SHORE-BASED BALLAST WATER TREATMENT IN CALIFORNIA

TASK 2: RETROFITTING AND OUTFITTING OF VESSELS

PREPARED FOR

DELTA STEWARDSHIP COUNCIL
SACRAMENTO, CALIFORNIA

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PREPARED	CHECKED	APPROVED
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Revision History

Section	Rev	Description	Date	Approved
All	-	Released as final.	20 Feb 2018	KJR

References

1. *Shore-Based Ballast Water Treatment in California, Task 3: Assessment of Retrofitting Ports and Wharves,* KPFF Consulting Engineers, 4 August 2016.
2. *Shore-Based Ballast Water Treatment in California, Task 4: Assessment of Shore-Based Ballast Water Treatment Facilities,* Kennedy/Jenks Consultants, Rev. P0, 4 August 2016.
3. *Shore-Based Ballast Water Treatment in California, Task 5: Assessment of Treatment Technologies,* Kennedy/Jenks Consultants, 4 August 2016.
4. *Guidance Notes on Fire-Fighting Systems*, American Bureau of Shipping (ABS), 2016.
5. *Recommendation for Oil Tanker Manifolds and Associated Equipment*, OCIMF, Fourth Edition, August 1991.
6. National Ballast Information Clearinghouse, Smithsonian Environmental Research Center & United States Coast Guard, http://invasions.si.edu/nbic/, accessed 11 April 2015.
7. *Ballast Water Treatment Advisory 2014: Table 13 – Ballast Water Capacity & Ballast Pump Rates by Vessel Type*, American Bureau of Shipping (ABS), Rev. 3, 2014.

Executive Summary

This report is part of an overall coordinated study evaluating the feasibility of using shore-based mobile or permanent ballast water treatment facilities to meet California's Interim Ballast Water Discharge Performance Standards (CA Interim Standards). Tasks 2 through 5 are submitted together to discuss the practical necessities for shore-based treatment system implementation, from the modifications onboard vessels through to the treatment technologies used in the facilities.

This ***Task 2*** report assesses the ***retrofitting and outfitting of marine vessels,*** ships, as part of the larger overall study of Shore-based Ballast Water Treatment in California. The assessment considers the feasibility and required modifications so that a ship can pump its ballast water to a new exterior piping connection where shore facilities can receive and process the ballast water in accordance to California requirements.

- Feasibility considerations include: ballast water flow rates, volumes, and pressures delivered to shore facilities; available deck space and arrangement impacts to make the shore connection; changes and additions to shipboard operational procedures; and costs.
- Required modifications include: new exterior pipe manifolds, piping of ballast water to the manifold, relocation of equipment interferences.

Leveraging Tankship and Terminal Experience

Tank ships and marine tank terminal facilities provide valuable insight on high volume ship-to-shore and ship-to-ship liquid transfers. Organizations such as OCIMF provide the roughly 8,000 tankships and 4,500 terminals world-wide with standards and practices that can be applied to shore-based ballast water transfers.

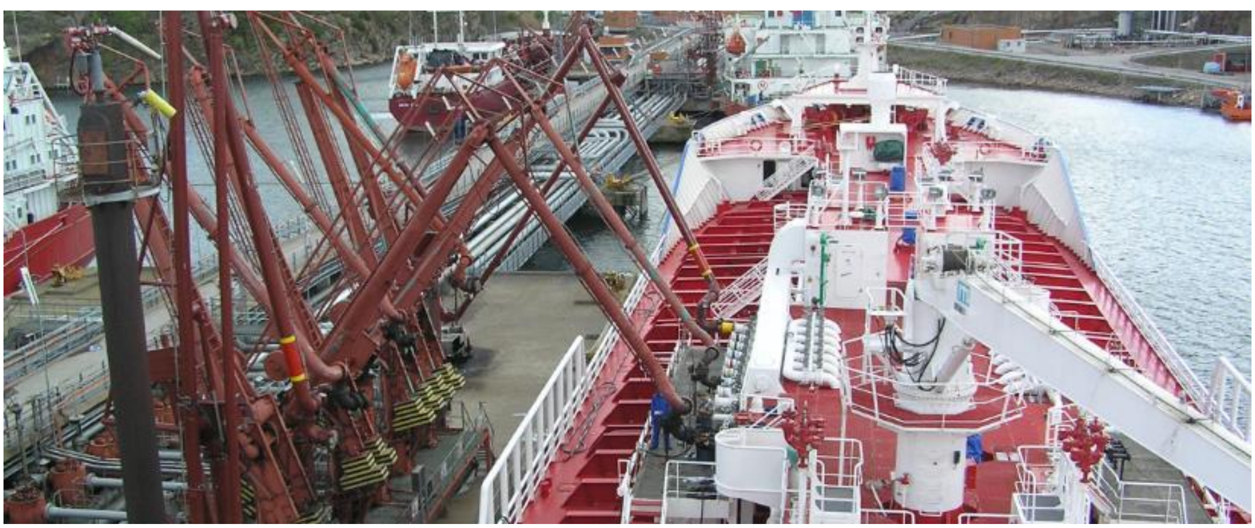


Figure 1 Brofjorden marine terminal. Loading arms are similar in size to that needed for SA Recycling ballast water handling operations, but smaller than required for Stockton or El Segundo case studies. (Marcus Bengtsson, wikicommons)

1.1 Assessment Approach

The assessment of transferring ballast water from a marine vessel to a shore-based facility was broken into three aspects:

- General modifications and operational considerations applicable to most marine vessels, such as installing a deck manifold and operational considerations.
- Modifications and operational impacts particular to each of the six vessel types studied, such as new piping runs and particulars such as explosive vapors on tank ships.
- Determining the vessel interface particulars at a given case study location, such as height of ballast water manifold presentation flange, flow rates, volumes, and pressures.

Details on the assessment methods are provided in Section 3.

1.2 General Modifications and Operational Considerations

The offloading of ballast water from a marine vessel to a shore-based facility requires an external connection. As outlined in Figure 2, below, such a connection can be made at a main deck manifold, at a side port similar to those used on passenger cruise ships and car carriers, or at a hull fitting similar to existing overboards.

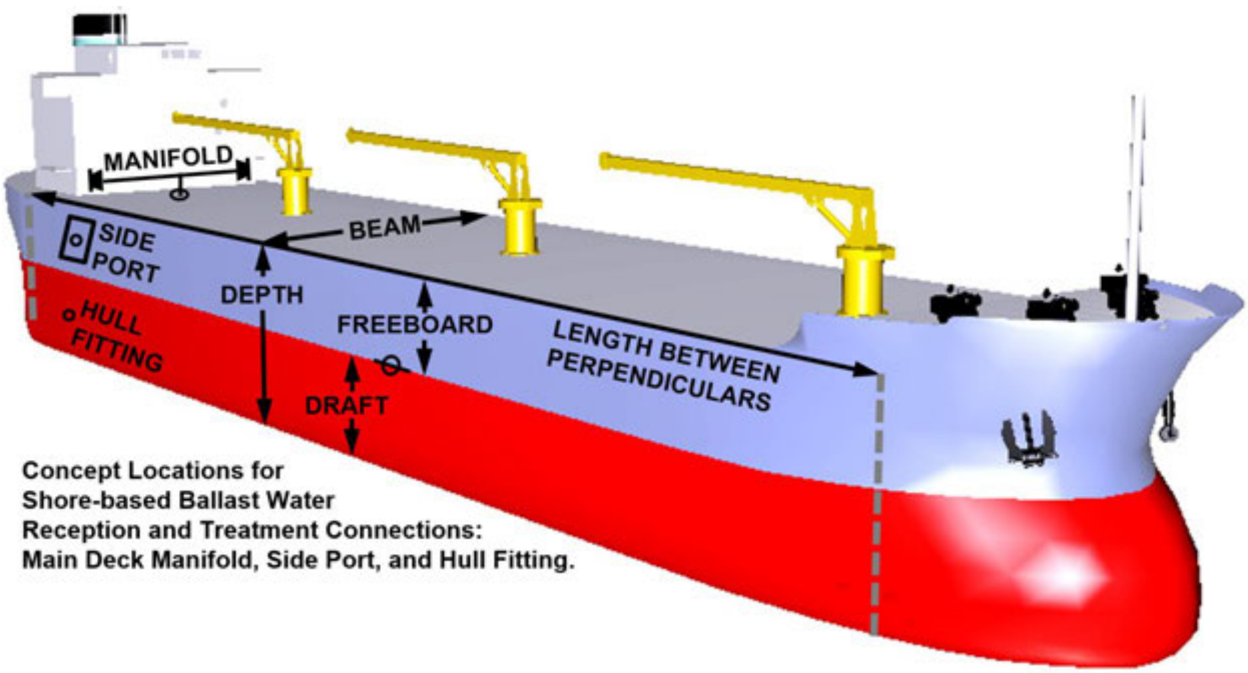


Figure 2 Marine vessel particulars used in analysis, and concept locations for ballast water shore connection fittings

Such fittings can be used for offloading ballast water to a land-based facility or to another marine vessel, such as a barge or ship. Each type of transfer operation requires careful consideration of arrangement impacts and safe operations. Figure 3, below, provides an outline of some considerations when discharging to a land-based reception facility during cargo operations.

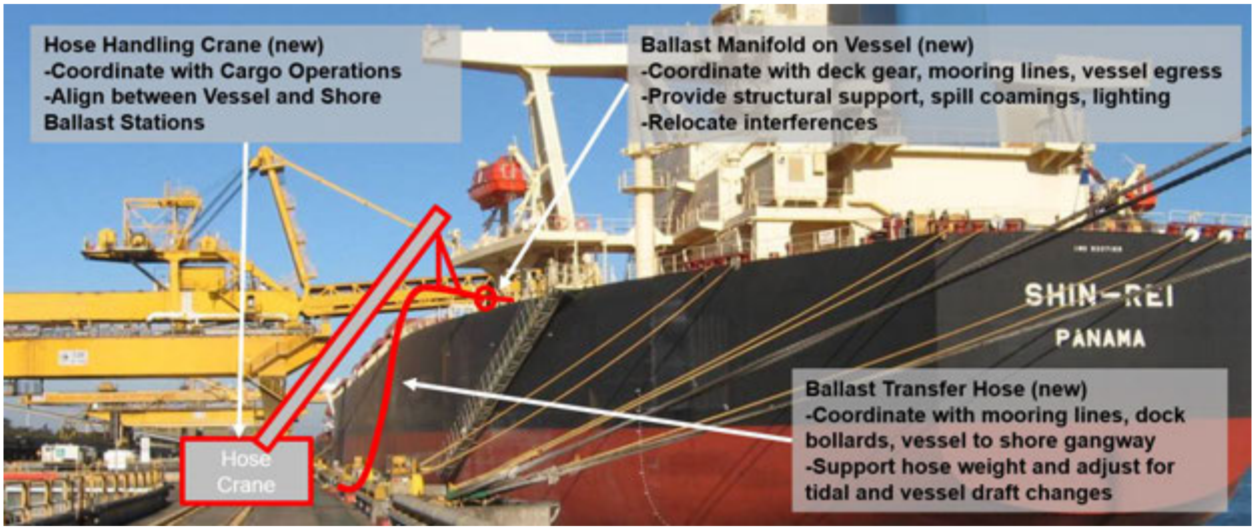
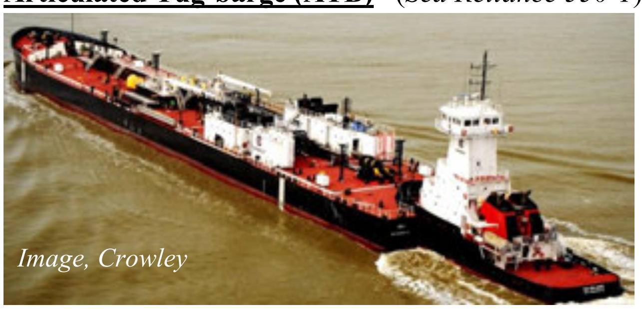


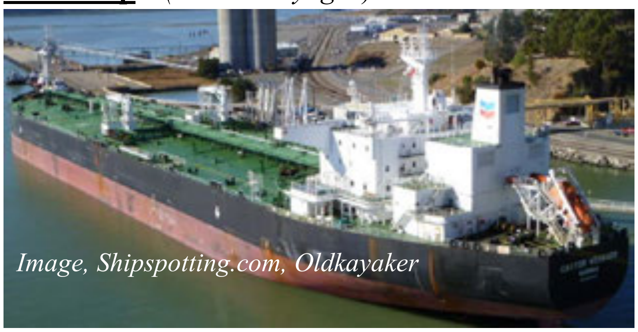
Figure 3 Operational considerations for land-based connection during cargo operations

1.3 Vessel Types

This report assesses vessel modifications required to transfer ballast water to shore-based treatment or conveyance systems for six different vessel types as detailed in Table 1 below. These images are typical for these vessel types, and are vessels that have discharged ballast water in their respective case study locations within the last few years.

Table 1 Vessel type examples in assessment

Vessel Example	Particulars
Articulated Tug-barge (ATB) (*Sea Reliance 550-1*)  	Length 150 m, Breadth 22.6 m, Depth 12.2 m Ballast capacity: 10,508 cubic meters (m^3) Example discharges (sister vessel 550-4): 2845 m^3, Long Beach 2377 m^3, Los Angeles 9441 m^3, San Diego 8190 m^3, San Francisco Case study – El Segundo.
Containership (*Sealand Intrepid*)  	Length 273 m, Breadth 32.2 m, Depth 21.2 m Ballast capacity: 17,708 m^3 Ballast water discharges, 1/2012 thru 6/2016: 18 out of 54 port calls in California Largest 3,069 m^3 in LA Smallest 189 m^3 in Oakland Case study: Oakland/Trapac Terminal.

Vessel Example	Particulars
<u>Bulk Carrier</u> *(Rosco Olive)*  	Length 218 m, Breadth 32.2 m, Depth 19.8 m Ballast capacity: 36,243 m^3 Ballast water discharges, 1/2012 thru 6/2016: 2 out of 2 port calls in California 32,890 m3, Stockton 4,536 m3, Richmond Case studies: Stockton, POLA/SA Recycling
<u>Tank Ship</u> *(Castor Voyager)*  	Length 218 m, Breadth 32.2 m, Depth 19.8 m Ballast capacity: 36,243 m^3 Ballast water discharges1/2012 thru 6/2016: 15 out of 55 port calls in California Largest 35,525 m^3 in Pacific Area Lightering Smallest 2,455 m^3 in Long Beach Average 18,400 m^3 Others in El Segundo, Richmond, Benicia Case study: El Segundo
<u>Passenger Cruise Ship</u> *(Carnival Inspiration)*  	Length 261 m, Breadth 31.5 m, Depth 22.6 m Ballast capacity: 4,027 m^3 Ballast water discharges, 1/2012 thru 6/2016: 440 out of 664 port calls in California Largest 1,799 m^3 in Long Beach Smallest 100 m^3 in Long Beach One discharge in San Francisco, no others Average 866 m^3 Case study: POLB/Cruise Terminal
<u>Automobile Carrier (RoRo)</u> *(Green Bay)*  	Length 192 m, Breadth 32.2 m, Depth 14.2 m Ballast capacity: 9,761 m^3 Ballast water discharges, 1/2012 thru 6/2016: 1 out of 17 port calls in California 75 m^3 in Port Hueneme Case study: Port Hueneme

The ballast water discharge characteristics were determined for each of these vessels types, particular to those that call to any of the case study locations. This portion of the assessment assumed no reduction of the vessel types ballast rates, and required modifications in order to support operations at any port of call in California or elsewhere that might consider shore-based ballast water treatment. This does not consider limitations at the specific case study ports, which based on historical data, might require lower flow rates and smaller diameter connections than calling vessels might be capable of. This is based on the premise that a vessel, if undergoing such a modification, would want the flexibility to discharge ballast water volumes at full rate.

Table 2 Summary of interfaces by vessel type for shore-based ballast connections

	Ballast Water		Presentation Flange			
	Capacity	Rate	AWL Deep	AWL Light	Press Deep	Press Light
Vessel Type	*(m3)*	*(m3/hr)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
ATB Tanker	20,000	1,700	1.90	9.80	280	40
Tankers	41,000	3,400	7.60	16.60	360	110
Bulk Carriers	33,000	2,800	5.40	14.80	340	100
Containerships	42,000	2,300	6.20	13.50	480	120
Cruiseships	4,000	300	3.50	7.10	400	80
Car Carriers	13,000	700	3.90	7.20	250	90

Table Notes:

Figures were developed to represent 95% of vessels within a type and class. Vessels outside of this range will require special consideration.

Presentation flange distances are given above water line (AWL) for the in ballast (Light) and laden with cargo (Deep) conditions.

Presentation flange pressure is at the flange itself, for both light and deep conditions.

Cruiseships and Car Carriers use water tight deck cut-outs for bunkering stations. In general, these stations are 5 meters above the water line, but vary based on arrangement.

1.4 Vessel Interfaces at Case Study Locations

Each case study location and its vessel type pairing was examined to determine characteristics that would impact Task 3 and 4 studies. It was found that the vessels calling on each of these locations would likely present a different range of ballast connection heights, hose sizes, and flow rates – impacting reception. The frequency and volume of discharges also varied significantly – impacting storage and treatment facility sizing.

Table 3 Vessel interface particulars for each case study

	Disch. Rate	Connection		Volume		
		Flange	Hose	Period	Total	
Port/Terminal	*(m3/hr)*	*(mm)*	*(mm)*	*(days)*	*(m3)*	**Vessel Types**
Port of Stockton (1)	2,800	600	300	1	34,000	*Bulk carriers.*
Port of Oakland/Trapac (2)	750	300	200	1	7,500	*Containerships. Basis for reception facility.*
Adjacent terminals	1,500	400		1	14,000	*Basis for piping works to treatment plant.*
Total for processing plant.	2,400	500		1	22,500	*Basis for treatment plant sizing.*
Port Hueneme (3)	350	200	150	20	4,000	*Various. Base ship connection on car carriers.*
El Segundo Marine Term.(4)	3,400	600	300	1	32,000	*Tankers.*
PoLA/SA Recycling (5)	1,400	400	200	5	24,000	*Bulk carriers.*
PoLB/Cruise Terminal (6)	400	200	150	1	2,400	*Cruise ships.*

(1) Port of Stockton ballast discharges are tightly linked to cargo discharge rates, which are occur daily and in high volumes. Due to this tight pattern of consistent high rates and volumes, the design basis is set at the maximum rates with a small margin. Often, there are multiple consecutive days with high volume discharges, resulting in as much as 98,000 tons in a single seven-day period.

(2) Port of Oakland Trapac facility parameters are used to develop a baseline design reception from ship to shore and intermediate storage. The adjoining facility details are then used for sizing transfer station pumps and piping. The total for processing plant considers the rate and total of ballast water to the centralized processing plant. The totals provided use Trapac specific as well as port wide historic ballast water discharge volumes and rates.

(3) Hueneme sees discharges from multiple vessel types, but car carriers provide a reasonable design basis for presentation flange pressure and dimensions. The discharge rates and volumes vary significantly, and there is more than one approach. The design rate is based on slowing down some of the larger vessels discharge rates, but allowing typical discharge volumes to be offloaded in less than eight hours. There are various ways to consider the volume period and amounts. The design basis here is based uses a 20-day period for the ballasting cycle, i.e. how many vessels and ballast discharge volumes per 20-day period. This approach is based on 12 years of data, showing that such a 20-day period will see no more than 4,000 tons of ballast discharge. For the rare, every five years, higher volumes additional barge or other means would be required.

(4) El Segundo vessel discharges are strictly governed by cargo loading rates, which are impractical to slow for all but extreme cases. The discharge volumes and rates are based on typical highest discharges, noting that one vessel called in last several years with higher rates and volumes. That case will require additional time, split discharge, or other special accommodation.

(5) POLA/SA Recycling processes cargo on weekly basis, seeing ballast discharges of as much as 22,000 tons per week. Although ship discharge rates are as high as 2,800 m3/hr, it is reasonable to slow this rate significantly during port collection, as the amount of ballast water to be discharged on a daily basis is no more than 6,000 metric tons. This reduced rate, over an eight-hour period would be only 750 m3/hr. However, it is important to not stress ship's pumps by running at too slow of a rate, i.e. less than 50% of rated. As such, design rate for port reception is 1,400 m3/hr, 50% of ship pumps.

(6) POLB cruise terminal discharges have seen only three vessels routinely discharging over the last several years. That noted, these vessels are typical of the industry in terms of volume discharges and rates, discharging less than 2,000 tons of ballast water in a 4-hour period. That noted, the design basis provides some margin to holding capacity, to account for some growth given newer cruise ships having larger capacities, based on analysis of other cruiseship discharges at other ports. The rate is increased to 400 m3/hr to correspond to 6-hour processing of larger volumes.

(7) Hose sizing follows OCIMF guidance, generally keeping less than 12 meters per second velocity. Actual size considers the available head from the vessels pumps at the presentation flange, and assumes 70 kPa suction lift from the receiving facility (lift station). Hose is assumed to be smooth bore with Hazen Williams friction factor of 140 or less, and total length between 30 and 50 meters. In hose velocities are a special case, where in pipe velocities use the much slower rate of 3 meters per second (10 feet per second) as a guideline.

1.5 Summary of Findings

Cost estimates were developed to inform the economic feasibility of modifying vessels for shore-based treatment, and are summarized below.

Table 4 Modification costs by vessel type and size

Vessel Type	Case Study	Discharge Rate (m^3/hr)	Modification Cost
Articulated tug-barge	El Segundo	1,700	$151,400
Containership	Oakland – TraPac	750	$152,600
Bulk carrier	Stockton/SA Recycling	2,800/1,400	$308,900
Oil tanker	El Segundo	3,400	$425,900
Passenger cruise ship	Long Beach Cruise Terminal	400	$297,300
Automobile carrier	Hueneme	350	$297,300

Section 2 Methods

2.1 Example Vessel Selection Process and Data Sources

All marine vessels of 300 gross registered tons or more must comply with California ballast water management requirements. This requirement captures a broad range of marine vessels types of very different sizes, cargos or missions, and ballast water characteristics. Military vessels are not subject to California requirements, but rather comply with internal military vessel requirements. Marine vessel types were prescribed by the study scope to include analysis of: containerships, tank ships, articulated tug-barges (ATBs), bulk carriers, automobile carriers, and passenger cruise ships. Figure 4, below, provides the volume of ballast water discharged by these various vessel types in 2015. ATBs are included in the 'unmanned barge' category.

California had 9,055 vessel arrivals in 2015, with 1,349 (15%) discharging ballast water. Many of the arrivals were repeat calls by the same vessel. For reference, there are an estimated 50,000 marine vessels worldwide that carry ballast water. The vessel selection process screened for those that discharged ballast water in California, and if possible at the case study locations.

