Glosten

kpff

DELTA STEWARDSHIP COUNCIL

Kennedy/Jenks Consultants

SHORE-BASED BALLAST WATER TREATMENT IN CALIFORNIA

TASK 3: RETROFITTING OF PORTS AND WHARVES

PREPARED FOR

DELTA STEWARDSHIP COUNCIL
SACRAMENTO, CALIFORNIA

11 AUGUST 2016
FILE NO. 15086.01
REV. P2

THIS IS A PRELIMINARY REPORT. FINAL VERSION TO BE SIGNED AFTER INCORPORATED REVIEWER COMMENTS.

PREPARED	CHECKED	APPROVED
TODD GRAHAM, P.E.	**ROSS DUNNING, P.E.**	**KEVIN J. REYNOLDS, PE**
KPFF CONSULTING ENGINEERS	KENNEDY/JENKS CONSULTANTS	GLOSTEN

Table of Contents

Revision History

Section	Rev	Description	Date	Approved
All	P2	Draft release for external review.	8/11/16	N/A

References

1. *Summary of Select Ballast Discharging Facilities,* Kennedy/Jenks Consultants, March 2016.
2. *Shore-Based Ballast Water Treatment in California, Task 2: Assessment of Retrofitting and Outfitting of Vessels,* Glosten, Rev. P0, 4 August 2016.
3. *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.
4. *Shore-Based Ballast Water Treatment in California, Task 5:Assessment of Treatment Technologies*, Kennedy/Jenks Consultants, Rev. P0, 4 August 2016.
5. *Port of Long Beach Wharf Manual 5th Edition.*
6. *2014 Annual Report, Port of Stockton,* Port of Stockton, http://www.portofstockton.com/wp-content/uploads/annual-reports/annual-report-2014/, accessed 13 May 2016.
7. National Ballast Information Clearinghouse 2016. *NBIC Online Database*. Electronic publication, Smithsonian Environmental Research Center & United States Coast Guard. Available from http://invasions.si.edu/nbic/search.html; searched May 2016.
8. Porte, M. (email) [TraPac, Inc.], “FW: Feasibility Study on Shore-Based Ballast Water Reception and Treatment in California,” 20 April 2016.
9. *Port Facts,* Port of Hueneme, http://www.portofhueneme.org/about/port-facts/, accessed 2 August 2016.

Section 1 Introduction

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 Treatment Performance Standard.

1.1 Study Overview

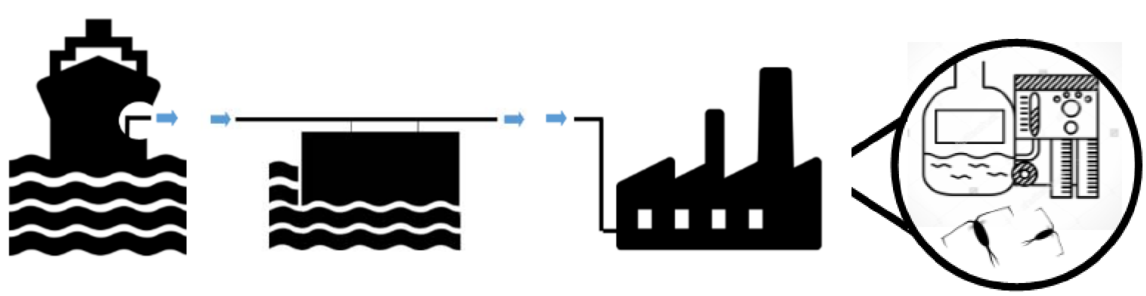
Marine vessels routinely uptake ambient sea or harbor water as ballast, transit to another port, and then discharge that ballast water. Unfortunately, the resulting ballast water discharges have been linked to the introduction of aquatic invasive species and harmful pathogens. In an effort to reduce 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 U.S. 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 California's interim standard. Shore-based ballast water reception and treatment is under consideration as an approach to meet the California interim standard.

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.

1.2 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 1).



Task 2 Vessel Outfitting — Task 3 Port Retrofitting — Task 4 Shore Facilities — Task 5 Treatment Technologies

Figure 1 Scope of Tasks 2 through 5

Task 2 of the larger study assesses the retrofitting and outfitting of marine vessels calling California ports. 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.

This Task 3 report 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 California's interim performance standards and how the efficacy of such systems can be measured.

1.3 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 1 summarizes the case studies and assigned approaches.

