Ship Navigation Study of Changes to Federal Deep-Draft Navigation Channels due to the Interstate 5 Columbia River Crossing Replacement Bridge

Study Performed for
Columbia River Crossing Commission
State of Oregon Department of Transportation
and
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by
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1 Introduction

1.1 Project Background

Interstate Highway I-5 crosses the Columbia River and the Oregon Slough connecting Washington and Oregon states and Portland and Vancouver with intermediate connections to Hayden Island. This highway is congested with road traffic and the bridge creates a navigation challenge to the marine traffic passing under the bridge. When the water level limits the air draft for vessels passing under the bridge, a vessel must pass through the lift span causing disruption and congestion to the road traffic. In order to avoid disruption of the highway traffic crossing the I-5 Bridge, tow barge navigation channels were authorized two and three spans south of the primary navigation channel with the lift span. The “Barge Channel” is the widest of the two barge channels and is two spans south of the primary navigation channel with the centerline of the Barge Channel 655 ft (203m) off the centerline of the primary channel. This barge channel is the widest at 300 ft (91.4m) in a bridge span of approximately 530 ft (91m) and has the lowest vertical clearance of the two barge channels from the water surface to the lowest point on the bridge. The “Alternate Barge Channel”, which according to the official Corps of Engineers engineering drawings has no connection to the other channels on the downstream side of the I-5 Bridge, is three spans south of the primary navigation channel, making the centerline of this channel 1080 ft (325m) south of the primary navigation channel centerline. This alternate barge channel has the highest vertical clearance of all the three navigation channels and is the smallest channel at only 200 ft (61m) width in a bridge span approximately 300 ft (82m) wide. To use this span downbound barge tows must move toward the Oregon side of the river from the barge channel or primary channel in a distance of approximately 1 nm and then cross back to the Washington side of the river the same distance in 4550 ft, respectively, to align and pass through the 150-ft wide (45.7m) center swing span of the Burlington Northern Santa Fe Railroad (BNSF RR) Bridge. This creates a critical maneuver, especially for downbound tows being pushed downstream by the currents in the Columbia River; the seriousness of this maneuver being a function of the river discharge.

The I-5 Bridge is aging and congested with highway traffic. Therefore, a replacement bridge has been proposed which is called the Columbia River Crossing (CRC). The proposed bridge will be located downstream of the present I-5 bridge and the placement of the piers will not be in alignment with the existing I-5 piers (Figure 1). Rather than having a lift span that would disrupt vehicular traffic, as the existing bridge does now, the new bridge will be constructed to a maximum height of 116 ft relative to 0.0 on the Columbia River vertical datum gauge (0 CRD). This design will allow the navigation channels to be more in alignment with the narrow railroad swing span bridge downstream. The bridge will not be replaced under the Hobbs Act as a navigation hazard but as a replacement of an old, outdated congested bridge with highway funding.

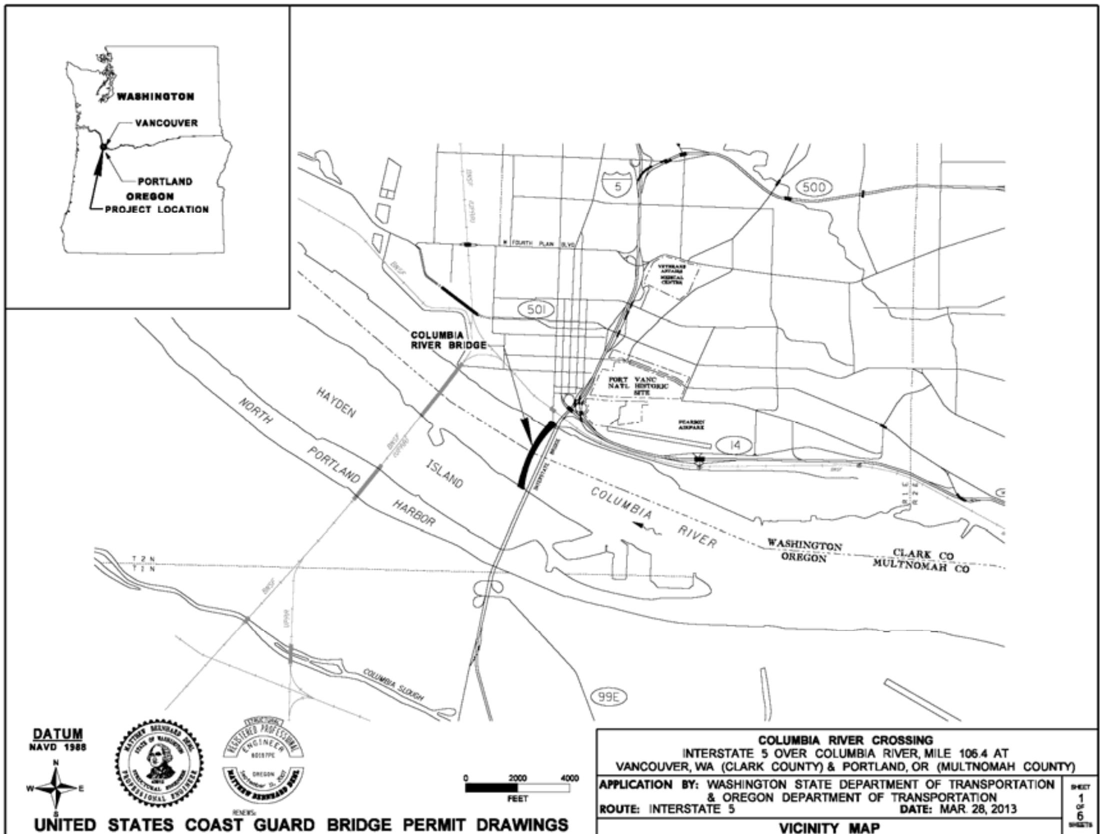


Figure 1: Site Map for CRC (New bridge location shown)

1.2 Existing Federal Navigation Projects

Passing under the existing I-5 Bridge are four authorized waterway projects (Figure 2) that have been constructed and are maintained by the U.S. Army Engineers (USAE) Portland District with short range aids to navigation placed and maintained by the U.S. Coast Guard. These projects are:

- Vancouver to the Port of The Dalles (VPOTD) Deep-Draft Navigation Channel authorized to a depth of 27 ft below 0 Columbia River Datum (CRD) but presently maintained to only 17 ft, as indicated on USAE hydrographic survey charts. The passage of this channel under the I-5 bridge constitutes the "primary" span for tow/barge transits.
- The Upper Vancouver Turning Basin (UVTB) authorized to a depth of -35 ft below 0 ft CRD,
- The Barge Channel authorized to a depth of -15 ft and which begins at the upper end of the Vancouver Turning Basin and passes through the widest span between the I-5 piers then rejoins the Vancouver to the Port of The Dalles Deep-Draft Channel upstream at Ryan Point Junction and proceeds through the Bonneville Lock to the Port of The Dalles. There shallow-draft navigation continues throughout rest of the Columbia and Snake Navigation System,
- The Alternate Barge Channel authorized to a depth of -15 ft begins at the western edge of the Vancouver Turning Basin, passes between the piers of the highest span of the I-5 Bridge, widens immediately upstream and merges with both the Vancouver - Port of The Dalles Deep-Draft Channel and the Barge Channel at Ryan Point Junction.

Currently no deep-draft navigation uses the UVTB or the VPOTD; although sea-going barges do call on the Lafarge Terminal just above the BNSF RR Bridge.

1.3 Past Project Documentation

A search for past documentation on the general design and authorization of these navigation projects was not been fruitful and little is known about the basis of the deep-draft navigation projects dimensions and layouts. Furthermore, no historical documentation was located that defines the basis of the two barge channels and their relation to the I-5 bridge.

2 Simulation Requirements

Engineering Manuals 1110-2-1643 and 1110-2-1611 require that all proposed modifications to a new or authorized federal navigation channel be modeled for the final design, either with a physical model or ship and/or tow maneuvering model study, to assure safe and efficient navigation. Engineering Regulation 1110-2-1403 regulates this modeling. The proposed bridge design and the intervening construction of the new bridge while the existing bridge remains in place will have an impact on navigation. The purpose of the ship/tow maneuvering simulation study being described herein was to determine if construction of the proposed CRC will cause significant navigation impacts and whether these impacts will be beneficial or detrimental to navigation and, if detrimental, to recommend mitigation.

2.1 Deep-Draft Simulation Conditions

The vessel simulation study for the replacement of the Interstate 5 highway bridge consists of two phases: 1) deep-draft ship tests and 2) tow/barge tests. The present report focuses on the first phase with tests for prospective ship navigation in the USAE authorized deep-draft channel proposed for the post-replacement bridge project. The CRC and its planning and design are administered by the Oregon Department of Transportation.

With the replacement of the I-5 bridge, vertical clearances will be greater and the highway lift will be eliminated. Since no deep-draft vessels pass under the I-5 bridge presently, deep-draft simulation tests for this study phase were conducted only in the proposed channel configuration focusing on the UVTB and the VPOTD channel. For tow/tug vessels there will be an interim phase of navigation during which time both the existing I-5 bridge and the new bridge will be in place. The proposed configuration of the authorized channels is shown in Figure 3. In the proposed condition the VPOTD channel will take the path of the Main Channel shown in the figure. The Barge Channel and the Alternate Barge Channel will switch positions compared to the original naming before bridge replacement – they will serve as alternative paths for tow/tug traffic as navigation conditions require.

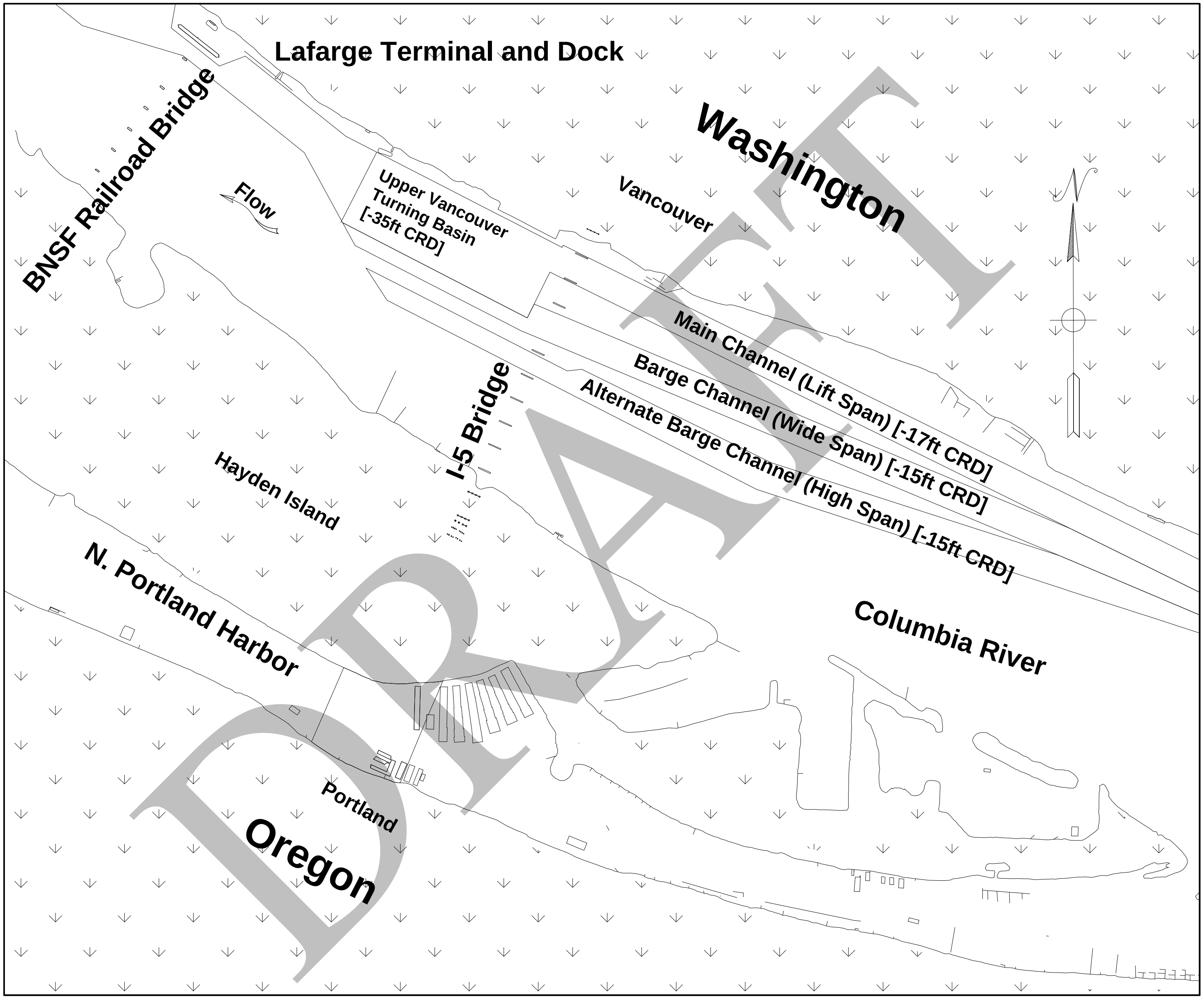


Figure 2: Existing Channel Configuration for Study Area

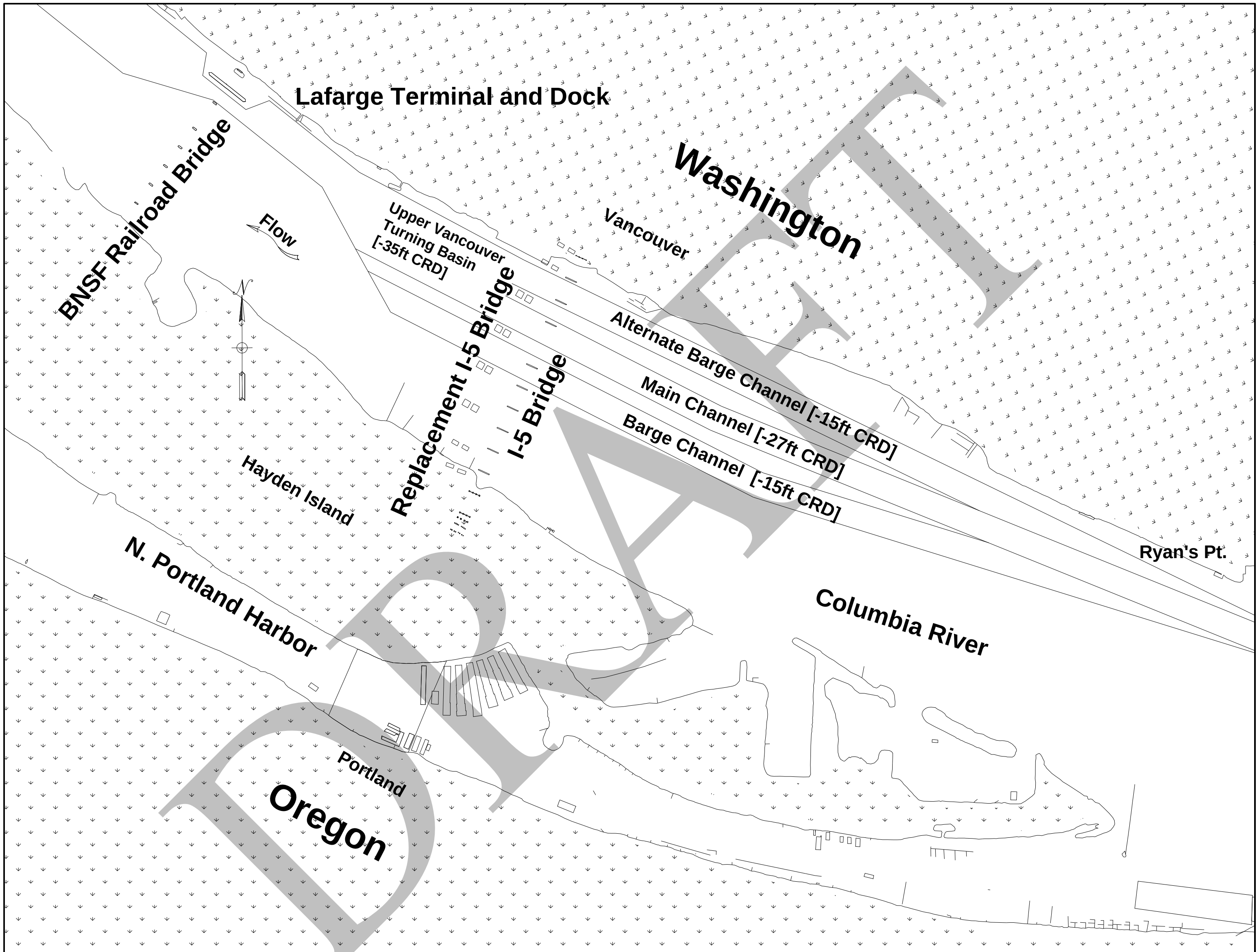


Figure 3: Proposed Channel Configuration with Replacement Bridge (Existing Bridge for Comparison)

2.2 Navigation Study Elements

In order to perform ship/tow maneuvering simulation studies, a number of database elements must be defined. These elements are discussed below including vessel hydrodynamic models, specification of environmental conditions and an organized test program.

2.3 Navigation Channel Characteristics

The dimensions, layout, and dredged characteristics of the navigation project(s) must be defined in uniform coordinate and datum systems. The Corps of Engineers provided project definition and layout in an engineering drawing with coordinate points in one of the state planar coordinate systems and depths were provided from hydrographic surveys relative to a defined vertical datum. Authorized side slopes of dredged portions of the project channel were defined where applicable to properly account for bank effects on vessels although generally the CRC study area river bottom was relatively deep and, therefore, overbank depths were large, thus making bank effects minimal. River bottom depths entered into the simulation model databases were from the hydrodynamic model data provided by HDR[1].

2.4 Design Vessels

The marine equipment using the study reach of the Columbia River is varied and subject to changes with river, weather, and economic factors. However, the marine traffic is almost exclusively shallow-draft barges being pushed by towboats or tugs. All the navigation projects were authorized prior to the availability of simulation technology and records of the basis on which these navigation channel designs were developed and authorized were not located. Therefore, a special effort was made to evaluate the ongoing present use of the navigation projects by existing commercial shipping interests and operators and to obtain insight into potential future uses of these projects without consideration of any further project improvements such as deepening, widening and straightening. These efforts were performed by telephone interviews, mailed out questionnaires, and follow-up telephone or in-person interviews and are documented in another report. The resulting recommendations for the deep-draft design vessels to be used in evaluating the potential impacts of the CRC bridge and construction are presented in this section.

Presently no existing deep-draft traffic passes above the BNSF RR Bridge other than the ocean going barge traffic that services the Lafarge Terminal immediately above the BNSF bridge and those barges do not make use of the UVTB.

[redacted] The Upper Vancouver Turning Basin

The best that can be determined, the UVTB was designed for the Port of Vancouver (POV) for the use of the port's Terminal 1. The POV had requested that the UVTB have the dimensions of 800 ft by 2,000 ft. with a depth of 30 ft. The Corps of Engineers determined that the depth was only justified at a depth of 28 ft but apparently accepted the horizontal dimensions requested by the POV.

[1] HDR report on hydrodynamic modeling Need to get reference

2.4.1.1.1 Definition of the Upper Vancouver Turning Basin Project

No specific definition of the UVTB in terms of coordinates and dimensions was located or provided prior to the simulation study other than an interim report[2] which recommended dimensions of 800 ft by 2,000 ft by 35 ft deep. Drawings of the navigation project hydrographic surveys indicated project extent as shown in dark shading in Figure 4 since the survey depths within this area are less that 35 ft (which appears to be the project depth according to the note in the upper right corner designating the change from a 35-foot project to a 27-foot project presently being maintained at 17 feet) and deeper than the barge channel projects maintained at 17 ft. It appears from a rough scaling that the UVTB dimensions are about 800 ft wide and approximately 2,250 ft long.

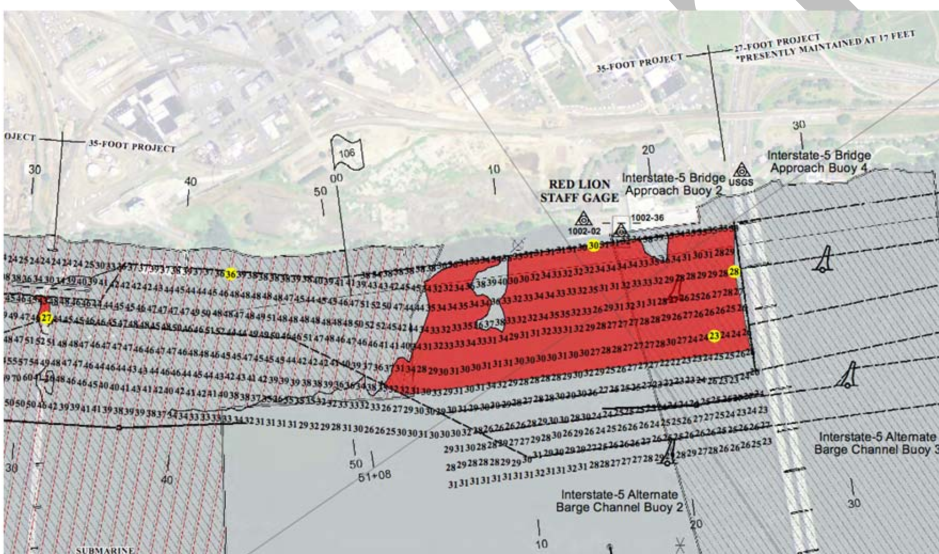


Figure 4: Hydrographic Survey Sheet CL_29_VTB_20130311 Dated 11 March 2013

Following a request by Columbia River Crossing (CRC) the Corps of Engineers sent the figure shown in Figure 5. This seems to show the UVTB downstream of the present I-5 Bridge about 250 ft; although it is still not specifically identified; identification was made by measurement of the 2000ft by 800 ft.