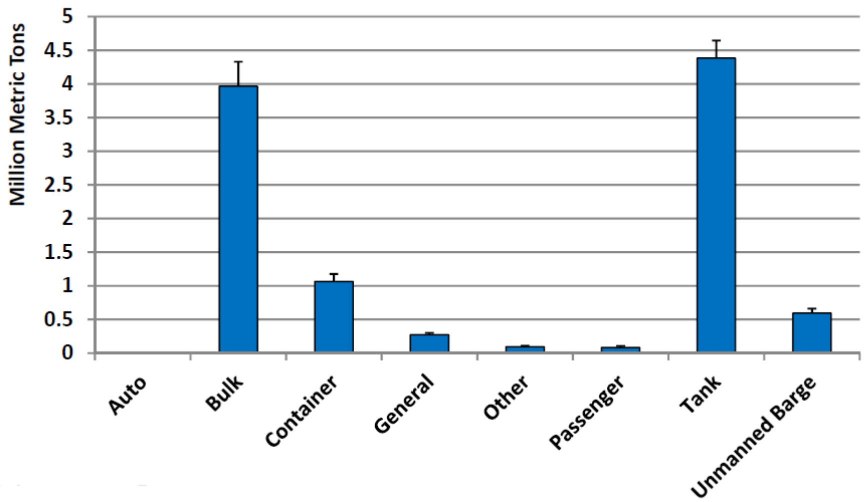


Figure 4 2015 Ballast discharges in California by vessel type (CA State Lands Commission, 2016)

2.1.1 Selection Process

Example vessels were selected that discharged ballast water at a case study port. Within each vessel type that met the case study port criteria, a variety of vessel sizes and variations in ballasting characteristics was selected. A sub-set of vessels was then down-selected based on availability of data for key characteristics to perform the analysis, ensuring that enough variety in configurations remained in the set. These characteristics were then compared to reference materials on typical characteristics for those vessel types.

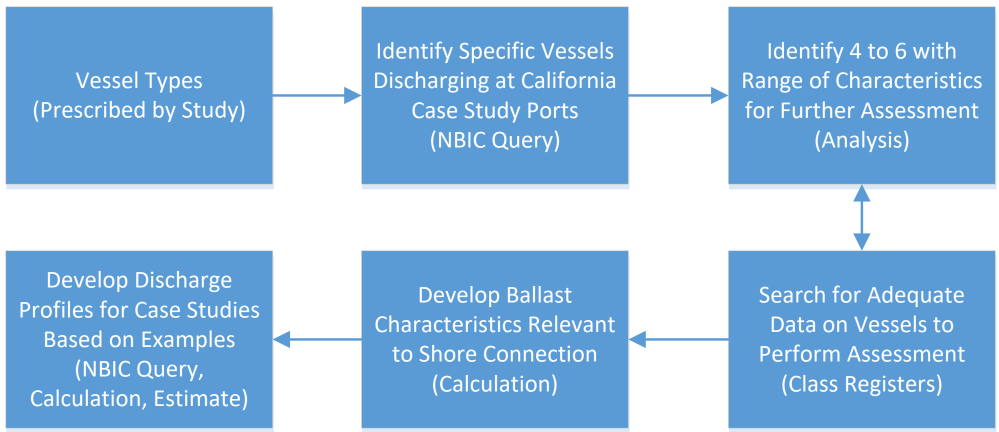


Figure 5 Example vessel selection and screening process

2.1.2 Data Sources

The National Ballast Information Clearinghouse (NBIC), a joint program of the Smithsonian Environmental Research Center (SERC) and the United States Coast Guard, provides an online tool to access ballast water management reports from all vessels reporting in the United States. This resource was accessed to first locate discharging vessels within case study locations, and then to gain details of those ballast water discharges.

					Discharge Status (# of arrivals) (See Note 1)		Transit Type (# of arrivals)			Treatment system (# of arrivals)
State	Arrival Port	# Forms Submitted	Earliest Arrival	Latest Arrival	Not Discharging	Discharging	Overseas	Coastwise	Unknown	AMS
CA	Alameda (USA, CA)	1	2012-07-26	2012-07-26	0	1	0	1	0	0
CA	Antioch (USA, CA)	48	2012-01-10	2016-02-13	48	0	44	4	0	0
CA	Benicia (USA, CA)	39	2012-02-27	2015-12-16	1	38	21	18	0	1
CA	Carquinez (USA, CA)	8	2012-01-31	2014-08-13	7	1	8	0	0	0
CA	Crockett (USA, CA)	49	2012-01-09	2016-03-17	49	0	46	3	0	0
CA	Eureka (USA, CA)	23	2012-02-24	2016-06-15	0	23	14	9	0	0
CA	Long Beach (USA, CA)	1114	2012-01-01	2016-07-04	418	696	736	378	0	11
CA	Long Beach Anchorage (USA, CA)	4	2013-04-16	2015-07-28	4	0	4	0	0	0
CA	Los Angeles (USA, CA)	406	2012-01-01	2016-05-11	324	82	344	62	0	5
CA	Los Angeles Anchorage (USA, CA)	1	2012-02-18	2012-02-18	1	0	0	1	0	0
CA	Los Angeles-Long Beach (USA, CA)	4	2012-06-06	2016-05-28	2	2	1	3	0	0
CA	Martinez (USA, CA)	2	2016-05-24	2016-06-23	1	1	1	1	0	0
CA	Oakland (USA, CA)	81	2012-01-02	2016-05-27	1	80	57	24	0	0
CA	Pittsburg (USA, CA)	223	2012-01-17	2016-04-29	103	120	210	13	0	0
CA	Redwood City (USA, CA)	174	2012-01-06	2016-04-20	134	40	35	139	0	1
CA	Richmond (USA, CA)	279	2012-01-03	2016-04-27	133	146	60	219	0	1
CA	Sacramento (USA, CA)	101	2012-01-21	2016-05-23	26	75	85	16	0	1
CA	San Diego (USA, CA)	42	2012-03-02	2016-04-25	34	8	27	15	0	0
CA	San Francisco (USA, CA)	171	2012-01-07	2016-04-18	132	39	51	120	0	0
CA	San Francisco Anchorage #9 (USA, CA)	100	2012-01-04	2016-01-25	92	8	10	90	0	0
CA	San Francisco Bay (USA, CA)	11	2012-06-30	2015-04-26	7	4	9	2	0	0
CA	Stockton (USA, CA)	422	2012-01-02	2016-06-07	174	248	306	116	0	5
CA	Wilmington (USA, CA)	12	2012-12-30	2016-02-25	1	11	11	1	0	0

Figure 6 NBIC screening for period 1/2012 to 6/2016 for bulk carriers

CA	Stockton (USA, CA)	2014-04-13	9610688	Jervis Bay	Yokohama	Japan	Bulker	0	0		0	0	0	0	
CA	Stockton (USA, CA)	2014-04-12	9387633	Ecomar G.O.	Jingtang	China, Peoples Republic of	Bulker	33585	0	0	14557	19002	0	0	
CA	Stockton (USA, CA)	2014-04-11	9618513	Trident Legacy	Busan	South Korea	Bulker	0	0		0	0	0	0	
CA	Stockton (USA, CA)	2014-04-04	9585651	Cielo Di Dublino	Topolobampo	Mexico	Bulker	0	0		0	5448	0	0	
CA	Stockton (USA, CA)	2014-04-03	9527180	Asahi Bulker	Pittsburg (USA, CA)	USA	Bulker	0	0		917	0	0	0	
CA	Stockton (USA, CA)	2014-03-29	9442483	Ikan Bagat	Yeosu	South Korea	Bulker	37877	0	0	1158	36310	0	0	
CA	Stockton (USA, CA)	2014-03-28	9593361	Western Tokyo	Xiamen	China, Peoples Republic of	Bulker	0	0		0	0	0	0	
CA	Stockton (USA, CA)	2014-03-27	9646728	Abyssinian	Yeosu	South Korea	Bulker	11692	0	0	11692	0	0	0	
CA	Stockton (USA, CA)	2014-03-25	9647887	Tenacity	Yeosu	South Korea	Bulker	10203	0	0	10203	0	0	0	
CA	Stockton (USA, CA)	2014-03-16	9544700	Bryant	Tianjin	China, Peoples Republic of	Bulker	34351	0	0	34351	0	0	0	
CA	Stockton (USA, CA)	2014-03-10	9628570	Bunun Ace	New Westminster	Canada	Bulker	0	0		0	0	0	0	
CA	Stockton (USA, CA)	2014-02-28	9336610	Navios Esperanza	Dalian	China, Peoples Republic of	Bulker	31216	0	0	19939	11277	0	0	
CA	Stockton (USA, CA)	2014-02-24	9682899	Atlantic Rainbow	Stockton (USA, CA)	USA	Bulker	0	5972	0	0	0	5972	0	AMS-2013-PANASIA-GloEn-Patrol-001
CA	Stockton (USA, CA)	2014-02-24	9193692	Elena Topic	Busan	South Korea	Bulker	0	0		0	0	0	0	
CA	Stockton (USA, CA)	2014-02-18	9542465	Rosco Olive	Kakogawa	Japan	Bulker	32090	0	0	16786	15304	0	0	

Figure 7 NBIC database selected for Stockton (notice *Rosco Olive* on bottom)

Ballast Report

Is this an *amended* Ballast Reporting Form? **No**

1. Vessel Information		2. Voyage Information		3. Ballast Water Usage and Capacity		
Vessel Name	Rosco Olive	Arrival Port	Stockton (USA, CA)		Volume [mt]	Tanks
IMO number	9542465	Arrival Date	2014-02-18	Total Ballast Water on Board	37148	13
Owner	JIANXIN JINSI LEASING(TIANJIN) C	Agent	General Steamship Corporation Ltd	Total Ballast Water Capacity	36243	13
Vessel Type	Bulker	Last Port	Kakogawa			
Tonnage	40325	Country of Last Port	Japan			
Call Sign	VRHK8	Next Port	Richmond (USA, CA)			
Flag	Hong Kong	Country of Next Port	USA			

4. Ballast Water Management

Total number of Ballast Water Tanks to be discharged: **13**

Of tanks to be discharged, how many: Underwent Exchange: **13** Underwent Alternative Management: __

Please specify alternative method(s) used, if any: ____________________

If no ballast treatment conducted, state reason why not: ____________________

Ballast management plan on board? **Yes** Ballast management plan implemented? **Yes**

IMO ballast water guidlines on board [res. A.868(20)]? **Yes**

5. Ballast Water History

Tanks/Holds	BW Sources				BW Management Practices						BW Discharge			
	Date	Port or Lat Long.	Volume [mt]	Temp.	Date	Endpoint Lat Long.	Volume [mt]	% Exch.	Method	Sea Hgt. [m]	Date	Port or Lat Long.	Volume [mt]	Salinity
NO.1 DBT &TST(P)	2014-01-28	Kakogawa	1274	17 C	2014-02-03	35.77 151.34	4459	350	FT	2	2014-02-25	Stockton (USA, CA)	1274	1.025 SG
NO.1 DBT &TST(S)	2014-01-28	Kakogawa	1274	17 C	2014-02-03	35.77 151.34	4459	380	FT	2	2014-02-25	Stockton (USA, CA)	1274	1.025 SG
NO.2 DBT &TST(S)	2014-01-28	Kakogawa	1651	17 C	2014-02-03	35.63 150.03	5778	380	FT	2	2014-02-25	Stockton (USA, CA)	1476	1.025 SG
NO.2 DBT &TST(P)	2014-01-28	Kakogawa	1651	17 C	2014-02-03	35.63 150.03	5778	350	FT	2	2014-02-25	Stockton (USA, CA)	1476	1.025 SG
NO.3 DBT &TST(S)	2014-01-28	Kakogawa	3344	17 C	2014-02-04	36.33 155.82	11704	350	FT	2	2014-02-25	Stockton (USA, CA)	1776	1.025 SG
NO.3 DBT &TST(P)	2014-01-28	Kakogawa	3344	17 C	2014-02-04	36.33 155.82	11704	350	FT	2	2014-02-25	Stockton (USA, CA)	1776	1.025 SG
NO.4 DBT &TST(S)	2014-01-28	Kakogawa	2571	17 C	2014-02-03	36.59 158.00	8998	350	FT	2	2014-02-25	Stockton (USA, CA)	2071	1.025 SG
NO.4 DBT &TST(P)	2014-01-28	Kakogawa	2571	17 C	2014-02-03	36.59 158.00	8998	350	FT	2	2014-02-25	Stockton (USA, CA)	2071	1.025 SG
NO.5 DBT &TST(S)	2014-01-28	Kakogawa	1055	17 C	2014-02-08	38.79 176.16	3692	351	FT	3	2014-02-25	Stockton (USA, CA)	1055	1.025 SG
NO.5 DBT &TST(P)	2014-01-28	Kakogawa	1055	17 C	2014-02-08	38.79 176.16	3692	351	FT	1	2014-02-25	Stockton (USA, CA)	1055	1.025 SG
FPT	2014-01-28	Kakogawa	2070	17 C	2014-02-09	39.52 -177.67	2070	100	ER	3	2014-02-25	Stockton (USA, CA)	2070	1.025 SG
APT	2014-01-28	Kakogawa	1038	17 C	2014-02-08	39.05 -178.30	1038	100	ER	2	2014-02-25	Stockton (USA, CA)	1038	1.025 SG
NO.4 CH	2014-02-02	35.17 146.65	13678	18 C	2014-02-10	39.98 -173.70	13678	100	ER	2	2014-02-25	Stockton (USA, CA)	13678	1.025 SG

Figure 8 Ballast report from *Rosco Olive* (NBIC)

The ABS Record is one of several vessel registers by classification societies. These registers provide basic vessel data, such as length, beam, freeboard, and ballast water capacity.

Name:	Class Number:	IMO Number:	Status:
ROSCO OLIVE	10215343	9542465	In Operation, Active, Classed, ISM, ISPS, MLC

Details | Survey Status

General Characteristics | Hull | Machinery | Capacity | Lifting Equipment | Owner/Manager Address

Designation	
Official Registry Number	HK-2864
Call Sign	VRHK8
Flag Name	The Hong Kong Special Administrative Region of the People's Republic of China
Port of Registration	HONG KONG
Date Of Registry	
Steel Cutting Date	23 Jan 2010
Keel Laying Date	07 May 2010
Launch Date	09 Jul 2010
Delivery Date	14 Sep 2010

Categories	
Description	Bulk Carrier
Vessel Type	Bulk Carrier
SOLAS CATEGORY	Bulk Carrier
MARPOL CATEGORY	Not an Oil Tanker
IBC_IGC CATEGORY	Not Applicable
ISM CATEGORY	Bulk Carrier

ABS Class Notations

✠A1, Bulk Carrier, BC-A (holds Nos. 2, 4 and 6 may be empty), ESP, Ⓔ, ✠AMS, ✠ACCU, CPS, CSR AB-CM

Figure 9 Vessel particulars (ABS record on *Rosco Olive*)

Name:	Class Number:	IMO Number:	Status:
ROSCO OLIVE	10215343	9542465	In Operation, Active, Classed, ISM, ISPS, MLC

Details | Survey Status

General Characteristics | Hull | Machinery | Capacity | Lifting Equipment | Owner/Manager Address

Compartment Capacity	Volume 100% Full (CuM)	Weight 100% Full (Tonnes)
Cargo Ballast Capacity	13345	
Diesel Oil Capacity	89.2	80.28
Freshwater Capacity	391.3	391.3
Fuel Oil Capacity	2649	2596.02
Hold Capacity	90771	
Lube Oil Capacity	94.6	85.14
Other Capacity	49.7	
Tank Ballast Capacity	22898	23470.45

Figure 10 Vessel capacities including ballast water (ABS record on *Rosco Olive*)

2.2 Data Review and Analysis

Collected data was tabulated into spreadsheets, sorted by vessel type. The data was reviewed and compared to typical values from experience and references such as the ABS Ballast Water Treatment Advisory, 2014. Where values were found to be outside of typical, additional research was performed to ensure that data samples were representative.

Based on discussion within the study team, a series of vessel ballast characteristics were identified as relevant to the ship-to-shore and ship-to-ship interface, i.e. how to get the ballast water off the ship. Table 5 below lists these characteristics and describes the process for deriving the estimated values.

2.2.1 Review of Terms used in Analysis

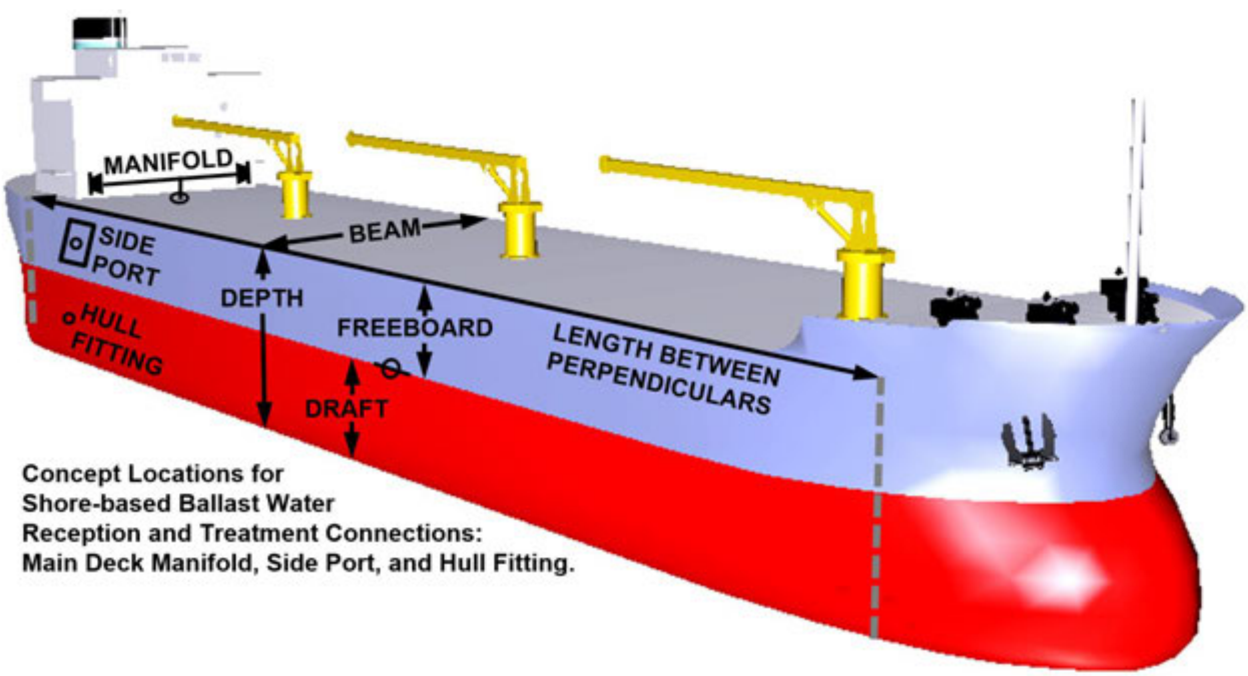


Figure 11 Marine vessel particulars used in analysis

The following list is aligned with Figure 11, above, and expresses typical marine vessel terms and their relevance to the ballast water analysis.

Breadth – also expressed as breath, it is the extreme width of the vessel. This assists estimating piping distances for pressure losses and new piping runs.

Depth – the vertical distance between the keel (bottom) and the uppermost continuous deck. This impacts the ballast water pumping head (pressure) as well as new piping lengths.

Deadweight (DWT) – the carrying capacity of a marine vessel including cargo, people, stores, fuel oil, and all other items that can be removed from the vessel. This offers a rough concept of ballast water capacity for high ballast water dependent vessels such as bulk carriers and oil tankers. However, there is no reliable relationship between deadweight and ballast water capacity for low ballast water dependent vessels such as car carriers, passenger cruiseships, or containerships.

Draft – the vertical distance between the keel (bottom) and the waterline at any given moment. Often the forward (bow) draft and the after (stern) draft will be significantly different, particularly when not carry cargo 'in ballast.' This impacts the distance above the waterline that a shore reception facility will have to reach to make the ballast water connection.

Freeboard (Frbd) – the required distance between the waterline and the uppermost continuous deck. This distance governs the reserve buoyancy for a vessel, which is part of the stability criteria. Bulk carriers and oil tankers will typically 'load to the marks' which means to load until they reach this minimum allowable freeboard.

Length between perpendiculars (LBP) – this is the distance between the aftmost and foremost collision bulkheads, and offers a consistent estimate of the length of the vessel that can carry cargo. The extreme length would be length overall (LOA) including bulbous bows and propeller apertures. This impacts piping losses when pumping out distant ballast water tanks, and changes in vertical head when the vessel is trimmed aft.

Table 5 Vessel ballast water shore-based connection characteristics

Characteristic	Description
Ballast Water Flow Rate	Ballast water flow rate is communicated as cubic meters per hour (m^3/hr). For example, a vessel discharging at 2,000 m^3/hr could discharge 20,000 m^3 in ten hours. The ballast water flow rate is not, however, a published characteristic. For each of the marine vessel examples, typical discharge times were assigned in order to estimate a rate. Vessels are typically designed to be able to complete cargo operations, i.e. discharge or load all cargo, within a defined window. Ballast water pumps are typically designed to these same time windows, i.e. pump out all ballast water in no less time than the cargo loading window. These windows vary by vessel type, size, and the preference of the builder/owner at the time of design. This typically varies between 8 and 18 hours.
Presentation Flange Height Above Waterline (ABL)	The ballast manifold presentation flange (BMPF) is a concept exterior pipe flange that a shore-based hose or mechanical arm could connect to for receiving ballast water discharges. The vertical height of this flange above the shore-based facility will significantly impact the mechanics and hydraulics of the transfer, as follows: • Vertical height to lift the hose or mechanical arm to make the connection.

<table>
<tr><th>Characteristic</th><th>Description</th></tr>
<tr><td></td><td>
The static head that might help move the ballast water from the marine vessel to the shore-based facility.
The reference datum is the height above the waterline (AWL). The flange height AWL will change depending on its draft. When a vessel is full of cargo, this height will be a minimum as it is “loaded to its marks.” When a vessel is empty of cargo, and likely loaded with a much lighter load of ballast water, this height will be a maximum. During a typical cargo loading sequence, the presentation flange height AWL will be at a maximum at the start of the loading (ballast draft), and drop to a minimum when the cargo is fully loaded (deep draft). The shore-based facility needs to consider the compounding impact of tidal changes.
Calculation process:

Height AWL Deep:

Calculate deep draft by deducting required minimum freeboard from depth.
Add one meter for height of flange above deck.

Height AWL Light:

Estimate hull displacement change should all cargo be discharged, based on principal dimensions of vessel.
Estimate hull displacement change should all ballast water capacity be loaded.
Start with AWL minimum, add cargo vertical displacement, and subtract ballast vertical displacement.

</td></tr>
<tr><td>Presentation Flange Ballast Water Pressure</td><td>
The ballast water pressure at the presentation flange will significantly impact the hydraulics of the shore-based facility. This pressure will change significantly over the course of the ballast water discharge. The ballast pump is required to lift the ballast water in the ballast tanks to the presentation flange.
When a tank is full, that vertical distance can be very small, difference between the tank liquid level and the presentation flange height, in some cases just one meter. As that tank nears empty, that vertical distance can be very large, in some cases nearly 30 meters. This variation in total head required by the pump, directly translates to differences in pressure at the presentation flange and the resulting discharge flow rates. This is illustrated below.
Calculation process:

Estimate pump head, nominal:

Assume pump is sized to fill furthest forepeak tank that is as deep as vessel depth, while vessel is trimmed aft. Pump is also able to overcome reasonable piping velocity losses.
Sum vessel depth and aft trim.
Estimate piping losses to forepeak, and add to value.

