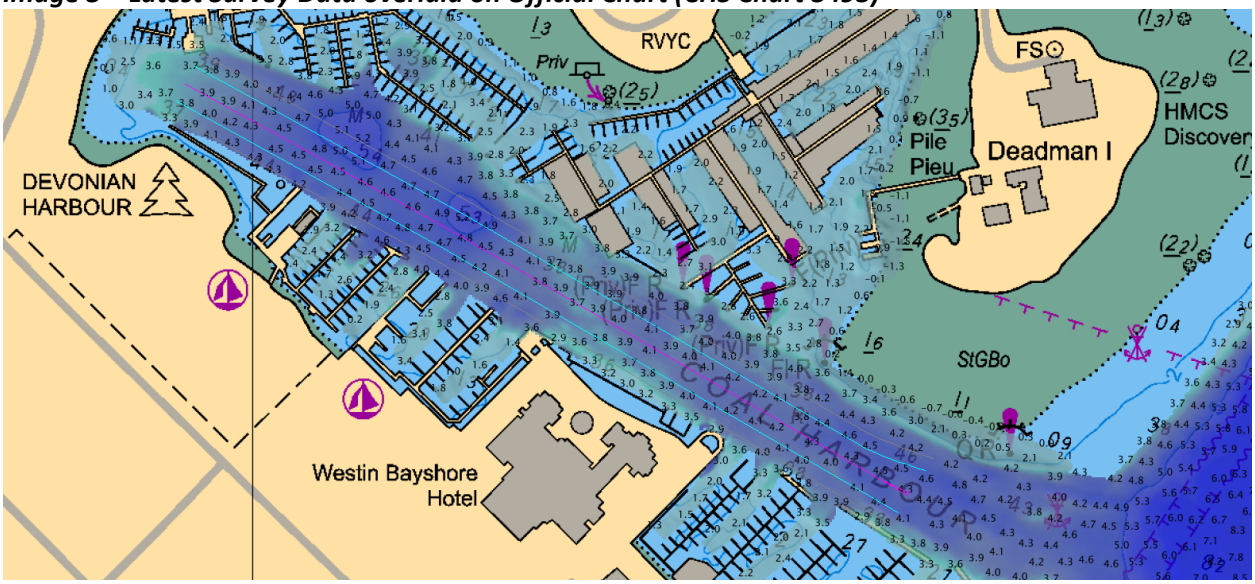
According to the Canadian Hydrographical Service Chart (CHS Chart 3493) the bathymetry indicates a relatively smooth bottom comprising of mud as shown by the letter "M" in the image below.

Image 2 - Bottom Surface (CHS Chart 3493 - Coal Harbour Portion)



Overlaying the latest hydrographic survey data onto the CHS chart, additional soundings are shown allowing a thorough analysis of the depths and slopes within the channel and adjacent areas. The image below clearly indicates a relatively flat bottom with little side slope at the channel edges.

Image 3 – Latest Survey Data overlaid on Official Chart (CHS Chart 3493)



In reference to the 2014 PIANC guidelines, a bottom surface rating of "smooth and soft" with a vessel speed less than 8 knots is applied.

The Bottom Surface rating of "Smooth and Soft" results in additional channel width of 0.0 m.

Table 7: Bottom Surface			
Item	**Rating**	**Factor**	**Width (m)**
Bottom Surface	Smooth and Soft	0.0	0.0

4.3 Bank Suction Effect

When a vessel moves through water, the water is displaced at the bow and transported around the hull to fill the void behind the stern. This produces lateral pressure on the hull which is balanced on either side of the vessel when proceeding in an open waterway or on the centre-line of a symmetrical channel.

When the vessel is operating off channel centre-line, the forces are asymmetrical resulting in a yawing moment. This effect is called bank suction and increases directly with the distance the sailing line is from the channel centre-line. The steeper the banks, the greater the effect.

Although the navigational channel for Coal Harbour is located in an area surrounded by shoreline, the navigation channel itself is away from any natural steep banks providing a very gentle side slope at both edges of the navigation channel.

Evaluation of recent bathymetry indicates Coal Harbour has a fairly flat bottom with generally less than 1v:20h slopes except for one small location at a pile structure at the half moon walkway near entrance to Coal Harbour and directly opposite of the east end of RVYC – see image 2 and 3 above.