[2] Interim Report on Portion of Columbia and Lower Willamette Rivers Project, Oregon and Washington, between Interstate Bridge at Vancouver, Washington, and Mouth of Willamette River, 8 April 1959.

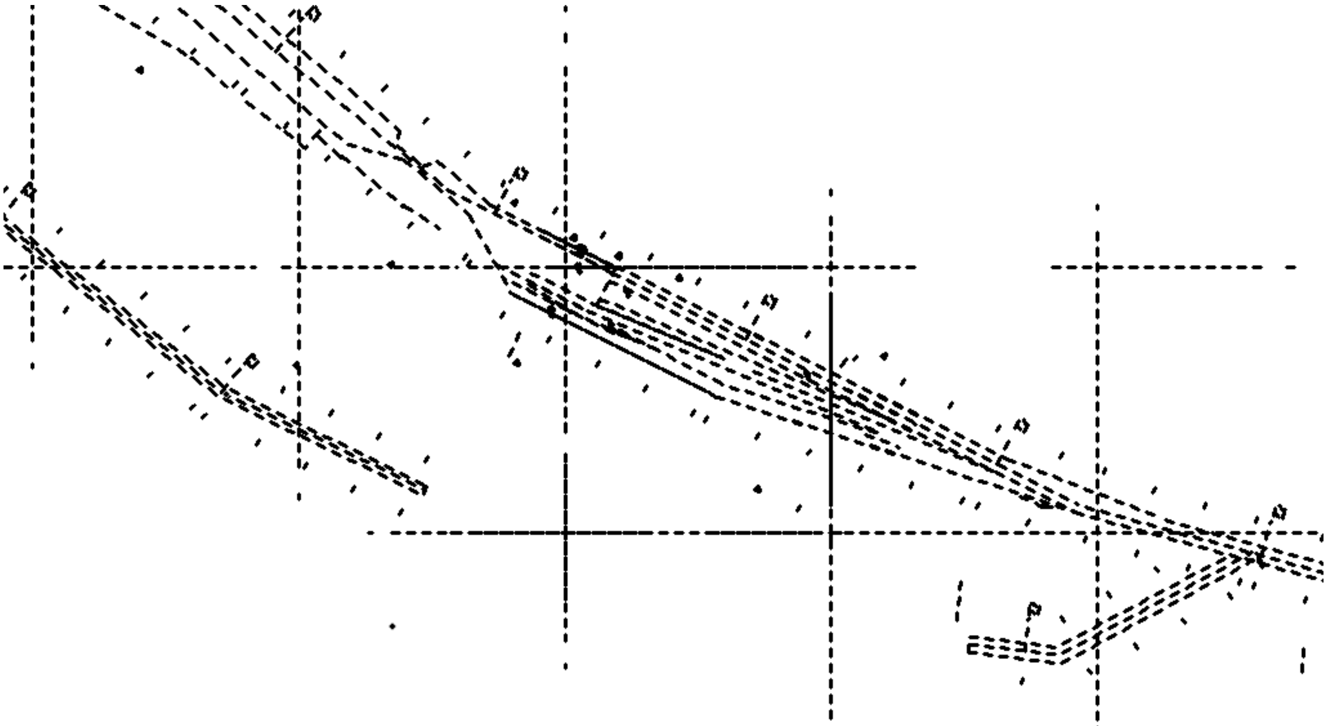


Figure 5. Corps of Engineers, Portland District, Drawing of Project in CRC Project Area

A document located by CRC, Figure 6, showed the UVTB located downstream from the I-5 Bridge apparently ending at the beginning of the taper to the navigation channel approaching the BNSF Railroad Bridge.

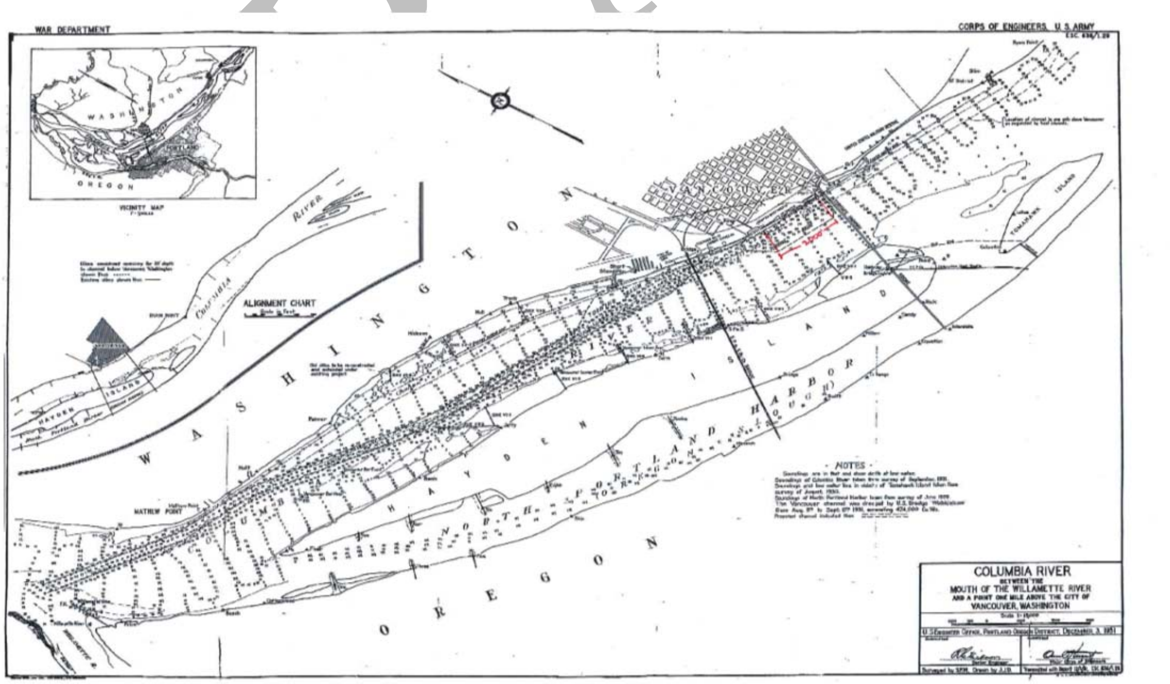


Figure 6. Portland District Hydrographic Chart Dated December 3, 1931

This lead to the speculation that the CRC I-5 Bridge replacement project will only effect the UVTB by reducing its length by 200 ft, see Figure 7.

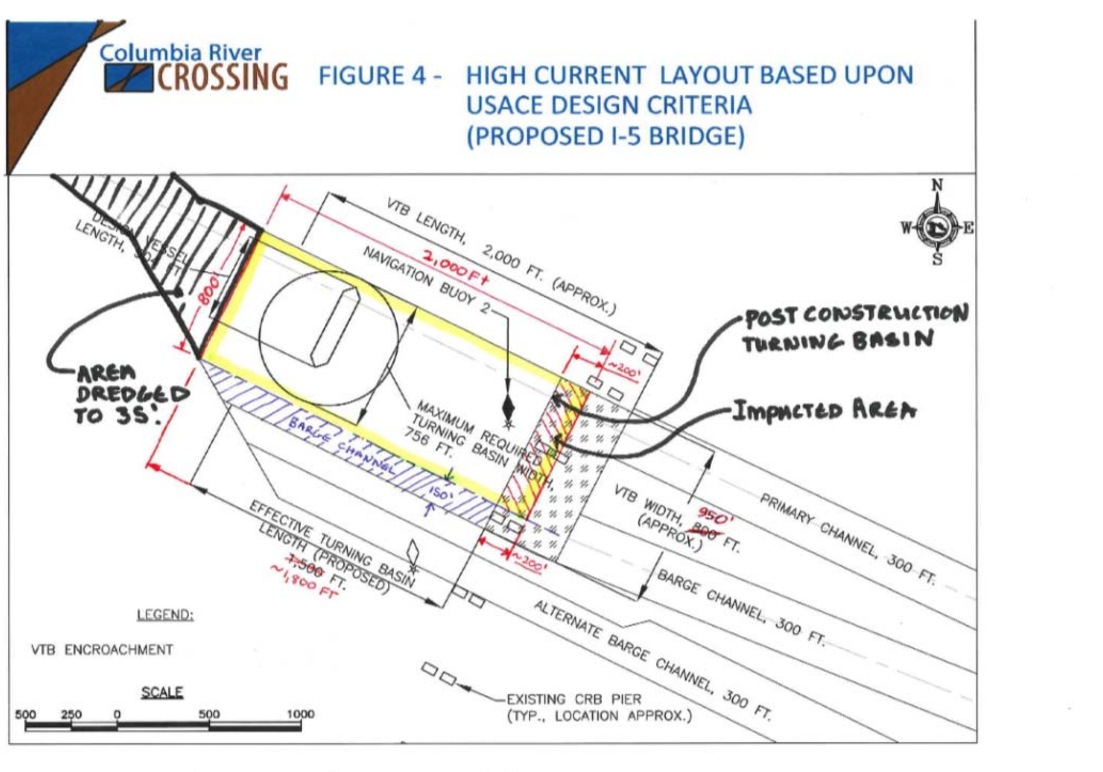


Figure 7: High Current Layout Based Upon USACE Design Criteria (Proposed I-5 Bridge)

In an attempt to obtain guidance on the channel projects layout for the conduct of the ship simulation study, WST requested guidance on the design of the navigation project channel layouts for the Post-CRC Project condition. Figure 3 above shows the final layout of the post-project navigation projects as agreed upon by the Corps of Engineers and CRC.

[redacted] The Upper Vancouver Turning Basin Traffic and Design Vessel

The traffic used as the design basis for future expected UVTB traffic in the interim report referred to above[2] is shown in Table 1. The Bulk carrier is the largest ship and would most likely be the design ship for the project. However, the design analysis, Appendix A[3], used the T-2 tanker (jumbo) as the design ship; dismissing the larger Bulk carrier requiring widths greater than the recommended and later approved 500 ft width. This width was based on the same criteria as in Engineering Manual 1110-2-1613 (1983) for vessels with good controllability in a straight channel for a maneuvering lane of 180 percent of the ships beam; however, the criteria used required a full beam width separation between ships rather than the 80 percent beam width required in the 1983 EM. Assuming that the T-2 tanker (jumbo) was expected to call at POV Terminal 1, the design criteria for the UVTB would be 1.4 the ship's length. The same EM

[3] Columbia River Crossing, Interstate 5 Columbia River Crossing – DRAFT – Proposed Ship Simulation including Design Vessels and Test Methodology, May 2013.

calls for turning basin widths of 1.2 times the ship's beam for channels having currents less than 0.5 knots and 1.5 times the beam for channels with currents up to 1.5 knots.

Table 1. Expected Future Traffic for the Columbia River Project

Draft (feet)	Steamers and motor vessels							
	1950	1951	1952	1953	1954	1955	1956	1957
32			2				2	3
31	1	2	3	2		2	9	18
30	2	10	23	13	13	15	14	22
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Based on interviews with personnel at Lafarge, the only terminal within the service area of the UVTB, they have plans to expand the terminal and storage facilities to accommodate Handymax bulk carriers. These ships have a capacity of 32,000 DWT and similar ships call at the Glacier Terminal on the Willamette. The Columbia River Pilots provided a log file of the vessels calling at this terminal for reference to the size of these ships. The listing of ships of this size calling at the Glacier Terminal is given in Table 2. The ships ranged in length overall (LOA) from 555 ft to 590 ft with the majority of the ships in the range of 580-590 ft LOA. The range of ship's beams (B) in this table was between 89 ft to 96 ft with an average of about 93 ft. This gives a LOA/B of 6.2. The sizes of these ships were larger than the design ship (T-2 Jumbo); 590 ft > 572 ft and 96 ft > 75 ft. These dimensions made the LOA-to-turning-basin-width ratio 1.36; compared to the design criterion ratio of 1.5. Therefore, this required a ship simulation to confirm that this turning basin would provide sufficient room to turn a ship of this length.

The shipping operation described by Lafarge was for the ship to enter through the BNSF bridge loaded and immediately berth port-side-to for unloading. The ship would then proceed off the dock upstream to the UVTB, turn in the UVTB, align with the BNSF bridge navigation opening, and then proceed downstream through the BNSF bridge opening and maneuver to clear the grain terminal immediately below the BNSF bridge. Therefore, the only deep-draft design vessel identified prior to the simulation study with interest in the UVTB reach was the ballasted Handymax bulk carrier.

Research to identify a vessel in this class of ship resulted in identifying a design ship model that was slightly smaller but had a significant set of model and sea trial data to use in development of the ship simulation model. This ship was originally the *Oregon Voyager*, then *HVIDE Ambrose*, subsequently the *Seabulk Energy*. A ship model was specified for development that had a bulk carrier hull with a LOA of 580.56 ft, a beam of 101.68 ft, and a ballasted draft of 20 ft aft and 16 ft forward for a trim of 4 ft. This ship was slightly wider than the Handymax ships calling on the Glacier terminal but had a Panamax beam and would represent the largest ship possibly calling at the Lafarge terminal. The draft for the ballasted ship was decided in agreement with the Columbia River Pilots as being representative of the ballasted draft of these size ships.

Table 2. Vessels Calling on the Glacier Terminal, Willamette River, OR.

FromBerth	TimeFinish	TimeAway	ToBerth	VesselName	VesselType	Length	Beam	MaxDraft	MouDep	GroRegTon	Draft
GLACR	27-Jul-12	26-Jul-12	WLOGB	PACIFIC LOGGER	BULK	580.08	96.58	0.00	44.00	19717	19.33
GLACR	14-Aug-12	13-Aug-12	LGV A	CLEARWATER BAY	BULK	557.83	88.58	0.00	46.58	18465	19.42
GLACR	27-Aug-12	27-Aug-12	KA EL	MOLAT	BULK	564.25	88.58	31.33	44.58	17928	20.33
GLACR	06-Jan-12	06-Jan-12	GLACR	LUZON STRAIT	BULK	575.89	96.46	31.39	44.95	19796	19.69
GLACR	28-Nov-12	27-Nov-12	SEA	TIMARU STAR	BULK	575.89	96.46	31.39	44.95	19779	19.75
GLACR	06-Jan-12	06-Jan-12	WLOGB	LUZON STRAIT	BULK	575.89	96.46	31.39	44.95	19796	18.83
GLACR	18-Oct-12	17-Oct-12	SEA	CAPE MORETON	BULK	590.25	93.33	33.50	46.25	20987	20.58
GLACR	24-Feb-12	24-Feb-12	ASTAN	SUN RUBY	BULK	580.67	93.17	32.87	46.75	19887	21.33
GLACR	16-Jan-13	15-Jan-13	WLOGA	MOUNT RAINIER	BULK	580.67	93.18	0.00	0.00	19887	19.17
GLACR	03-May-12	03-May-12	SEA	BLACK FOREST	BULK	580.71	93.18	32.87	46.75	19887	20.90
GLACR	12-Jun-12	11-Jun-12	VAN L	SANTIAGO BASIN	BULK	590.22	93.35	0.00	46.29	20987	20.50
GLACR	23-Sep-12	22-Sep-12	SEA	SILVER LAKE	BULK	590.22	93.31	0.00	46.26	20987	29.00
GLACR	06-Apr-13	06-Apr-13	SEA	CAPE NELSON	BULK	557.75	88.58	32.08	45.25	17433	18.92
GLACR	28-Mar-13	27-Mar-13	SEA	ORIENT HOPE	BULK	575.79	96.46	0.00	44.95	19828	19.67
GLACR	27-Oct-12	27-Oct-12	SEA	PORT PEGASUS	BULK	580.71	93.18	32.87	46.75	19887	20.08
GLACR	01-Mar-13	01-Mar-13	SEA	GLOBAL AQUARIUS	BULK	555.68	89.36	0.00	44.62	17021	29.00
GLACR	06-Jul-12	06-Jul-12	BULK	PORT PHILLIP	BULK	590.22	93.31	0.00	46.26	20418	22.58
GLACR	27-Feb-13	26-Feb-13	SEA	GOLD RIVER	BULK	580.67	93.17	32.83	46.75	19872	21.00
GLACR	15-Apr-12	15-Apr-12	BULK	RIVERTEC	BULK	590.22	93.18	0.00	46.26	20763	20.33

TimeFinish	TimeAway	ToBerth	FromBerth	VesselName	Length	Beam	MaxDraft	MouDep	GroRegTon	Draft
18-Nov-12	18-Nov-12	GLACR	LS	TIMARU STAR	575.89	96.46	31.39	44.95	19779	32.00
27-Jun-12	26-Jun-12	GLACR	LS	PORT PHILLIP	590.22	93.31	0.00	46.26	20418	33.92
06-Jan-12	06-Jan-12	GLACR	GLACR	LUZON STRAIT	575.89	96.46	31.39	44.95	19796	19.69
15-Feb-12	15-Feb-12	GLACR	LS	SUN RUBY	580.67	93.17	32.87	46.75	19887	33.00
20-Jul-12	20-Jul-12	GLACR	LS	PACIFIC LOGGER	580.08	96.58	0.00	44.00	19717	32.00
21-Aug-12	21-Aug-12	GLACR	LS	MOLAT	564.25	88.58	31.33	44.58	17928	32.33
09-Aug-12	08-Aug-12	GLACR	LS	CLEARWATER BAY	557.83	88.58	0.00	46.58	18465	27.25
29-Apr-13	29-Apr-13	GLACR	LS	ENGLISH BAY	580.67	93.18	32.87	46.75	19925	33.17
20-Oct-12	20-Oct-12	GLACR	LS	PORT PEGASUS	580.71	93.18	32.87	46.75	19887	31.75
27-Feb-13	26-Feb-13	GLACR	LS	GLOBAL AQUARIUS	555.68	89.36	0.00	44.62	17021	32.25
07-Apr-12	07-Apr-12	GLACR	LS	RIVERTEC	590.22	93.18	0.00	46.26	20763	33.33
08-Jan-13	08-Jan-13	GLACR	LS	MOUNT RAINIER	580.67	93.18	0.00	0.00	19887	33.42
10-Oct-12	09-Oct-12	GLACR	LS	CAPE MORETON	590.25	93.33	33.50	46.25	20987	33.08
19-Feb-13	19-Feb-13	GLACR	LS	GOLD RIVER	580.67	93.17	32.83	46.75	19872	33.25
04-Jun-12	03-Jun-12	GLACR	LS	SANTIAGO BASIN	590.22	93.35	0.00	46.29	20987	33.83
04-Apr-13	03-Apr-13	GLACR	LS	CAPE NELSON	557.75	88.58	32.08	45.25	17433	19.42
27-Apr-12	27-Apr-12	GLACR	LS	BLACK FOREST	580.71	93.18	32.87	46.75	19887	30.12
21-Sep-12	20-Sep-12	GLACR	LS	SILVER LAKE	590.22	93.31	0.00	46.26	20987	34.25
18-Mar-13	18-Mar-13	GLACR	LS	ORIENT HOPE	575.79	96.46	0.00	44.95	19828	31.92

Since the ships will always be departing the Lafarge terminal in ballast and will turn in that condition in the UVTB, the ship simulations to be performed for the study to define the impact of relocating the I-5 Highway Bridge (CRC Project) downstream of the present I-5 Bridge were conducted with the ballasted bulk carrier. This was also in agreement with the preferred operations of the Columbia River Pilots who preferred to turn these ships while in the ballast condition rather than in the loaded condition because of the following reasons::

- The ship would be much lighter to move and hold with tugs while turning and keeping the ship from drifting downriver ,and
- The ship would have less draft and, therefore, more room within the channel to maneuver even if required go outside the official UVTB.

It was not anticipated that the ship would leave in a loaded condition and use the UVTB unless in an extreme emergency. In that event, it was considered more likely that the ship would be moved off the dock and backed down through the BNSF bridge with the assistance of tugs since there would be little time in an emergency to start and bring the engines up to working power. Upon consideration, this maneuver could be used by the pilots to move a ballasted ship downstream rather than upstream thereby avoiding the risk of the ship drifting downstream into the BNSF bridge; particularly with a loss of engine power and/or an assist tug. In discussions with the Columbia River Pilots, they expressed concern about a ship coming off the dock with a cold engine and the ship's engineer refusing to, or not being able to, give the ship full power when ordered; thus causing the ship, after being turned with tug assistance, to start downstream without sufficient speed, i.e., a speed in which the ship's rudders were fully effective.

It should be clearly noted that all ship turning operations in the UVTB were performed with tug assistance. The Columbia River Pilots stated that this would be a requirement for safety of operations. This was considered good practice particularly since a large ship was being turned between two heavily used bridges across a major river. Therefore, at least two tugs were made available to the pilots at their request and on their advice of tug power and type.

Summarizing, the ship modeled for use in testing the Vancouver Turning Basin Navigation Project is shown in Table 3.