Pressure, Maximum:

Assume that tank being discharged is full. Deduct from pump head only the height of presentation flange above local deck, 1 meter.
Estimate piping losses to presentation flange, and deduct value.

Pressure, Minimum:

Assume that tank being discharged is nearing empty. Deduct from pressure, maximum, the depth of vessel.

</td></tr>
</table>

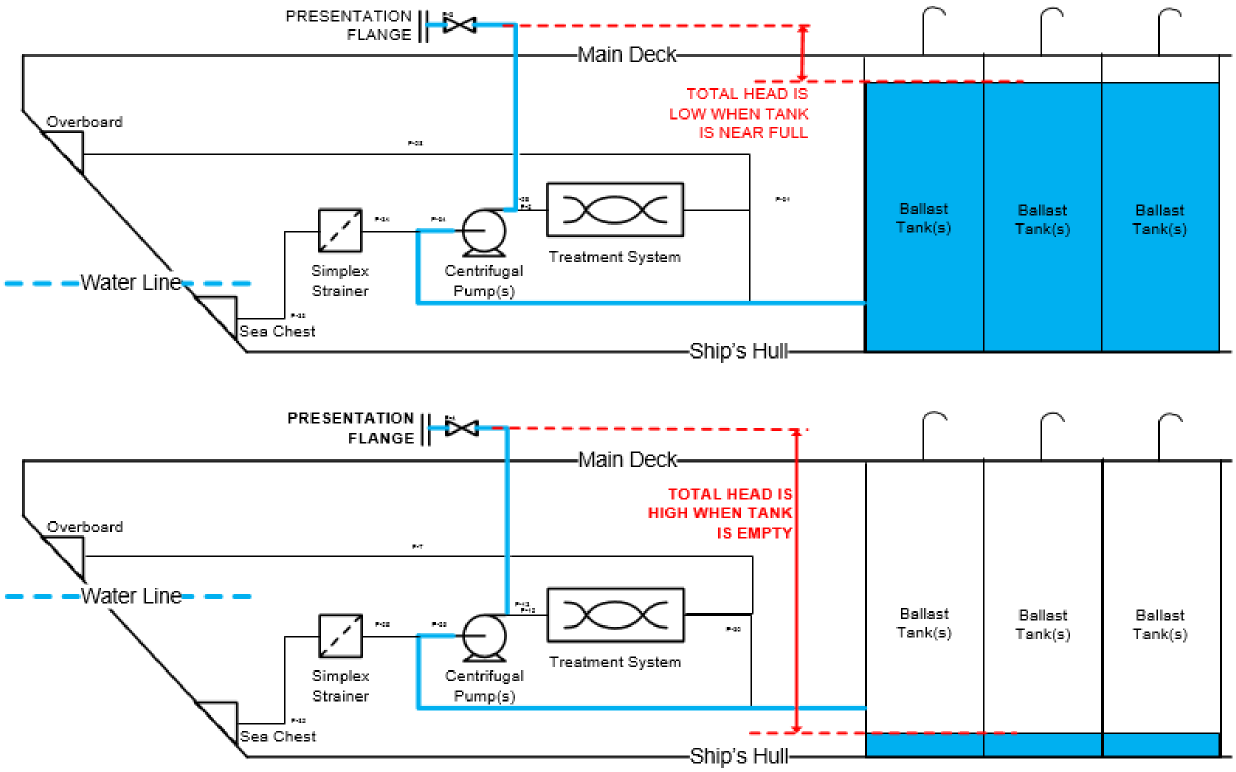


Figure 12 Illustration of impact of tank level on pressure at presentation flange

Table 6 Tabulation of collected data on single vessel type (bulk carrier example)

Vessel		Vessel Dimensions					Capacities			Ballast		
Type	Class	LBP	Breadth	Depth	Frbd	Block	Dwt	Cargo		Tanks	Hold	
		(m)	*(m)*	*(m)*	*(m)*	*(coeff.)*	*(tonnes)*	*(m3)*	*(sp.g)*	*(m3)*	*(m3)*	*(sp.g)*
Bulk Carriers												
	Rosco Olive	218	32.2	19.8	5.72	0.95	74,951	90,771	0.85	22,898	13,345	1.025
	Jian Hua	216	32.26	19.2	5.37	0.95	73,747	87,298	0.85	33,375		1.025
	Santa Emilia	220	32.26	19.79	5.42	0.95	76,800	87,463	0.85	21,492	40,144	1.025
	Abyssinian	177	30	14.7	4.43	0.95	36,063	46,732	0.8	11,335		1.025
	Jade	185	32.26	17.8	5.33	0.95	55,090	69,505	0.8	16,440	13,498	1.025
	Clipper Bliss	173	29.8	15	4.5	0.95	38,200	47,125	0.8	15,124		1.025
	Sum Low	***173***	***29.8***	***14.7***	***4.43***		***36,063***	***46,732***		***11,335***	***13,345***	
	Sum High	***220***	***32.26***	***19.8***	***5.72***		***76,800***	***90,771***		***33,375***	***40,144***	
	Design Basis									***33,000***	***40,000***	

Table 7 Calculated characteristics from collected data (bulk carrier example)

Vessel		Volumes			Ballast Water			Draft (est)		Presentation Flange			
		Hull	Ballast	Cargo			Pump			AWL	AWL	Press	Press
Type	Class	Plane	Displ.	Displ.	Disch.	Rate	Press	Deep	Light	Deep	Light	Max	Min
		(m2)	*(m)*	*(m)*	*(hours)*	*(m3/hr)*	*(kPa)*	*(m)*	*(m)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
Bulk Carriers													
	Rosco Olive	6,669	3.52	11.57	12	1,908	440	14.08	6.03	6.72	14.77	336	138
	Jian Hua	6,620	5.17	11.21	12	2,781	430	13.83	7.79	6.37	12.41	327	135
	Santa Emilia	6,742	3.27	11.03	10	2,149	440	14.37	6.61	6.42	14.18	336	138
	Abyssinian	5,037	2.31	7.42	10	1,134	340	10.28	5.16	5.43	10.54	250	103
	Jade	5,670	2.97	9.81	10	1,644	390	12.47	5.64	6.33	13.16	290	112
	Clipper Bliss	4,898	3.17	7.70	10	1,512	340	10.50	5.97	5.50	10.03	249	99
	Sum Low				***10***	***1,134***				***5.43***	***10.03***	***249***	***99***
	Sum High				***12***	***2,781***				***6.72***	***14.77***	***336***	***138***
	Design Basis					***2,800***				***5.40***	***14.80***	***340***	***100***

Calculation assumptions:

- Kilopascals (kPa) estimates assume seawater at 1.025 specific gravity. One (1) meter of seawater column is equivalent to 10.05 kPa.
- Pump pressure design assumptions, using calculation (Depth * Depth Correction) + (((LBP + Breadth) * Fitting Correction) * (Friction Loss Factor/100))
- 16 Pump factor for depth correction due to trim (10 would be even trim, 20 would mean bow is completely out of water when trimmed aft).
- 1.25 Pump factor for piping fittings. 1.0 would mean only piping with no fittings.
- 40 Pump factor for friction loss in mPa per 100 meters of piping. 60 is for 4.5 meters/sec flow rate in DIN 250 piping. 25 is for 3 meters/sec in DIN 300 piping.

Section 3 Operational Requirements and Restrictions

Ballast water off-vessel transfer operations, similar to outfitting, would likely be very similar to:

- Taking on fuel oil bunkers for small volume flow rates on car carriers, passenger cruiseships, and some containerships.
- Discharging liquid petroleum cargo for higher volume flow rates on bulk carriers, oil tankers, ATBs, and some containerships.

These transfers and required procedures are well known and documented in the bunker and oil tanker market sectors, with guidelines published by Oil Companies International Marine Forum (OCIMF), International Chamber of Shipping, and others. Some of those aspects are discussed in brief here, only to outline the scope of such communications and procedures.

3.1 Simultaneous Operations

Certain marine vessel types are required to conduct ballasting operations to offset cargo operations, in order to maintain stability and reduce hull stresses. As cargo is loaded, ballast water must be discharged at the same time. This is typical for bulk carriers, oil tankers, ATBs, and some containerships. For these vessel types, the offloading of ballast water would need to be done simultaneously with cargo operations, called SIMOPS in the oil and gas industry.

The execution of SIMOPS means that vessel and shore-based crews will have their attention split between different activities, in this case it might be shifting containers on board the marine vessel, while also discharging ballast water to a shore-based facility. Because these operations are different, there is significant risk that the operators can become distracted by one or the other activity, and lose focus on the other.

Industry response is typically to avoid SIMOPS when possible, given that failures can result in oil spills, injuries or fatalities, and damaged equipment. For example, oil terminals may not allow ship's stores or fuel oil bunkers to be taken on at the same time as cargo operations. When SIMOPS cannot be avoided, it is typical to perform a safety risk assessment and develop a SIMOPS procedure that includes additional personnel to oversee the combined operations, in addition to leads on each individual operation.

3.2 Communications between Vessel and Reception Facility

An integral component of successful ballast water transfer is communication between the vessel and shore-based transfer operations. As the vessel's pumps will be working in series with booster pumps on shore/barge, both parties must work in concert to prevent any damage to equipment.

A pre-transfer conference should be conducted to establish agreement on flow rates, pressures, and connection, start-up, and shutdown procedures. Typically, a pre-transfer checklist is used to ensure communications between the marine vessel and the facility.

Marine Insight

www.marineinsight.com

Checklist - Pre-Transfer of Bunkers

This checklist must be filled in before a vessel receives bunkers from a bunker vessel or Shore Installation

Bunkering Vessel / Shore Installation Name: ______________________

Receiving Vessel: ____________

Place of Bunkering: ____________ Date of Bunkering: ____________

Expected Time to Start Bunkering: ______

	Bunker Vessel	Receiving Vessel	Remarks
1. Have both the receiving vessel and the bunker vessel/shore Installation accepted the bunker area under the given weather forecast ?			
2. Is the bunker area outside normal traffic areas?			
3. Have port authorities been notified?			
4. Is there an agreed moorings plan and are both vessels following this plan?			
5. Is the bunker vessel equipped with sufficient fenders?			
6.Are watch personel appointed at the bunker station?			
7. Is the agreed ship to ship/shore communication system (VHF/UHF Radio) operative and a backup channel agreed on ?			
8. Are all scuppers on decks used for bunkering effectively plugged on board the receiving vessel and the bunker vessel?			
9. Have the bunker hoses been inspected and are the hoses appropriate for the service intended?			
10. Have all the tanks in the receiving vessel been measured and has the amount of bunkers to be transferred been agreed?			
11. Are all the valves on the receiving vessel lined up in the right position?			
12. Are all connections not in use between the vessels or vessel/shore shut down and blanked off?			
13. Are bunker hoses on both ends properly rigged?			
14. Are drip trays in position beneath the bunker hose on both ends and are they of a suitable size?			
15. Is a blank flange ready for use when the bunker hose is disconnected?			
16. Have responsible officers on vessel/vessel or vessel/shore agreed a maximum pumping rate and topping up rate?			
17. Has the responsible person onboard the bunker vessel or shore installation close to the emergency stop been instructed?			
18. Is equipment for prevention of oil pollution ready for use and in sufficient amount available?			
19. Is there a comprehensive oil pollution emergency plan and has it been checked to which authorities contact should be made in case of oil pollution.?			
20. Fire fighting equipment for immediate use ready?			
21. Are both vessels showing navigation signals for bunkering?			
22. Has Hydrogen Sulphide measurement in the bunker vessel's tanks been carried out and found to be below 200 ppm			
23. Is there a safe access between the vessels or vessel/ashore?			
24. High level alarms are not inhibited?			
25. Sounding pipe caps on, unless taking a reading?			

The Bunker Vessel/Shore Installation: I, the undersigned, have controlled all items on this checklist and, to the best of my knowledge, all records are correct.	The Receiving Vessel:I, the undersigned, have controlled all items on this checklist and, to the best of my knowledge, all records are correct.

(Date) (Signature) (Date) (Signature)

For more free resources visit www.marineinsight.com

Figure 13 Example pre-transfer checklist (Marine Insight)

3.3 Additional Considerations

There are numerous additional considerations in developing the operating procedures for transferring ballast water between marine vessels or to shore. Each of these topics will require detailed study to develop ballast water specific guidelines to ensure safe transfer. In general, it is recommended that a no-spill tolerance and no-incident objectives be in place for ballast water transfers. To achieve this, the petroleum industry guidelines offer a suitable starting place. These additional considerations include:

- Suitable transfer areas
- Ship-to-ship and ship-to-shore compatibility
- Weather conditions
- Safety drills
- Check lists
- Action in case of infringement of safety
- Safe watchkeeping
- General communications
- Language
- Initial communications between vessel and reception facility
- Communications during transfer
- Procedures for communications failure
- Pre-transfer procedures
- Responsibility for ballast water transfer
- Planning for ballast water transfer
- Ballast water transfer requirements
- Operations after transfer is complete
- Documentation requirements
- Contingency planning
- Emergency signals
- Emergency situations

3.4 Coordination with Booster Pumps/Lift Stations

The marine vessel's ballast water pumps have been found suitable for lifting the ballast water from the ballast water tanks to the ballast transfer stations. However, there is not adequate head (pressure) remaining to send this ballast water to reception facility storage tanks or treatment facilities. This requires the reception facility to provide either a lift station or a booster arrangement.

In the lift station configuration, the ballast water will fill a wet well that new pumps take suction from, and send the ballast water to the storage tanks. In the booster pump configuration, there is no wet well or intermediate tank. Rather, the reception facility pump is directly in series with the marine vessel pump. It serves to 'add head' to the ballast water and allow the water to reach the storage tanks.

The coordination between the marine vessel and the reception facility in these arrangements will require careful analysis on a case by case basis. In general, this arrangement will follow:

- Pre-transfer plan that includes constant communications.
- Possible use of a wired manual stop that allows either the facility or the vessel to stop all pumps and secure critical valves.
- The marine vessel pump will likely operate at fixed speed with no adjustments.
- The reception facility lift station approach will operated to maintain a range of levels in the wet pit using either on/off controls or variable speeds.
- The booster pump arrangement will likely need to be variable speed monitoring its suction pressure to avoid outpacing the marine vessel pump(s) resulting in surging.

This coordination also requires careful monitoring of the hoses and mooring lines for safety. For example, a storm surge or a surge from another passing vessel can move the marine vessel relative to the reception facility. The rigging of the hoses need to account for this potential relative motion.

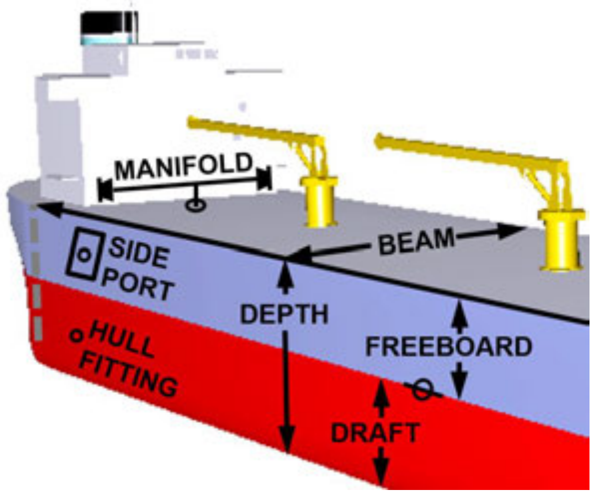
Section 4 General Modifications

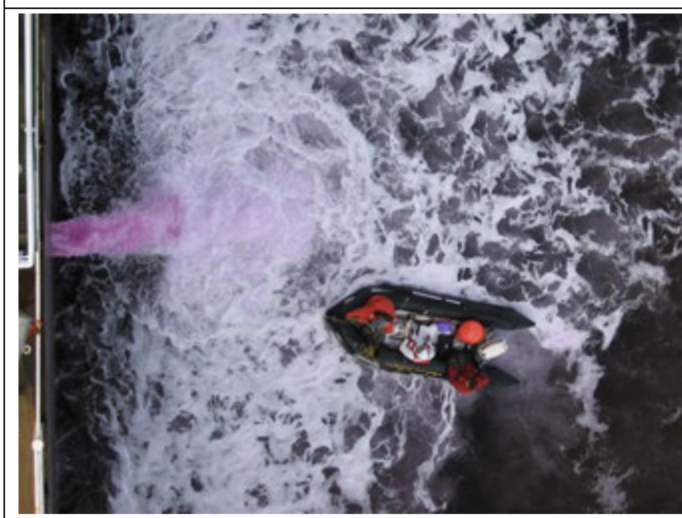
This section describes the general vessel modifications that would be required for any marine vessel that would transfer ballast water to a shore-based or marine vessel-based treatment system.

4.1 Ship Connection Options

Connection between a vessel's ballast system and shore-based treatment facilities can be made in several manners as outlined in below table. These same connections might be considered for either a ship-to-shore or a ship-to-ship connection.

Table 8 Ship connection options

Representative Image	Concept
	**<u>Concept Locations for Connection</u>** This image, repeated from the Summary section, identifies possible locations for capturing ballast water discharges from marine vessels. A **<u>deck manifold</u>** connection is the more obvious location for oil tankers, bulk carriers, containerships, and ATBs. A **<u>side port</u>** connection is likely for car carriers and passenger cruise ships that already use such locations for fuel oil bunkering operations. The direct use of **<u>existing hull fittings</u>** has been considered for capturing ballast water, avoiding the need to modify the marine vessels.
	**<u>Deck Manifold – Mechanical Loading Arm</u>** This image shows a mechanical loading arm connected between a dock and a marine vessel. It would be very unusual for a marine vessel to already be outfitted with a ballast water deck fitting. The rare exceptions would be very old tank ships that are still outfitted with non-segregated ballast water. It is also possible that some vessels will have their ballast water crossed over to the fire main, which would have a main deck connection. However, that connection would be DIN100, and unlikely to support needed ballast water discharge rates. Mechanical loading arms have many advantages, in particular that they avoid interferences with mooring lines, and readily adjust for changes in tides. They are also flexible in size, and very useful for handling high flow rates and pressures.

Representative Image	Concept
	**<u>Deck Manifold – Use of Hoses</u>** This image shows a small fuel oil bunker hose connected between a barge and a ship. Like discussed with mechanical loading arms, a new deck connection for ballast water would be required on the marine vessels. Hoses are widely used for transfer of liquids between marine vessels and to shore facilities. This image likely shows a DIN100 hose transferring fuel oil bunkers. The hose is supported by a boom crane that is lifted high above the hose, in order to relieve stress of the hose fittings and to compensate for relative motions between the two vessels.
	**<u>Side Port Connection</u>** This image shows side ports on a passenger cruiseship being used to offload passengers to excursion craft. Very similar ports are used for fuel oil bunker operations. These side ports for fire, sewage, and fuel oil bunker connections commonly exist on passenger cruiseships and car carriers. However, it is on a case-by-case basis if there is adequate room to add an additional connection. In such a case, the existing lines would need to be refitted to accommodate the additional ballast water connection, or a new side port would be required.
	**<u>Hull Fitting – Capturing Existing Discharge Point</u>** This approach considers capturing ballast water discharge at the hull fitting. In some cases this hull fitting will be above the waterline, as shown in the image to the right. In other cases, the hull fitting will be below the water line. The scale of the ballast water discharge can be seen by the image to the right, as well as how the ballast water discharge spreads over distance. A Norwegian company, Top Water Flow, promoted using a barge with an articulated crane to perform this capture. That concept does not, however, appear to still be pursued. If using the petroleum transfer analogy, it is unlikely that oil products would be transferred by means of a hull fitting. If there is zero tolerance of ballast water spills, then use of a hull connection might not be acceptable.

This report focuses on the cost and feasibility of retrofitting vessels with deck connections and bunkering side ports. In order to maintain operational flexibility, it is assumed that vessels would install both connections on both port and starboard sides.

Hull connections, on the other hand, would require little or no vessel modifications. Thus, effective connection directly to the hull of a vessel has the potential to significantly reduce barriers for making a shore-based connection. This concept should be examined further, with a focus on technical feasibility, required research and development, and logistics for performing the connection. Commercial technologies attempting to connect to existing penetrations in ships' hulls are currently in development, e.g. Top Water Flow, but so far technical feasibility has not been demonstrated.

4.2 Piping System

Ballast water is lifted from the vessel's ballast tanks to the connection on the main deck or the side port. For most vessels, modifications to accomplish this include the following:

- Routing new pipe from the existing ballast main to the vessel's main deck.
- Any removals or relocations of items in way of new piping.
- Deck/bulkhead penetrations required to reach the main deck.

In the proposed system, the vessel's pumps need only provide enough suction to lift water to the main deck. Booster pumps on the shore-side provide additional suction to achieve desired flow rates for ballast transfer. Flow control is maintained by the transfer facility using regulating valves and aforementioned booster pumps. Details of the shore-side pump configuration are provided in the Task 3 and 4 reports.

4.3 Installation of Ballast Transfer Stations

Locating universal connection points at "ballast transfer stations" on the vessel's main weather deck and side ports offer a convenient means of connecting to that vessel's ballast system with minimal operational impacts. Ballast transfer stations should be located on both port and starboard sides of the vessel and be located near bunkering stations or cargo manifolds to take advantage of any existing piping runs, deck tackle, and hose handling gear.

A typical ballast transfer station should include:

- Standard, universal connection flange.
- Deck tackle to handle hoses or mechanical arms provided by the shore-based facility.
- Structural modifications to support equipment and piping installed on deck.
- Containment coaming to prevent spillage of ballast water.
- Adequate lighting for ballast transfer operations.

4.3.1 Connection Flange

In order to prevent the accidental leakage of ballast water that might contain invasive species, a leak-free connection is required. Ideally, such a connection is standardized such that vessels investing in modifications to connect with shore-side facilities can discharge at any such facility.

A universal connection standard for ballast water discharge has yet to be established, but there is precedent for such connections in bunker stations, cargo manifolds, and firemain shore couplings. The International Maritime Organization (IMO) International Convention for Safety of Life at Sea (SOLAS), for example, specifies an international shore connection standard for connecting with a vessel's firemain for firefighting purposes. Every SOLAS-compliant vessel greater than 500 gross tons is required to supply this bolted flange connection on both sides of the vessel, as well as accompanying gasket, bolts, nuts, and washers. The connection requirements for this international shore connection can be found in Reference 4.

4.3.2 Piping Manifold Support Gear

There is standard industry guidance for connecting hoses and mechanical loading arms to marine vessel to support liquid transfers. For discharge rates requiring large hoses (e.g., >DN200), deck tackle must be in place on the deballasting vessel to support the hose. Depending on the vessel type, adequate deck tackle may already be in place to support bunkering or cargo operations. However, for the purposes of this study, it is assumed that new deck tackle must be installed on the vessel for both port and starboard ballast transfer stations. Typical deck fittings to support hose handling include bollards, fairleads, deck rings, and a hose rest.