Based on the bathymetric analysis, the bank suction effect is rated "low" which results in no additional channel width on either side of the channel.

Table 8: Bank Suction Effect			
Item	**Rating**	**Factor**	**Width (m)**
Bank Suction - Left	Low	0.0	0.0
Bank Suction - Right	Low	0.0	0.0

4.4 Aids to Navigation

The determination of the navigational aids requirements is generally based on the complexity of the channel and the optimum number of navigational aids provided along its length.

Navigation aids requirements should be determined concurrently with the channel design process.

Navigational aids provide guidance to mariner and lighted aids are extremely important, particularly at night or during times of poor visibility.

Coal Harbour is well charted and is monitored by Canadian Coast Guard's Marine Communication and Traffic Services (MCTS) via radar and AIS.

In addition, there are Government and private navigation aids that are visible upon approach/departure.

The Coal Harbour area is well lit with backlighting from local marinas as well as the City of Vancouver itself.

Aids to Navigation in Coal Harbour are deemed to be good in which a factor of 0.4 is applied.

An Aids to Navigation rating of "Good" results in additional channel width of 3.2 m.

Table 9: Aids To Navigation			
Item	**Rating**	**Factor**	**Width (m)**
Aids to Navigation	Good	0.4	3.2

5. Environmental Factors

5.1 Cross Winds

The force of wind on a vessel's hull produces two effects: a sideways drift and a turning moment. The former is overcome by steering a course to counteract it, and the latter is overcome by applying a certain amount of helm. Counteracting the drift will induce vessel yaw; this requires a widening of the channel.

The degree to which wind affects a vessel depends on the relative direction of the wind, the ratio of wind speed to vessel speed, the depth to draught ratio and whether the vessel is loaded or in ballast.

Cross wind can cause the ship to drift sideways or take up an angle of leeway. Both of these result in the need to increases the channel width to ensure sufficient vessel manoeuvring room.

Cross winds affect vessel manoeuvrability at all speeds but have the greatest effect at low speeds. Given Coal Harbour is in sheltered waters, cross winds are minimal and seldom reach 15 knots in any direction – see wind rose information below.