Table 3: Ship Model for the Vancouver Turning Basin

Description	Existing Kongsberg Model	Methodology	Config. Drawing	Scope of Work
Small Tanker BALLASTED (580.56' x 101.68' x BALLAST DRAFT')	Tank12L (39' draft)	Modify Tank12L	N/A	Hydro: Modify Tank12L to BALLAST DRAFT
				Visual: Tank12L Modified

2.4.2.1 *Vancouver to the Port of The Dalles Navigation Channel*

For the 27-ft Vancouver to the Port of The Dalles navigation project, it was decided that the simulation study would focus on loaded and unloaded ships transiting both upbound and downbound. At the time of the study it was not known who would be demanding the ship traffic, where the ship traffic would be going to or coming from, and/or what the ship would be carrying. Therefore, it was impossible to predict if the ships using the 27-ft channel would be operating loaded inbound and in ballast outbound or vice versa. There was no basis for determining the ship traffic in the 27-ft project channel. However, it was planned to model the design vessel loaded in both directions of travel through the project reach and, also, in ballast conditions upbound and downbound to satisfy the requirements of determining if a ship using this channel would be positively or negatively impacted by the relocation and redesign of the I-5 Bridge.

During most of the investigation, no deep-draft shipping through the project reach that would or had used the 27-ft navigation channel was identified. During discussions with the Columbia River Pilots it was learned that in the 1980s and 1990s a few deep-draft ships had moved through the reach and the original Bonneville Lock to the Port of The Dalles. Pictures were obtained of one of these ships, the *Charles Wheeler*, and it was also learned that the historical portion of the Port of The Dalles internet web page also contained a picture. A subsequent interview with the Executive Director of the Port of The Dalles identified several other trial shipments and proposed operations that would use deep-draft vessels in the Vancouver to the Port of The Dalles waterway.

While an economic analysis of the region served by the Vancouver to the Port of The Dalles channel that would normally be conducted to justify a navigation channel improvement or rehabilitation was not performed in this study, there appeared to be only three locations that have the possibility for development of deep-water marine facilities due to limitations of available land with access to the Columbia River. This was partially due to restrictions on building within the Columbia River Gorge National Scenic Area that limit developments from Troutdale on the Oregon side and Washougal on the Washington side of the Columbia River upstream to beyond the end of the Vancouver to the Port of The Dalles Navigation Project. The three locations were the Columbia Business Center in Vancouver, Troutdale, OR, and Camas/Washougal, WA. Most of these sites are already in use with facilities that use the shallow-draft towing industry.

Development of a deep-draft navigation channel upstream of the Bonneville Locks and Dam would be restricted to a draft limit in the new locks due to the sill depth of 19 ft between the low pool elevation of 70 ft and sill elevation of 51 ft NGVD. Hydraulic testing with a physical model at the U.S. Army Corps of Engineers Waterways Experiment Station (WES) set this sill level for a vessel draft of 14 ft. In order to obtain a deeper draft to make more efficient use of a deep-draft vessel, the first lock chamber would need to be used. While it is not known if hydraulic tests were performed on the lock entrance and exit conditions of this lock chamber, using the guideline of a 5 ft required clearance (19-14=5), this chamber would allow a draft of 25 ft since the upper sill is at elevation 40 ft (70-40-5=25). However, at low water, the depth over the lower sill for this chamber is only 23 ft (low tail water = 7.0 ft, lower sill elevation = -16 ft for a water depth of only 23 ft). This would limit drafts when the tail water is low to only 18 ft. So the draft of ships proceeding upstream when the water is low below the Bonneville Locks and Dam would be limited to 18 ft. This would mean that an economical operation of a deep-draft ship would be limited to a relatively small ship by today's standards. It might be considered that a complete economic study to justify this project for deep-draft traffic could result in unfavorable conclusions.

In addition, it should be noted that during the testing and development of the Vancouver to the Port of The Dalles, special modifications were made to the lower approach channel to the Bonneville Lock, The design was based on a hydraulic model at WES in which a C2 ship model was used as the design vessel. The results of the evaluation of this model tested under a variety of conditions by the Columbia River Pilots was that they could only bring a ship up to 500 ft in length to the lock using tug assistance. This ship could not pass through the lock since the length of the lock chamber is only 500 ft.

Furthermore, the upper and lower lock approaches were modified significantly during the addition of the second lock chamber. Both approaches were realigned and bendway weirs were put in the upper approach to control the currents to improve safety and control of tows entering the locks. The upper elevation of the weirs nearest the lock are the highest and are at elevation 45 ft NVGD. With a 70 ft minimum pool elevation this would provide a water depth over these weirs of only 25 ft. Requiring a 2-ft minimum underkeel clearance would restrict ships to 23-ft draft; however, since this channel receives currents higher than normal channel currents, the under keel clearance requirements could restrict the draft to even more for upbound ships moving against the current; possibly an additional 2 ft to a maximum draft of 21 ft. Finally, it should be noted that no model testing has been done with a ship entering or exiting either of the lock chambers through the upper or lower approach channels; so the hydraulic conditions of such approaches must be given consideration prior to improving the channel for deep-draft vessels.

As a result of these discussions, it was recommended that a design vessel that would represent a potential deep-draft vessel that could use this waterway be included in the simulation testing program. The design vessel was a ship with dimensions of the largest vessels that the navigation project was designed to accommodate. There were several ways to decide on a design ship for this simulation maneuvering study. One would be to determine the ship that could pass through the deep-draft (initial) Bonneville Lock chamber.

Based on the limiting size of the vessel that could pass through the deep-draft lock at Bonneville (length of 500 ft, width of 76 ft, and sill depth of 23 ft, ignoring potential extra squat in the upper approach), a ship that was in the Kongsberg ship library and installed at the ERDC Ship/Tow Simulator was recommended as the design vessel for the Vancouver to the Port of The Dalles. This ship model, TANK15L, had a length overall of 440 ft, a beam of 75 ft and draft of 27 ft. Thus, this ship model would have to be narrowed in beam by a foot and the draft would have to be lowered by approximately 4 ft.

Not limiting the ship to requiring passage through the Bonneville Locks, a second way to determine the design ship without an historical record, a design memorandum or an economic study of the potential demand for the navigation channel, was to determine the ship beam based on engineering design guidance. Most pilots require channel width to be four times the vessel width, allowing for two times the vessel width for beam clearance between passing vessels. EM 1110-2-1613 details the Corps engineering guidance on this and other aspects. In addition, PIANC provides guidance on navigation channel width design. Using first the Corps design criteria, assuming two-way traffic of vessels with good control operating in water currents of up to 2.5 feet per second (fps) in shallow water channels, the width required would be 6 times the ship's beam. For a 300 ft wide channel, as this channel is, would be designed for a maximum ship beam of 50 ft. For higher currents, the ship beam would be limited to 37.5 ft or 1/8th the channel width. Using the PIANC design criteria, considering a ship of moderate maneuverability operating at moderate vessel speeds with moderate prevailing cross winds and current and moderate prevailing longitudinal currents and moderate aids to navigation with infrequent poor visibility and water depths greater and 1.5 times the draft and medium hazardous cargo, the channel width should be 3.6 times the ship's beam. Therefore, the design ship should have a beam of 83 ft.

Considering that a ship using this channel would have to also pass through the BNSF RR Bridge with a navigation channel width of 150 ft (based on the channel toelines of the Corps of Engineers Navigation Chart #18526 CL _29_VTB_20130311 and the NOAA navigation chart USOR_15M; see Appendix A), in a one-way traffic mode, the design guidance would suggest a ship beam limit of 30 ft by the Corps of Engineers and 57.6 ft by PIANC guidance. However, tows with a length of 650 ft length and 84 ft breadth pass through this bridge regularly. Therefore, it could be considered that a ship of similar size could do this also. However, towboats have more power and steering control than a ship and have less draft.

Finally, consider the ship used in the hydraulic tests of the last reach of this channel to be designed and constructed, the C2. These ships had a length of 459 ft, a beam of 63 ft, a depth of 40 ft, and a draft of 25 ft. These ship principle characteristics seem to be ideal for this channel based on the discussion above, particularly for passing through the first Bonneville Lock.

An analysis of ships calling at the Glacier Terminal provided by the Columbia River Pilots over the past year for which dimensions could be identified found that the ship's height (keel to top mast) ranged from 2.9 to 3.3 times the depth of the ship (deck to keel). In addition, the ship's molded depth to maximum draft had a ratio of 1.42 to 1.45. Present bulk carriers and tankers with a maximum draft of 27 ft will have a height of 117.5 ft (27*1.45*3). Considering a draft of 25 ft, the air draft will be 92.5 ft. Considering a maximum draft of 39.6 ft (Panamax), the air draft would be 147.3 ft (39.6*1.45*3-25). Therefore, the design ship for this channel should have a maximum draft of approximately 30 ft in order to provide a 2 ft clearance under the CRC Bridge (116-2+25)/1.45/3).

Thus, the design ship selected was a product tanker that would have a beam of approximately 75-85 ft and a maximum draft of approximately 25 ft. Kongsberg had models of a product carrier (ELLEN KNUTSEN) that has a length overall of 452 ft, beam of 75.5 ft, drafts loaded and ballasted of 29.5 ft and 16.4 ft, respectively, and air drafts of 99 ft and 111 ft, respectively. This ship was adjusted to have a 25 ft draft for testing the 27 ft navigation channel. The ship models used in the VPOTD Navigation Project are shown in Table 4.

Table 4: Ship Models the Vancouver to The Dalles Navigation Project

Product Tanker (452.64' x 75.44' x 25')	PRODC08B (16.4' Draft X 75.44' Beam) PRODC08L (29.5' Draft x 75.44' Beam) **PRODC08B = LOA 452': (19.35' Draft AFT, 13.45' Draft FWD X 75.44' Beam)** **PRODC08L = LOA 452': (25' Draft x 75.44' Beam)**	Modify PRODC08B/L	N/A	Hydro: Modify PRODC08B/L to Drafts (25' and 19.35'') Visual: PRODC08B/L

3 Study Purpose

The primary purpose of this study phase was to evaluate suitability of the UVTB and VPOTD for deep-draft ship navigation after bridge replacement. Despite the fact that, at present, no deep-draft vessels transit above the BNSF RR Bridge, it is anticipated that the two channel projects will remain authorized, thereby introducing the possibility of ships utilizing both after completion of the bridge replacement project. Therefore, the deep-draft ship tests were limited to testing of the proposed channel condition with the new I-5 Bridge constructed.

4 Study Approach

The primary study approach for the CRC deep-draft study was to conduct real-time simulation with Columbia River Pilots operating the simulator. ERDC, WST or the professional pilots served as helmsmen during the simulations. Two professional pilots conducted tests for the CRC deep-draft channels simulation study, which included tests for the UVTB and VPOTD. ERDC staff and engineers developed the visual scene and channel databases for the simulation. The current model data were obtained from steady-state numerical modeling developed by HDR, Inc. and ERDC and WST personnel formatted and implemented them in the simulator. A ship hydrodynamicist working with Kongsberg Maritime Simulation, Inc developed the ship models. Prior to study testing, the ship models were tested and calibrated by ERDC, Kongsberg and WST personnel based on the experience of Columbia River Pilots.

Analysis and reporting for the deep-draft CRC simulation study were accomplished through evaluation of trackplots and recorded data files of navigation parameters. Questionnaires eliciting pilot evaluations, ratings, comments and recommendations were completed after each run and at the end of the simulation week to summarize the pilot's experiences on the simulator. A list of the study attendees during the week of Dec 16-20, 2013 is shown below.

Study Participants and Attendants:

ERDC Representatives:

- Mr. Dennis Webb
- Mr. Gary Lynch
- Mr. Keith Martin
- Mr. Mario Sanchez
- Ms. Mary Allison

Columbia River Pilot Representatives:

- Captain Steve Dobbins
- Captain Darren Olsen

Waterway Simulation Technology (WST):

- Dr. Larry Daggett
- Mr. Chris Hewlett

HDR Representatives:

- Mr. Ron Mason
- Mr. Kyle Donovan

Kongsberg Maritime Simulation, Inc.

- Dr. Wei-yuan Hwang

Rodino, Inc.

- Mr. Tom Rodino

5 Simulation Study and Database

In general a simulation study requires development of several databases. The critical data are the visual scene with the channel definition (location, vertical and horizontal dimensions), current magnitude and direction and ship model files (including assist tugs). The visual databases usually provide input for a radar and ECDIS display on the bridge for use by the conning pilot. Other environmental factors such as wind and ambient visibility usually are more easily implemented and are normally handled operationally from a simulator instructor station. The specific details of the deep-draft simulation study for the CRC have been presented in the report introduction. The following sections discuss the databases and information required in relation to the simulation study.

5.1 Visuals

Three-dimensional graphic images of the river, terminals, aids to navigation, towns and various buildings, were constructed in the geographically correct locations. These shore structures and objects were included in the visual scene to a limited degree because the greatest effort for the CRC study was expended constructing the three bridges through which the pilots would steer the vessels. The three bridges were the BNSF railroad bridge, the existing I-5 bridge and the proposed CRC I-5 replacement bridge. For the deep-draft channel simulations tests were restricted to proposed channel conditions which included only the railroad and I-5 replacement bridges since no ships use the ACOE authorized deep-draft channels at present. All three bridges were to be used during the later shallow-draft simulation portion of the CRC study. Critical additional structures included in the visual scene were the Lafarge dock and shore-based terminal, the grain terminal on the north shore of the river below the BNSF bridge and navigation aids marking the UVTB and VTPOD. Realism was enhanced by including a replica of the *Cape Bird* docked at the Lafarge Terminal during the VTPOD tests – see Figure 10. Figure 11 shows the overhead view of the study area seen on the simulator's instructor station.

Figure 10: Visual Scene approaching BNSF Bridge downbound aboard *Sulphur Guardian*

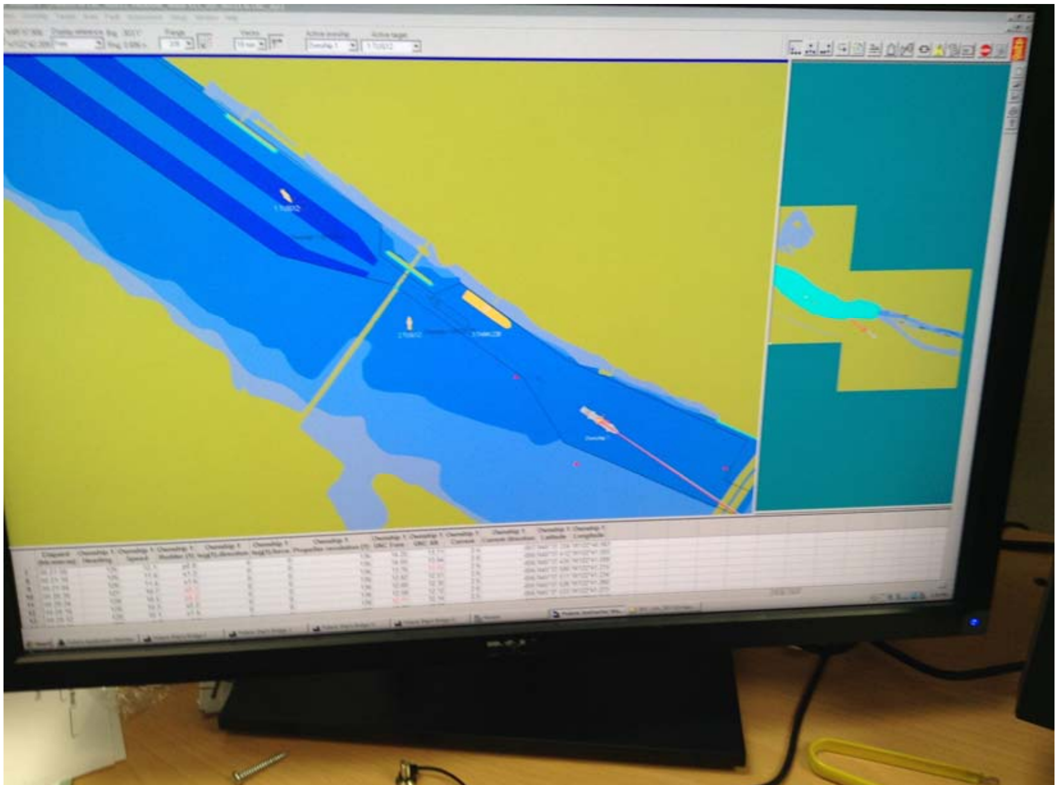


Figure 11: Instructor Station overhead View of UVTB Area

5.2 Channels

The various ACOE authorized channels were described in the Introduction report section. Figure 12 shows some of the specific channel dimensions for the proposed conditions after bridge replacement. The VPOTD is marked as the Main Channel in the figure. Because of the authorized depths the barge channels were not tested during the deep-draft tests but are the subject of the shallow-draft simulations phase of the CRC study reported in a separate report.[4] The clear span between the bridge piers will be 390 ft; however, the authorized toe-to-toe channel width will be 300 ft for the three channels above the bridge. The clear length of the VOTB as indicated in Figure 12 will be shortened in the proposed configuration because of the relative positions of the existing and replacement I-5 bridges (see Figure 3).

[4] INTERSTATE 5 COLUMBIA RIVER CROSSING – DRAFT Proposed Ship Simulation Study including Design Vessels and Test Methodology, May 2014

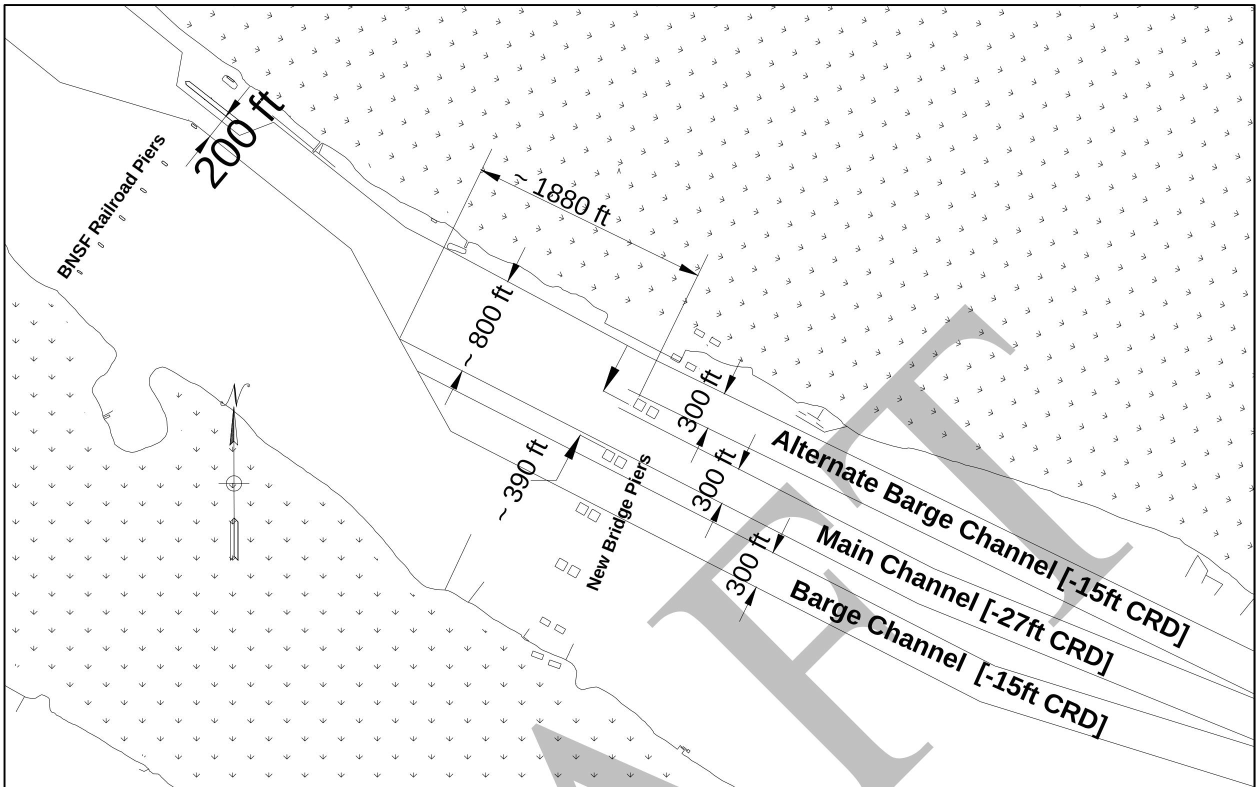


Figure 12: Layout and Dimensions for ACOE Authorized Channels in Study Area

5.3 Ships

The effort to decide on design ships for the UVTB and VPOTD was a difficult process, which is detailed in earlier report sections and in the proposal document[5]. Portions of this approved document are included in sections above. For the VPOTD one of the critical factors for ship dimensions concerned development of a ship model with realistic length and beam which also had an air-draft less than the vertical clearance of the main channel span under the new bridge. Additionally, the ship required a beam less than the width of the Bonneville lock upstream for the channel going to the Port of the Dalles. Based on these criteria the ship modeler settled on a draft-modified version of a small product carrier called *Sulphur Guardian* with dimensions 453ft LOA, 75ft beam and drafts of 19 and 25ft for ballasted and loaded conditions, respectively. The design ship decision for the -35ft UVTB was based on future operations anticipated at the Lafarge facility on the Washington side of the river adjacent to the BNSF railroad bridge (Figures 2 & 3). Since it was not intended for the UVTB design ship to be passing under the new CRC I-5 bridge, a larger ship was chosen than for the VPOTD channel – a bulker called the *Cape Bird* with dimensions of 580 ft LOA, 101ft beam and 20/33ft draft for ballasted and loaded conditions, respectively. Pilot cards for these design ships are included in Appendix B.

[5] Columbia River Crossing, Interstate 5 Columbia River Crossing – DRAFT – Proposed Ship Simulation including Design Vessels and Test Methodology, May 2013.