The OCIMF provides guidance for lighting and deck fittings required to handle hoses or mechanical arms for oil tanker manifolds (Reference 5). OCIMF guidance can be applied to the ballast transfer station considered in this report. A summary of the required lighting deck tackle is provided in Table 9. Load requirements for deck tackle vary based on vessel deadweight tonnage (DWT), per the following OCIMF categories:

- Category A: 16,000 to 25,000 DWT
- Category B: 25,001 to 60,000 DWT
- Category C: 60,001 to 160,000 DWT
- Category D: Ships over 160,000 DWT

Table 9 Deck tackle and lighting required for each ballast transfer station

Item	Category	Size/Quantity	Description
Cruciform bollard	A, B, C	600-mm height, qty one (1)	25 ton working load
	D	600-mm height, qty one (1)	40 ton working load
Bollards	A, B, C	300-mm diameter, qty two (2)	25 ton working load, each
	D	350-mm diameter, qty two (2)	40 ton working load, each
Fairleads	A, B	400 x 250 mm, qty two (2)	25 ton working load, each. Place in clear, open area
	C, D	400 x 250 mm, qty two (2)	40 ton working load, each. Place in clear, open area
Deck Rings	A, B, C, D	Qty two (2)	15 ton working load, each
Hose Rest	A, B, C	150-mm radius of curvature	Construct using DN 300 Pipe
	D	300-mm radius of curvature	Construct using DN 600 Pipe
Floodlights	A, B, C, D	50 lux at manifold, qty one (1)	Including cabling and switch

In addition to the equipment listed above, the side rail shall be modified to suit the support of a hose resting over it, in accordance with OCIMF guidelines, and as shown in Figure 14.

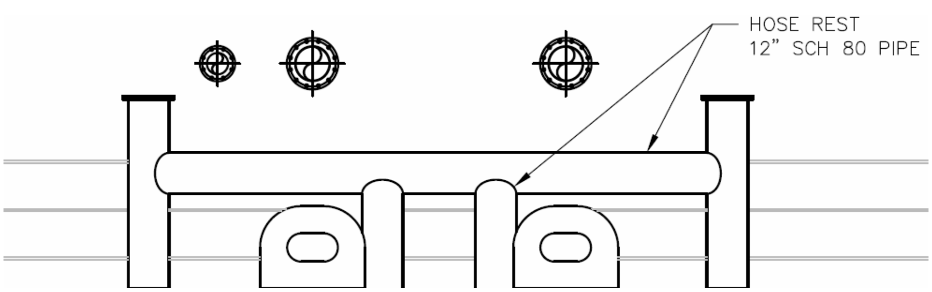


Figure 14 Diagram of hose rest

For Category A, B, and C vessels, the radius of the curvature of the hose rest should be at least 150 mm. For Category D vessels, the radius of curvature should be at least 300 mm. The hose rest may be constructed from pipe sections, and this report assumes that DN 300 and DN 600 pipe is used for Category A, B, C vessels and Category D vessels, respectively.

4.3.3 Containment Coaming/Spill Tank

A secondary containment coaming to catch any leaks that do occur, as well as leakage when making and breaking the coupling.

4.4 General Specifications

These general specifications are applicable to the modifications of all vessel types. Vessel specific guidance is provided in the following section. These specifications are worded for use by a shipyard to perform the actual modifications.

4.4.1 General Requirements

The modifications described herein allow ballast water discharges to be diverted from the ship's existing ballast water overboard to new main deck or side port ballast water transfer stations, port and starboard. These stations will enable ballast water to be transferred to shore-based ballast water reception facilities by means of shore-based hoses or mechanical arms.

This scope of work describes Contractor's responsibilities relative to this modification. Approximate values for pipe lengths, number of fittings, etc. are provided to scope the intended modifications.

The work includes:

- Piping modifications, including new ballast water piping to the main weather deck.
- New transfer stations, port and starboard, including piping, deck fittings, and lighting.
- Relocation of ducting, vents, and lighting in way of new piping.

Modifications shall conform with general shipbuilding practice, including those listed below.

Table 10 General requirements

Task	Requirement
General	• All material, installation, testing, and workmanship shall be in accordance with the regulatory requirements of the SOLAS, MARPOL, classification society, and Administration. • All equipment and materials shall be new. • All coating damage shall be repaired to original condition. • All deck and bulkhead penetrations shall meet the watertight, weathertight, and fire boundary requirements.
Piping	• All piping shall be hydrostatically tested after completion to 1.5 times the working pressure (1.5 x 10 bar = 15 bar). • Piping low points shall be avoided, and where not possible to avoid, shall be outfitted with drains. • All piping shall be properly supported by pipe hangers. Install a sufficient number of flanged take-down joints for ready access or removal. Expansion and contraction of piping due to ship motions shall be accounted for by offsets or bends. • All valves shall be labeled with fluid name and service.

Task	Requirement
Electrical	• All equipment shall be grounded. • All cables shall be tested for insulation resistance. • All cables shall be sized in accordance with the applicable regulatory body.

4.4.2 Ballast Transfer Stations

Two transfer stations shall be provided, one port and one starboard. These shall be located in a position for ready access to hoses or mechanical arms provided by shore-based services, i.e. near the side shell on the main weather deck.

Each station shall be outfitted with lighting and deck rings to secure a connection hose, as specified in Table 11.

Table 11 Quantities for two "limited" ballast transfer stations

Item	Size/Quantity	Description
Deck Rings	Qty four (4)	15 ton working load, each
Floodlights	50 lux at manifold, qty two (2)	Including cabling and switch

In addition to the above listed equipment, the side rail shall be modified to suit the support of hose resting over it, in accordance with OCIMF guidelines (Reference 5). 10 meters of DN 300 hose shall be used to construct the hose rest, configured as shown in Figure 14.

4.4.3 Relocations

Ducting, piping, and equipment in way of the new piping shall be removed to make room for the new ballast piping, and rerouted in accordance with Owner direction.

Lights and cabling in way of the new piping shall be relocated in accordance with Owner direction to make room for the new ballast piping.

Section 5 Description of Vessel Modifications

This section provides background on the vessel types, outlines the required modifications, and provides summary costs for each vessel type.

5.1 Articulated Tug-barge (ATB)

5.1.1 General Description – ATB

Articulated tug-barges utilize purpose-built tugs and barges that are capable of being joined together through an articulating coupling system. This coupling system allows the head of the tug to push into a notch in the barge stern, and then engage this positive coupling system. The coupling provides a rigid connection in the fore-and-aft direction, as well as port-to-starboard. The coupling permits pitching movement.

ATBs are primarily used for moving liquid petroleum products in California. Most are engaged in the product trade running between California and other states on the U.S. West Coast. Some of these vessels frequently discharge ballast water in high volumes when calling in California, while others rarely discharge and then only in small volumes.

Figure 15 Crowley 550 Series ATB (image, Crowley)

5.1.2 Analysis – ATB

Marine vessel terms are discussed above in Section 2.2.1, Review of Terms used in Analysis.

An analysis of ATBs that discharge ballast water in California was performed, and not limited to only those vessels discharging at the case study location, which is broadly applicable to other in-state locations. This analysis provides a general understanding of the impact of state-wide implementation of a shore-based treatment requirement on this vessel type.

The particulars for typical ATBs discharging ballast water is provided in Table 12, below. This table provides the range of vessel dimensions, cargo capacities, and ballast water capacities of this type of vessel calling in California and discharging ballast water. The range is important, as reception facilities must be able to handle not only the larger vessels, but also the smaller vessels. Following is Table 13, which digests the particulars into ballast connection interface estimates for those vessels. Specifically, considering the height of the connection, flow rates, and pressures at the vessel connection.

Table 12 ATB particulars, California ballast water discharge examples

		Vessel Dimensions				Capacities		Ballast
Type	Vessel	LBP	Breadth	Depth	Frbd	Dwt	Cargo	Tanks
		(m)	*(m)*	*(m)*	*(m)*	*(tonnes)*	*(m3)*	*(m3)*
ATB Tanker								
	550-1	152	22.56	12.19	3.88	18,148	24,766	10,508
	750-3	177	32.16	17.37	4.61	48,812	45,000	19,855
	DBL 105	128	23.7744	8.5344	1.19	16,574	16,440	3,016
	DBL 82	103	22.5552	7.62	0.94		13,064	3,680
	Morro Bay	110	23.38	9.64	1.74	14,589	11,869	486
	Penn 121	124	22.12	12.5	3.23	19,162	20,928	9,571
	Sum Low	103	22.12	7.62	0.94	14,589	11,869	486
	Sum High	177	32.16	17.37	4.61	48,812	45,000	19,855
	Design Basis							***20,000***

Table 13 ATB ballast connection interfaces, estimates for California ballast water discharges

		Ballast Water		Draft (est)		Presentation Flange			
						AWL	AWL	Press	Press
Type	Vessel	Disch.	Rate	Deep	Light	Deep	Light	Max	Min
		(hours)	*(m3/hr)*	*(m)*	*(m)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
ATB Tanker									
	550-1	10	1,051	8.31	4.33	4.88	8.86	207	86
	750-3	12	1,655	12.76	8.53	5.61	9.84	281	107
	DBL 105	8	377	7.34	2.44	2.19	7.09	142	57
	DBL 82	8	460	6.68	2.70	1.94	5.92	116	39
	Morro Bay	4	122	7.90	3.43	2.74	7.21	151	54
	Penn 121	10	957	9.27	5.33	4.23	8.17	198	73
	Sum Low	4	122			1.94	5.92	116	39
	Sum High	12	1,655			5.61	9.84	281	107
	Design Basis		***1,700***			***1.90***	***9.80***	***280***	***40***

The particulars were digested to determine the key parameters for interfacing between the marine vessel and the reception facility. Those particulars for the range of containerships studied are in the table below, as follows:

- Ballast water discharge duration and rate assist in sizing hose connections and planning support logistics. That noted, some port facilities can select to reduce the flow rate and therefore hose size, if the historically calling vessels do not discharge at the higher rates.

- Presentation flange is the location where the shore-based facility connects to receive the ballast water.
    - AWL (above waterline) Deep indicates the distance of the flange above waterline when the vessel is loaded with cargo, typically at the end of the ballast water discharge cycle.
    - AWL Light indicates this distance when the vessel is in ballast, and lighter in the water, typically at the start of the ballast water discharge cycle.
    - Pressure Max is the highest expected pressure at the flange, typically when a ballast tank is full. Often this pressure will fluctuate during operations as one set of tanks is emptied, and then a full set of tanks starts transfer.
    - Pressure Min is the least expected pressure, typically when discharging from a distant and empty ballast water tank on the marine vessel.

5.1.3 Compatibility for Deck Connection – ATB

Pump Capacity and Pipe Sizing

The studied ATBs all had adequate pumping head to lift the ballast water to the presentation flange for discharge to shore. In fact, ATBs all have their pump discharges for ballast water already on deck. Of all the vessel types, ATBs present the least challenge to providing an accessible deck connection.

Pipe sizing ranges from DN150 for the lower flow rate to as high as DN400 for the larger discharges. It should be noted that this is very different than the requirement for deballasting at the case study terminal El Segundo, which will consider the much higher flow rates expected from an oil tanker.

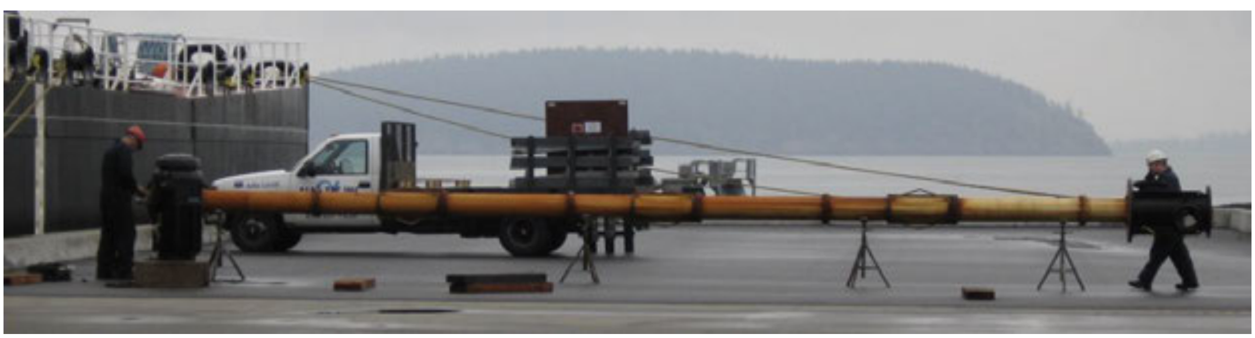


Figure 16 Typical deepwell pump being serviced dockside

Routing of New Ballast Water Piping to Main Deck

The ATBs examined are arranged such that the ballast pumps already discharge on the weather deck of the vessel. These are of the deepwell configuration.

Figure 17 Deepwell pump as installed, with discharge flange on Main Deck

Deck Arrangement

ATB arrangements can be tight. However, routing piping to a new ballast water manifold presentation flange is likely possible for most vessels.

Ballast transfer stations and associated deck tackle meeting the OCIMF requirements in Reference 5 would require an approximate footprint of 5x5 meters. This amount of deck space may be available on ATBs. In addition, it might be possible to locate the transfer station close enough to existing hose handling cranes to assist support of the hose. However, these cranes would likely be servicing cargo hoses instead.

5.1.4 Modifications – ATB

Note: The specifications provided below pertain to the generic, representative ATB. Based on the range of ballast water discharge rates, a piping size of DN400 is assumed to be representative for this vessel type in California.

5.1.4.1 General Requirements

General requirements are listed in the Section 5 – General Modifications.

5.1.4.2 Piping Modifications

The following tabulates pipe fittings and equipment, and describes the required piping runs.

Table 14 Piping materials and equipment

Item	Size, Quantity	Description
Pipe	DN400, 40 meters horizontal	ASTM A53B, Schedule 40
Valves	DN300, three (3)	Butterfly, wafer, with manual gear operator
Elbows	DN300, six (6)	ASTM A234, Schedule 40, Butt weld
Tees	DN300, three (3)	ASTM A234, Schedule 40, Butt weld
Flanges	DN300, four (4)	ASTM A105, Class 150, Slip-on

Main Deck Connection

The new piping shall be connected to each of the two existing ballast water pump discharges, located on the main deck, each by means of a new tee fitting. Any internal coating of the existing piping that is damaged shall be repaired.

Pipe Run to Transfer Stations

New piping shall be run from each of these connections to a common header and then to the two ballast water transfer stations, port and starboard, including:

- Tee fitting to split the flow to the two stations.
- Valves at each station.
- Blank flanges to secure openings when not in use.

Presentation Flange

A special pipe spool shall be provided that presents to the transfer station an international ballast water presentation flange.

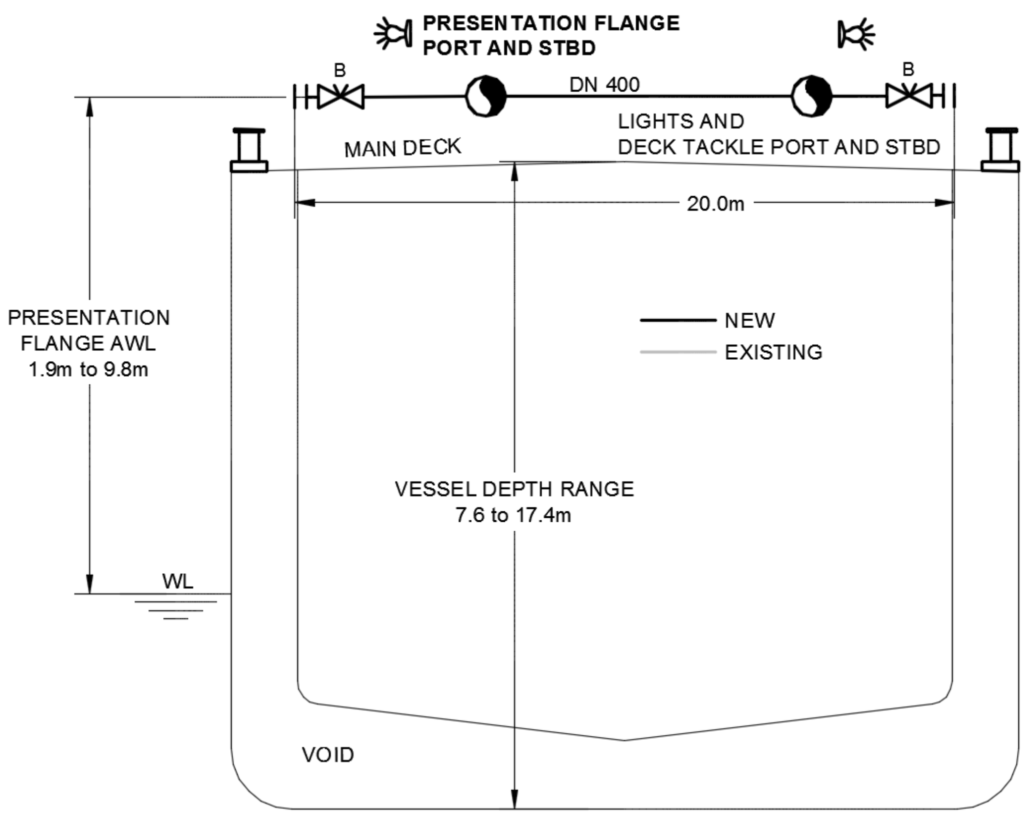


Figure 18 Diagram of ATB piping modifications

5.1.4.3 Ballast Transfer Stations

Two transfer stations shall be provided, one port and one starboard. These shall be located in a position for ready access to hoses or mechanical arms provided by shore-based services, i.e. near the side shell on the main weather deck.

Each station shall be outfitted with lighting and deck rings to secure a connection hose, as specified in Table 15.

Table 15 Deck tackle and lighting required for each ballast transfer station

Item	Size/Quantity	Description
Cruciform bollard	600-mm height, qty one (1)	25 ton working load
Bollards	300-mm diameter, qty two (2)	25 ton working load, each
Fairleads	400 x 250 mm, qty two (2)	25 ton working load, each. Place in clear, open area
Deck Rings	Qty two (2)	15 ton working load, each
Hose Rest	150-mm radius of curvature	Construct using DN 300 Pipe
Floodlights	50 lux at manifold, qty one (1)	Including cabling and switch

In addition to the above listed equipment, the side rail shall be modified to suit the support of hose resting over it, in accordance with OCIMF guidelines (Reference 5). 10 meters of DN 300 hose shall be used to construct the hose rest, configured as shown in Figure 14.

5.1.4.4 Relocations

Piping that interferes with the new arrangement will need to be reworked to suit, and rerouted in accordance with Owner direction.

Lights and cabling in way of the new piping shall be relocated in accordance with Owner direction to make room for the new ballast piping.

Table 16 Relocations

Item	Size/Quantity	Description
Piping	DN400, 20 linear meters	ASTM A53B, Schedule 40 with fittings
Lighting	Four (4)	Florescent machinery lights

5.1.5 Cost Estimate – ATB

This estimate assumes that the vessel is modified during the vessel's regularly scheduled shipyard period. A full, OCIMF-compliant transfer stations is assumed, assuming connection hoses are supported by shore-side equipment.

Table 17 Summary of ATB cost estimate

Vessel	Ballast Capacity (m^3)	Modification	Cost
ATB	20,000	Piping Modifications	$61,100
		Ballast Transfer Stations	$58,100
		Engineering and Regulatory Review	$22,000
		Material Markup	$10,200
		Total:	**$151,400**

5.2 Containerships

5.2.1 General Description – Containership

Containerships transport multiple cargo types stowed in marine shipping containers in twenty, forty, forty-five, and fifty-three foot lengths to International Organization for Standardization (ISO) specifications. The cargo carrying capacity of containerships is generally defined as the maximum number of twenty-foot equivalent unit (TEU) containers they can carry. Most containerships operate on fixed service routes with multiple port calls with exacting schedules. Cargo operations at each port call are extremely time sensitive to maintain overall schedule integrity and on-time delivery of cargo.

It is common for containerships to load and unload cargo at several ports of call, rather than fully loading or unloading at a single port. They discharge small volumes of ballast water relative to their capacity, and some can transfer ballast internally (between tanks) to minimize the amount of ballast that must be discharged. These ballasting operations are performed to accommodate changes in loading conditions, while managing hull stresses, stability, propeller immersion, bridge visibility, and trim. Due to their small discharge volumes, containerships are considered "low ballast-dependent vessels."

Figure 19 6,724-TEU containership *MOL Mission*, which calls at Port of Oakland (image, Klaus Kehrls)

5.2.2 Analysis – Containership

Marine vessel particulars are discussed above in Section 2.2.1, Review of Terms used in Analysis. Digest terms, i.e. AWL and Press Max, are discussed above in Section 5.1.2, Analysis – ATB.

An analysis of containerships that discharge ballast water in California was performed, and not limited to only those vessels discharging at the case study location. This analysis provides a general understanding of the impact of state-wide implementation of a shore-based treatment requirements on this vessel type.

The particulars for typical containerships discharging ballast water is provided in Table 18, below. This table provides the range of vessel dimensions, cargo capacities, and ballast water capacities of this type of vessel calling in California and discharging ballast water. The range is important, as reception facilities must be able to handle not only the larger vessels, but also the smaller vessels. Following is Table 19, which digests the particulars into ballast connection interface estimates for those vessels. Specifically, considering the height of the connection, flow rates, and pressures at the vessel connection.

Table 18 Containership particulars, California ballast water discharge examples

Type	Vessel	Vessel Dimensions				Capacities	Ballast
Type	Vessel	LBP	Breadth	Depth	Frbd	Dwt	Tanks
		(m)	*(m)*	*(m)*	*(m)*	*(tonnes)*	*(m3)*
Containerships							
	Maersk Algol	321	45.6	27.2	6.83	122,110	42,090
	UASC Jilfar	287	48.2	24.8	5.76	112,160	28,998
	Kauai	206	28.95	16.46	6.14	24,667	7,031
	Mokihana	247	32.2	20.1	5.51	24,167	10,146
	Sealand Intrepid	273	32.2	21.2	8.24	59,986	17,708
	Ever Ursula	268	40	24.2	5.16	63,131	24,037
	APL Japan	262	40	24.3	6.17	49,000	19,668
	Sum Low	206	28.95	16.46	5.16	24,167	7,031
	Sum High	321	48.2	27.2	8.24	122,110	42,090
	Design Basis						***42,000***

Table 19 Containership estimates, California ballast water discharge interfaces

Type	Vessel	Ballast Water		Draft (est)		Presentation Flange			
						AWL	AWL	Press	Press
Type	Vessel	Disch.	Rate	Deep	Light	Deep	Light	Max	Min
		(hours)	*(m3/hr)*	*(m)*	*(m)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
Containerships									
	Maersk Algol	18	2,338	20.37	15.99	7.83	12.21	479	207
	UASC Jilfar	18	1,611	19.04	13.94	6.76	11.86	419	171
	Kauai	12	586	10.32	7.70	7.14	9.76	288	124
	Mokihana	12	846	14.60	13.19	6.51	7.91	356	155
	Sealand Intrepid	12	1,476	12.96	8.72	9.24	13.48	384	172
	Ever Ursula	12	2,003	19.04	16.02	6.16	9.18	414	172
	APL Japan	12	1,639	18.13	16.00	7.17	9.30	414	171
	Sum Low	12	586			6.16	7.91	288	124
	Sum High	18	2,338			9.24	13.48	479	207
	Design Basis		***2,300***			***6.20***	***13.50***	***480***	***120***

5.2.3 Compatibility for Deck Connection – Containership

Pump Capacity and Pipe Sizing

The studied containerships all had adequate pumping head to lift the ballast water to the presentation flange for discharge to shore. It is expected that the shore-based facilities will have high-lift booster pumps that can assist the ships pumps and maintain design ballasting rates.