Table 1 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

[1] City of Stockton Sewage Treatment Plant (POTW) located at 2500 Navy Drive, Stockton, CA

1.4 Definitions

ABS	American Bureau of Shipping
ANSI	American National Standards Institute
ASTM	ASTM International - 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
BWTP	Ballast Water Treatment Plant
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	Backwash water used to clean ballast water treatment filters that has been separated from any particulate matter.
GA	General Arrangement
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
Head	
IMO	International Maritime Organization
ISO	International Organization for Standardization
JIS	Japanese Industrial Standards (organization)

L	Liter
Lift Station	
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 (City of Stockton, CA)

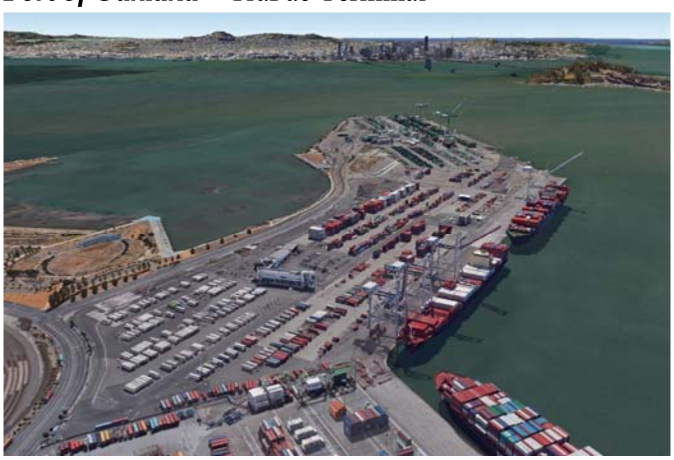
Shipboard Ballast Water Treatment	Ballast water management approaches that do not require support from shore-based infrastructure and are conducted entirely by a vessel's crew.
Shore-Based Ballast Water Treatment	Ballast water management approaches that require support from shore-based infrastructure in order to meet ballast water treatment requirements. Such infrastructure includes: means of transferring ballast water to a land-based or another marine vessel facility for storage and/or processing. This also includes deployment of shore-based equipment and personnel for onboard treatment approaches.
Slurry	Mixture of filtrate and filter residuals resulting from cleaning ballast water treatment filters.
Slurry Handling	Slurry handling includes all 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 it 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 any of 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 management, irrespective of the treatment technology utilized. Treatment approaches include mobile systems, land-based facilities, shipboard systems, etc.
Treatment Technology	Specific technique for removal or inactivation organisms in ballast water (e.g., UV disinfection, filtration, ozonation, etc.)
TRO	Total Residual Oxidant
TSS	Total Suspended Solids
UF	Ultrafiltration
UL	A global independent safety consulting and certification company (formerly Underwriters Laboratories).
USCG	United States Coast Guard
UV	Ultraviolet light
UVT	UV Transmittance

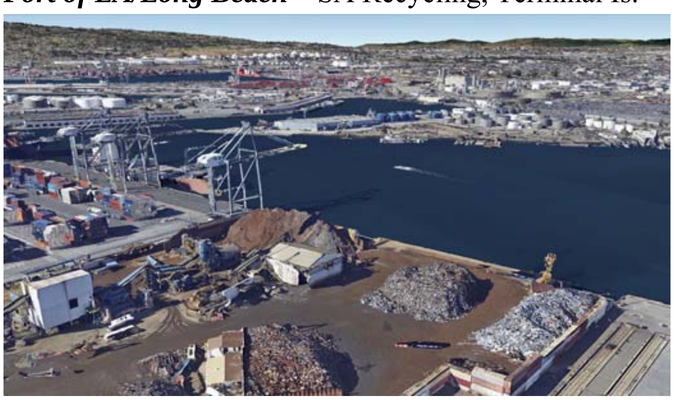
VLCC	Very Large Crude Carrier
WWTF	Waste Water Treatment Facility
WWTP	Waste Water Treatment Plant

Section 2 Task 3 Summary

This Task 3 report considers the modifications to ports and wharves that are required to receive ballast water from the vessels that call on each case study terminal.

Table 2 Case study ports/terminals

Port/Terminal Name	Details
Port of Stockton – East Complex 	**Port/Terminal Description:** bulk import/export **Primary Vessel Type(s):** bulk carriers, tank vessels **Primary Cargo Type(s):** bulk cement, sand, tire chips, liquid fertilizer, anhydrous ammonia, food grade oil, molasses, bagged magnesium, project cargo. Annual Discharge Volume (m^3) (2015 data): 1,194,000 Number of Discharge Events (2015): 59 90^{th} Percentile Discharge Volume (m^3) (2015): 29,500 Approx. Period per Discharge (days): 1 Approx. Discharge Rate (m^3/hr): 2,800
Port of Oakland – TraPac Terminal 	**Port/Terminal Description:** container import/export **Primary Vessel Type(s):** containerships only **Primary Cargo Type(s):** containers only Annual Discharge Volume (m^3) (2015 data): 7,200 Number of Discharge Events (2015): 2 90^{th} Percentile Discharge Volume (m^3) (2015): 7,500 Approx. Period per Discharge (days): 1 Approx. Discharge Rate (m^3/hr): 750
Port of Hueneme – North, South & Joint-use Terminals 	**Port/Terminal Description:** auto import and bulk import/export **Primary Vessel Type(s):** reefer ships, general cargo, ro-ro **Primary Cargo Type(s):** autos, break-bulk agricultural products (e.g. bananas and other fresh fruit), liquid fertilizer, oil, containers, fish, project cargo) Annual Discharge Volume (m^3) (2015 data): 4,800 Number of Discharge Events (2015): 4 90^{th} Percentile Discharge Volume (m^3) (2015): 4,000 Approx. Period per Discharge (days): 1 Approx. Discharge Rate (m^3/hr): 350