5.4 Environment

[redacted] Current

The primary factor in the deep-draft channel tests is the currents in the Columbia River. Primarily the currents are generated by the flows released at the Bonneville Dam upstream of the study area. While there is tidal influence in the study reach, the effect on river flows is minimal, i.e., there is no flow reversal or salinity intrusion. The primary effect is on water level and this was accounted for in adjusting vessel air-draft as necessary. Three flows were chosen for testing as presented in Table 6 (shown in thousand cubic feet per second). The river stages relative to the vertical datum of 0ft CRD (Columbia River Datum) are shown on the figure also. The transition flow was chosen to represent the threshold river stage approximately when tow captains reduce their tows from four barges to three or two barges. For study continuity the simulations for the ships used the same flows.

Currents modeled using the existing bathymetry within, above, and below the project area could be different from those that exist now if the 27-ft VPOTD is deepened. The effect of this deepening would be to possibly direct more flow through the deeper channel, thus altering the currents in that channel and in the barge channels. Since this would not be done until after the proposed CRC project is completed, the effects of these changes were dependent on which channel is declared the 27-ft deep channel. The middle channel (second span from the Washington shoreline) was selected as the Primary Channel and the 2-D hydrodynamic modeling was run with the dredged channel to compute the current strength and pattern for this condition. These currents were used in the deep-draft ship simulations.

For each of these discharges the current field throughout the project reach was generated using steady flow conditions with the U.S. Bureau of Reclamation’s Sediment and River Hydraulics - Two-Dimensional (SRH-2D) depth-averaged modeling software. Current data (magnitude and direction) from this model were integrated into the ship simulator and generated forces on the ships transiting through the simulated project reach. The model grid and boundary conditions were developed and the model was run by engineers at HDR, Inc. and vector data were provided to ERDC for formatting in the simulator. For comparative purposes, Table 6 also shows an example current magnitude extracted from a central location in the VOTB below the CRC replacement bridge for each of the three river flows. Figure 9 shows current vectors in the study area for the lowest of the three flows (140kcfs). The vector directions shown in the figure are essentially the same as those for the higher flows with only the magnitude significantly different between the three. Higher resolution in the vicinity of the replacement bridge piers was used in the current model grid in order to include possible effects of the flow obstructions on the current pattern.

Table 6. Columbia River Flows for Simulation Tests

Designation	Discharge at the Dalles (kcfs)	River Gage @ I-5 NAVD88 (ft)	River Gage @ I-5 CRD (ft)	Current Magnitude in UVTB (feet/sec)
Normal	140	8.1	2.8	1.84 (1.09 knots)
Transition	400	19.8	14.5	3.65 (2.16 knots)
10-Year	540	24.4	19.1	4.35 (2.58 knots)

[redacted] Waves

While wind waves can be generated in the simulator to improve the realism of the visual model being generated, the waves generated by the winds will not be significant to the tow and ship maneuvering. The effects of waves and when they should be considered in navigation channel design is discussed at length in EM 1110-2-1613, Chapter 5-2 and 6-4. For large ships and tows, waves must have a length of approximately half the length of the vessel. This would require swell waves that occur near the entrance of the river to the ocean. In this area, the waves that would be present would be wind generated waves which have a much shorter wave length than would be required to affect the ship's behavior. A report was identified by HDR that analyzed the wave conditions as part of the bank protection design for the Alcoa terminal just downriver from the project reach. This report determined the wind generated waves as well as the vessel-induced waves.

A study of wave conditions developed for a rip-rap protection project at an Alcoa terminal downstream of the project area was identified and made available for this project study[6]. This study found that only waves with short periods and low wave heights (<4 sec. and < 4.6 ft, respectively) would be generated at the Alcoa site. The results of the wave analysis are shown in Table 7.

Table 7: Wind Speed Adjustment and Wave Growth Results for the Alcoa Dock

ACES Input				ACES Output		
Direction (°N)	100-year Wind Speed (miles per hour)	Restricted Fetch (miles) – Input as a Block at 30-degrees Radials	Representative Fetch Distance Calculated by ACES (miles)	Wave Height H_s (feet)	Wave Period T_p (seconds)	Duration of the Final Wind Speed DurF (minutes)
10				Not applicable – Wind does not affect from this direction		
110						
120	45.4		4.6			
130	45.4	5.8	4.6	3.3	3.4	2
140	45.4		4.6			2
150	53.03		4.59	3.97	3.69	**2**
160		0.62				
180	73.5		4.59	4.6	3.94	2
190		0.47				
220		0.49				
230	80.1		1.66	3.19	3.19	2
250		0.62				
260	54.9		1.76	2.59	2.92	2
280		1.97				
290	39.6		1.76	1.74	2.45	2
300	33.8			Not applicable – Wind does not affect from this direction		
310	31.9	0				
360	27.5					

[6] Memorandum to Alcoa, Inc. from Anchor Environmental, L.L.C. dated March 5, 2008, Subject: Wind- and Vessel-induced Wave Analysis for Alcoa Vancouver.

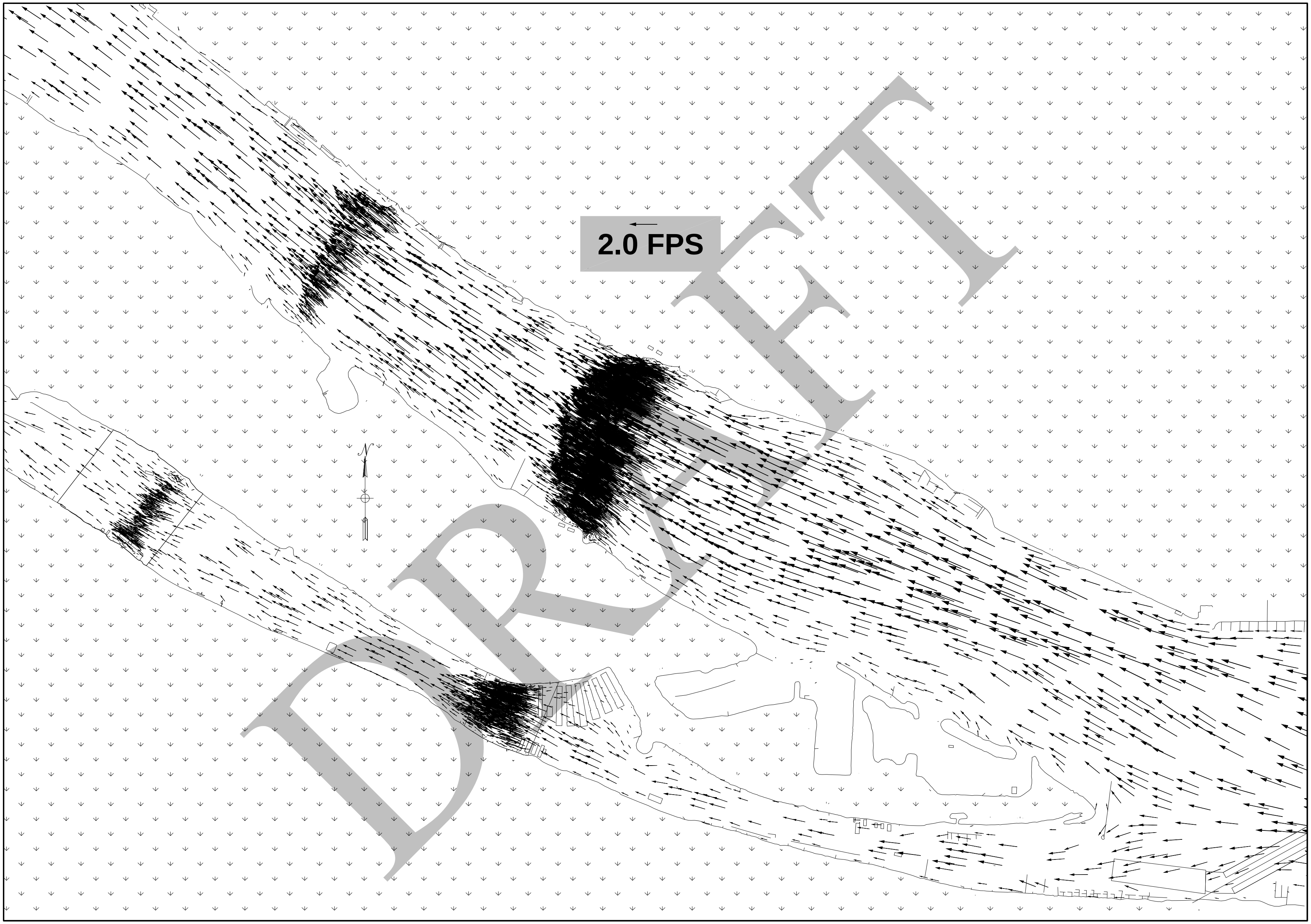


Figure 8: Study Area Current Vectors for 140,000 cfs Columbia River Flow (at the Dalles)

These results are for 100-year wind speeds and for much longer fetch distances than would be applicable for the project area; approximately half the fetch length, see Figure 8. Therefore, one might expect the wave conditions to be at least half of those reported for the Alcoa Vancouver site. Waves in the order of 8-12 second periods would be required to have a significant effect on ships and tows of the design vessels.

Figure 8: Fetch Direction and Distance for Alcoa Vancouver

[redacted] Wind

Wind data used for determining simulator environmental factors were obtained from measurements made at the Portland International Airport during the period 1961 to 2004 (Figure 9) - and from a gage on the I-5 bridge for a period from 2004 to 2006 (Figure 10). The figures show the data converted to statistical wind rose format with the airport data showing higher refinement of directional data compared to the I-5 data which was combined into only the eight cardinal directions. The I-5 data indicates significant winds of up to 15 knots from the Northwest, up to 20 knots from the Southeast, and, a smaller percentage of the time, from the South as well as the East at 15-20 knots. The airport data shows that the large percentage of time that the wind comes from the southeastern quadrant (shown in the I-5 data) the precise wind direction is East-southeast which is basically lined up with the river in the study area. Furthermore, a very small percentage of the time wind of 20-25 knots comes from the South and East as well.

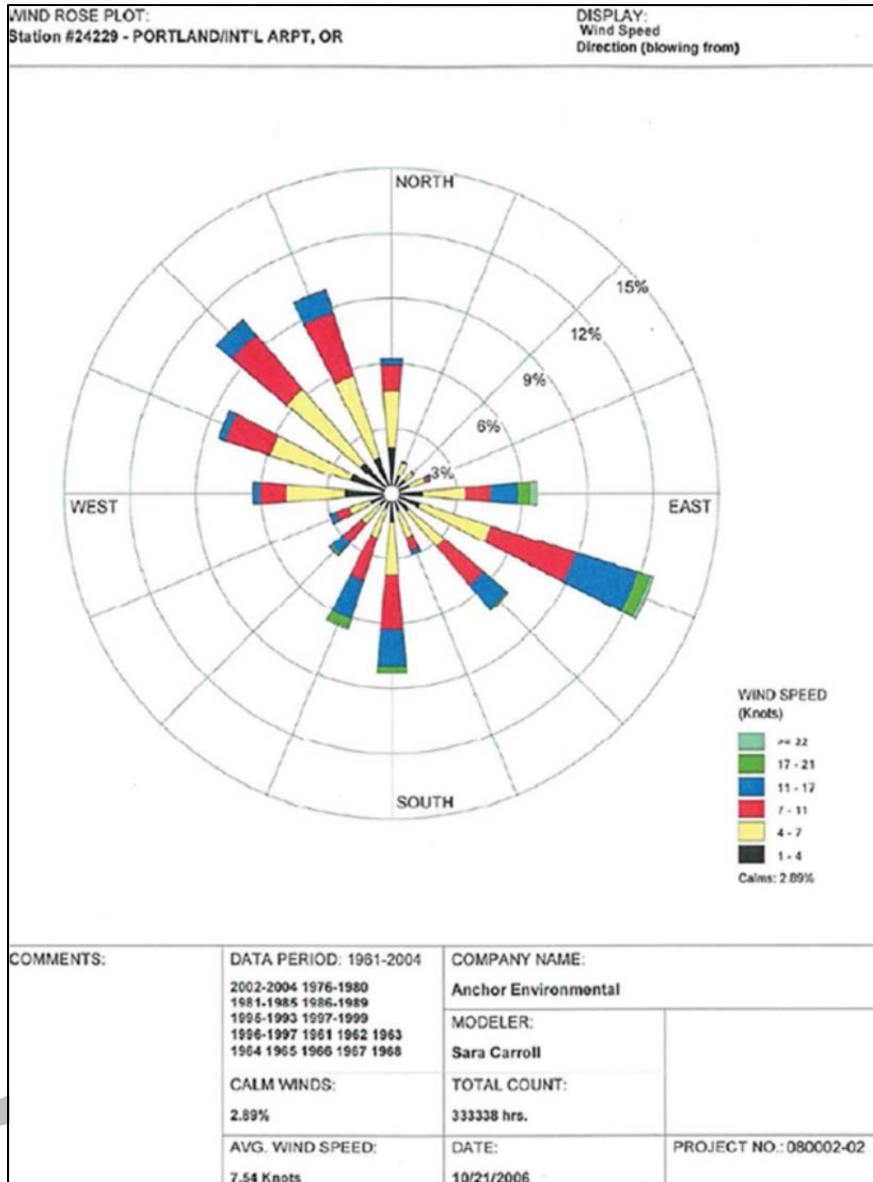


Figure 9: Wind Rose from Portland International Airport

For the deep-draft ship testing it was not anticipated that wind would be a critical factor for navigation in the area, except on the ballasted ships. Wind from the ESE and NW tends to be in line with the navigation channel. It was clear that wind from the S would be nearly perpendicular to the channel and turning basin and would have the most impact on control of tows and ships transiting the study reach – especially ships engaged in turning maneuvers in the VOTB. It was decided that in order to test with a critical wind factor, the decision of wind speed and direction would be left up to the pilots. During the testing, discussions were held and different wind conditions were tested during pre-testing which resulted in the S wind at 15 knots being chosen as the critical condition.

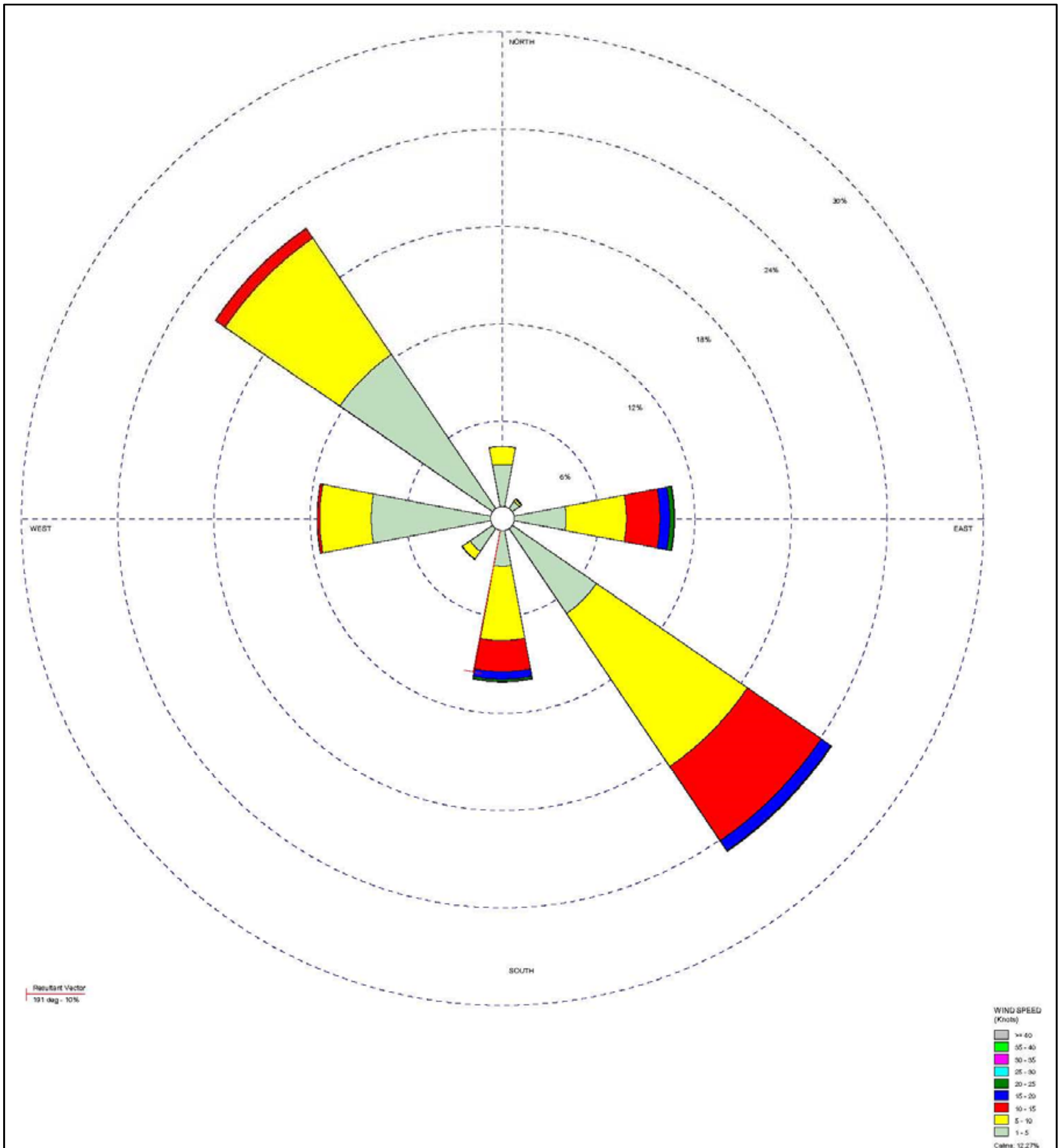


Figure 10: Wind Rose from I-5 Bridge Gauge.

[redacted] Pilots

Local licensed pilots were involved in operating the simulated ships. Columbia River Pilots (COLRIP) conned, (i.e., control by command) the ships during the testing of the UVTB and the VPOTD navigation channel.

5.5 Simulation Results

Twenty-four runs were completed (Table 8) for the CRC deep-draft simulation of proposed USAE authorized channels following construction of the replacement I-5 bridge. Trackplots for individual runs are shown in Appendix A. Ship traffic in the area above the BNSF bridge is practically non-existent at the present time and, with the exception of ships possibly calling at the Lafarge site, will most likely remain so for the foreseeable future. However, there were four scenarios tested during the simulations with the deep-draft ships. The first with the *Cape Bird* was passing upbound through the BNSF bridge, turning around in the UVTB with tug assist and departing through the BNSF bridge. The second scenario was with the *Cape Bird* departing the Lafarge terminal, docked port-side-to, turning around in the VOTB with tug assist and departing through the BNSF bridge. The third scenario had the *Cape Bird* departing the Lafarge dock and backing through the BNSF bridge with tug assist. The fourth scenario had the smaller product carrier - *Sulphur Guardian* - transiting both directions in the primary 27-ft deep channel (VPOTD) in the proposed condition with the replacement bridge in place.

Results from the piloted simulations for these scenarios are discussed below. Composite trackplots showing several of the runs completed for the each of the scenarios are shown in Figures 16-19. The scenarios including the turn in the UVTB are plotted together. Pilot responses for the questionnaires filled out after each simulation are tabulated in Table 8 and discussed below.

Table 8: Simulation Tests for CRC Deep-draft Vessel Study

Run	Figure #	Vessel	Load Cond. /Draft	Wind (knots)	River Flow (kcfs)	Pilot	Scenario	Tugs
Simulations in Upper Vancouver Turning Basin								
1	A-1	*Cape Bird*	Ballast/20ft	0	400	B	BNSF/Up/Turn/BNSF	Two 3000 hp
2	A-2	*Cape Bird*	Ballast/20ft	NW 15	400	A	BNSF/Up/Turn/BNSF	Two 3000 hp
3	A-3	*Cape Bird*	Ballast/20ft	S 15	400	B	Lafarge/Up/Turn/BNSF	Two 3000 hp
4	A-4	*Cape Bird*	Ballast/20ft	S 15	400	A	Lafarge/Up/Turn/BNSF	Two 3000 hp
5	N/A	*Cape Bird*	Ballast/20ft	S 15	400	B	Lafarge/Back thru BNSF	Two 3000 hp
6	A-5	*Cape Bird*	Ballast/20ft	0	0	A	Lafarge/Back thru BNSF	Two 3000 hp
7	A-6	*Cape Bird*	Ballast/20ft	S 15	540	B	Lafarge/Up/Turn/BNSF	Two 3000 hp
8	A-7	*Cape Bird*	Loaded/33ft	S 15	400	A	Lafarge/Up/Turn/BNSF	Two 3000 hp
9	A-8	*Cape Bird*	Loaded/33ft	S 15	540	B	Lafarge/Up/Turn/BNSF	Two 3000 hp
10	A-9	*Cape Bird*	Loaded/33ft	S 15	400	A	Lafarge/Back thru BNSF	Two 3000 hp
23	A-10	*Cape Bird*	Ballast/20ft	S 15	400	A	Lafarge/Up/Turn/BNSF	Two 3000 hp
Simulations in VPOTD Channel under Proposed I-5 Bridge								
11	A-11	*Sulphur Guardian*	Loaded/25ft	S 15	140	A	Upbound	None
12	A-12	*Sulphur Guardian*	Loaded/25ft	S 15	400	B	Upbound	None
13	A-13	*Sulphur Guardian*	Loaded/25ft	S 15	540	A	Upbound	None
14	A-14	*Sulphur Guardian*	Loaded/25ft	S 15	140	B	Downbound	None
15	A-15	*Sulphur Guardian*	Loaded/25ft	S 15	400	A	Downbound	None
16	A-16	*Sulphur Guardian*	Loaded/25ft	S 15	540	B	Downbound	None
17	A-17	*Sulphur Guardian*	Ballast/19ft	S 15	400	A	Downbound	None
18	A-18	*Sulphur Guardian*	Ballast/19ft	S 15	140	B	Downbound	None
19	A-19	*Sulphur Guardian*	Ballast/19ft	S 15	540	A	Downbound	None
20	A-20	*Sulphur Guardian*	Ballast/19ft	S 15	140	B	Upbound	None
21	A-21	*Sulphur Guardian*	Ballast/19ft	S 15	400	A	Upbound	None
22a	A-22	*Sulphur Guardian*	Ballast/19ft	S 15	540	B	Upbound	None
22b	A-23	*Sulphur Guardian*	Ballast/19ft	S 15	540	A	Upbound	None

[redacted] Ship Tracklines and Questionnaire Responses

5.5.1.1 Simulated Maneuvers in UVTB

Figure 11 shows the composite trackplot for the runs with the *Cape Bird* which included a turn in the UVTB. The proposed CRC I-5 replacement bridge piers are shown along with the piers for the existing BNSF railroad bridge downstream of the former. The scenarios initiated with the ship either in a starting position below the BNSF bridge heading upriver or docked port-side-to at the Lafarge terminal. The channel and turning basin below the proposed CRC bridge piers had a depth of -35ft CRD. The composite shown includes runs for all wind, current and ship load conditions; however, runs 1 & 2 are not included because they were considered familiarization runs and at the time the pilots were not clear as to the location of the limits of the turning basin. Trackplots for these two runs are included in Appendix A.