Pipe sizing ranges from DN250 for the lower flow rate to as high as DN500 for the larger discharges. It should be noted that this is very different than the requirement for deballasting at the case study terminal, TraPac, which only considers a 750 m3/hr design flow rate, and would only require DN250 piping.

Routing of New Ballast Water Piping to Main Deck

The containerships examined are arranged such that their machinery spaces are directly under the house, with cargo holds located both fore and aft of the house. Their arrangements limit the routing of new ballast piping to the vertical space under the house. This requires routing of pipe from the ballast main on the tank top vertically up to the main deck, with a varying distances of horizontal piping runs (depending on vessel arrangement) required to reach the ballast transfer stations on the main deck.

Deck Arrangement

There are significant space limitations on deck for the new ballast shore-connection. Main deck space on containerships is mostly committed to cargo holds (see Figure 20). Open, main deck space located adequately close to the vessel's side is limited to the fore deck, aft deck, and areas port and starboard of the house.

For the containerships examined, the areas port and starboard of the house are the most promising locations to install ballast transfer stations. However, the limited space (typically less than four meters between the house and the railing) prohibits the installation of a complete, OCIMF-compliant ballast transfer station. In some cases, accommodation ladders are located on the side shell directly port and starboard of the house and in the way of the connection between ship and shore.

Figure 20 Aerial view of the 6,763-TEU *Hyundai Tokyo*, which frequents TraPac (photo credit: Fei Weng)

The aft and fore decks are committed to mooring and deck equipment (anchor windlass, winches, etc.), with little, if any, available room. Deck space aft is often limited to an enclosed mooring station below the main deck (Figure 20). Regardless, routing piping from forward or aft of the house is impractical due to the cargo holds.

Ballast transfer stations and associated deck tackle meeting the OCIMF requirements in Reference 5 would require an approximate footprint of 5x5 meters. This amount of deck space is generally not available on containerships. It may be possible, however, to install limited ballast transfer stations at these locations that include only the following:

- Presentation flange.
- Spill tank.
- Deck rings to secure hose.
- Hose rest.

This limited ballast transfer station would require that all hose handling and support be provided by shore-side equipment.

5.2.4 Modifications – Containership

Note: The specifications provided below pertain to the generic, representative containership. Based on the range of ballast water discharge rates, a piping size of DN300 is assumed to be representative for this vessel type in California.

5.2.4.1 General Requirements

General requirements are listed in the Section 5 – General Modifications.

5.2.4.2 Piping Modifications

The following tabulates pipe fittings and equipment, and describes the required piping runs.

Table 20 Piping materials and equipment

Item	Size, Quantity	Description
Pipe	DN300, 65 meters horizontal DN300, 20 meters vertical	ASTM A53B, Schedule 40
Valves	DN300, three (3)	Butterfly, wafer, with manual gear operator
Elbows	DN300, ten (10)	ASTM A234, Schedule 40, Butt weld
Tees	DN300, two (2)	ASTM A234, Schedule 40, Butt weld
Flanges	DN300, four (4)	ASTM A105, Class 150, Slip-on

Overboard Tee

The new piping shall be connected to the existing ballast water overboard, located in the main machinery room, by means of a new tee fitting. Any internal coating of the existing piping that is damaged shall be repaired. This connection shall be inboard of the existing overboard stop and check valves.

Pipe Run to Weather

New piping shall be run from the overboard to the weather deck forward of the house, including:

- Watertight penetrations at the 2nd Deck and Upper Deck.
- Weathertight penetrations in the house's forward bulkhead.

Pipe Run to Transfer Stations

New piping shall be run from this house penetration to the two ballast water transfer stations, port and starboard, including:

- Tee fitting to split the flow to the two stations.
- Valves at each station.

- Blank flanges to secure openings when not in use.

Presentation Flange

A special pipe spool shall be provided that presents to the transfer station an international ballast water presentation flange.

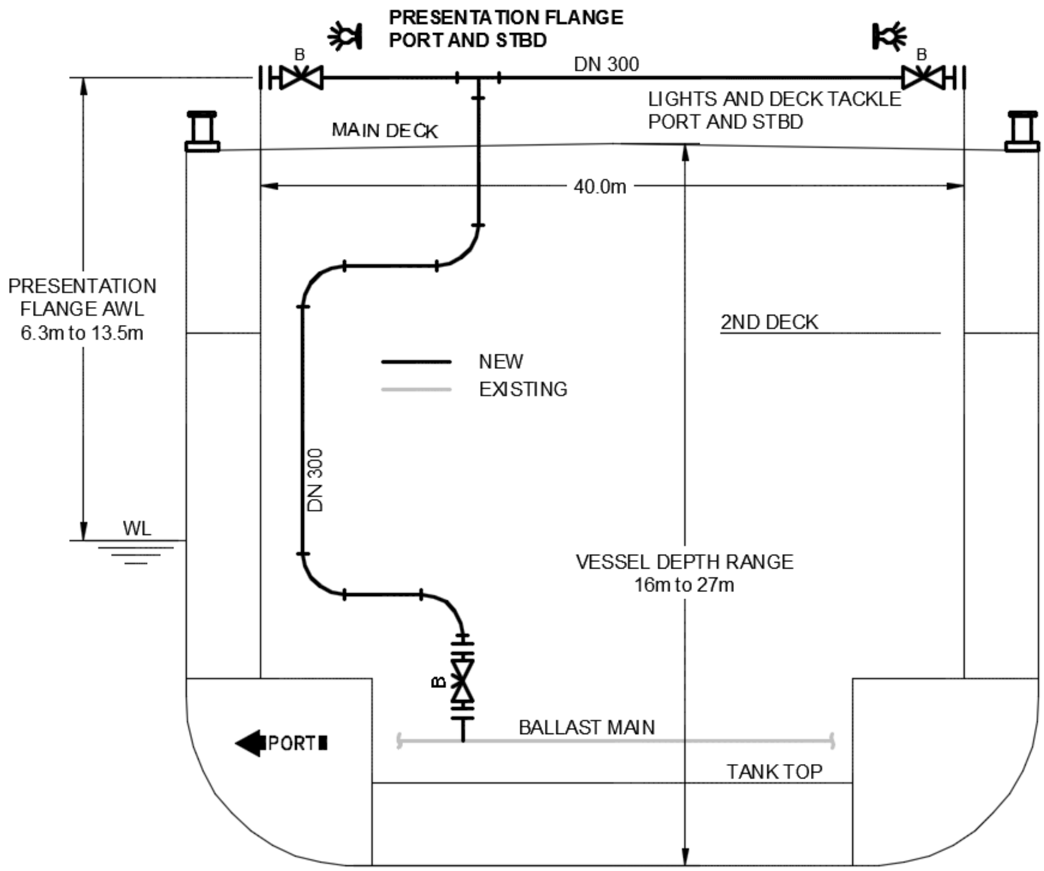


Figure 21 Diagram of containership piping modifications

5.2.4.3 Ballast Transfer Stations

Two transfer stations shall be provided, one port and one starboard. These shall be located in a position for ready access to hoses or mechanical arms provided by shore-based services, i.e. near the side shell on the main weather deck.

Each station shall be outfitted with lighting and deck rings to secure a connection hose, as specified in Table 21.

Table 21 Quantities for two "limited" ballast transfer stations

Item	Size/Quantity	Description
Deck Rings	Qty four (4)	15 ton working load, each
Floodlights	50 lux at manifold, qty two (2)	Including cabling and switch

In addition to the above listed equipment, the side rail shall be modified to suit the support of hose resting over it, in accordance with OCIMF guidelines (Reference 5). 10 meters of DN 300 hose shall be used to construct the hose rest, configured as shown in Figure 14.

5.2.4.4 Relocations

Ducting and vents in way of the new piping shall be removed to make room for the new ballast piping, and rerouted in accordance with Owner direction.

Lights and cabling in way of the new piping shall be relocated in accordance with Owner direction to make room for the new ballast piping.

Table 22 Relocations

Item	Size/Quantity	Description
Ducting	DN200, 40 linear meters	Galvanized carbon steel
Lighting	Four (4)	Florescent machinery lights

5.2.5 Cost Estimate – Containership

This estimate assumes that the vessel is modified at an Asian shipyard, and during the vessel's regularly scheduled shipyard period. As there is not adequate space for full, OCIMF-compliant transfer stations, the cost for the ballast stations below are for the minimum equipment required (see Section 5.2.4.3), assuming connection hoses are supported by shore-side equipment.

Table 23 Summary of containership cost estimate

Vessel	Ballast Capacity (m^3)	Modification	Cost
Containership (Panamax)	13,100	Piping Modifications	$87,000
		Ballast Stations	$24,000
		Engineering and Regulatory Review	$36,000
		Material Markup	$5,700
		Total:	**$152,600**

5.3 Bulk Carriers

5.3.1 General Description – Bulk Carrier

Bulk Carriers, also called bulkers or bulk freighters, are marine vessels that transport products in bulk, such as coal, ore, cement, and grain. They consist of about one third of the world's fleet that transports ballast water, and range in size from 'mini-bulkers' of less than 10,000 deadweight tonnage to the Capesize and Very Large Bulk Carriers that can exceed 200,000 deadweight tonnage. The image below shows the world's largest bulk carrier, the *Ore Brasil* (previously known as *Vale Brasil*), in comparison to other familiar vessels.

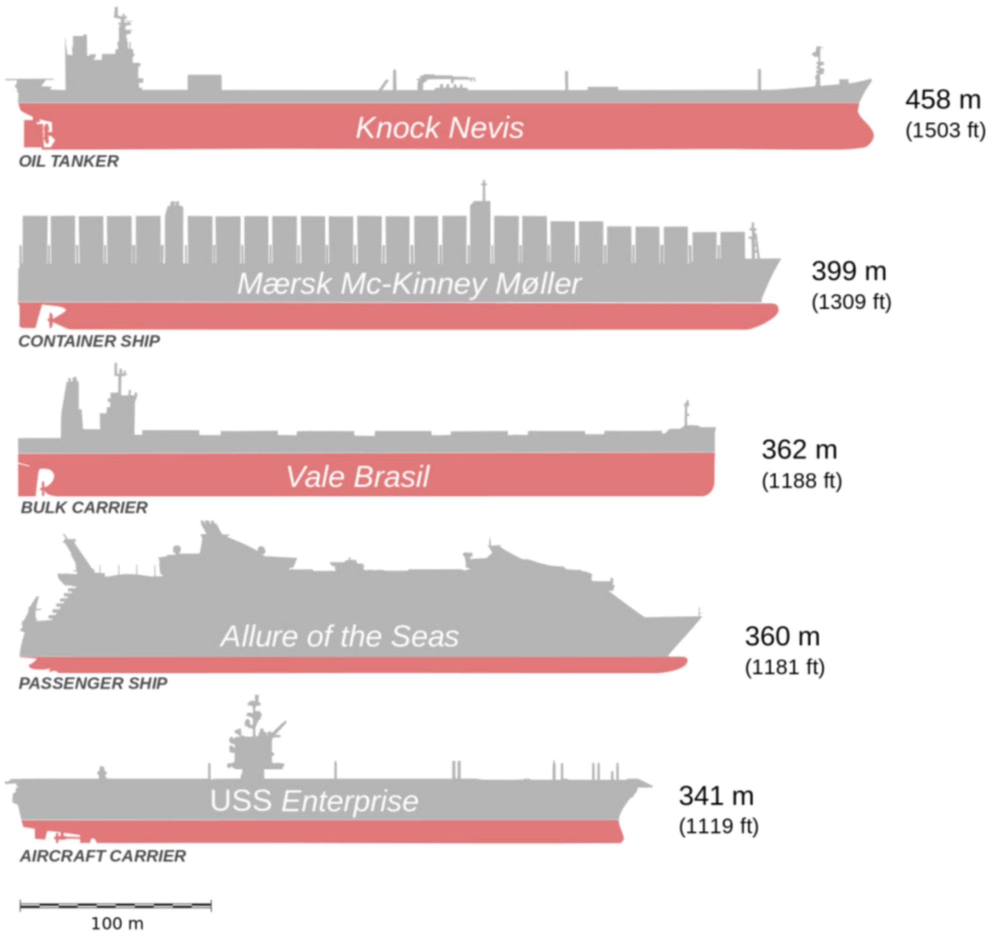


Figure 22 Scale of the largest bulk carrier as of 2016 (Maritime Reporter.com)

These vessels vary greatly in configuration, although they are often classified as either having their own unloading gear, or not. The unloading gear is often specialized for unloading by means of boom cranes, conveyor belts, or other specific cargos or arrangements. Relative to ballast water offloading, it is more typical for the cargo handling to be performed by the shore facility that is loading the bulk products into the vessel. Any new ballast water hoses or mechanical arms will need to be closely coordinated with these systems.

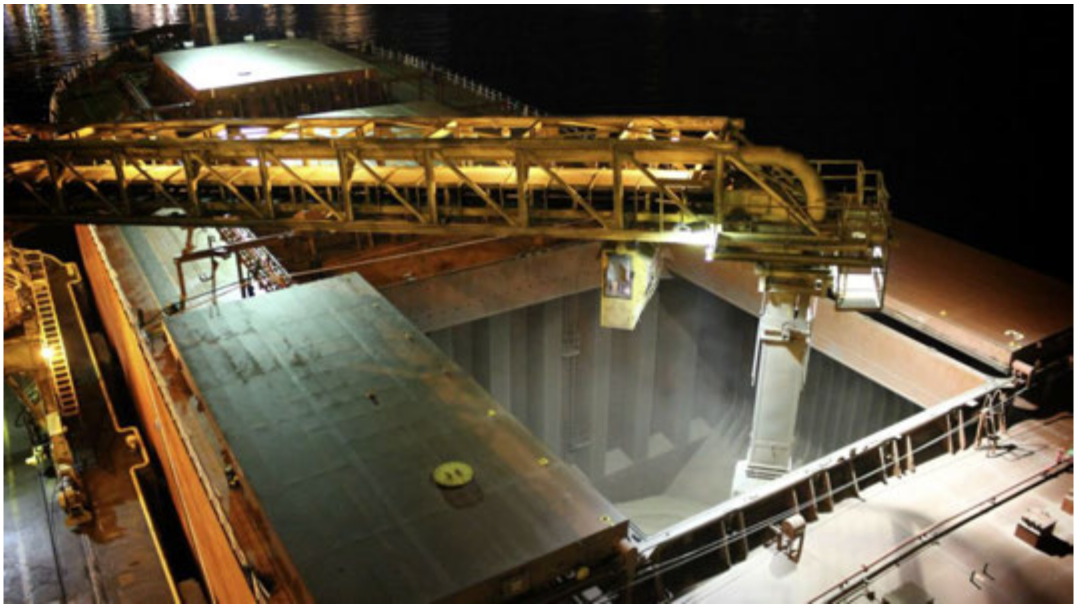


Figure 23 Loading bulk cargo (image, Port of Stockton)

The ballast water discharge volumes for bulk carriers is tightly linked with cargo loading activities. Typically, the bulker will discharge one ton of ballast water for each three to four tons of cargo loaded. These ballasting operations are performed to accommodate changes in loading conditions while managing hull stresses, stability, propeller immersion, bridge visibility, and trim. Due to the high volumes of ballast water typically discharged, and the very tight link between ballasting and cargo operations, bulk carriers are considered "highly ballast-dependent vessels."

5.3.2 Analysis – Bulk Carrier

Marine vessel particulars are discussed above in Section 2.2.1, Review of Terms used in Analysis. Digest terms, i.e. AWL and Press Max, are discussed above in Section 5.1.2, Analysis – ATB.

An analysis of bulk carriers that discharge ballast water in California was performed, and not limited to only those vessels discharging at the case study locations (Port of Stockton and SA Recycling in PoLA). This analysis provides a general understanding of the impact of state-wide implementation of a shore-based treatment requirements on this vessel type.

The particulars for typical bulk carriers discharging ballast water is provided in Table 24 below. This covers a range of vessel configurations and types within this vessel type, such that a range of interface requirements could be established. The ballast water reception facilities need to be able to receive not only the larger vessels, but also the smaller vessels. Following is Table 25, which digests the particulars into ballast connection interface estimates for those vessels. Specifically, considering the height of the connection, flow rates, and pressures at the vessel connection.

Table 24 Bulk carrier particulars, California ballast water discharge examples

		Vessel Dimensions				Capacities		Ballast	
Type	Vessel	LBP	Breadth	Depth	Frbd	Dwt	Cargo	Tanks	Hold
		(m)	*(m)*	*(m)*	*(m)*	*(tonnes)*	*(m3)*	*(m3)*	*(m3)*
Bulk Carriers									
	Rosco Olive	218	32.2	19.8	5.72	74,951	90,771	22,898	13,345
	Jian Hua	216	32.26	19.2	5.37	73,747	87,298	33,375	
	Santa Emilia	220	32.26	19.79	5.42	76,800	87,463	21,492	40,144
	Abyssinian	177	30	14.7	4.43	36,063	46,732	11,335	
	Jade	185	32.26	17.8	5.33	55,090	69,505	16,440	13,498
	Clipper Bliss	173	29.8	15	4.5	38,200	47,125	15,124	
	Sum Low	***173***	***29.8***	***14.7***	***4.43***	***36,063***	***46,732***	***11,335***	***13,345***
	Sum High	***220***	***32.26***	***19.8***	***5.72***	***76,800***	***90,771***	***33,375***	***40,144***
	Design Basis							***33,000***	***40,000***

Table 25 Bulk carrier estimates, California ballast water discharge interfaces

		Ballast Water		Draft (est)		Presentation Flange			
						AWL	AWL	Press	Press
Type	Vessel	Disch.	Rate	Deep	Light	Deep	Light	Max	Min
		(hours)	*(m3/hr)*	*(m)*	*(m)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
Bulk Carriers									
	Rosco Olive	12	1,908	14.08	6.03	6.72	14.77	336	138
	Jian Hua	12	2,781	13.83	7.79	6.37	12.41	327	135
	Santa Emilia	10	2,149	14.37	6.61	6.42	14.18	336	138
	Abyssinian	10	1,134	10.28	5.16	5.43	10.54	250	103
	Jade	10	1,644	12.47	5.64	6.33	13.16	290	112
	Clipper Bliss	10	1,512	10.50	5.97	5.50	10.03	249	99
	Sum Low	***10***	***1,134***			***5.43***	***10.03***	***249***	***99***
	Sum High	***12***	***2,781***			***6.72***	***14.77***	***336***	***138***
	Design Basis		***2,800***			***5.40***	***14.80***	***340***	***100***

5.3.3 Compatibility for Deck Connection – Bulk Carrier

Pump Capacity and Pipe Sizing

The studied bulk carriers all had adequate pumping head to lift the ballast water to the presentation flange for discharge to shore. It is expected that the shore-based facilities will have high-lift booster pumps that can assist the ships pumps and maintain design ballasting rates.

Pipe sizing ranges from DN400 for the lower flow rate to as high as DN500 for the larger discharges. It should be noted that this is very different than the requirement for deballasting at the case study terminals, Stockton would require the higher discharge rates, while SA Recycling would only need to consider the lower rates based on the terminal profile. In other words, the marine vessel may often have a higher capacity than the marine terminal is required to support.

Routing of New Ballast Water Piping to Main Deck

Bulk carriers, although varied, follow the typical pattern of an engine machinery room that includes the ballast pumps, located below the accommodations block. The ballasting mains then run forward to the cargo body ballast tanks, as well as aft to any ballast tanks outboard of the engine machinery room and the aftpeak tank in the stern. This arrangement offers the possibility to run a ballast water connection to the main deck in the cargo block where there may be less interferences.

The cargo block, however, can often contain complex cargo handling equipment, such as conveyor belts that could interfere with running large piping from the ballast main(s) to the main deck. A further consideration is that there are often access tunnels just below the main deck and outboard of the cargo holds. Any piping would need to keep clear of these access tunnels as they tend to be too narrow to support a DN400 or DN500 pipe passing through.

Deck Arrangement

Bulk carrier deck arrangements are highly varied. Figure 24 shows a bulk carrier that has hatches that open forward and aft. This appears to leave some room outboard of the cargo holds for a main deck ballast manifold. However, one can see a small bulldozer on the deck, which requires clear room to move forward and aft.

This same image shows that there may be room between the cargo holds for a main deck ballast manifold. However, this space is dedicated for access to the cargo cranes and maintenance of the hatches. Some accommodations and use tradeoffs can be made, but this will be on a case by case basis. Further, it is more practical to locate the manifold as far aft as possible, towards the accommodations block, to limit new piping run distances.

Also seen from this image is that the inboard, closer to the shore-based loading arm, activity is very busy and more difficult to coordinate new activities such as ballast water off-loading. It is likely more practical to discharge the ballast water to another marine vessel, rather than into the already busy cargo operational area.

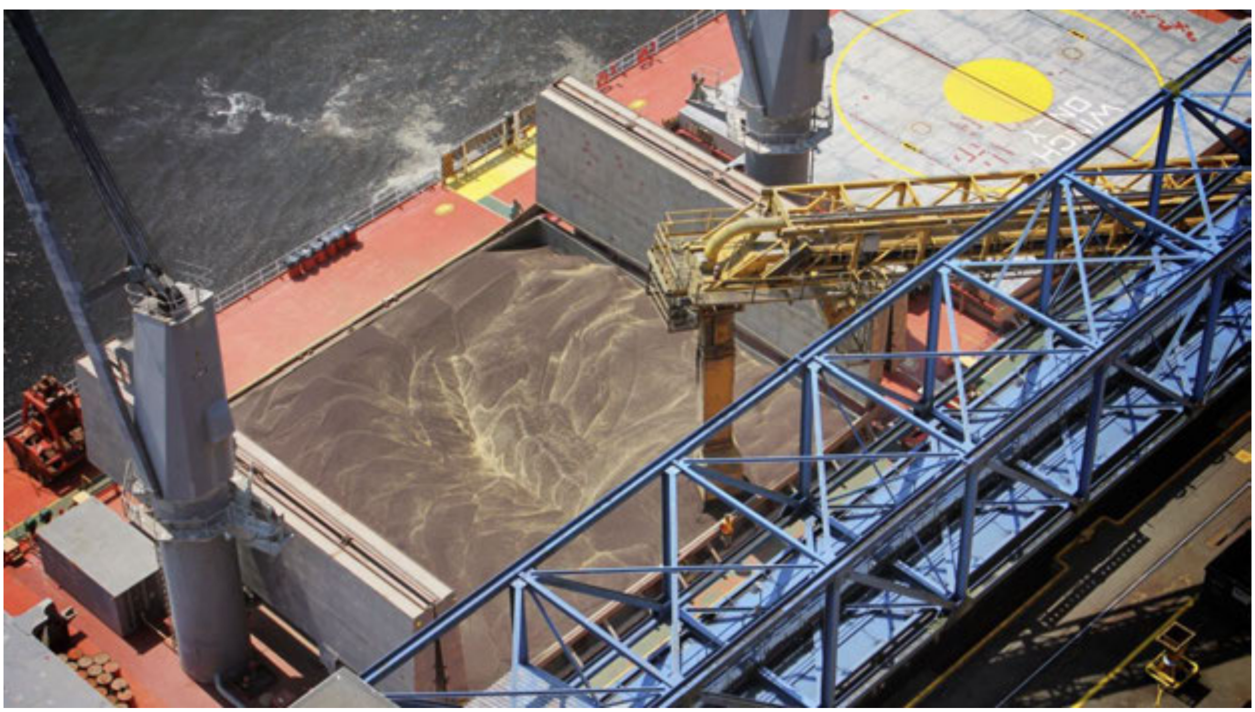


Figure 24 Aerial view of Bulk Carrier loading (image, Port of Stockton)

Ballast transfer stations and associated deck tackle meeting the OCIMF requirements in Reference 5 would require an approximate footprint of 5x5 meters. This amount of deck space not be readily available. However, given the very large piping sizes and ballast flow rates, it is very important that fully compliant deck tackle be provided.