Image 3 – Wind Rose – Vancouver Harbour

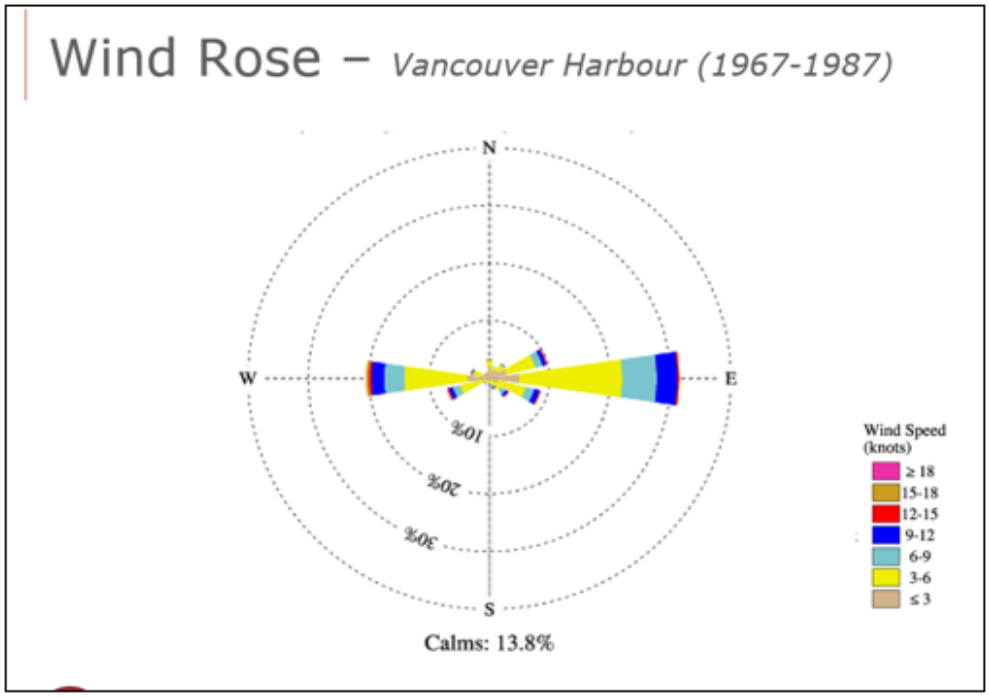
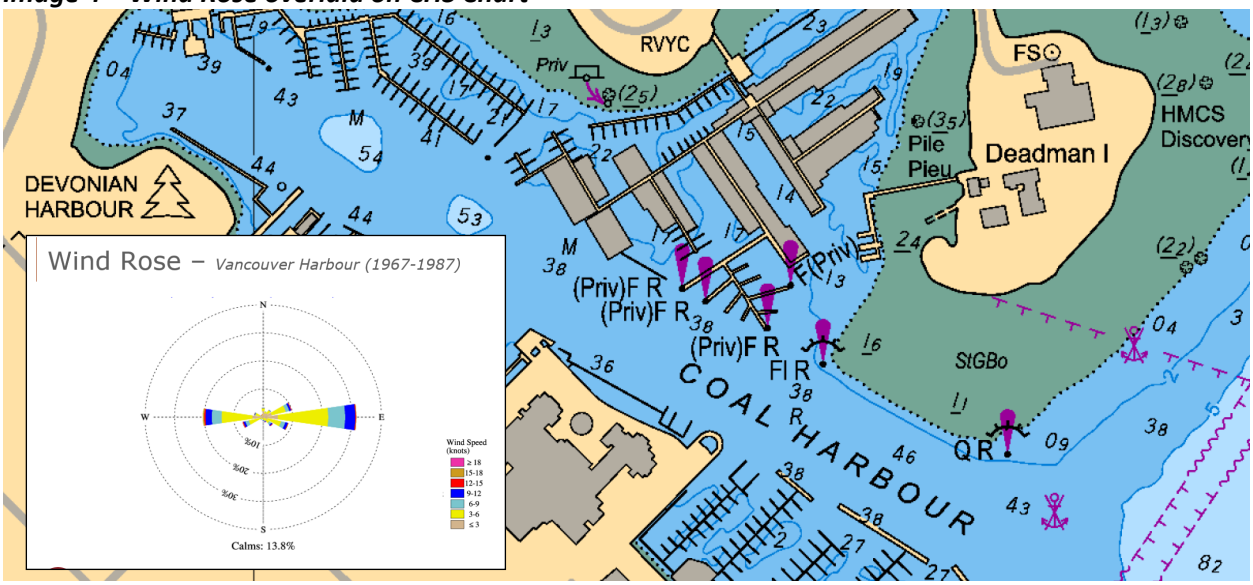


Image 4 below overlays the wind rose on the CHS chart and confirms cross winds are less than 15 knots, which results in a cross wind rating of mild.

Image 4 – Wind Rose overlaid on CHS Chart



Given the slow speed of vessels transiting and the mild cross wind in Coal Harbour, a rating of “Mild" has been applied to the “Cross Wind” portion of the Coal Harbour design for a two-lane channel.

The Cross Wind rating of “Mild” results in additional channel width of 4.75 m.

Table 10: Cross Wind			
Item	**Rating**	**Factor**	**Width (m)**
Cross Wind	Mild	0.6	4.75

5.2 Cross Current

Cross currents affect a ship’s ability to maintain a course in a similar fashion as wind which is described in the section above.

That is to say that the force of current on a vessel’s hull produces the same two effects as wind which is a sideways drift and a turning moment. The former is overcome by steering a course to counteract it, and the latter is overcome by applying a certain amount of helm.

Counteracting the drift will induce vessel yaw; this requires a widening of the channel.