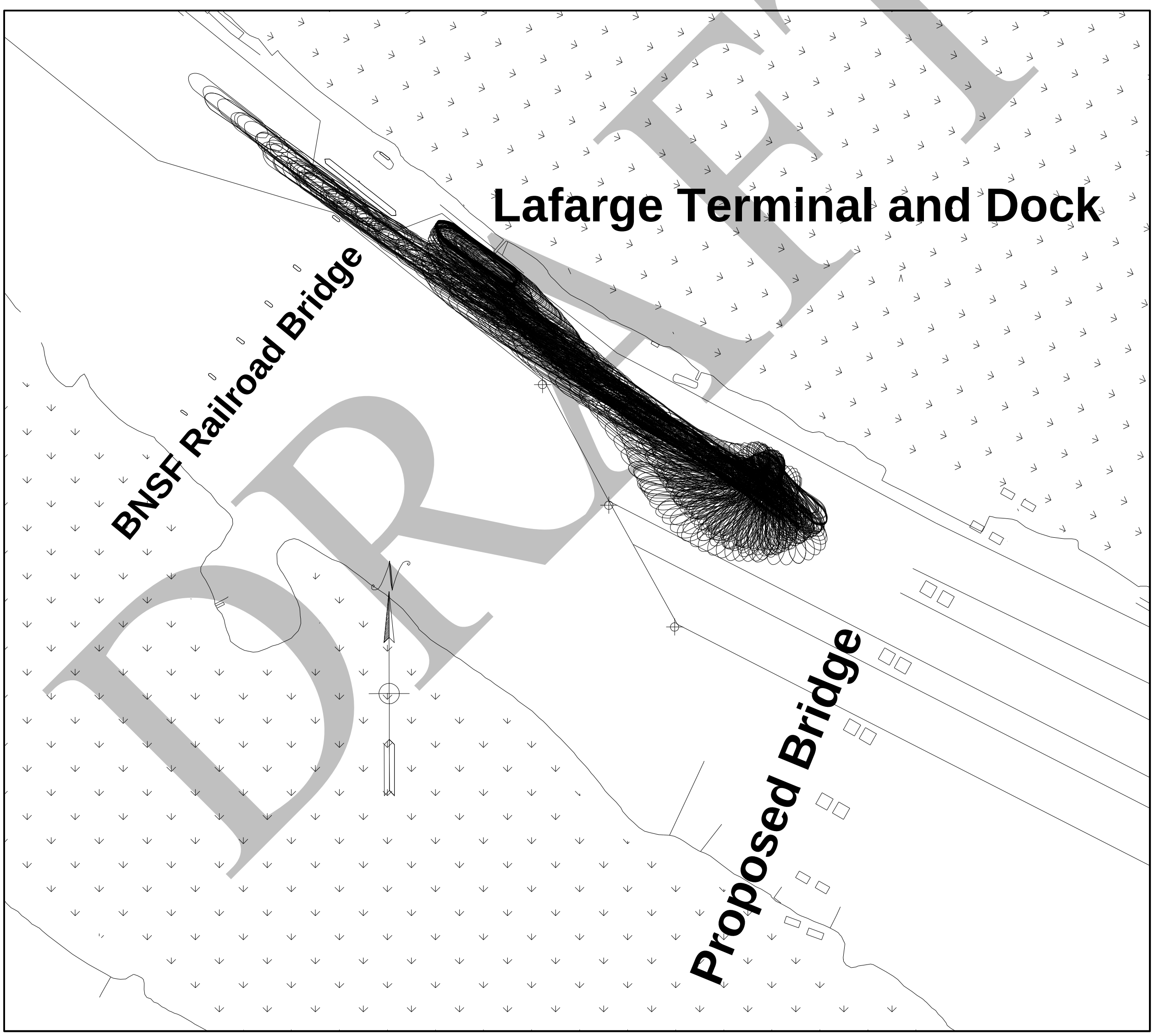


Figure 11: Runs 3,4,7,8,9,23, UVTB, *Cape Bird* Ballast/Loaded (580ft x 101ft x 20/33ft)
All Wind and Current, Two 3000hp Tractor Tugs, Proposed CRC

The pilots generally used two tractor tugs for assistance during the maneuvers through the railroad bridge and while turning in the UVTB. Most frequently the tugs were made up on the bow and stern of the ship and the pilot's stated objective was to turn the ship with its stern swinging as close to the Washington side of the basin as possible – in this fashion, the pilots could use the river flow to best advantage in pushing the bow of the ship around. Adequate clearances to the edge of the basin were observed during the simulations and the turn was accomplished well downstream of the proposed I-5 bridge piers. Passage back through the clear span of the BNSF railroad bridge was made without incident.

The pilots' mean difficulty rating (Table3) for this scenario was 6 which indicated a maneuver slightly more difficult than average. For the same runs the pilots thought the safety of the maneuver was average with a rating of about 5. At the same time the pilots thought the assist tugs were very effective during the maneuver with a rating of 8.5 on a scale of 1 to 10. There was general pilot agreement that two 3000hp tractor tugs would be adequate for the scenario tested in the UVTB. Both pilots commented that they would perform the tested maneuver in real life. Turns with the ballasted ship appeared to be the more difficult because of wind effects. The pilots did not make any critical comments concerning the tested dimensions of the turning basin.

5.5.1.2 Backing Maneuver through BNSF Railroad Bridge

Figure12 shows one successful simulation in which the pilot maneuvered the design ship away from a port-side-to docking at the Lafarge terminal and backed it through the railroad bridge channel span using two assist tractor tugs. The run shown was conducted without wind and current. Two other similar maneuvers were conducted during testing with the 400cfs and 540cfs river currents along with wind – one of these (Run 10) is shown in Figure A-9 in Appendix A. The track and record for the other run (Run 5) was lost during post-processing and is not shown. Neither of these latter two runs was successful as evidenced by ship contact with the bridge pier on the south side of the channel span. However, both pilots agreed that in the real world they would conduct this maneuver (Table 9) because tugs at the bow and stern would actually be more responsive than in the simulation and visibility in such close quarters would be much improved in real life compared to the restricted visibility on the simulator screen.

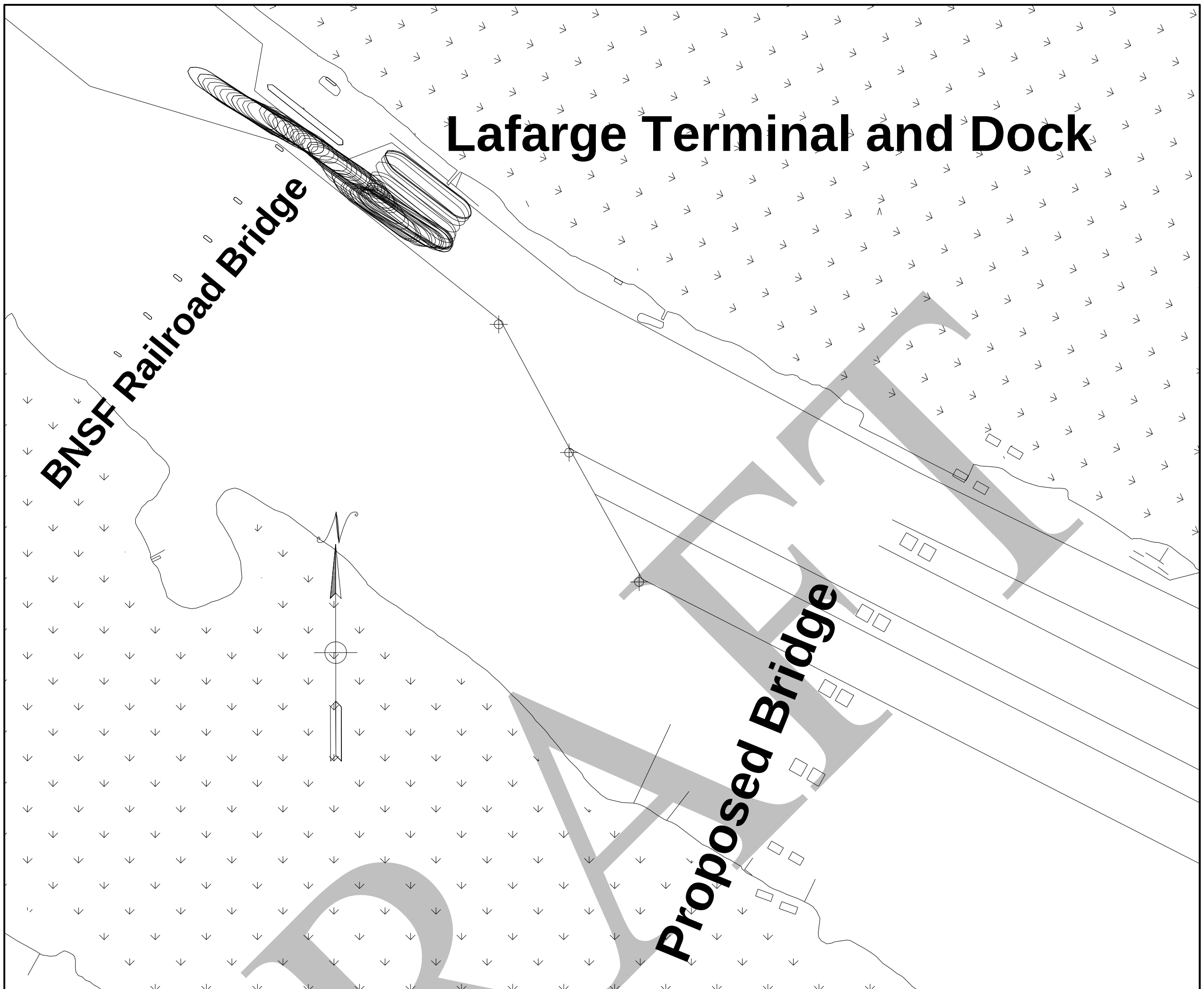


Figure 12: Run 6, UVTB, *Cape Bird* Ballast (580ft x 101ft x 20ft) Backing 0 Wind and Current, Two 3000hp Tractor Tugs

5.5.1.3 Product Carrier Transits through the VOPTD

Figures 13 and 14 show the runs for the *Sulphur Guardian* in the proposed deep-draft channel through the BNSF railroad bridge and under the primary channel span of the proposed I-5 replacement bridge. The deep-draft channel had a depth of -27ft CRD above the I-5 replacement bridge. Predominantly, the composite trackplot indicated no problems maneuvering through the channel and the pilots rated the scenario as less than average difficulty and better than average safety (Table 9). From pilot comments it was evident that the passage through the BNSF railroad bridge required the most attention – especially downbound when they wished for an assist tug to slow the ship. For the upbound scenario, the loaded ship in Run 13 (Figure A-13) drifted slightly beyond the channel edge above the proposed bridge, which, according to the pilot's comment, was probably due to the added cross current component in the 540kcfs river flow. There was pilot agreement that the maneuver would be conducted in the real world; however, they noted that visibility should be good. This is a common theme for navigation through the bridges, especially the BNSF RR Bridge, and generally means that there should be no visibility limitations due to fog.

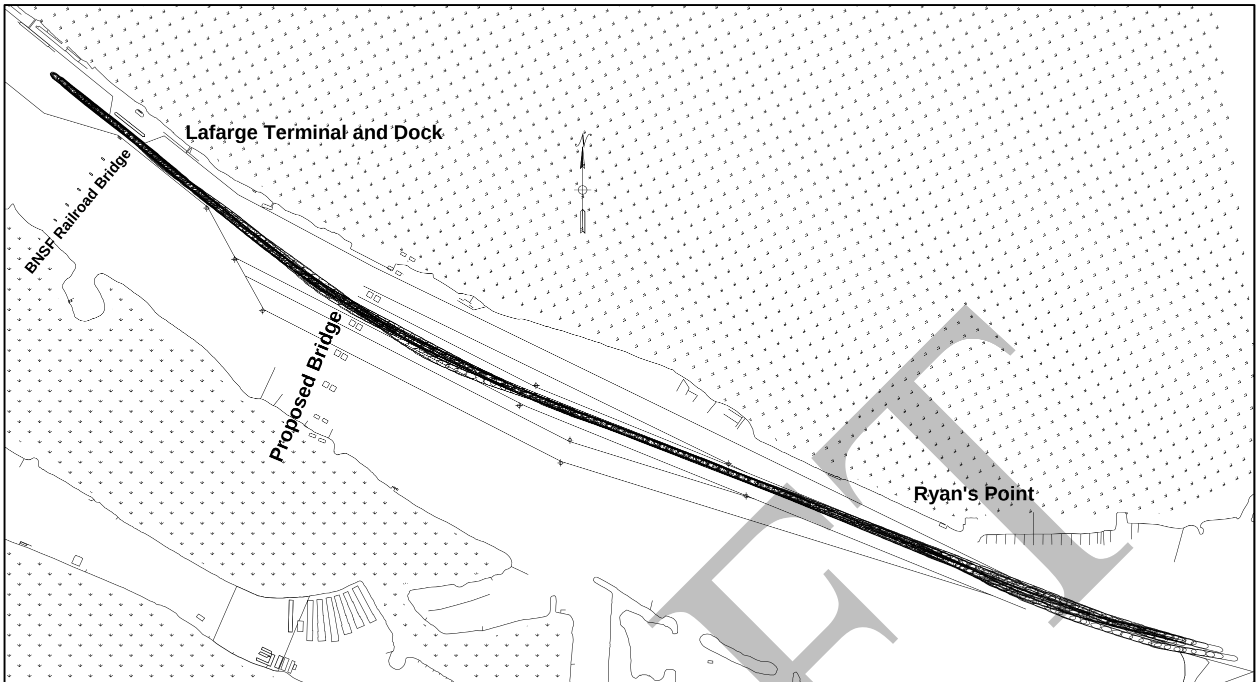


Figure 13: Run 11,12,13,20,21,22a,22b, VPOTD, Proposed CRC, Upbound
***Sulphur Guardian* Ballast/Loaded (453ft x 75ft x 19/25 ft), All Wind and Current**

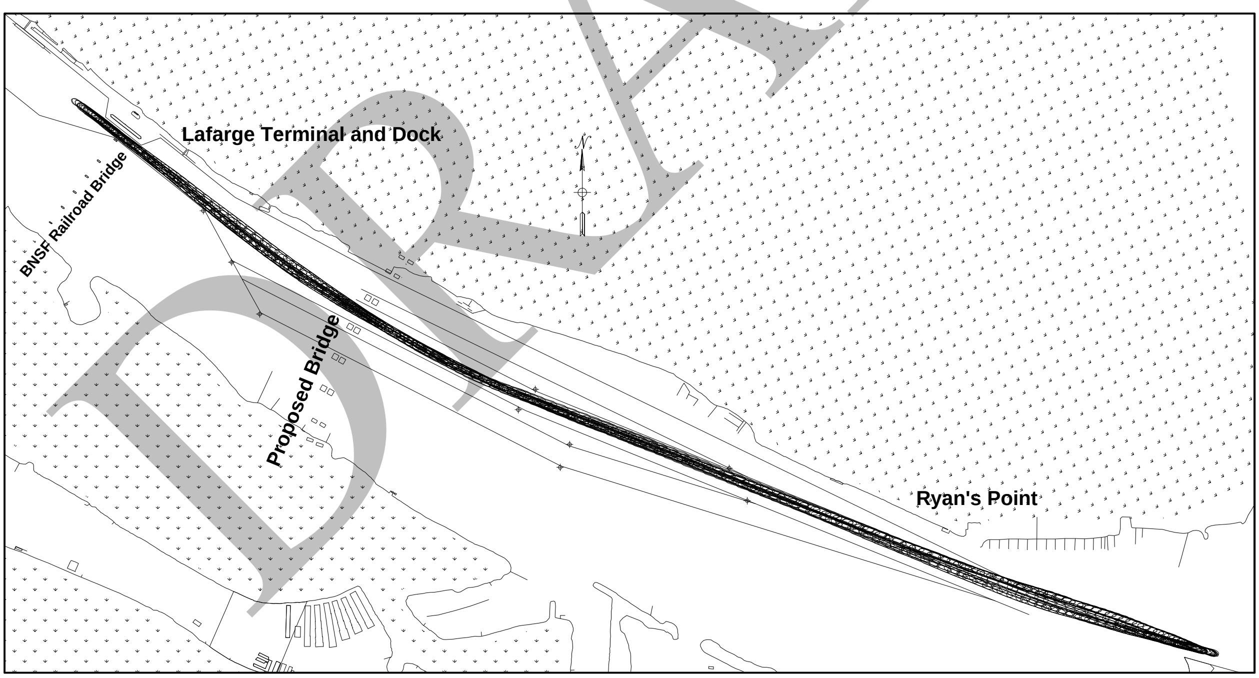


Figure 14: Run 14,15,16,17,18,19, VPOTD, Proposed CRC, Downbound
***Sulphur Guardian* Ballast/Loaded (453ft x 75ft x 19/25 ft), All Wind and Current**

Table 9: Ship Pilot Individual Questionnaire Responses

Run/ Pilot	Maintain Track	Navigation Impact		Difficulty	Safety	Safety Qualifiers	Tug Effectiveness	Tug Comments	Perform in Real World	Additional Comments & Recommendations
		River flow	Wind							
1 B	Yes	Ebb tide - 2 knots	No wind	5	5	2 tugs needed for this maneuver; good vis.	8	2 tugs - 3000 HP	Yes	
2 A	Slightly to Washington of intended track (by habit) inbound and turning	Approx. 2 knots of current	Wind no effect	8	5		9	Tractor tugs for lessening the effect of the tug on the ship only for r/R Bridge-do not need 5000 HP; 3000 HP would have been plenty.	Yes	
3 B	Yes	Ebb Tide	South Wind	7	6	Good visibility, good tugs; 2- 3000 HP tractor	7	2 tugs - 3000 HP	Yes, but I would keep my speed below 8-0 knts	the south wind has a lot of effect on the ship.
4 A	Yes		Downstream wind 20knts- slowed ship's heading, took more tug power on stern to override wind during turn,	6	5		10	Bow tug wouldn't need to be as big - and would have removed tug after turning for transit through bridge	Yes	
5 B	No		S15	10	1	Good visibility	4	2 tugs 3000 HP Tractor	Yes, tugs would be more responsive in real world situations	There seemed like a delayed response between the tug and ship. I had a hard time getting the tugs working together.

Run/ Pilot	Maintain Track	Navigation Impact		Difficulty	Safety	Safety Qualifiers	Tug Effectiveness	Tug Comments	Perform in Real World	Additional Comments & Recommendations
		River flow	Wind							
6 A	Not really - tug reaction with o wind or current was too immediate.	Nil	nil	4	8	With strong S wind, job would be more difficult	3	With bridge clearance, tugs will or should be able to effectively maneuver directly astern and directly forward.	Yes	Would have to be able to use entire 200' of span width and tractor tugs if strong southerly wind.
7 B	Yes	2-6 knts ebb tide	S wind 15knts	5	8	Good visibility and good boats	8	2-3000 HP Tractor Tugs	Yes	It went well; the wind was more of a factor than the currents.
8 A	Yes-loaded ship took tug power to check swing after turning (unlike ballast ship)	River flow/current was not difficult to overcome, extra underkeel clearance helped with current	15knts Southerly no effect on ship	7	4	The only thing that makes this maneuver more difficult is getting shaped up for bridge after turning. Tug power was adequate but I wouldn’t recommend less power. Daylight would help see orientation to bridge sooner.	8	As above I would not recommend more power but I wouldn't settle for much less	Yes	Basin width is adequate for turning, length of basin I just as critical, requiring starting turn close to bridge.