5.3.4 Modifications – Bulk Carrier

Note: The specifications provided below pertain to the generic, representative Bulk Carrier. Based on the range of ballast water discharge rates, a piping size of DN500 is assumed to be representative for this vessel type in California.

5.3.4.1 General Requirements

General requirements are listed in the Section 5 – General Modifications.

5.3.4.2 Piping Modifications

The following tabulates pipe fittings and equipment, and describes the required piping runs.

Table 26 Piping materials and equipment

Item	Size, Quantity	Description
Pipe	DN500, 60 meters horizontal DN500, 30 meters vertical	ASTM A53B, Schedule 40
Valves	DN500, three (3)	Butterfly, wafer, with manual gear operator
Elbows	DN500, eight (8)	ASTM A234, Schedule 40, Butt weld
Tees	DN500, two (2)	ASTM A234, Schedule 40, Butt weld
Flanges	DN500, four (4)	ASTM A105, Class 150, Slip-on

<u>Overboard Tee</u>

The new piping shall be connected to the existing ballast water overboard, located in the main machinery room, by means of a new tee fitting. Any internal coating of the existing piping that is damaged shall be repaired. This connection shall be inboard of the existing overboard stop and check valves.

<u>Pipe Run to Weather</u>

New piping shall be run from the overboard to the weather deck forward of the house, including:

- Watertight penetrations at main deck.
- Weathertight penetrations in the machinery space forward bulkhead.

<u>Pipe Run to Transfer Stations</u>

New piping shall be run from this penetration to the two ballast water transfer stations, port and starboard, including:

- Tee fitting to split the flow to the two stations.
- Valves at each station.
- Blank flanges to secure openings when not in use.

<u>Presentation Flange</u>

A special pipe spool shall be provided that presents to the transfer station an international ballast water presentation flange.

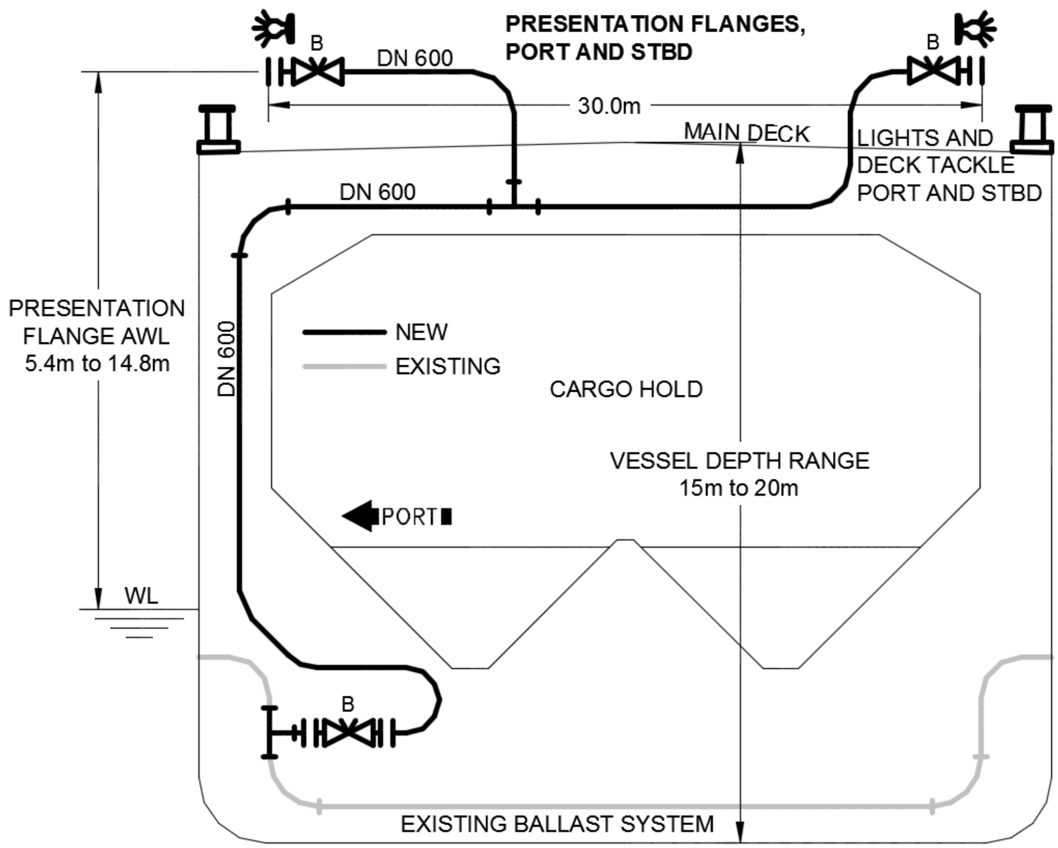


Figure 25 Diagram of bulk carrier piping modifications

5.3.4.3 Ballast Transfer Stations

Two transfer stations shall be provided, one port and one starboard. These shall be located in a position for ready access to hoses or mechanical arms provided by shore-based services, i.e. near the side shell on the main weather deck. Each station shall be outfitted with lighting and deck rings to secure a connection hose, as specified in Table 27.

Table 27 Deck tackle and lighting required for each ballast transfer station

Item	Size/Quantity	Description
Cruciform bollard	600-mm height, qty one (1)	25 ton working load
Bollards	300-mm diameter, qty two (2)	25 ton working load, each
Fairleads	400 x 250 mm, qty two (2)	25 ton working load, each. Place in clear, open area
Deck Rings	Qty two (2)	15 ton working load, each
Hose Rest	150-mm radius of curvature	Construct using DN 300 Pipe
Floodlights	50 lux at manifold, qty one (1)	Including cabling and switch

In addition to the above listed equipment, the side rail shall be modified to suit the support of hose resting over it, in accordance with OCIMF guidelines (Reference 5). 10 meters of DN 300 hose shall be used to construct the hose rest, configured as shown in Figure 14.

5.3.4.4 Relocations

Ducting and vents in the way of the new piping shall be removed to make room for the new ballast piping, and rerouted in accordance with Owner direction.

Lights and cabling in way of the new piping shall be relocated in accordance with Owner direction to make room for the new ballast piping.

Table 28 Relocations

Item	Size/Quantity	Description
Ducting	DN200, 40 linear meters	Galvanized carbon steel
Lighting	Four (4)	Florescent machinery lights

5.3.5 Cost Estimate – Bulk Carrier

This estimate assumes that the vessel is modified at an Asian shipyard, and during the vessel's regularly scheduled shipyard period. A full, OCIMF-compliant transfer stations is assumed, assuming connection hoses are supported by shore-side equipment.

Table 29 Summary of bulk carrier cost estimate

Vessel	Ballast Capacity (m^3)	Modification	Cost
Bulk Carrier (Panamax)	13,100	Piping Modifications	$183,100
		Ballast Stations	$58,100
		Engineering and Regulatory Review	$48,000
		Material Markup	$19,600
		Total:	**$308,800**

5.4 Tankships

5.4.1 General Description – Tankships

Tankships, also called tankers and oil tanker, are marine vessels that transport liquid petroleum products in bulk, such as crude oil, heavy oils such as number six oils, and refined products such as gasoline or jet fuel. Chemical carriers are similar in many regards, but should be separately considered given their unique ballasting configurations.

Tankships are similar to bulk carriers in that they also vary greatly in size from small handy sized tankers that might only transfer ballast water at 1,500 m3/hr to Suezmax vessels that reach rates of 5,000 m3/hr and more, or the even larger very large crude oil carriers and ultra large crude oil carriers.

Figure 26 Tankship *Castor Voyager* at 105,000 deadweight, estimated ballasting at 3,400 m3/hr

A primary consideration of tankships is that the ballast water is typically considered to contain flammable gases, as the ballast tanks are typically adjacent to cargo tanks that certainly contain flammable gases. Piping leaks, or cracks in the steel bulkheads between these tanks, can result in hydrocarbon leaking into the ballast water tanks. As such, all tankship ballast water taken from tanks that are adjacent to the cargo tanks must be dealt with as potentially explosive. This requires terminals to take special precautions in the manner that hose or loading arm connections are made, and lines are secured, in order to avoid creating an electric spark and igniting an explosion. Further, once the ballast water is landed at the shore-based facility, it must still be handled as if it contains explosive gases.

Another primary consideration is that tankships also typically have non-hazardous ballast water. This ballast water is typically handled in complete isolation from the cargo block ballast water, using different pumps, piping, and no crossovers. It is assumed that tankers will require two ballast water connections, although combining the non-hazardous and hazardous streams, and treating both as hazardous, could be reviewed further.

The ballast water discharge volumes for a tanker are tightly linked with cargo loading activities. Typically, the vessel will discharge one ton of ballast water for each three to four tons of cargo loaded. These ballasting operations are performed to accommodate changes in loading conditions, while managing hull stresses, stability, propeller immersion, bridge visibility, and trim. Due to the high volumes of ballast water typically discharged, and the very tight link between ballasting and cargo operations, tankships are considered "highly ballast-dependent vessels."

5.4.2 Analysis – Tankships

Marine vessel particulars are discussed above in Section 2.2.1, Review of Terms used in Analysis. Digest terms, i.e. AWL and Press Max, are discussed above in Section 5.1.2, Analysis – ATB.

An analysis of tankers that discharge ballast water in California was performed, and not limited to only those vessels discharging at the case study location (El Segundo). This analysis provides a general understanding of the impact of state-wide implementation of a shore-based treatment requirements on this vessel type.

The particulars for typical tankers discharging ballast water is provided in Table 30 below. This covers a range of vessel configurations and types within this vessel type, such that a range of interface requirements could be established. The ballast water reception facilities need to be able to receive not only the larger vessels, but also the smaller vessels. Following is Table 25, which digests the particulars into ballast connection interface estimates for those vessels. Specifically, considering the height of the connection, flow rates, and pressures at the vessel connection.

Table 30 Tanker particulars, California ballast water discharge examples, focus on El Segundo

		Vessel Dimensions				Capacities		Ballast
Type	Vessel	LBP	Breadth	Depth	Frbd	Dwt	Cargo	Tanks
		(m)	*(m)*	*(m)*	*(m)*	*(tonnes)*	*(m3)*	*(m3)*
Tankers								
	Sea Hope	233	42	22	6.67	108,701	125,540	39,129
	Castor Voyager	233	42	21.3	6.57	105,000	120,113	40,578
	Oregon Voyager	180	32.2	19.15	6.96	45,671	55,396	21,688
	Overseas Anacortes	174	32.2	18.8	6.61	46,656	53,808	24,348
	Sum Low	174	32.2	18.8	6.57	45,671	53,808	21,688
	Sum High	233	42	22	6.96	108,701	125,540	40,578
	Design Basis							***41,000***

Table 31 Tanker estimates, California ballast water discharge interfaces

		Ballast Water		Draft (est)		Presentation Flange			
						AWL	AWL	Press	Press
Type	Vessel	Disch.	Rate	Deep	Light	Deep	Light	Max	Min
		(hours)	*(m3/hr)*	*(m)*	*(m)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
Tankers									
	Sea Hope	12	3,261	15.34	6.42	7.67	16.58	365	145
	Castor Voyager	12	3,382	14.73	6.55	7.57	15.75	356	143
	Oregon Voyager	10	2,169	12.19	6.77	7.96	13.38	308	116
	Overseas Anacortes	10	2,435	12.19	6.97	7.61	12.83	298	110
	Sum Low	10	2,169			7.57	12.83	298	110
	Sum High	12	3,382			7.96	16.58	365	145
	Design Basis		***3,400***			***7.60***	***16.60***	***360***	***110***

5.4.3 Compatibility for Deck Connection – Tankships

Pump Capacity and Pipe Sizing

The studied tankers all had adequate pumping head to lift the ballast water to the presentation flange for discharge to shore. It is expected that the shore-based facilities will have high-lift booster pumps that can assist the ships pumps and maintain design ballasting rates.

Pipe sizing ranges from DN400 for the lower flow rate to as high as DN600 for the larger discharges. These rates are well aligned with the case study rates.

Routing of New Ballast Water Piping to Main Deck

Tankers, although varied, follow the typical pattern of the cargo block ballast water pumps being located in the cargo pump room, which is classified as known to contain explosive gases. These pumps are frequently steam-turbine driven, and sometimes electric-motor driven – with those drives located outside of the cargo pump room. A sealed shaft passes through a gas-tight bulkhead between the drives located in a safe area and the hazardous cargo pump room.

This arrangement, however, keeps the ballast water piping very low in the tankship. There is typically no piping that reaches towards the vessel's main deck. As such, the pumps tend to be low head (pressure) and typically suitable only for pumping ballast water to the main deck with little remaining head to pump through a shore station. As such, lift or booster stations would be required at the reception facility.

Some tankers, however, will use deepwell pumps. That case is not explored here, as it is similar to ATB arrangement discussed earlier.

Deck Arrangement

Tankships already perform high volume bulk liquid transfers, and as such are familiar with the equipment and procedures that would be similar for ballast water transfers. It is possible that most tankships will have room for needed deck manifolds, although they might need to be new. The below Figure 23 shows a typical loading arm connection with two lines rigged, similar to what might be needed for typical tankship ballast water transfer to shore-based facilities.

Figure 27 Loading arms to tanker

Ballast transfer stations and associated deck tackle meeting the OCIMF requirements in Reference 5 would require an approximate footprint of 5x5 meters. This amount of deck space may be available. Given the very large piping sizes and ballast flow rates, it is important that fully compliant deck tackle be provided.

5.4.4 Modifications – Tankships

Note: The specifications provided below pertain to the generic, representative Bulk Carrier. Based on the range of ballast water discharge rates, a piping size of DN500 is assumed to be representative for this vessel type in California.

5.4.4.1 General Requirements

General requirements are listed in the Section 5 – General Modifications.

5.4.4.2 Piping Modifications

The following tabulates pipefittings and equipment, and describes the required piping runs for both the cargo block and engine machinery room ballast water systems.

Table 32 Piping materials and equipment (cargo block)

Item	Size, Quantity	Description
Pipe	DN600, 60 meters horizontal DN600, 30 meters vertical	ASTM A53B, Schedule 40
Valves	DN600, three (3)	Butterfly, wafer, with manual gear operator
Elbows	DN600, eight (8)	ASTM A234, Schedule 40, Butt weld
Tees	DN600, two (2)	ASTM A234, Schedule 40, Butt weld
Flanges	DN600, four (4)	ASTM A105, Class 150, Slip-on

Table 33 Piping materials and equipment (aftpeak and engine room tanks)

Item	Size, Quantity	Description
Pipe	DN150, 100 meters horizontal DN150, 40 meters vertical	ASTM A53B, Schedule 40
Valves	DN150, three (3)	Butterfly, wafer, with manual gear operator
Elbows	DN150, twelve (12)	ASTM A234, Schedule 40, Butt weld
Tees	DN150, two (2)	ASTM A234, Schedule 40, Butt weld
Flanges	DN150, four (4)	ASTM A105, Class 150, Slip-on

Overboard Tee

The cargo block new piping shall be connected to the existing ballast water overboard, located in the main machinery room, by means of a new tee fitting. The overboard is the discharge point on the ship where the ballast water is pumped into the harbor or sea. Any internal coating of the existing piping that is damaged shall be repaired. This connection shall be inboard of the existing overboard stop and check valves.

The engine machinery room ballast system shall be similarly outfitted, connecting to the existing overboard in the engine machinery room.

Pipe Run to Weather

New piping shall be run from each of the overboards to the weather deck forward of the house, including:

- Watertight penetrations at main deck.
- Weathertight penetrations in the cargo pump room and machinery space bulkheads.

Pipe Run to Transfer Stations

New piping shall be run from these penetration to the two ballast water transfer stations, port and starboard. Each shall contain two connections, one for the cargo block and one for the machinery room, including:

- Tee fitting to split the flow to the two stations.
- Valves at each station.
- Blank flanges to secure openings when not in use.

Presentation Flange

Special pipe spools shall be provided that presents to the transfer station an international ballast water presentation flange.

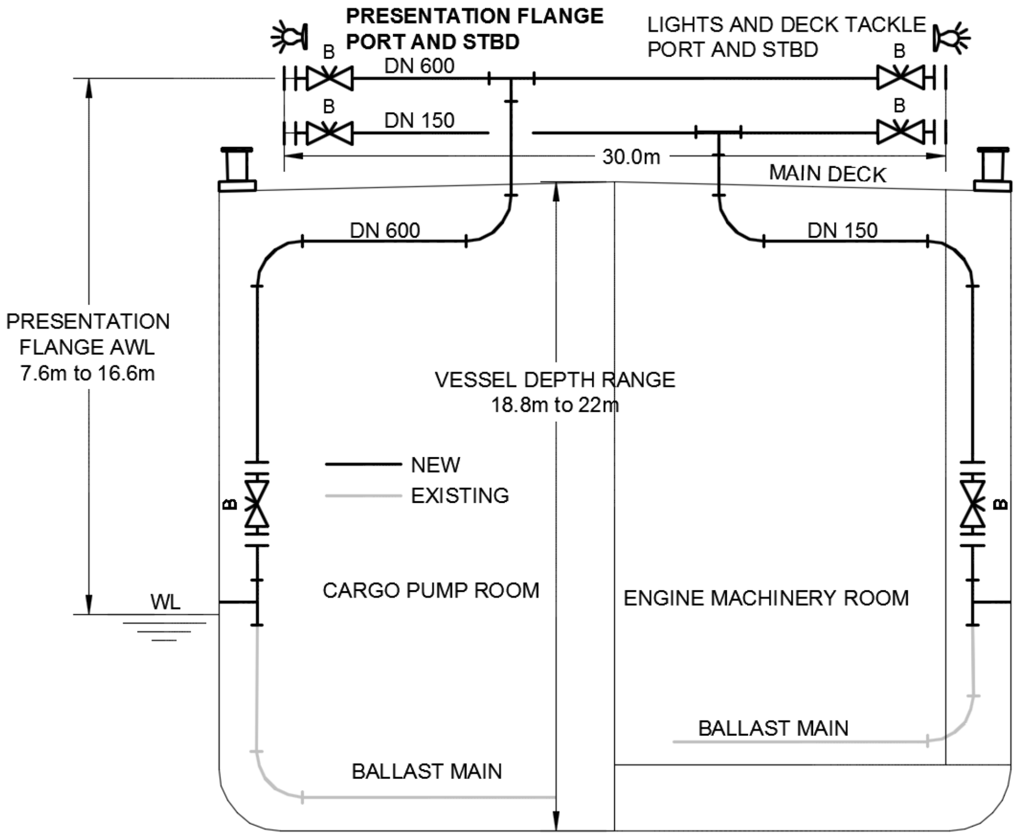


Figure 28 Diagram of tankship piping modifications

5.4.4.3 Ballast Transfer Stations

Two transfer stations shall be provided, one port and one starboard. These shall be located in a position for ready access to hoses or mechanical arms provided by shore-based services, i.e. near the side shell on the main weather deck. Each station shall be outfitted with lighting and deck rings to secure a connection hose, as specified in Table 34.

Table 34 Deck tackle and lighting required for each ballast transfer station

Item	Size/Quantity	Description
Cruciform bollard	600-mm height, qty one (1)	25 ton working load
Bollards	300-mm diameter, qty two (2)	25 ton working load, each
Fairleads	400 x 250 mm, qty two (2)	25 ton working load, each. Place in clear, open area
Deck Rings	Qty two (2)	15 ton working load, each
Hose Rest	150-mm radius of curvature	Construct using DN 300 Pipe
Floodlights	50 lux at manifold, qty one (1)	Including cabling and switch

In addition to the above listed equipment, the side rail shall be modified to suit the support of hose resting over it, in accordance with OCIMF guidelines (Reference 5). 10 meters of DN 300 hose shall be used to construct the hose rest, configured as shown in Figure 14.

5.4.4.4 Relocations

Ducting and vents in way of the new piping shall be removed to make room for the new ballast piping, and rerouted in accordance with Owner direction.

Lights and cabling in way of the new piping shall be relocated in accordance with Owner direction to make room for the new ballast piping.

Table 35 Relocations

Item	Size/Quantity	Description
Ducting	DN200, 40 linear meters	Galvanized carbon steel
Lighting	Four (4)	Florescent machinery lights

5.4.5 Cost Estimate – Tankship

This estimate assumes that the vessel is modified at an Asian shipyard, and during the vessel's regularly scheduled shipyard period. A full, OCIMF-compliant transfer stations is assumed, assuming connection hoses are supported by shore-side equipment.

Table 36 Summary of tankship cost estimate

Vessel	Ballast Capacity (m^3)	Modification	Cost
Tankship	40,000	Piping Modifications	$289,500
		Ballast Stations	$58,100
		Engineering and Regulatory Review	$52,000
		Material Markup	$26,300
		Total:	**$425,900**

5.5 Passenger Cruise Ships

5.5.1 General Description – Passenger Cruise Ships

Passenger cruise ships provide entertainment and transportation to passengers on board marine vessels. These vessels range in size from smaller vessels, such as the *Silver Galapagos* accommodating 175 total crew and passengers, that promotes a special experience:

> *There is something uniquely satisfying about a smaller ship. The intimacy. The friendly camaraderie. The excitement of exploring secluded harbours where others cannot go. Our intimate, ultra-luxury ships can sail up narrow waterways into the heart of a city, or tie up right at the pier while others must anchor off shore. (Silversea Cruises)*

to giant ships, such as the *Harmony of the Seas* accommodating over 9,000 total crew and passengers, that offer a grand range of activities:

> *The world's biggest ship with the world's best features just got even better. There's no turning back once you take the plunge 10 stories into the mysteries of the deep on the tallest slide at sea, Ultimate Abyss, as well as the exhilarating multilevel Perfect Storm slides. (Royal Caribbean)*

Cruiseships typically manage ballast water to offset fuel oil bunkering and consumption, potable water generation and consumption, taking on and consumption of stores, and changes in weather for passenger comfort. As a result, some ballasting can be performed at sea, while some ballasting is required in port. For example, the case study PoLB Cruise Terminal sees a ballast water discharge nearly every day.

Figure 29 3,334 passenger and crew *Jewel of the Seas*, taking fuel oil bunkers (image, Robbie Cox)

5.5.2 Analysis – Passenger Cruise Ship

Marine vessel particulars are discussed in section, 2.2.1, above, Review of Terms used in Analysis. Digest terms, i.e. AWL and Press Max, are discussed in section 5.1.2, above, Analysis – ATB.