The degree to which current affects a vessel depends on:

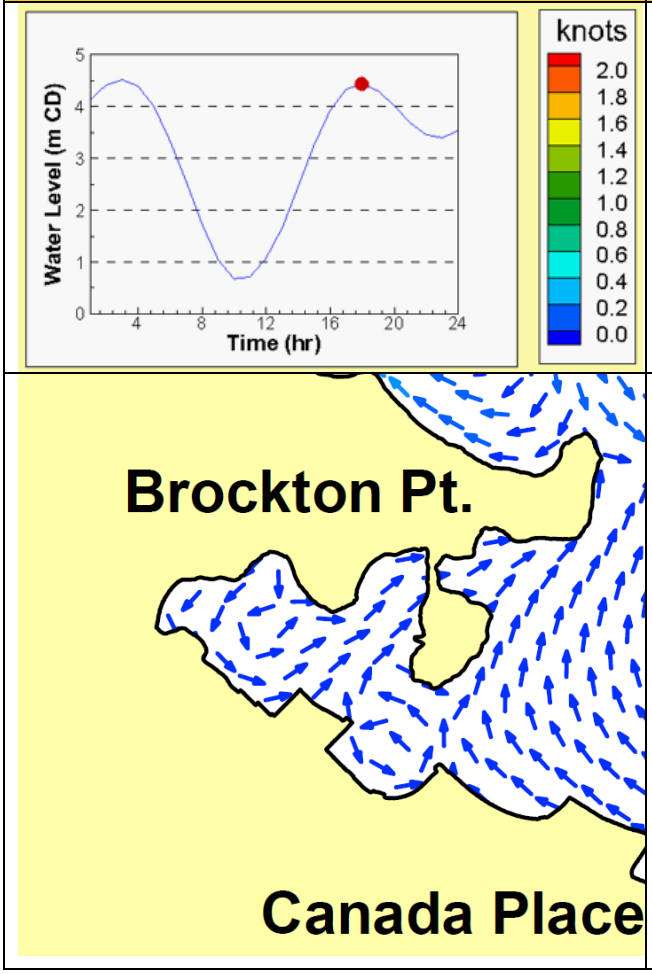
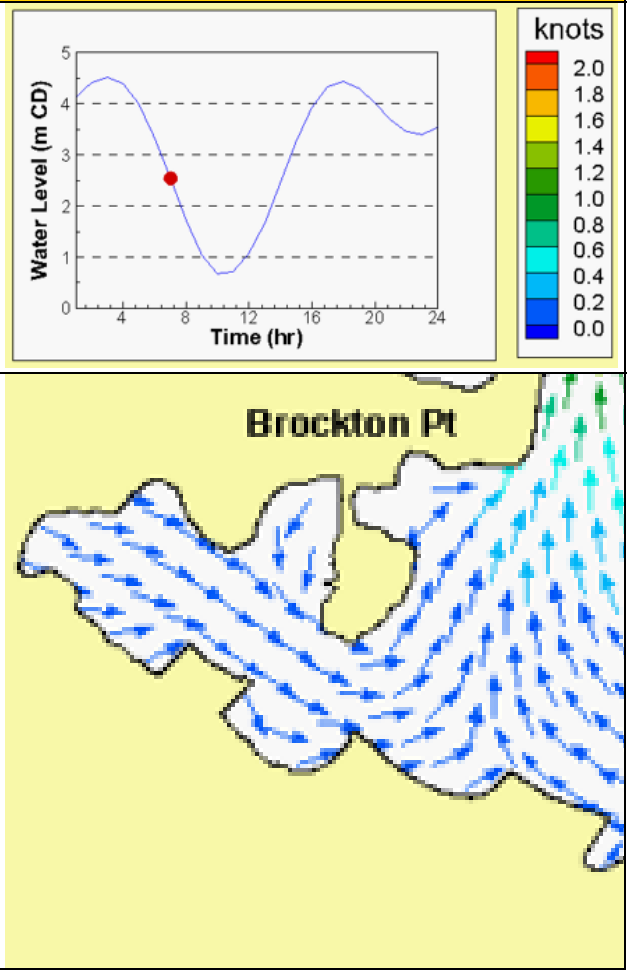
- the relative direction and strength of the current
- the ratio of current speed to vessel speed
- the depth to draught ratio
- and whether the vessel is loaded or in ballast.

Cross current can cause the ship to drift sideways or take up an angle of leeway. Both of these result in the need to increases the channel width to ensure sufficient vessel manoeuvring room.

Cross currents affect vessel manoeuvrability at all speeds but have the greatest effect at low speeds.

The table below shows the current direction and strength for slack water and when the current is running the strongest.

Table 11 – Currents – Coal Harbour

Tide – Slack Water	Tide – Strong Ebb
	

Little, if any, cross current exists in Coal Harbour and as such, a "Negligible" cross current factor (less than 0.2 knots) has been applied.