Run/ Pilot	Maintain Track	Navigation Impact		Difficulty	Safety	Safety Qualifiers	Tug Effectiveness	Tug Comments	Perform in Real World	Additional Comments & Recommendations
		River flow	Wind							
9 B	Yes	2.5 knt current	South wind	6	5	Good visibility and good tugs	8	2-3000 HP tractor tugs	Yes, If I was worried about the current, I may use 1 more boat.	the wind wasn't much of an issue.
10 A	I was able to maintain track line I thought that looked good visually, but upon approach to bridge ship was actually in line with Oregon pier. I did not notice this on the ECDIS until it was too late. Had I noticed it sooner, I would have corrected ship position. Pilot had control of ship but out of position. Visually looked good.	Current from river flow actually helps ship drop through bridge without much power from ship.	Wind effect nil	7	4	Highly visual maneuver (not in restricted visibility)	10	Adequate tugs (power) bow tug went wrong direction above the bridge for a short time. I don't believe it affected the outcome.	Yes	Current is a factor because the ship doesn't develop excess speed in short distance. Wind is not a factor with loaded ship.
23 A	No- Intended to be farther off Washington shore, overcoming wind effect was difficult	I don't believe current was an issue	I think the set was from Southerly wind	6	4	Wind affect probably greater than reality	10	Adequate	Yes	Going through bridge was closer than expected most likely from wind effect.
11 A	Yes	1.5 knts ebb tide	South 15knts of wind	4	8	Good visibility	N/A	Had one tug at swing bridge for safety	Yes	No big deal

Run/ Pilot	Maintain Track	Navigation Impact		Difficulty	Safety	Safety Qualifiers	Tug Effectiveness	Tug Comments	Perform in Real World	Additional Comments & Recommendations
		River flow	Wind							
12 B	Able to stay within channel boundaries but not exactly in the middle- not sure of exact turn points and shoals.	Current was not a major factor just slowed headway	Wind nil	4	8		N/A	No tug	Yes, if water depth allowed for it.	
13 A	Yes	2.5 knts of current	15 knot South Wind	4	8	Good visibility	N/A	1 tug for safety at the swing bridge	Yes	The only difference in this run was the added cross currents. The wind wasn't a factor.
14 B	Yes		south wind 15kts	3	8	Good visibility	N/A	N/A	Yes	I didn't notice any cross currents and the wind wasn't a factor.
15 A	Yes	River flow made it hard to keep speed down without dropping RPM;s that affect maneuverability. Started out too fast because display was m/s instead of knots, after correction was at 13.5 knts and reducing.		4	8	None	N/A	N/A	Yes	See #2 [Navigation Impact]
16 B	Yes	2.5 knots of current	South wind 15 knts	7	5	Good visibility and 1 tug	N/A	N/A	Yes	There was no influence by the wind but the slowest I could go under the conditions was about 10 knts. I would have used a tug at the swing bridge to slow me down a bit.

Run/ Pilot	Maintain Track	Navigation Impact		Difficulty	Safety	Safety Qualifiers	Tug Effectiveness	Tug Comments	Perform in Real World	Additional Comments & Recommendations
		River flow	Wind							
17 A	Yes	River flow no problem	Slight wind effect, easily overcome with 2 deg steering angle.	2	9	Anytime	N/A	N/A	Yes	
18 B	Yes	Normal conditions	15knts South wind	3	8	Good condition visibility	N/A	N/A	Yes	there was not much effect from the wind
19 A	Yes	Same as the 2 yr flow with a 2 deg steering angle; about 1 knt increase in speed overall from 2 year flows		3	8	Not in restricted visibility	N/A	N/A	Yes	-for downbound only more current does not hinder safety and decreases time on task -Increased flows would make it harder to overcome emergency situations, i.e., steering propulsion - the more southerly wind increases the more difficult the maneuver.
20 B	Yes	Normal conditions	15knot south wind	3	8	Good visibility	N/A	N/A	yes	There was no effect to the ship from the wind and current
21 A	Yes	Nil on current	Some affect from southerly wind not much	3	8	No restrictive visibility	N/A	N/A	Yes	Transits inbound and outbound not much problem through bridges
22a/B & 22b/A	Yes	There was 2.5knts of current	15knts South wind	3	8	Good visibility	N/A	N/A	Yes	There was no effect on the ship from the wind but the cross currents affected the ship.

5.5.1.4 Final Pilot Questionnaire

Table 9 shows the responses from the pilots from the questionnaire at the end of the deep-draft simulation runs. The table also shows the final recommendations provided by the two pilots. The loaded condition of both ships was considered a little more realistic than the ballast condition. Judging by some of the comments in Table 10 concerning the effects of wind on the individual run questionnaires, the comment by Pilot B that the wind effect on the empty ship while underway seemed to be excessive seems to be contradictive. If this pilot in fact considered the wind effects excessive, he did not note that earlier in the individual run evaluations; the fact that the wind effects were considered to be excessive and transits were still considered safe, this means the simulation was on the safe side. Overall the pilot safety rating was high throughout the channel reaches tested; although, both pilots stated that good visibility would be required to conduct the maneuver in real life.

Table 10: Final Pilot Questionnaire for Deep-draft Vessel Simulations

Pilot	**Ship Model Realism**					**Environmental Realism**		**Overall Safety**		
	Cape Bird LD	Cape Bird BL	Sulphur Guardian LD	Sulphur Guardian BL	Tugs	Wind	River Currents	UVTB	CRC Bridge	VPOTD
A	**6**	**4**	**6**	**4**	**5**	**5**	**6**	**8**	**8**	**10**
B	**6**	**4**	**6**	**5**	**5**	**4**	**5**	**7**	**8**	**9**

Pilot	**Recommendations and Comments**		**Additional Comment/Recommendations**
	UVTB	VPOTD	
A	I would recommend having good visibility when turning a ship around in the turning basin and using 2 good tractor tugs	I would recommend center lights on the new bridge and buoys placed below the piers and also above the piers.	-
B	I think because of close quarters, tractor tugs would be preferred 3000 HP +; no restricted visibility	Buoys on one side of channel both above and below bridge, buoys on a turn should not be gate style opposite each other.	Tug reaction to empty ship was positive, should be more lag time to be realistic; wind effect on empty ship while underway 3+ knts was a little excessive.

6 Conclusions and Recommendations

Based on the deep-draft vessel navigation simulations described in this report the following conclusions and recommendations are presented.

6.1 Conclusions

- Two distinct scenarios for approaching the UVTB and performing a tug-assisted turn of the design ships (580ft x 101ft) were tested. The simulations showed that both of the scenarios were safe for the design ships using two 3000 hp tractor tugs. These two scenarios were a) transiting directly through the BNSF railroad bridge into the turning basin and b) coming off of the Lafarge dock and driving into the turning basin.
- Both loaded and ships in ballast were tested and found to be safely turned in the UVTB and aligned for departure through the BNSF RR Bridge.
- The scenario in which the design ship departed the Lafarge dock (port-side-to) and backed through the BNSF RR Bridge with tug assist was not shown to be safe. However, restricted capabilities of the simulator visuals and tug operations limited the ability of the pilots to direct this maneuver; therefore, definitive evaluation was not possible based on the limited number of runs completed.
- The pilots did note that they do the backing through the bridge at other sites and that this is a common practice and they did not expect that there would be a problem in real lift if the ship beams were in the range of 88 ft-96 ft rather than the test ship's beam of 101ft.
- Transit of the deep-draft design vessel (435ft x 75ft) for the proposed 27-ft VPOTD channel was shown to be safe. The controlling factor for these maneuvers was passing through the BNSF railroad bridge.
- The pilots thought that an assist tug should be used to slow a downbound ship passing through the BNSF RR Bridge.

6.2 Recommendations

- Two 3000 hp tractor tugs are recommended for turning the design ship (580ft x 101ft) in the UVTB.
- Navigation markers are needed to mark the southern (Oregon side) edge of the UVTB – Figure 14.
- For transits of deep-draft ships (435ft x 75ft) under the proposed I-5 replacement bridge, navigation markers are needed above and below the two bridge piers bordering the 27-ft VPOTD. The channel above the bridge should have un-gated buoys marking the channel bends (see Figure 15).
- The pilots requested that they lateral buoys marking the bend north of the CRC Bridge near the present junction buoy should be staggered or offset rather than gated.

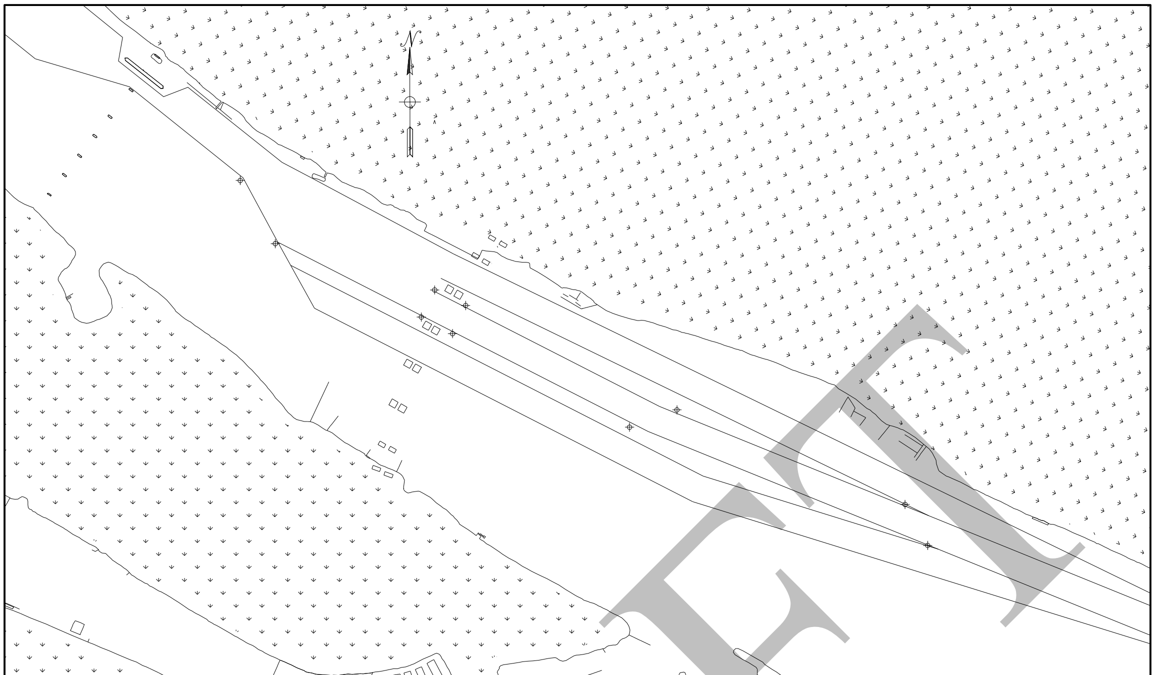


Figure 15: Recommended Aids to Navigation for Deep-draft Vessels

Appendix A – Trackplots

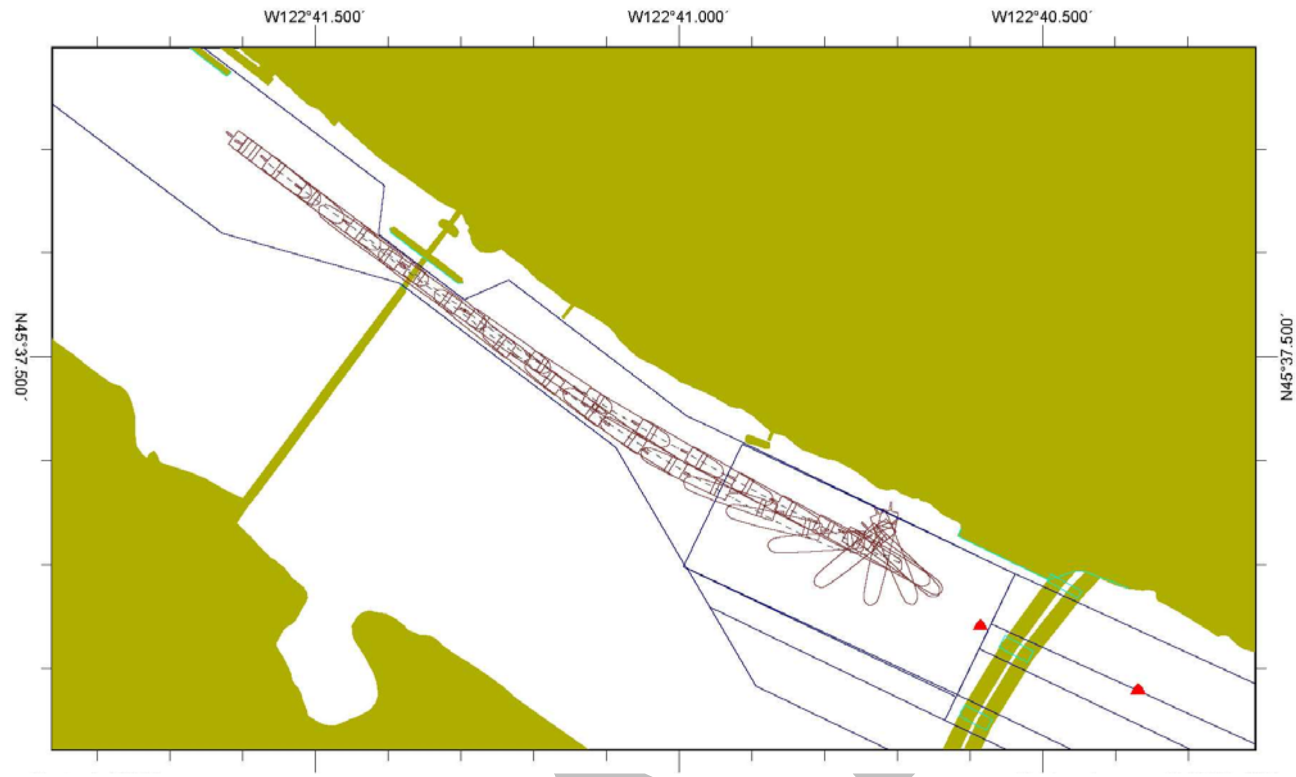


Figure A - 1: Run 1 VTB, *Cape Bird* Ballast (580ft x 101ft x 20ft)
2-yr River Flow, 0 Wind, Two 3000hp Tractor Tugs, Pilot B, Proposed CRC

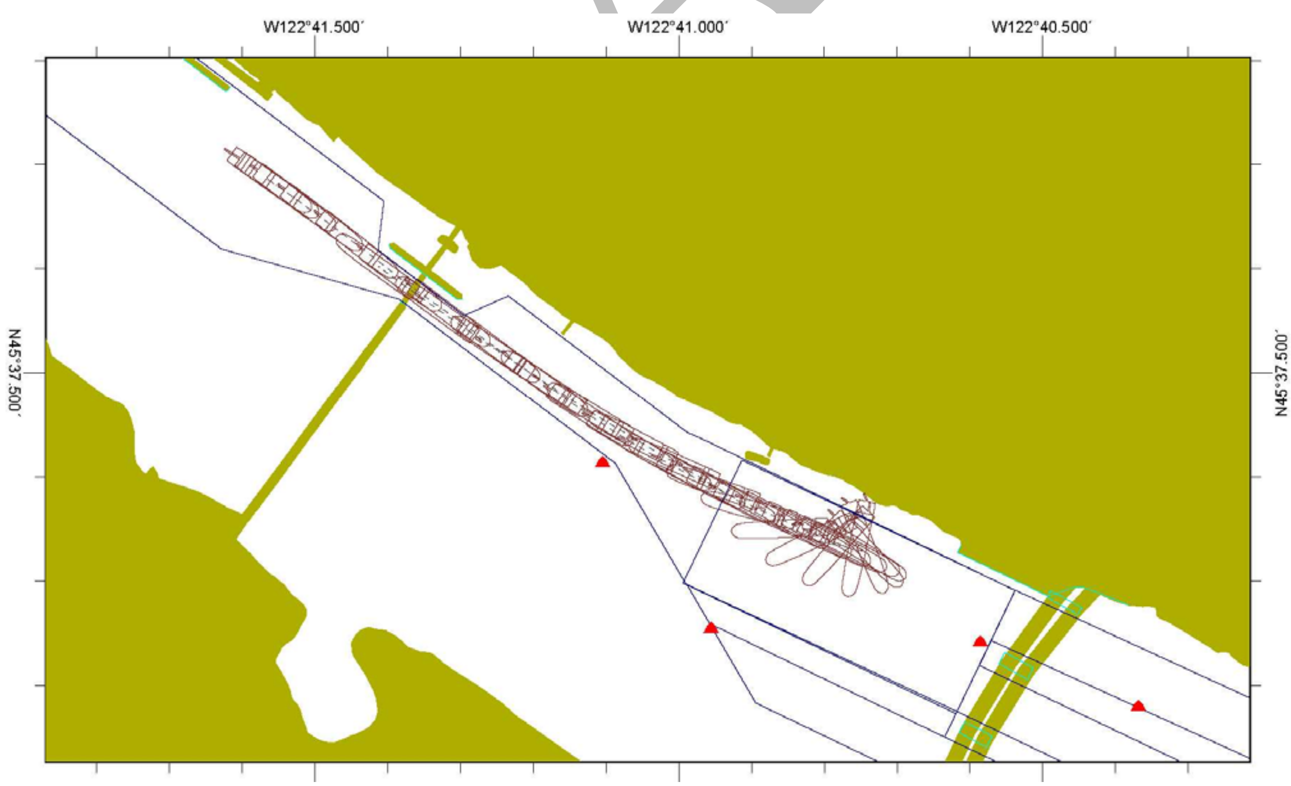


Figure A - 2: Run 2 VTB, *Cape Bird* Ballast (580ft x 101ft x 20ft), 2-yr River Flow
Wind NW 15 Knots, Two 3000hp Tractor Tugs, Pilot A, Proposed CRC

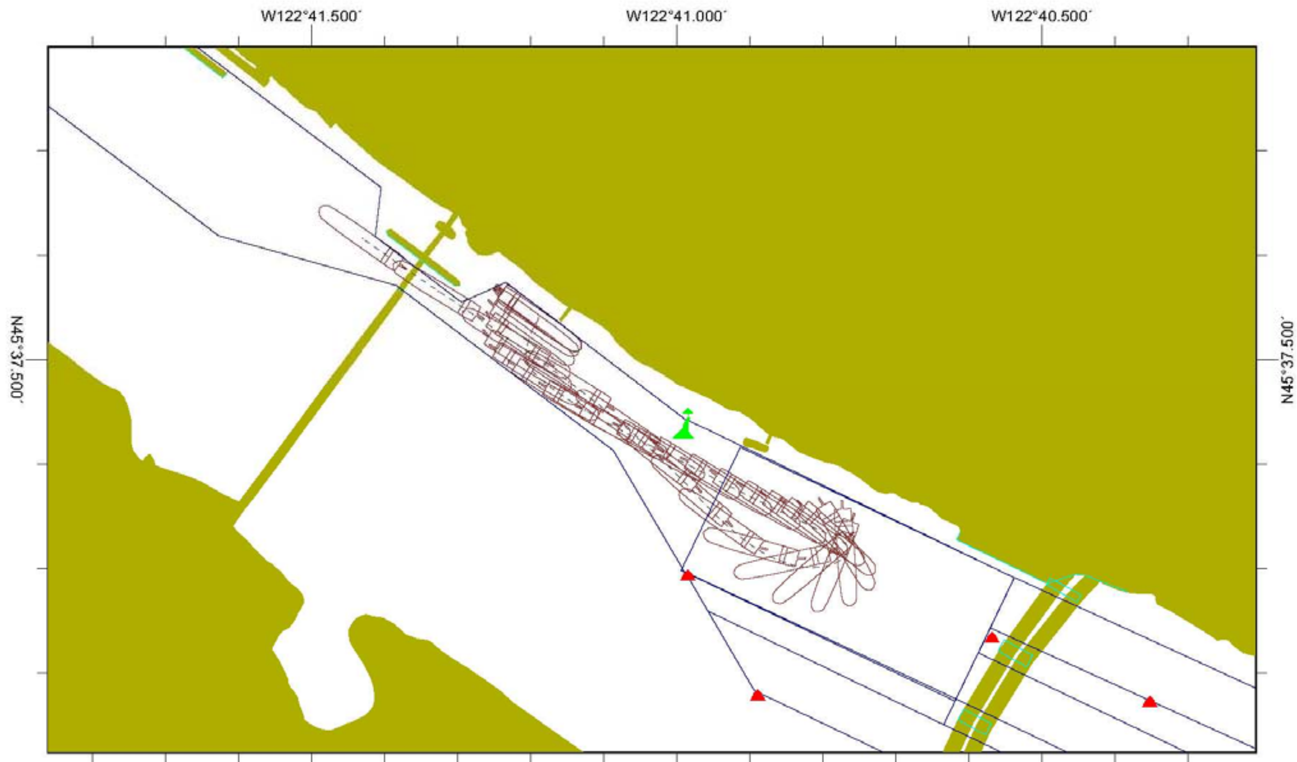


Figure A - 3: **Run 3 VTB, *Cape Bird* Ballast (580ft x 101ft x 20ft) Downbound Turning 2-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot B, Proposed CRC**

Figure A - 4: **Run 4 VTB, Cape Bird Ballast (580ft x 101ft x 20ft) Downbound Turning 2-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot A, Proposed CRC**