Two cruiseships were considered in the analysis: *AIDAaura* that discharges generally in California and the *Carnival Inspiration* that routinely discharges at the case study location of

PoLB Cruise Terminal. Additional vessels were considered, but inadequate data was available to include in the assessment.

The particulars of these vessels are summarized in Table 37. The estimated ballast water particulars as combined in the same table, including the height of the connection, flow rates, and pressures at the vessel connection. The presentation flange height assumes use of a side port instead of a main deck connection.

Table 37 Containership particulars, California ballast water discharge examples

		Vessel Dimensions				Ballast	Ballast Water		Presentation Flange			
									AWL	AWL	Press	Press
Type	Vessel	LBP	Breadth	Depth	Frbd	Tanks	Disch.	Rate	Deep	Light	Max	Min
		(m)	*(m)*	*(m)*	*(m)*	*(m3)*	*(hours)*	*(m3/hr)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
Cruiseships												
	AIDAaura	179	28.1	8.75	2.45	1,589	12	132	3.45	4.04	164	76
	Carnival Inspiration	261	31.5	22.55	14.8	4,027	12	336	6.75	7.14	403	177
	Sum Low	179	28.1	8.75	2.45	1,589	12	132	3.45	4.04	164	76
	Sum High	261	31.5	22.55	14.8	4,027	12	336	6.75	7.14	403	177
	Design Basis					***4,000***		***300***	***3.50***	***7.10***	***400***	***80***

Figure 30 Aerial view of the 3,054 passenger and crew *Carnival Miracle*, taking fuel oil bunkers by barge (image, FleetMon.com)

5.5.3 Compatibility for Deck Connection – Passenger Cruise Ship

Pump Capacity and Pipe Sizing

The studied cruise ships had adequate pumping head to lift the ballast water to the presentation flange for discharge to shore. Pipe sizing ranges from DN100 to DN200 to cover the range of flow rates.

Routing of New Ballast Water Piping to Main Deck

The cruise ships examined are typical in that bunkering connections are located in side ports, which are water or weather tight pockets cut into the side shell of the ship. This is above the waterline of the vessel, but well below the upper decks. Pipe routing will follow routing of the fire main, fuel oil bunkering, and sewage lines to the same from the engine machinery room to the side port.

Side Port Arrangement

There are significant space limitations within these side ports. These locations will already, in most cases, be optimized for the planned shore-based piping connections. It is expected that the side ports will generally require reconfiguration of the existing piping, and in some cases a structural expansion of the side port.

The ballasting rates are very similar to fuel oil bunkering. This significantly relieves the need to provide large foundations and ground tackle to support high flow rate hoses. Standard bunkering routines can be followed, and side ports are readily outfitted the needed supports for connecting smaller hoses, i.e. DN150.

Some of these vessels have already undergone expansions to be able to receive shore-power. In some of those cases, an additional side port was added to provide a location to plug in these cables, see Figure 31, below. The ballast water port would need to be significantly larger, but provides the general concept.

Figure 31 Use of new side port for plugging in passenger ship in San Diego (image, Port of San Diego)

5.5.4 Modifications – Passenger Cruise Ships

Note: The specifications provided below pertain to the generic, representative containership. Based on the range of ballast water discharge rates, a piping size of DN300 is assumed to be representative for this vessel type in California.

5.5.4.1 General Requirements

General requirements are listed in the Section 5 – General Modifications.

5.5.4.2 Piping Modifications

The following tabulates pipe fittings and equipment, and describes the required piping runs.

Table 38 Piping Materials and Equipment

Item	Size, Quantity	Description
Pipe	DN200, 40 meters horizontal DN200, 15 meters vertical	ASTM A53B, Schedule 40
Valves	DN200, three (3)	Butterfly, wafer, with manual gear operator
Elbows	DN200, ten (10)	ASTM A234, Schedule 40, Butt weld
Tees	DN200, two (2)	ASTM A234, Schedule 40, Butt weld
Flanges	DN200, four (4)	ASTM A105, Class 150, Slip-on

Overboard Tee

The new piping shall be connected to the existing ballast water overboard, located in the main machinery room, by means of a new tee fitting. Any internal coating of the existing piping that is damages shall be repaired. This connection shall be inboard of the existing overboard stop and check valves.

Pipe Run to Side Port

New piping shall be run from the overboard to the side port, including:

- Watertight penetrations at the vessel sideshell.
- Rework and expansion of the sideshell to support an expanded side port.

Pipe Run to Transfer Stations

New piping shall be run from this house penetration to the two ballast water transfer stations, port and starboard, including:

- Tee fitting to split the flow to the two stations.
- Valves at each station.
- Blank flanges to secure openings when not in use.

Presentation Flange

A special pipe spool shall be provided that presents to the transfer station an international ballast water presentation flange.

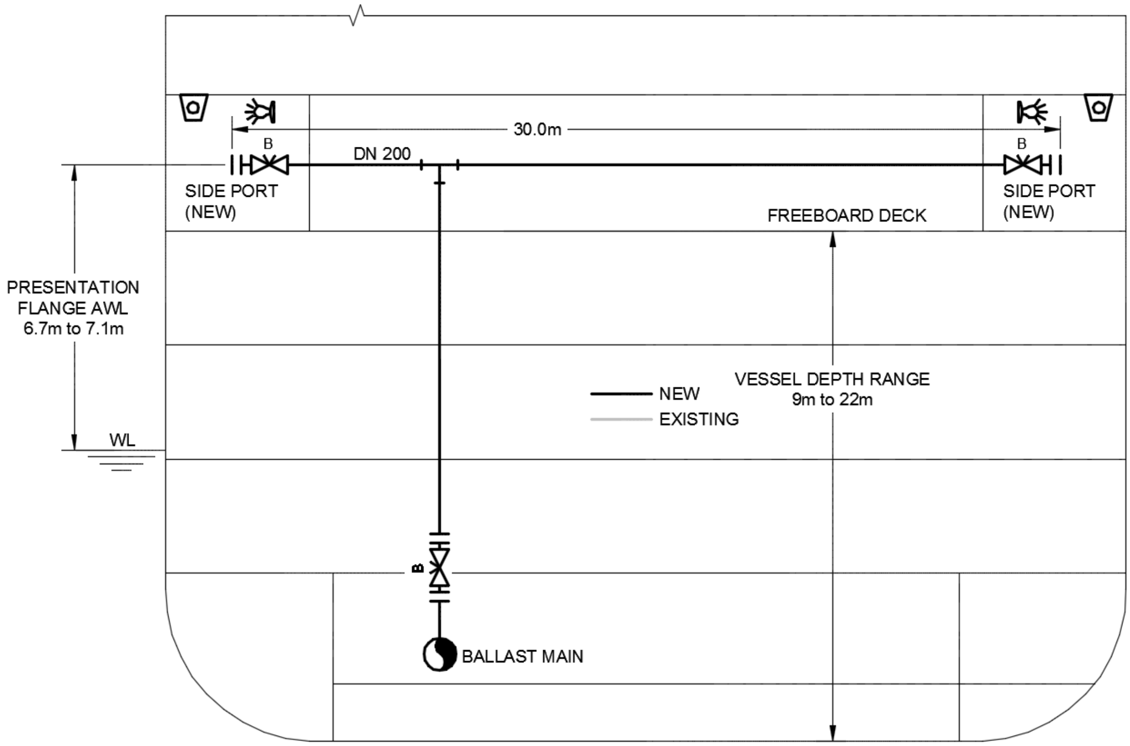


Figure 32 Diagram of passenger cruise ship piping modifications

5.5.4.3 Ballast Transfer Stations

Two transfer stations shall be provided, one port and one starboard. These shall be located in a position for ready access to hoses or mechanical arms provided by shore-based services, i.e. near the side shell on the main weather deck.

Each station shall be outfitted with lighting and deck rings to secure a connection hose, as specified in Table 21.

Table 39 Quantities for two side port ballast transfer stations

Item	Size/Quantity	Description
Hose Support	Qty two (2)	15 ton working load, each
Floodlights	50 lux at manifold, qty two (2)	Including cabling and switch

In addition to the above listed equipment, the side port shall be created, including water tight closure with alarm indication on navigation bridge, and safety rails.

5.5.4.4 Relocations

Ducting and vents in way of the new piping shall be removed to make room for the new ballast piping, and rerouted in accordance with Owner direction.

Lights and cabling in way of the new piping shall be relocated in accordance with Owner direction to make room for the new ballast piping.

Table 40 Relocations

Item	Size/Quantity	Description
Ducting/Piping	DN200, 40 linear meters	Galvanized carbon steel
Lighting	Four (4)	Florescent machinery lights

5.5.5 Cost Estimate – Passenger Cruise Ship

This estimate assumes that the vessel is modified at an Asian shipyard, and during the vessel's regularly scheduled shipyard period. It is assumed that a new side port access, or rework of an existing side port, will be required to support the ballast transfer operations.

Table 41 Summary of containership cost estimate

Vessel	Ballast Capacity (m^3)	Modification	Cost
Cruise Ship	4,000	Structure/Side Ports	$162,000
		Piping Modifications/Relocations	$49,400
		Ballast Stations	$19,500
		Engineering and Regulatory Review	$44,000
		Material Markup	$22,400
		Total:	**$297,300**

5.6 Automobile Carriers

5.6.1 General Description – Automobile Carrier

Automobile carriers, also called car carriers or pure car and truck carrier (PCTC), a specific type of roll-on/roll-off (ro/ro) vessel. The cargo for ro/ros drive onto and off of the marine vessel. Ro/ros are commonly used in the military for overseas transport or pre-positioning of tanks, tanker trucks, and cargo trucks. A prominent feature of ro/ros is a larger stern ramp, side ramp, or both. In many instances, the ro/ro is combined with containership functions or lift-on/lift-off functions increasing vessel capability.

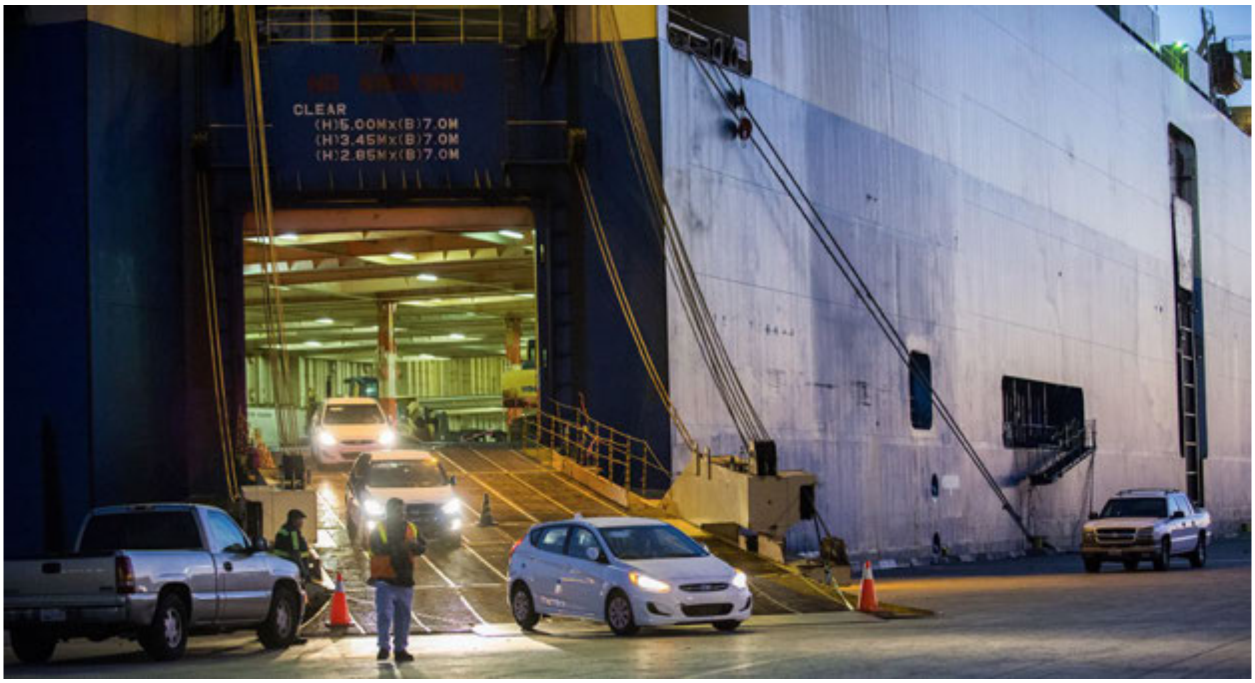


Figure 33 Automobile carrier during offload, also visible is bunkering side port (image, Port Hueneme)

There is little difference in ballast handling between the various ro/ros, including automobile carriers. One exception is that some military vessels will include counter-heeling tanks, to counter significant shifts in weight by a large tank driving across the vessel.

Like passenger cruise ships, ro/ros typically manage ballast water to offset fuel oil bunkering and consumption, potable water generation and consumption, taking on and consumption of stores, changes in weather, and to counter for changes in cargo weights and locations. As a result, some ballasting can be performed at sea, while some ballasting may be required in port. Frequently, ro/ros can avoid deballasting or limit the deballasting amount.

Figure 34 ***Grand Mark*** **automobile carrier (blue and white) berthed at Port Hueneme (image, Port Hueneme)**

5.6.2 Analysis – Automobile Carrier

Marine vessel particulars are discussed in section, 2.2.1, above, Review of Terms used in Analysis. Digest terms, i.e. AWL and Press Max, are discussed in section 5.1.2, above, Analysis – ATB.

Four automobile carriers were considered in the analysis, including those that routinely discharges at the case study location of Port Hueneme.

The particulars of these vessels are summarized in Table 42. The estimated ballast water particulars as combined in the same table, including the height of the connection, flow rates, and pressures at the vessel connection. The presentation flange height assumes use of a side port instead of a main deck connection.

Table 42 Automobile carrier particulars, California ballast water discharge examples

		Vessel Dimensions				Ballast	Ballast Water		Presentation Flange			
									AWL	AWL	Press	Press
Type	Vessel	LBP	Breadth	Depth	Frbd	Tanks	Disch.	Rate	Deep	Light	Max	Min
		(m)	*(m)*	*(m)*	*(m)*	*(m3)*	*(hours)*	*(m3/hr)*	*(m)*	*(m)*	*(kPa)*	*(kPa)*
Automobile Carriers												
	Cougar Ace	190	32.26	12.17	2.87	6,965	18	387	3.87	5.41	220	98
	Cape Intrepid	195	31	11.2	7.08	199	4	50	4.08	7.22	204	92
	Green Bay	192	32.26	14.25	4.66	9,761	18	542	5.66	6.51	246	104
	Marjorie C	210	32	12	3	12,540	18	697	4.00	5.22	221	101
	Sum Low	190	31	11.2	2.87	199	4	50	3.87	5.22	204	92
	Sum High	210	32.26	14.25	7.08	12,540	18	697	5.66	7.22	246	104
	Design Basis					***13,000***		***700***	***3.90***	***7.20***	***250***	***90***

5.6.3 Compatibility for Deck Connection – Automobile Carriers

There are no significant differences between passenger cruise ships and automobile carriers in terms of compatibility for deck connections. The vessel type will need to outfit side ports to support transferring ballast water to a shore-based facility. Please refer to the Passenger Cruise Ship section for additional details.

5.6.4 Modifications – Automobile Carriers

There are no significant differences between passenger cruise ships and automobile carriers in terms of compatibility for deck connections. The vessel type will need to outfit side ports to support transferring ballast water to a shore-based facility. Please refer to the Passenger Cruise Ship section for additional details.

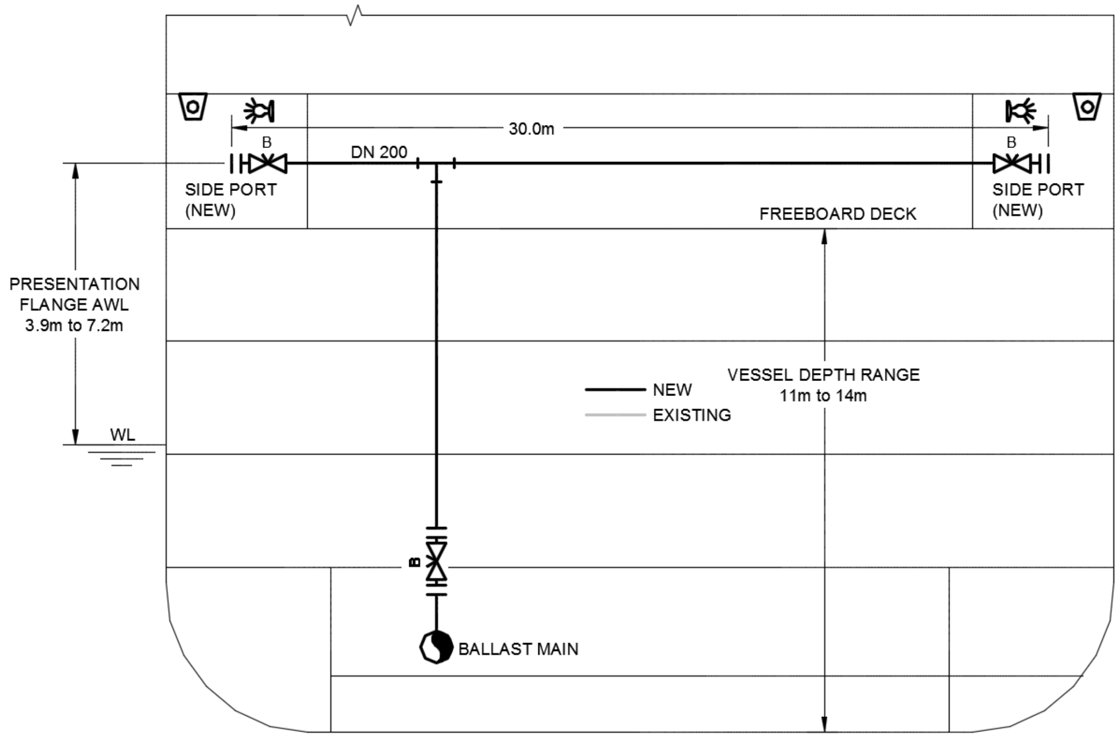


Figure 35 Diagram of automobile carrier piping modifications

5.6.5 Cost Estimate – Automobile Carrier

This estimate assumes that the vessel is modified at an Asian shipyard, and during the vessel's regularly scheduled shipyard period. It is assumed that a new side port access, or rework of an existing side port, will be required to support the ballast transfer operations.

Table 43 Summary of containership cost estimate

Vessel	Ballast Capacity (m^3)	Modification	Cost
Automobile Carrier	13,000	Structure/Side Ports	$162,000
		Piping Modifications/Relocations	$49,400
		Ballast Stations	$19,500
		Engineering and Regulatory Review	$44,000
		Material Markup	$22,400
		Total:	**$297,300**

Section 6 Further Considerations

6.1.1 Side Port Consideration

The containership, like most vessels, have their ballast water pumps located low in the engine machinery room. These are crowded machinery rooms with many levels of equipment, piping, and wireways between the ballast pumps and locations where a shore-based ballast water presentation flange might be located. A side port location might offer a needed alternative where a main deck connection is not practical.

Routing piping in these busy machinery areas will require evaluation on a case-by-case basis, considering interferences and integration with existing operations. Typically, this requires laser scanning of these spaces, using three-dimensional drafting techniques, and then reworking the arrangement of the new and existing equipment to suit.

The below image is a section cut of a large containership, providing a graphical image of these busy machinery spaces. The red text and lines communicate the ballast pump locations, tank locations, and where presentation flanges might be located. New locations are suggested at both the main deck and at new side port locations. This image highlights that in some cases it might not be practical to have a main deck ballast connection. Allowing the option for a side port location would provide the designer some flexibility, and increase the chances of successfully completing the modifications.

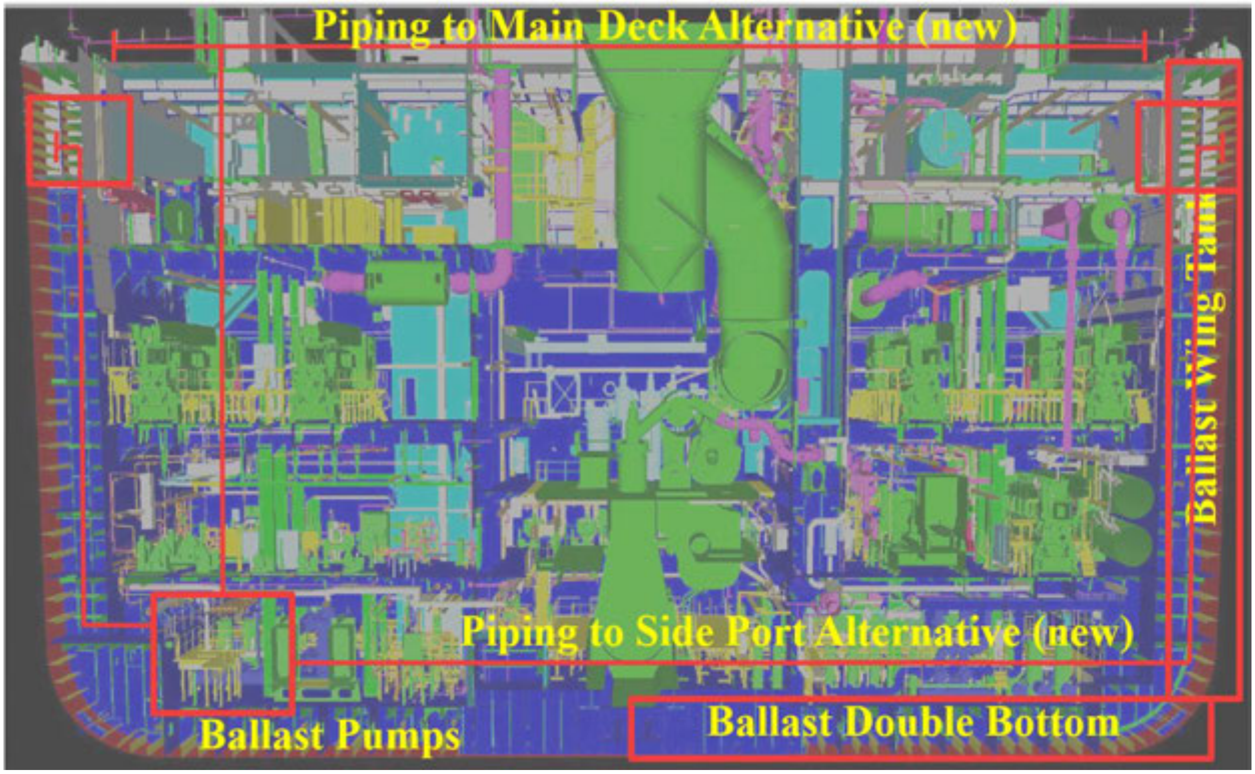


Figure 36 Containership engine room section view, with ballast side port connection alternative location (image, Maersk)

This analysis assumes a main deck location in the cost estimate, and does not evaluate the side port connection in detail. Aspects requiring further review include:

- Impact on intact and damage stability from locating a new and large penetration in the vessel's hull.
- Impact on global and local stresses by opening the sideshell with new and large penetration.
- Ability to access the new side port, considering watertight doors, ladders, lighting, and safety equipment.
- Assuming taking some ballast water tank volume for this new connection, impact on vessel trim and stability management.