The Cross Current rating of "Negligible" results in additional channel width of 0.0 m.

Table 12: Cross Current			
Item	**Rating**	**Factor**	**Width (m)**
Cross Current	Negligible	0.0	0.00

5.3 Longitudinal Current

The prevailing longitudinal current is also shown in table 11 above.

Based on the table above and additional current atlas information, the result of the analysis indicates a rating of "Low" should be applied to the Longitudinal Current portion of the Coal Harbour channel design.

The Longitudinal Current rating of "Low" results in additional channel width of 0.0 m.

Table 13: Longitudinal Current			
Item	**Rating**	**Factor**	**Width (m)**
Longitudinal Current	Low	0.0	0.00

5.4 Waves

The wave height and length within the sheltered Coal Harbour channel are rarely a concern for the design vessel.

Given the wave height in Coal Harbour is generally less than 1m, a rating of low is assigned.

A Wave rating of "Low" results in no additional channel width required.

Table 14: Waves			
Item	**Rating**	**Factor**	**Width (m)**
Waves	Low	0.0	0.00

6. Rowing Lanes

Port of Vancouver requires rowing lanes be included in the Coal Harbour channel design. Section 3.2.1 of the 2010 FISA "Guidelines for Rowing" recommends rowing lanes be 13.5 m wide.

As such, two rowing lanes of 13.5 m wide are included this proposed design.

Table 15: Rowing Lanes	
Item	**Width (m)**
Rowing Lane 1	13.5
Rowing Lane 2	13.5
Total – Rowing Lanes	**27.0**

7. Design Summary – Two-Way Traffic and Rowing Lanes

The table below provides a summary of the Coal Harbour horizontal channel design recommendations for two-way traffic of the design vessel

Table 16: Summary				
Design Vessel	**LOA**	**Beam**	**Draught**	
MV Britannia	38.50	9.66	2.50	
Harbour Princess	26.46	7.92	2.29	
Category	**Item**	**Rating**	**Beam Factor**	**Width (m)**
Vessel Particulars	Vessel Manoeuvrability	Excellent	2.6	20.6
	Vessel Speed	Slow	0.0	0.0
	Cargo Hazard	Low	0.0	0.0
Physical Aspects	Depth / Draught Effect	Deep	0.0	0.0
	Bottom Surface	Smooth & Soft	0.0	0.0
	Bank Suction Effect	Low	0.0	0.0
	Aids to Navigation	Good	0.4	3.2
Environmental Factors	Cross Wind	Mild	0.6	4.7
	Cross Current	Negligible	0.0	0.0
	Longitudinal Current	low	0.0	0.0
	Waves	low	0.0	0.0
Vessel Traffic Scheme	Two-Way Traffic	Two	1.0	7.9

	Traffic Density	Moderate	0.0	0.0
Sub-Total			**4.6**	**36.4**
Rowing Lanes	Rowing Lane 1	FISA 2011	1.7	13.5
	Rowing Lane 2	FISA 2011	1.7	13.5
Total			**8.0**	**63.4**

Based on the 2014 PIANC "Harbour Approach Channels - Design Guidelines" and the 2010 FISA "Guidelines for Rowing" the proposed channel width for the Coal Harbour channel is 63.4 m.

8. Channel Design – One-Lane Traffic

The channel design above is based on two-lane traffic of the control vessel as described in the Design Vessel Section above.

The largest vessel must also be evaluated to ensure it is able to use the channel in a one lane situation. In addition, the final design needs to consider if there is adequate room to accommodate marine construction equipment such as rigs with pile driving equipment, clamshell dredges and miscellaneous flat and bottom-dump scows.

For Coal Habour, it has been calculated that the proposed channel design can accommodate one-lane traffic for vessels up to 18.2 m beam. This more than accommodates the largest vessel identified in Coal harbour as well as the majority of marine construction equipment.

9.0 Channel Design – Overlaid on 2015 Orthophoto

Upon completion of the Coal Harbour channel design process, the navigation channel was drafted in AutoCAD and best alignment was determined based on channel depth, existing property lines, lease boundaries and appropriate offsets from various structures and objects.

The proposed Coal Harbour navigation channel is shown in the image below.

Image 5 – Proposed Coal Harbour Navigation Channel