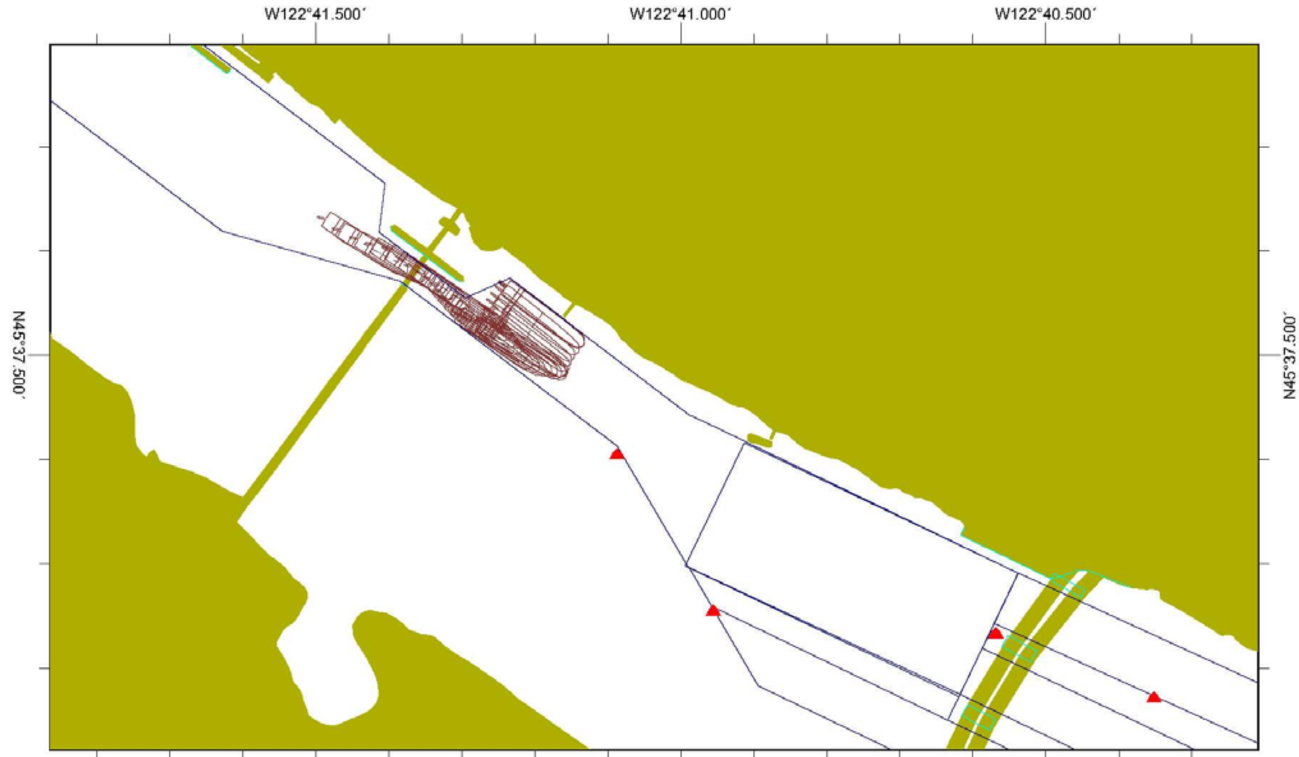


Figure A - 5: **Run 6 VTB,** ***Cape Bird*** **Ballast (580ft x 101ft x 20ft) Downbound Backing 2-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot A, Proposed CRC**

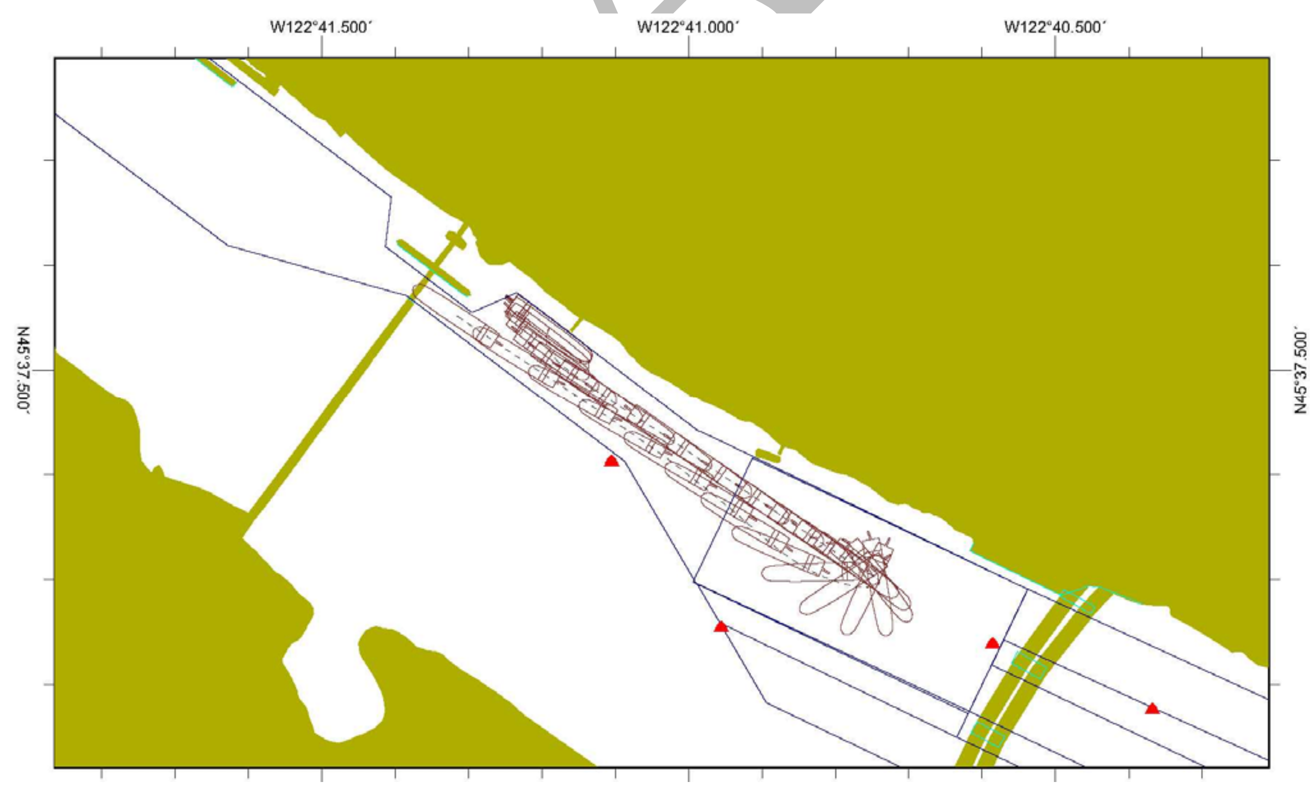


Figure A - 6: **Run 7 VTB,** ***Cape Bird*** **Ballast (580ft x 101ft x 20ft) Downbound Turning 10-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot B, Proposed CRC**

Figure A - 7: Run 8 VTB, *Cape Bird* Loaded (580ft x 101ft x 33ft) Downbound Turning 2-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot A, Proposed CRC

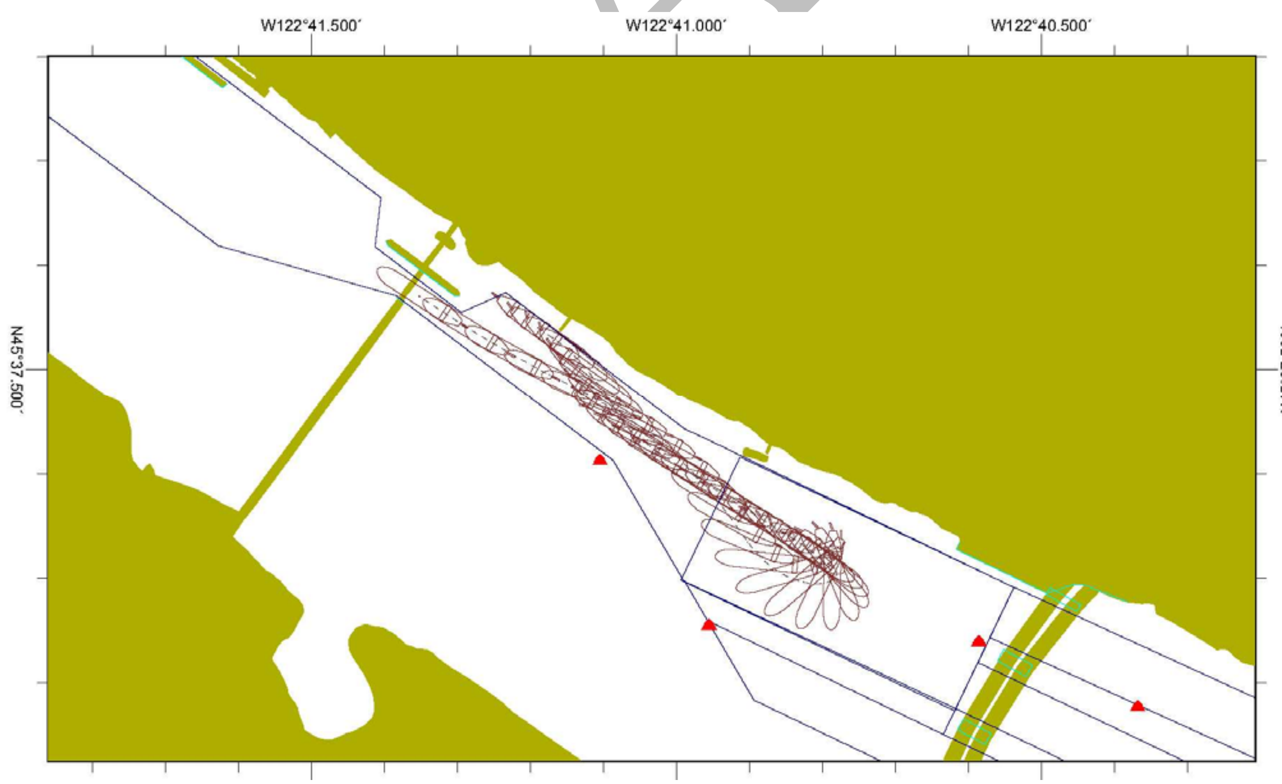


Figure A - 8: Run 9 VTB, *Cape Bird* Loaded (580ft x 101ft x 33ft) Downbound Turning 10-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot B, Proposed CRC

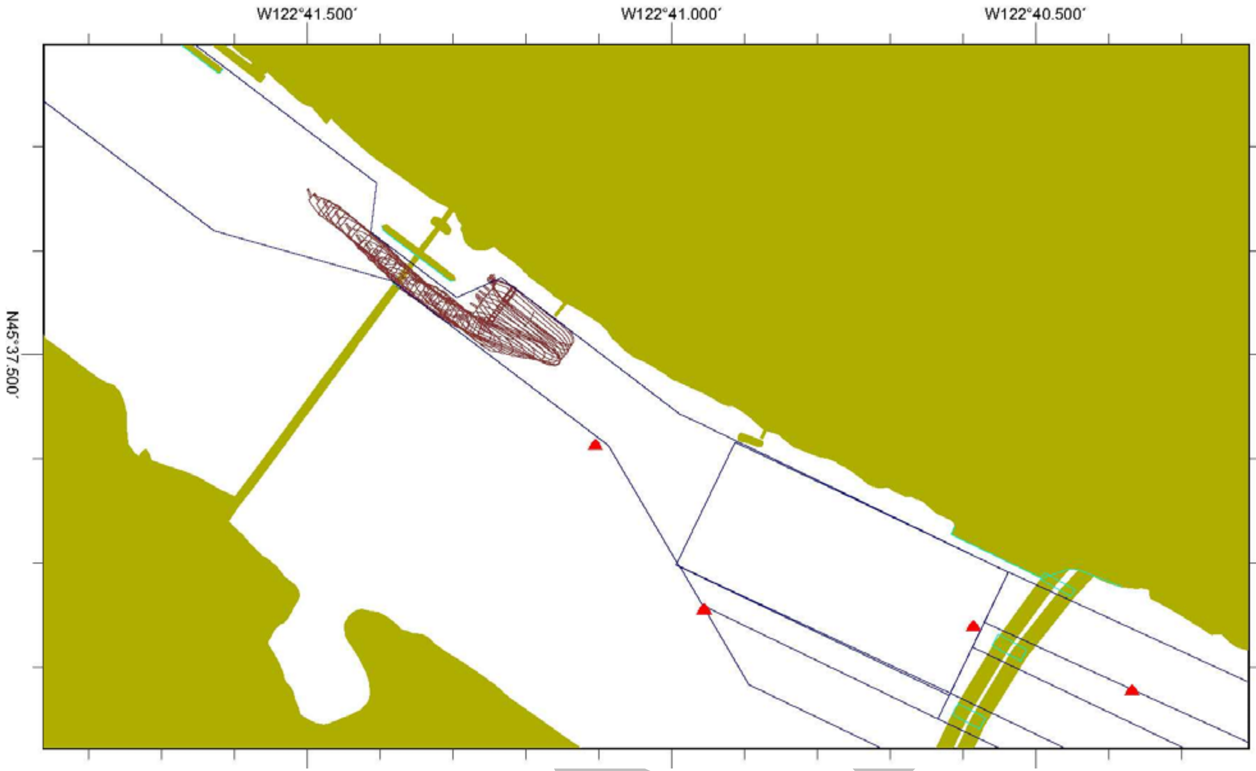


Figure A - 9: **Run 10 VTB, *Cape Bird* Loaded (580ft x 101ft x 33ft) Downbound Backing**
2-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot A, Proposed CRC

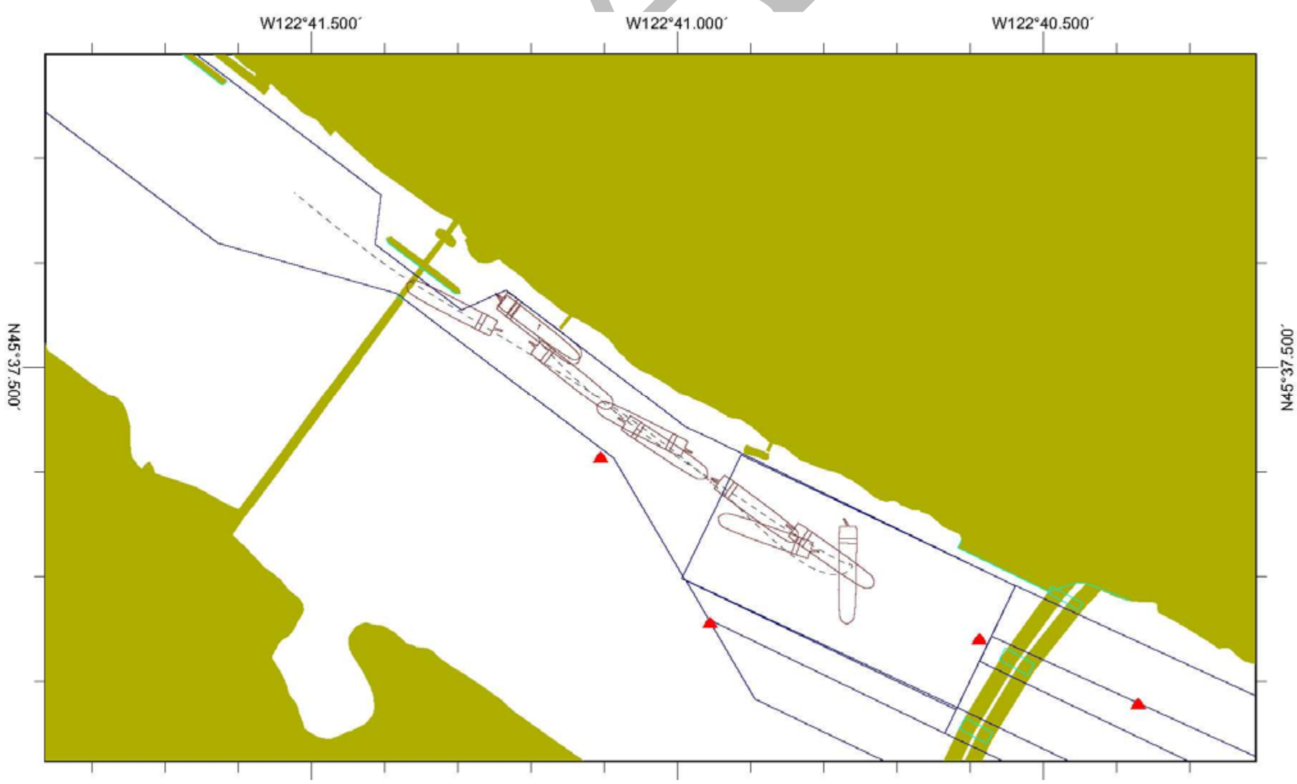


Figure A - 10: **Run 23 VTB, *Cape Bird* Ballast (580ft x 101ft x 20ft) Downbound Turning**
2-yr River Flow, Wind S 15 Knots, Two 3000hp Tractor Tugs, Pilot A, Proposed CRC

Figure A - 11: **Run 11, 27-ft Channel, *Sulphur Guardian* Loaded (453ft x 75ft x 25ft) Upbound Normal River Flow, Wind S 15 Knots, Pilot A, Proposed CRC Primary Span**

Figure A - 12: **Run 12, 27-ft Channel, *Sulphur Guardian* Loaded (453ft x 75ft x 25ft) Upbound 2-yr River Flow, Wind S 15 Knots, Pilot B, Proposed CRC Primary Span**

Figure A - 13: **Run 13, 27-ft Channel, *Sulphur Guardian* Loaded (453ft x 75ft x 25ft) Upbound 10-yr River Flow, Wind S 15 Knots, Pilot A, Proposed CRC Primary Span**

Figure A - 14: **Run 14, 27-ft Channel, *Sulphur Guardian* Loaded (453ft x 75ft x 25ft) Downbound Normal River Flow, Wind S 15 Knots, Pilot B, Proposed CRC Primary Span**

Figure A - 15: **Run 15, 27-ft Channel, *Sulphur Guardian* Loaded (453ft x 75ft x 25ft) Downbound 2-yr River Flow, Wind S 15 Knots, Pilot A, Proposed CRC Primary Span**

Figure A - 16: **Run 16, 27-ft Channel, *Sulphur Guardian* Loaded (453ft x 75ft x 25ft) Downbound 10-yr River Flow, Wind S 15 Knots, Pilot B, Proposed CRC Primary Span**

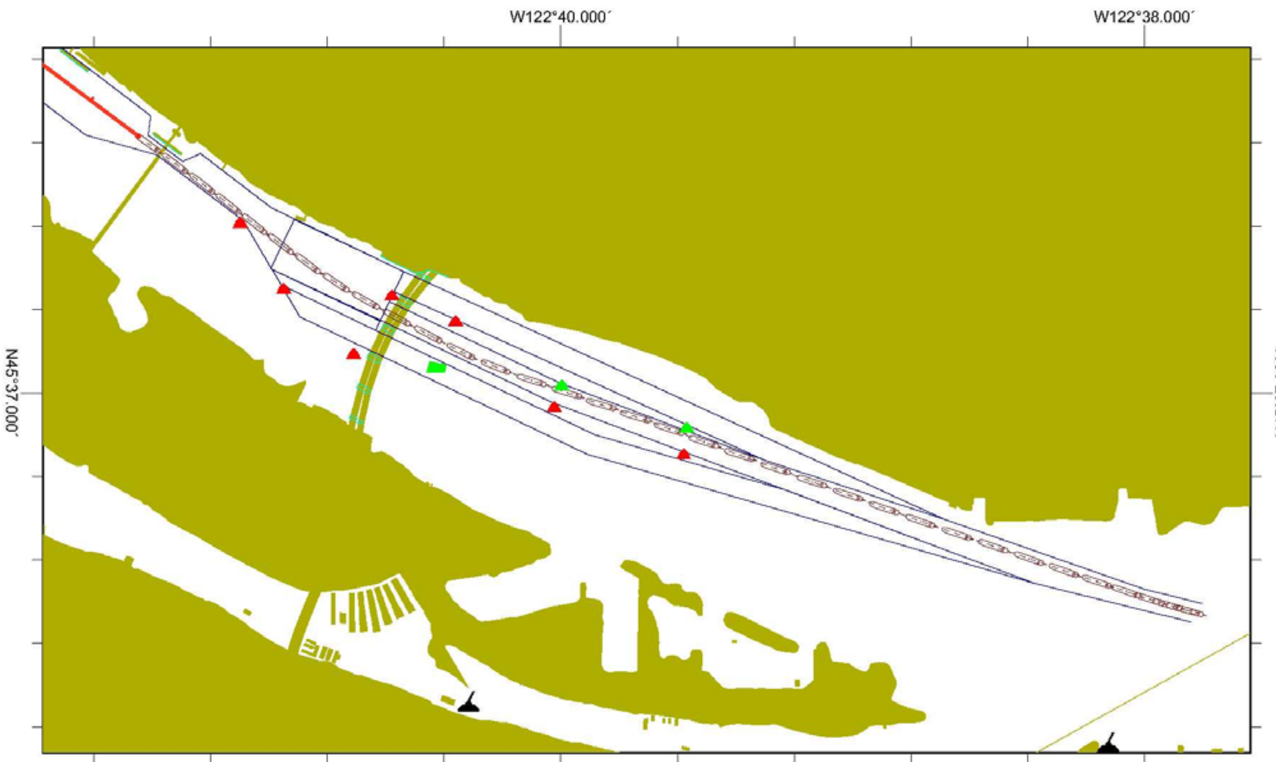


Figure A - 17: Run 17, 27-ft Channel, *Sulphur Guardian* Ballast (453ft x 75ft x 19ft) Downbound 2-yr River Flow, Wind S 15 Knots, Pilot A, Proposed CRC Primary Span