Appendix A Study Overview and Definitions

This report is part of an overall coordinated study evaluating the feasibility of using shore-based mobile or permanent ballast water treatment facilities to meet the CA Interim Standards.

Study Overview

Marine vessels routinely uptake ambient sea or harbor water as ballast, transit to another port, and then discharge that ballast water. Unfortunately, the resulting ballast water discharges have been linked to the introduction of aquatic invasive species and harmful pathogens. In an effort to reduce or possibly eliminate further introductions, marine vessels are being required to manage ballast water discharges by a myriad of international, federal, and regional guidelines and rules. Vessels discharging in California will be required to meet an interim standard that is more stringent than international and US federal standards.

In response, there has been significant development work and commercial installations of treatment systems located on board marine vessels themselves. However, there is a lack of data to determine if the treatment systems that are being installed on board marine vessels are capable of meeting the CA Interim Standards. Shore-based ballast water reception and treatment is under consideration as an approach to meet the CA Interim Standards.

This overall study evaluates the feasibility of such shore-based treatment systems in ten separate tasks, beginning with a review of shore-based treatment research and assessing potential all the way to cost estimates and an implementation timeline.

Tasks Overview

Tasks 2 through 5 are submitted together to discuss the practical necessities for shore-based treatment system implementation, from the modifications onboard vessels through to the treatment technologies used in the facilities (see Figure 37).

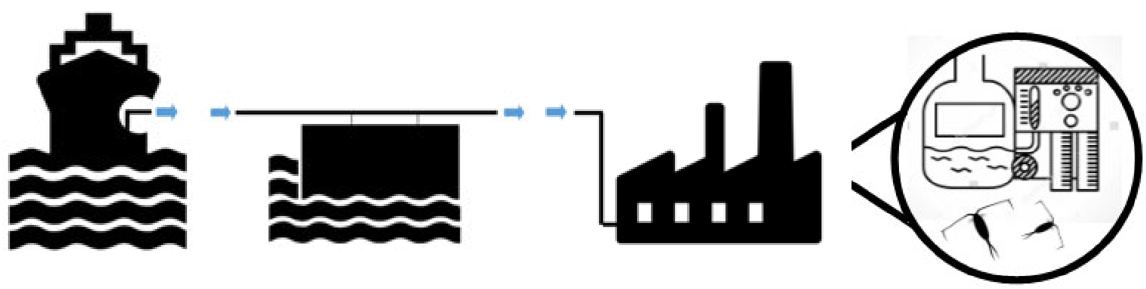


Figure 37 Scope of Tasks 2 through 5

This Task 2 report assesses the retrofitting and outfitting of marine vessels, as part of the larger overall study on Shore-based Ballast Water Reception and Treatment in California. This report considers the feasibility and required modifications so that vessels can pump ballast water out of the ship to a new exterior piping manifold where shore facilities can receive and process the ballast water in accordance with California requirements.

Task 3 of the larger study discusses retrofitting of ports and wharves to receive ballast water from the vessels that need to transfer to on-site reception and treatment facilities, minimizing the disruption of normal port and vessel operations.

Task 4 of the larger study assesses the needed shore facilities to transfer, store and treat the ballast water once it leaves the marine vessel, determining the most cost-effective approach to meet performance standards and capacity requirements.

Task 5 of the larger study assesses applicable types of treatment technologies available for shore-based reception facilities that show promise in the ability to meet the CA Interim Standards and how the efficacy of such systems can be measured.

Case Studies Overview

The overall study uses location-specific case studies to cover the range of ports and terminals within California. A case study approach allowed the study team to develop a specific solution for each case, based on actual berth locations, estimated piping distances, specific water transfer rates and volumes, and applicable regulations, among other tangible aspects. After examining these cases, the estimated costs, timelines, and considerations discovered in the case study process will be scaled up to inform stakeholders and policymakers about statewide implementation.

Collectively, the five selected port districts constitute a rough cross-section of commercial shipping activity in California. The case studies were structured to ensure that a range of feasibility challenges are considered, including: vessel types; ballast water reception and conveyance; and ballast water storage and treatment approaches. For each case study, actual vessels and feasible methods of ballast water conveyance were combined with the three storage approaches and five treatment approaches that the study was required to asses. These approaches were assigned according to what approach promised to be feasible for each case study port. Table 44 summarizes the case studies and assigned approaches.

Table 44 Summary of case studies

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
1	Port of Stockton/East Complex	Bulk Carriers	Rail & Pipeline	New onsite tank	Existing WWTP[1]
2	Port of Oakland/TraPac Terminal	Containerships	New pipeline	New onsite tank	New onsite WWTP
3	Port of Hueneme/South Terminal Wharf 1	Automobile Carriers	Onsite storage	New onsite tank	Mobile shore-based treatment
4	El Segundo Marine Terminal	Tank Ships; ATBs	Offload to mobile marine vessel	Mobile marine vessel	Mobile, marine vessel-based treatment
5	Port of Long Beach/Cruise Terminal, Los Angeles/SA Recycling	Bulk Carriers & Passenger Cruise Ships	Offload to mobile marine vessel	New offsite tank	New offsite WWTP

Definitions

ABS	American Bureau of Shipping
ANSI	American National Standards Institute
ASTM	An international standards organization.
ATB	Articulated Tug Barge
AWL	Height Above Waterline
AWWA	American Water Works Association
Ballast Water	Water taken on by a ship to maintain stability in transit.
Ballast Water Exchange	The process of exchanging a vessel's coastal ballast water with mid-ocean water to reduce concentration of non-native species in accordance with regulatory guidelines.
Ballast Water Management	The entire process of treatment and handling of a ship's ballast water to meet regulatory requirements and prevent spread of non-native species.
BMPF	Ballast Manifold Presentation Flange
Booster Pump	Pump, typically centrifugal, that adds additional pumping force to a line that is already being pumped.
BWDS	Ballast Water Discharge Standards
BWE	Ballast Water Exchange
BWM	Ballast Water Management
BWMS	Ballast Water Management System
BWTP	Ballast Water Treatment Plant
BWTB, BWT Barge	Ballast Water Treatment Barge
BWTS	Ballast Water Treatment System
Capture	Capture is the method by which ballast water is transferred onto or off a marine vessel.
CD	Chart Datum
CFU	Colony Forming Units
CMSA	California Marine Sanitation Agency
DAF	Dissolved Air Floatation
DIN	Deutches Institut für Normung (German Institute for Standardization)
Discharge	Discharge of ballast water is the method by which post-treatment ballast water is disposed of in compliance with applicable standards and regulations.
DOC	Dissolved Organic Carbon
DWT	Deadweight Tonnage
EPA	Environmental Protection Agency (US, unless otherwise noted)
Filtrate	Water that has been separated from any particulate matter (used to clean ballast water treatment filters).

GA	General Arrangement
GM	Metacentric height (a measure of a ship's stability).
gpm	Gallons per minute. Any measurements quoted in gallons of ballast water per minute will also be shown in MT of ballast water per hour, or MT/h.
HDPE	High-density Polyethylene
IMO	International Maritime Organization
ISO	International Organization for Standardization
JIS	Japanese Industrial Standards (organization)
L	Liter
Lift Station	Means of receiving a liquid, typically from a drain or low-pressure piping, and 'lifting' it with pump(s) to a different location such as a remote tank.
Lightering	Cargo transfer between vessels, commonly practiced to reduce a vessel's draft before entering port.
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MARPOL	International Convention for the Prevention of Pollution from Ships
MF	Microfiltration
mg	Milligram
MG	Millions of gallons. Any measurements quoted in MG of ballast water will also be shown in MT of ballast water.
MGD	Millions of Gallons/Day
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MPA	Megapascal (unit of pressure)
MSL	Mean Sea Level
MT	Metric tons. One cubic meter of seawater is roughly equivalent to 1.025 MT, but this value varies depending on temperature and salinity of the water. In this report, conversions between volume and weight of seawater are merely approximate and assume 1 m3 of seawater has a mass of roughly 1 MT, for convenience.
Navy Mole	A man-made peninsula in the Port of Long Beach that flanks entrance to the middle and inner harbor
NBIC	National Ballast Information Clearinghouse
NOM	Natural Organic Matter
Non-native Species	Species that are not indigenous to a particular region. Non-native species can be introduced to marine ecosystems through a ship's ballast water. "Invasive" species are non-native species with the potential to cause harm to the environment or human health.
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometric Turbidity Unit
NYSERDA	New York State Energy Research and Development Authority

O&M	Operations and Maintenance (cost)
OCIMF	Oil Companies International Marine Forum
POTW	Publicly Owned [Wastewater] Treatment Works
PSU	Practical salinity units.
Residuals	Particulate matter collected from cleaning ballast water treatment filters.
ROM	Rough Order of Magnitude (cost)
Ro-ro	Roll-on/roll-off (vessels designed to carry wheeled cargo such as car, trucks, trailers, and equipment)
RWCF	Regional Wastewater Control Facility (e.g. City of Stockton, CA)
Shipboard Ballast Water Treatment	Ballast water management approaches that do not require support from shore-based infrastructure and are conducted entirely by a vessel's crew.
Shore-Based Ballast Water Management	Ballast water management approaches that require support from shore-based infrastructure in order to meet ballast water management requirements. Such infrastructure may include: means of transferring ballast water to a land-based or another marine vessel facility for storage and/or processing, deployment of shore-based equipment and personnel for onboard treatment approaches, etc.
Slurry	Mixture of filtrate and filter residuals resulting from cleaning ballast water treatment filters.
Slurry Handling	Slurry handling includes activities related to the storage, treatment, and discharge of filtrate and residuals collected from cleaning ballast water treatment filters.
SOLAS	International Convention for Safety of Life at Sea
Storage	Storage of ballast water includes provision of space and containment for ballast water, either pre-or post-treatment.
STS	Ship-to-Ship. Transfer from one marine vessel to another.
TDS	Total Dissolved Solids
TEU	Twenty-foot Equivalent Unit
TOC	Total Organic Carbon
Transfer	Ballast water transfer considers the logistics and equipment required to capture the ballast water from the marine vessel and transport to a reception and treatment facility.
Transport	Transport is the method by which ballast water is moved post-capture from marine vessels to remote, non-mobile reception and treatment facilities – either land-based or otherwise.
Treatment	Treatment includes the various methods to process ballast water such that it is suitable for discharge in compliance with applicable standards and regulations.
Treatment Approach	A general method for implementing ballast water treatment. Treatment approaches may include mobile systems, land-based facilities, shipboard systems, etc.

Treatment Technology	Specific techniques for removal or inactivation of organisms in ballast water (e.g., UV disinfection, filtration, ozonation, etc.)
TRO	Total Residual Oxidant
TSS	Total Suspended Solids
UF	Ultrafiltration
UKC	Underkeel Clearance
UL	A global independent safety consulting and certification company (formerly Underwriters Laboratories).
USCG	United States Coast Guard
UV	Ultraviolet Light
UVT	UV Transmittance
VLCC	Very Large Crude Carrier
WWTF	Waste Water Treatment Facility
WWTP	Waste Water Treatment Plant

Appendix B Cost Estimates

ENGINEERS ESTIMATES - SUMMARY	FILE NO. 15086.01
	DSC Shore-based BWT in CA

Work Item	Description	Total
5	ATB Modifications	$ 152,360
1	Containership Modifications	$ 147,341
7	Bulker Modifications	$ 334,738
3	Tanker Modifications	$ 423,754
8	RoRo Modifications	in development
9	Cruise Ship Modifications	in development

ENGINEER'S ESTIMATE - DETAILS

PROJECT: 15086.01 DSC Shore-based BW Treatment in California

CALC: ____RHR_____ CHECKED: ___XXX___

Payment Item Number	Spec Sec ID		Description	Material				Labor			Total Cost (Mat'l & Labor)
				Units	Quantity	Unit Cost	Extended Material Cost	Unit Hours	Extended Hours	Labor Cost	
###			**ATB Modifications**								**$152,360**
	100		**STRUCTURAL**								
	200		**PROPULSION**								
	300		**ELECTRICAL**								
	400		**COMMUNICATIONS, NAVIGATION, AND SHIP CONTROL**								
	500		**AUXILIARY MACHINERY**								
			Piping								
			DN250 (10") STD Pipe (horizontal/long. runs)	meters	40	$275.00	$11,000	5	200	$7,000	$18,000
			90 deg elbows	each	6	$800.00	$4,800	7	42	$1,470	$6,270
			Tees	each	3	$1,400.00	$4,200	10	30	$1,050	$5,250
			Flanges, slip-on	each	4	$800.00	$3,200	7	28	$980	$4,180
			Butterfly valves, manual	each	3	$2,500.00	$7,500	10	30	$1,050	$8,550
			Relocations								
			Piping	meters	20	$800.00	$16,000	10	200	$7,000	$23,000
			Vents	meters	12	$0.00	$0	7	84	$2,940	$2,940
	600		**OUTFIT AND FURNISHINGS**								
			Deck Tackle (x2 P&S) (OCIMF Class B)								
			Cruciform bollard (rated 25 t)	each	2	$4,000.00	$8,000	32	64	$2,240	$10,240
			Deck rings (rated 15 t)	each	8	$500.00	$4,000	12	96	$3,360	$7,360
			Fairleads (rated 25 t)	each	4	$1,800.00	$7,200	24	96	$3,360	$10,560
			300mm bollards	each	4	$2,500.00	$10,000	24	96	$3,360	$13,360
			Hose rest (DN300 pipe)	meters	10	$330.00	$3,300	24	240	$8,400	$11,700
			Lighting								
			Lights at manifold (includes cable)	each	2	$500.00	$1,000	40	80	$2,800	$3,800
			Relocations								
			Lights	each	4	$0.00	$0	8	32	$1,120	$1,120
	800		**INTEGRATION AND ENGINEERING**								
			Engineering						80	$8,000.00	$8,000
			Class Review						20	$2,000.00	$2,000
			Documentation (update dwgs, not controls)						40	$4,000.00	$4,000
	900		**TESTING**								
			Material Mark-Up and Shipping								
			Markup (15%)	lump sum	1	$12,030.00	$12,030	0	0		$12,030

ENGINEER'S ESTIMATE - DETAILS

PROJECT: 15086.01 DSC Shore-based BW Treatment in California

CALC: ____RHR_____ CHECKED: ___XXX___

Payment Item Number	Spec Sec ID		Description	Material				Labor			Total Cost (Mat'l & Labor)
				Units	Quantity	Unit Cost	Extended Material Cost	Unit Hours	Extended Hours	Labor Cost	
###			**Containership Modifications**								**$147,341**
	100		**STRUCTURAL**								
	200		**PROPULSION**								
	300		**ELECTRICAL**								
	400		**COMMUNICATIONS, NAVIGATION, AND SHIP CONTROL**								
	500		**AUXILIARY MACHINERY**								
			Piping								
			DN300 (12") STD Pipe (horizontal runs)	meters	65	$330.00	$21,450	6	390	$13,650	$35,100
			DN300 (12") STD Pipe (vertical runs)	meters	20	$330.00	$6,600	8	160	$5,600	$12,200
			90 deg elbows	each	4	$990.00	$3,960	8	32	$1,120	$5,080
			Tees	each	2	$1,200.00	$2,400	12	24	$840	$3,240
			Flanges, slip-on	each	4	$990.00	$3,960	8	32	$1,120	$5,080
			Butterfly valves, manual	each	3	$4,000.00	$12,000	12	36	$1,260	$13,260
			Relocations								
			Ducting	meters	40	$0.00	$0	12	480	$16,800	$16,800
			Vents	meters	20	$0.00	$0	8	160	$5,600	$5,600
			Removals								
			Penetrations (2nd Deck, Main Deck)	each	2	$0.00	$0	40	80	$2,800	$2,800
			Penetration through bulkhead on 2nd deck	each	1	$0.00	$0	40	40	$1,400	$1,400
	600		**OUTFIT AND FURNISHINGS**								
			Deck Tackle (x2 P&S) ("Light" Ballast Station) (OCIMF Cat. C)								
			Deck rings (rated 15 t)	each	8	$500.00	$4,000	12	96	$3,360	$7,360
			Hose rest (DN300 pipe)	meters	10	$330.00	$3,300	24	240	$8,400	$11,700
			Lighting								
			Lights at manifold (includes cable)	each	2	$500.00	$1,000	40	80	$2,800	$3,800
			Relocations								
			Lights	each	4	$0.00	$0	8	32	$1,120	$1,120
	800		**INTEGRATION AND ENGINEERING**								
			Engineering						80	$8,000.00	$8,000
			Class Review						20	$2,000.00	$2,000
			Documentation (update dwgs, not controls)						40	$4,000.00	$4,000
	900		**TESTING**								
			Material Mark-Up and Shipping								
			Markup (15%)	lump sum	1	$8,800.50	$8,801	0	0		$8,801

ENGINEER'S ESTIMATE - DETAILS

PROJECT: 15086.01 DSC Shore-based BW Treatment in California

CALC: ____RHR_____ CHECKED: ___XXX___

Payment Item Number	Spec Sec ID		Description	Material				Labor			Total Cost (Mat'l & Labor)
				Units	Quantity	Unit Cost	Extended Material Cost	Unit Hours	Extended Hours	Labor Cost	
###			**Bulker Modifications**								**$334,738**
	100		**STRUCTURAL**								
	200		**PROPULSION**								
	300		**ELECTRICAL**								
	400		**COMMUNICATIONS, NAVIGATION, AND SHIP CONTROL**								
	500		**AUXILIARY MACHINERY**								
			Piping								
			DN500 STD Pipe (horizontal runs)	meters	60	$925.00	$55,500	11	660	$23,100	$78,600
			DN500 STD Pipe (vertical runs)	meters	30	$925.00	$27,750	15	450	$15,750	$43,500
			90 deg elbows	each	8	$1,800.00	$14,400	15	120	$4,200	$18,600
			Tees	each	2	$2,400.00	$4,800	22	44	$1,540	$6,340
			Flanges, slip-on	each	4	$1,800.00	$7,200	15	60	$2,100	$9,300
			Butterfly valves, manual	each	3	$3,500.00	$10,500	22	66	$2,310	$12,810
			Relocations								
			Piping	meters	40	$800.00	$32,000	22	880	$30,800	$62,800
			Removals								
			Penetrations (Main Deck)	each	2	$0.00	$0	40	80	$2,800	$2,800
	600		**OUTFIT AND FURNISHINGS**								
			Deck Tackle (x2 P&S) (OCIMF Class C)								
			Cruciform bollard (rated 25 t)	each	2	$4,000.00	$8,000	32	64	$2,240	$10,240
			Deck rings (rated 15 t)	each	8	$500.00	$4,000	12	96	$3,360	$7,360
			Fairleads (rated 40 t)	each	4	$1,800.00	$7,200	24	96	$3,360	$10,560
			300mm bollards	each	4	$2,500.00	$10,000	24	96	$3,360	$13,360
			Hose rest (DN300 pipe)	meters	10	$330.00	$3,300	24	240	$8,400	$11,700
			Lighting								
			Lights at manifold (includes cable)	each	2	$500.00	$1,000	40	80	$2,800	$3,800
			Relocations								
			Lights	each	4	$0.00	$0	8	32	$1,120	$1,120
	800		**INTEGRATION AND ENGINEERING**								
			Engineering						80	$8,000.00	$8,000
			Class Review						20	$2,000.00	$2,000
			Documentation (update dwgs, not controls)						40	$4,000.00	$4,000
	900		**TESTING**								
			Material Mark-Up and Shipping								
			Markup (15%)	lump sum	1	$27,847.50	$27,848	0	0		$27,848

ENGINEER'S ESTIMATE - DETAILS				PROJECT: 15086.01 DSC Shore-based BW Treatment in California CALC: ____RHR_____ CHECKED: ___XXX___							
				Material				Labor			
Payment Item Number	Spec Sec ID		Description	Units	Quantity	Unit Cost	Extended Material Cost	Unit Hours	Extended Hours	Labor Cost	Total Cost (Mat'l & Labor)
###			**Tanker Modifications**								**$423,754**
	100		**STRUCTURAL**								
	200		**PROPULSION**								
	300		**ELECTRICAL**								
	400		**COMMUNICATIONS, NAVIGATION, AND SHIP CONTROL**								
	500		**AUXILIARY MACHINERY**								
			Piping								
			DN600 STD Pipe (horizontal runs)	meters	62	$925.00	$57,350	11	682	$23,870	$81,220
			DN600 STD Pipe (vertical runs)	meters	23	$925.00	$21,275	15	345	$12,075	$33,350
			90 deg elbows	each	6	$1,800.00	$10,800	15	90	$3,150	$13,950
			Tees	each	2	$2,400.00	$4,800	22	44	$1,540	$6,340
			Flanges, slip-on	each	4	$1,800.00	$7,200	15	60	$2,100	$9,300
			Butterfly valves, manual	each	3	$5,500.00	$16,500	22	66	$2,310	$18,810
			DN150 STD Pipe (horizontal/long. runs)	meters	140	$200.00	$28,000	5	700	$24,500	$52,500
			DN150 STD Pipe (vertical runs)	meters	20	$200.00	$4,000	7	140	$4,900	$8,900
			90 deg elbows	each	8	$400.00	$3,200	7	56	$1,960	$5,160
			Tees	each	2	$400.00	$800	10	20	$700	$1,500
			Flanges, slip-on	each	4	$800.00	$3,200	7	28	$980	$4,180
			Butterfly valves, manual	each	3	$1,800.00	$5,400	10	30	$1,050	$6,450
			Relocations								
			Piping	meters	40	$800.00	$32,000	22	880	$30,800	$62,800
			Vents	meters	22	$0.00	$0	15	330	$11,550	$11,550
			Removals								
			Penetrations (Main Deck)	each	1	$0.00	$0	40	40	$1,400	$1,400
	600		**OUTFIT AND FURNISHINGS**								
			Deck Tackle (x2 P&S) (OCIMF Class C)								
			Cruciform bollard (rated 25 t)	each	2	$4,000.00	$8,000	32	64	$2,240	$10,240
			Deck rings (rated 15 t)	each	8	$500.00	$4,000	12	96	$3,360	$7,360
			Fairleads (rated 40 t)	each	4	$1,800.00	$7,200	24	96	$3,360	$10,560
			300mm bollards	each	4	$2,500.00	$10,000	24	96	$3,360	$13,360
			Hose rest (DN300 pipe)	meters	10	$330.00	$3,300	24	240	$8,400	$11,700
			Lighting								
			Lights at manifold (includes cable)	each	2	$500.00	$1,000	40	80	$2,800	$3,800
			Relocations								
			Lights	each	4	$0.00	$0	8	32	$1,120	$1,120
	800		**INTEGRATION AND ENGINEERING**								
			Engineering						80	$8,000.00	$8,000
			Class Review						20	$2,000.00	$2,000
			Documentation (update dwgs, not controls)						40	$4,000.00	$4,000
	900		**TESTING**								
			Material Mark-Up and Shipping								
			Markup (15%)	lump sum	1	$34,203.75	$34,204	0	0		$34,204