Figure A - 18: Run 18, 27-ft Channel, *Sulphur Guardian* Ballast (453ft x 75ft x 19ft) Downbound Normal River Flow, Wind S 15 Knots, Pilot B, Proposed CRC Primary Span

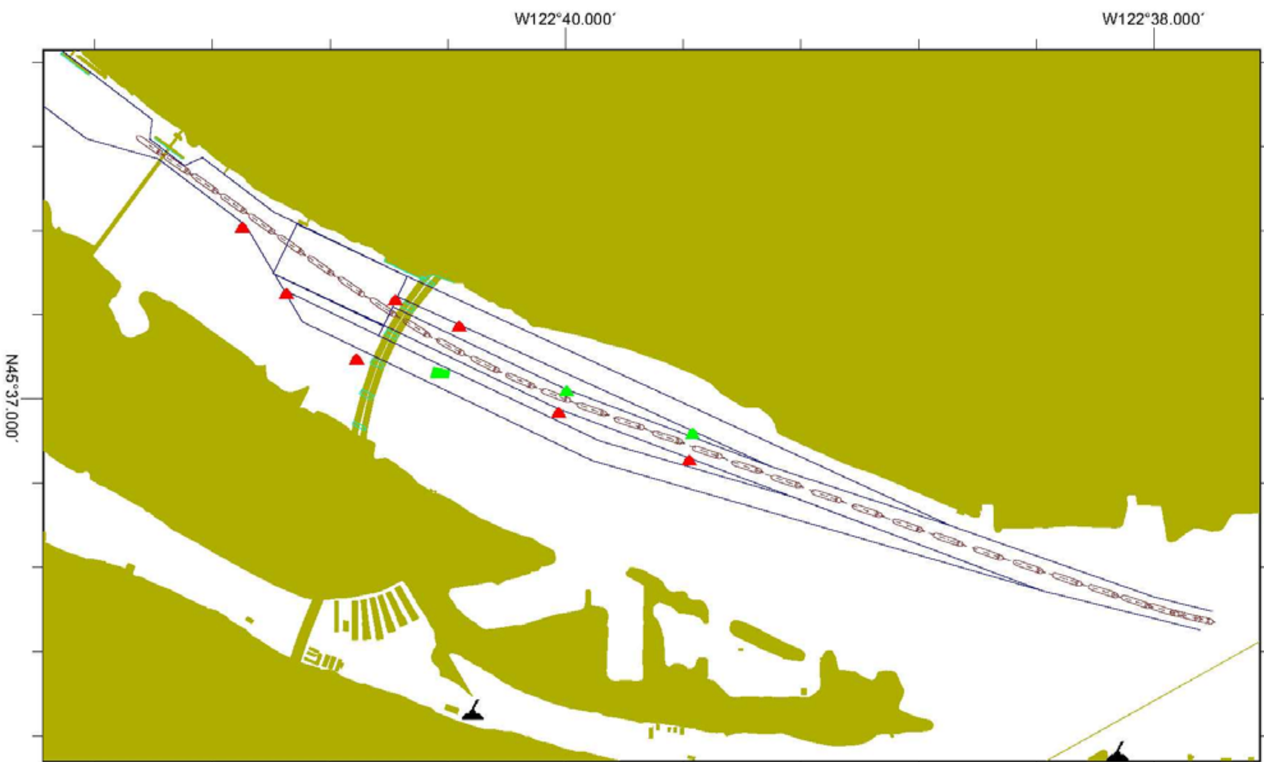


Figure A - 19: **Run 19, 27-ft Channel, *Sulphur Guardian* Ballast (453ft x 75ft x 19ft) Downbound 10-yr River Flow, Wind S 15 Knots, Pilot A, Proposed CRC Primary Span**

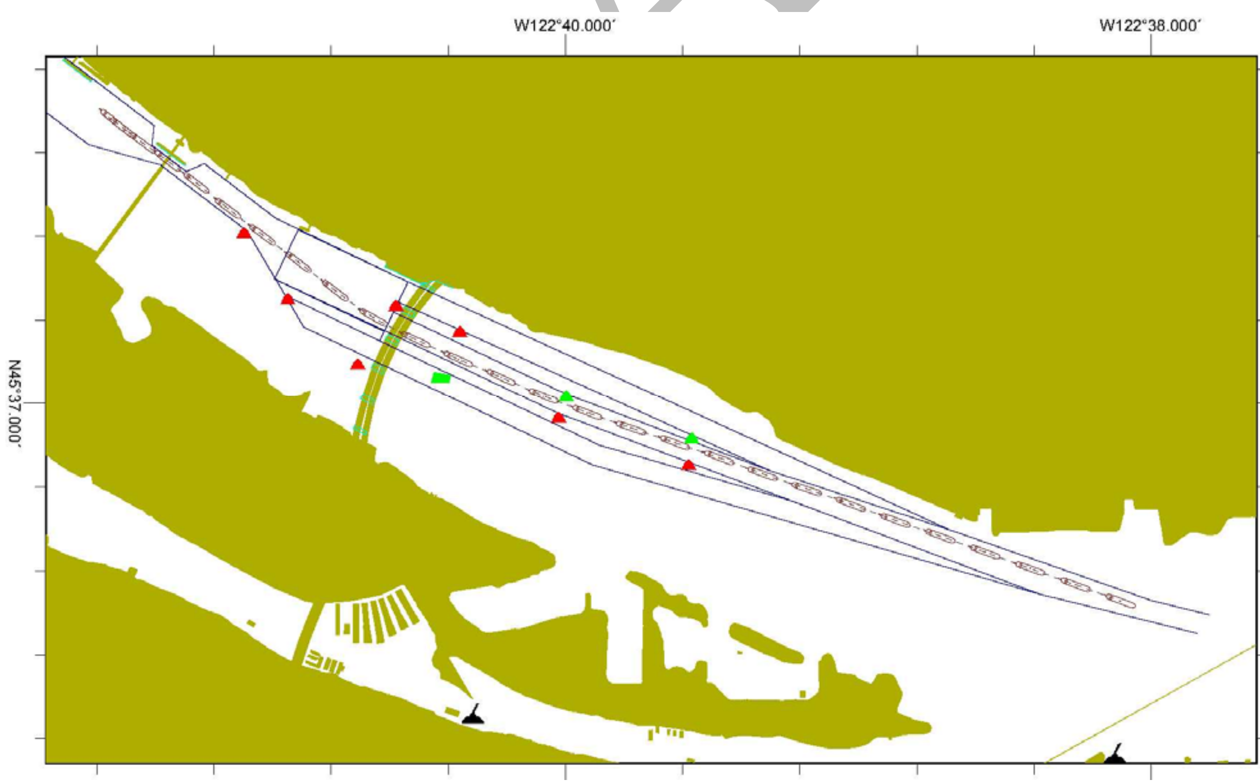


Figure A - 20: **Run 20, 27-ft Channel, *Sulphur Guardian* Ballast (453ft x 75ft x 19ft) Upbound Normal River Flow, Wind S 15 Knots, Pilot B, Proposed CRC Primary Span**

Figure A - 21: **Run 21, 27-ft Channel, *Sulphur Guardian* Ballast (453ft x 75ft x 19ft) Upbound 2-yr River Flow, Wind S 15 Knots, Pilot A, Proposed CRC Primary Span**

Figure A - 22: **Run 22a, 27-ft Channel, *Sulphur Guardian* Ballast (453ft x 75ft x 19ft) Upbound 10-yr River Flow, Wind S 15 Knots, Pilot B, Proposed CRC Primary Span**

Figure A - 23: **Run 22b, 27-ft Channel, *Sulphur Guardian* Ballast (453ft x 75ft x 19ft) Upbound 10-yr River Flow, Wind S 15 Knots, Pilot A, Proposed CRC Primary Span**

Appendix B – Design Ship Pilot cards

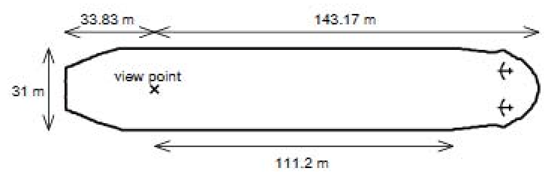
PILOT CARD

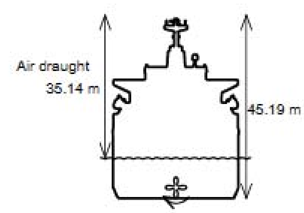
TANK22LV2
Version 2

Ship's name: Cape Bird | Date:
Call Sign: V7FA9 | Deadweight: 35070 tonnes | Year built: 2003
Draught aft: 10.06 m / 33 ft 0 in | Forward: 10.06 m / 33 ft 0 in | Displacement: 42320 tonnes

SHIP'S PARTICULARS

Length overall: 177 m | Anchor chain: Port: 12.0 shackles | Starboard: 12.0 shackles
Breadth: 31 m | Stern: shackles
Bulbous bow: Yes | (1 shackle = 27.432 m = 15 fathoms)





PROPULSION PARTICULARS

Type of engine: Diesel | Maximum power: 8561 kW (11640 hp)

Manoeuvring engine order		RPM	Pitch	Speed (knots)	
				Loaded	Ballast
Full sea speed	1	127.0		15.0	
Full Ahead	0.8	107.0		12.9	
Half Ahead	0.5	77.0		9.3	
Slow Ahead	0.25	51.0		6.1	
Dead Slow Ahead	0.125	36.0		4.2	
Dead Slow Astern	-0.125	-36.0			
Slow Astern	-0.25	-51.0			
Half Astern	-0.5	-77.0			
Full Astern	-1	-107.0			

Time limit astern: min:sec
Full ahead to full astern: min:sec
Max. No. of consecutive starts:
Minimum RPM: knots
Astern power: % ahead

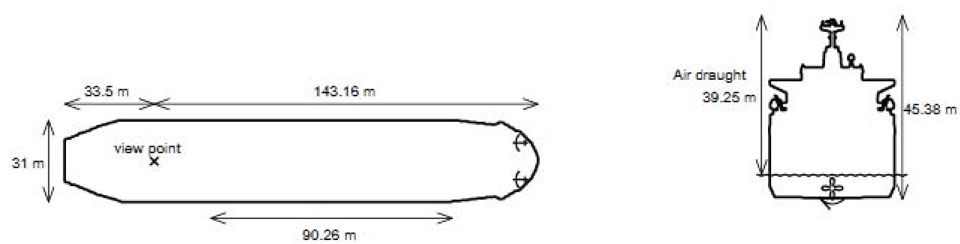
PILOT CARD

TANK22B
Version 1

Ship's name Cape Bird **Date** ______
Call Sign V7FA9 **Deadweight** 35070 tonnes **Year built** 2003
Draught aft 6.1 m / 20 ft 0 in **Forward** 4.88 m / 16 ft 0 in **Displacement** 22141 tonnes

SHIP'S PARTICULARS

Length overall 177 m **Anchor chain: Port** 12.0 shackles **Starboard** 12.0 shackles
Breadth 31 m **Stern** ______ shackles
Bulbous bow Yes (1 shackle = 27.432 m = 15 fathoms)



PROPULSION PARTICULARS

Type of engine Diesel **Maximum power** 8561 kW (11640 hp)

Manoeuvring engine order		RPM	Pitch	Speed (knots) Loaded	Speed (knots) Ballast
Full sea speed	1	127.0			15.8
Full Ahead	0.8	107.0			13.7
Half Ahead	0.5	77.0			10.0
Slow Ahead	0.25	51.0			6.5
Dead Slow Ahead	0.125	36.0			4.6
Dead Slow Astern	-0.125	-36.0			
Slow Astern	-0.25	-51.0			
Half Astern	-0.5	-77.0			
Full Astern	-1	-107.0			

Time limit astern ______ min:sec
Full ahead to full astern ______ min:sec
Max. No. of consecutive starts ______
Minimum RPM ______ ______ knots
Astern power ______ % ahead

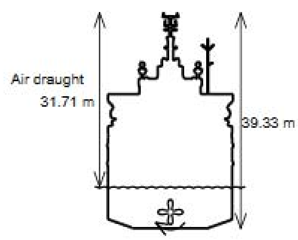
PILOT CARD

PRODC09LV2
Version 2

Ship's name Sulphur Guardian **Date**
Call Sign 3FMC3 **Deadweight** 14785 tonnes **Year built** 2011
Draught aft 7.62 m / 25 ft 0 in **Forward** 7.62 m / 25 ft 0 in **Displacement** 18300 tonnes

SHIP'S PARTICULARS

Length overall 138 m **Anchor chain: Port** 13.0 shackles **Starboard** 13.0 shackles
Breadth 23 m **Stern** shackles
Bulbous bow Yes **(1 shackle = 27.432 m = 15 fathoms)**



PROPULSION PARTICULARS

Type of engine Diesel **Maximum power** 5715 kW (7770 hp)

Manoeuvring engine order		RPM	Pitch	Speed (knots) Loaded	Speed (knots) Ballast
Full sea speed	1	136.0		14.7	
Full Ahead	0.8	115.0		12.9	
Half Ahead	0.5	82.0		9.4	
Slow Ahead	0.25	55.0		6.2	
Dead Slow Ahead	0.125	38.0		4.2	
Dead Slow Astern	-0.125	-38.0			
Slow Astern	-0.25	-55.0			
Half Astern	-0.5	-82.0			
Full Astern	-1	-115.0			

Time limit astern min:sec
Full ahead to full astern min:sec
Max. No. of consecutive starts
Minimum RPM knots
Astern power % ahead

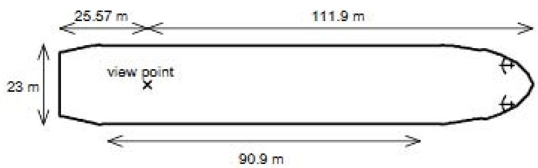
PILOT CARD

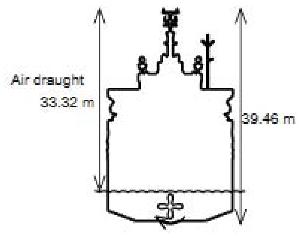
PRODC09BV2
Version 2

Ship's name: Sulphur Guardian — Date: ____
Call Sign: 3FMC3 — Deadweight: 14785 tonnes — Year built: 2011
Draught aft: 5.9 m / 19 ft 4 in — Forward: 4.1 m / 13 ft 5 in — Displacement: 11500 tonnes

SHIP'S PARTICULARS

Length overall: 138 m — Anchor chain: Port 13.0 shackles — Starboard 13.0 shackles
Breadth: 23 m — Stern ____ shackles
Bulbous bow: Yes — (1 shackle = 27.432 m = 15 fathoms)





PROPULSION PARTICULARS

Type of engine: Diesel — Maximum power: 5715 kW (7770 hp)

Manoeuvring engine order		RPM	Pitch	Speed (knots) Loaded	Speed (knots) Ballast
Full sea speed	1	136.0			15.7
Full Ahead	0.8	115.0			13.7
Half Ahead	0.5	82.0			10.0
Slow Ahead	0.25	55.0			6.6
Dead Slow Ahead	0.125	38.0			4.5
Dead Slow Astern	-0.125	-38.0			
Slow Astern	-0.25	-55.0			
Half Astern	-0.5	-82.0			
Full Astern	-1	-115.0			

Time limit astern ____ min:sec
Full ahead to full astern ____ min:sec
Max. No. of consecutive starts ____
Minimum RPM ____ ____ knots
Astern power ____ % ahead

Appendix C – Pilot Questionnaires

Pilot Questionnaire for VPOTD 27-ft Channel

<table>
<tr><td colspan="2">Run #:</td><td colspan="2">Date:</td><td colspan="2">Bridge/Operator:</td><td colspan="2">Pilot:</td></tr>
<tr><td>Circle Ship Used</td><td>S. Guardian (Ballast)</td><td colspan="2">S. Guardian (Loaded)</td><td colspan="2">Ship's Initial Speed:</td><td colspan="2">Ship's Initial Heading:</td></tr>
<tr><td rowspan="3">Environmental Conditions</td><td rowspan="2">River Flow (kcfs)</td><td colspan="4">Tugs (HP, IP)</td><td rowspan="2">Wind Dir. (from)</td><td rowspan="2">Wind Speed (knots)</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2">Run Start Time:</td><td colspan="6">Run End Time:</td></tr>
<tr><td colspan="2">Start Location:</td><td colspan="6">End Location:</td></tr>
<tr><td>Notes:</td><td colspan="7"></td></tr>
</table>

- Were you able to maintain the intended track line and voyage plan on this exercise? (If not, why?)

- What was the navigation impact of the (a) river flow and (b) wind?

- Rate the difficulty of this run with the number "5" indicating the difficulty level of an average transit in real-world pilotage conditions.

Increasing Difficulty →

1 2 3 4 5 6 7 8 9 10

- Rate the overall safety of this run. Use "1" as unsafe and "5" as indicating average.

Increasing Safety →

1 2 3 4 5 6 7 8 9 10

Do you have any "qualifiers" to the above safety rating (senior pilot only, restricted to daylight transits, wind direction/speed limitations, current, etc.)?

- If tugs were used rate their effectiveness. Use “1” as inadequate and “5” as indicating average

  Increasing Effectiveness →

  1 2 3 4 5 6 7 8 9 10

- Do you have any comments or recommendations concerning the power and number of tugs?

- Would you perform a similar transit / maneuver in a real-world situation? If not, why?

- If applicable, what additional conclusion or recommendations do you have regarding the vessel, channel, under keel clearance, current, etc.?

- Were you able to maintain the intended track line and voyage plan on this exercise? (If not, why?)

Pilot Questionnaire for VOTB

<table>
<tr><td colspan="2">Run #:</td><td colspan="2">Date:</td><td colspan="2">Bridge/Operator:</td><td colspan="2">Pilot:</td></tr>
<tr><td>Circle Ship Used</td><td>Cape Bird (Ballast)</td><td colspan="2">Cape Bird (Loaded)</td><td colspan="2">Ship’s Initial Speed:</td><td colspan="2">Ship’s Initial Heading:</td></tr>
<tr><td rowspan="3">Environmental Conditions</td><td rowspan="2" colspan="2">River Flow (kcfs)</td><td colspan="3">Tugs (HP, IP)</td><td rowspan="2">Wind Dir. (from)</td><td rowspan="2">Wind Speed (knots)</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Run Start Time:</td><td colspan="5">Run End Time:</td></tr>
<tr><td colspan="3">Start Location:</td><td colspan="5">End Location:</td></tr>
<tr><td>Notes:</td><td colspan="7"></td></tr>
</table>

- What was the navigation impact of the (a) river flow and (b) wind?

- Rate the difficulty of this run with the number “5” indicating the difficulty level of an average transit in real-world pilotage conditions.

Increasing Difficulty →

1 2 3 4 5 6 7 8 9 10

- Rate the overall safety of this run. Use “1” as unsafe and “5” as indicating average.

Increasing Safety →

1 2 3 4 5 6 7 8 9 10

Do you have any “qualifiers” to the above safety rating (senior pilot only, restricted to daylight transits, wind direction/speed limitations, current, etc.)?

- Rate the effectiveness of the assist tug(s). Use “1” as inadequate and “5” as indicating average

Increasing Effectiveness →

1 2 3 4 5 6 7 8 9 10

- Do you have any comments or recommendations concerning the power and number of tugs?

- Would you perform a similar transit / maneuver in a real-world situation? If not, why?

- If applicable, what additional conclusion or recommendations do you have regarding the vessel, channel, under keel clearance, current, etc.?

Study Final Questionnaire

Date:		Pilot/Captain:	

SECTION A = REALISM	"REALISM" Rating Scale	1	Unrealistic	5	Average	10	Excellent

Ship Model Realism		(Circle Choice)					Increasing Realism→→→				
1.	**Cape Bird Loaded**	1	2	3	4	5	6	7	8	9	10
Ship Model Realism		(Circle Choice)					Increasing Realism→→→				
2.	**Cape Bird Ballast**	1	2	3	4	5	6	7	8	9	10
Ship Model Realism		(Circle Choice)					Increasing Realism→→→				
3.	**Sulphur Guardian Loaded**	1	2	3	4	5	6	7	8	9	10
Ship Model Realism		(Circle Choice)					Increasing Realism→→→				
4.	**Sulphur Guardian Ballast**	1	2	3	4	5	6	7	8	9	10
Ship Model Realism		(Circle Choice)					Increasing Realism→→→				
5.	**Tugs**	1	2	3	4	5	6	7	8	9	10
Environmental Conditions Realism		(Circle Choice)					Increasing Realism→→→				
6.	**Wind**	1	2	3	4	5	6	7	8	9	10
Environmental Conditions Realism		(Circle Choice)					Increasing Realism→→→				
7.	**River Currents**	1	2	3	4	5	6	7	8	9	10

Section B = Safety	Overall "SAFETY" Rating Scale	1	Unsafe	5	Average	10	Very Safe

Overall Safety		(Circle Choice)					Increasing Safety→→→				
1.	Upper Vancouver Turning Basin (35ft)	1	2	3	4	5	6	7	8	9	10
2.	CRC Bridge Navigation Span	1	2	3	4	5	6	7	8	9	10
3.	Vancouver to the Port of The Dalles (27ft)	1	2	3	4	5	6	7	8	9	10

Section C = Recommendations and Comments

4. Please describe any recommendations you have for increasing the safety and/or efficiency of the channel design (tug assistance, visibility, wind, size, etc.) for:

a) Upper Vancouver Turning Basin

b) Vancouver to the Port of The Dalles

5. Please write additional comments you would like to make concerning this project. Use the attached project drawing for demonstration.

Appendix D – ERDC Ship/Tow Simulator