Port/Terminal Name	Details
El Segundo – Chevron Offshore Marine Terminal 	**Port/Terminal Description:** offshore mooring for load and discharge of liquid bulk (petroleum) products **Primary Vessel Type(s):** tankers and ATBs **Primary Cargo Type(s):** crude oil and refined fuels Annual Discharge Volume (m^3) (2015 data): 203,900 Number of Discharge Events (2015): 49 90^{th} Percentile Discharge Volume (m^3) (2015): 32,000 Approx. Period per Discharge (days): 1 Approx. Discharge Rate (m^3/hr): 3,400
Port of LA/Long Beach – Long Beach Cruise Terminal 	**Port/Terminal Description:** dedicated cruise ship terminal **Primary Vessel Type(s):** passenger cruise ships **Primary Cargo Type(s):** passengers and stores Annual Discharge Volume (m^3) (2015 data): 165,900 Number of Discharge Events (2015): 256 90^{th} Percentile Discharge Volume (m^3) (2015): 1,500 Approx. Period per Discharge (days): 1 Approx. Discharge Rate (m^3/hr): 400
Port of LA/Long Beach – SA Recycling, Terminal Is. 	**Port/Terminal Description:** bulk export **Primary Vessel Type(s):** bulk carriers **Primary Cargo Type(s):** scrap steel Annual Discharge Volume (m^3) (2015 data): 257,300 Number of Discharge Events (2015): 17 90^{th} Percentile Discharge Volume (m^3) (2015): 18,000 Approx. Period per Discharge (days): 5 Approx. Discharge Rate (m^3/hr): 1,400

2.1 Methods

Each of the subject terminals and ports were researched for available vacant space and location for ballast water storage and/or treatment facilities selected to match the vessels that frequently discharge ballast water and the frequency of their discharges in case study ports. Potential locations for the storage and treatment of ballast water were communicated to the team preparing the Task 4 and 5 reports. Reported vessel discharge data was then examined to estimate the practicality and cost of any new infrastructure required on-shore. In general, this included:

- Assessment of vessel hydraulics, including pumps, pipes, ballast water flow rates, volumes and pressures delivered to shore facilities.
- Assessment of vessel berthing arrangements at the terminal, both number of ships and locations.
- Assessment of piping size, backlands location, and routing to the first lift station.
- Scope and cost of piping modifications, including controls.
- Scope and cost of structure, outfitting, and electrical modifications required at shore-based connection locations.
- Assessment of terminal/yard geometry and the equipment required to establish ship to shore connections.

After assessing each terminal, notional ship-to-shore piping diagrams and cost estimates were developed to illustrate the scope of the modifications. Cost estimates are summarized in Table 4 and provided in full in Appendix A.

Table 3, Vessel Interface Particulars for each Case Study

Port/Terminal	Disch. Rate	Connection		Volume		Vessel Types
		Flange	Hose	Period	Total	
	(m3/hr)	*(mm)*	*(mm)*	*(days)*	*(m3)*	
Port of Stockton	2,800	600	300	1	34,000	*Bulk carriers.*
Port of Oakland/Trapac	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	350	200	150	20	4,000	*Various. Base ship connection on car carriers.*
El Segundo Marine Terminal	3,400	600	300	1	32,000	*Tankers.*
PoLA/SA Recycling	1,400	400	200	5	24,000	*Bulk carriers.*
PoLB/Cruise Terminal	400	200	150	1	2,400	*Cruise ships.*

Description of particulars basis is provided in Task 2 report.

2.2 Summary of Findings

<Preliminary report. Summary of findings will be developed following completion of peer review, panel review, and public comment process. Preliminary cost estimates are provided to inform the review process, but are subject to update.>

Cost estimates are summarized below to inform the economic feasibility of modifying wharves and piping routing to shore-based conveyance, storage, and treatment facilities considered under Tasks 4 and 5.

Table 4 Modification costs by terminal

Case Study	Terminal/Berths	Vessel Type	Modification Cost
Port of Stockton	Berths 5 & 6	Bulk Carriers	$1,650,000
Port of Oakland	Tra Pac Terminal	Containerships	$2,130,000
Port of Hueneme	South Terminal	Car Carriers	$1,970,000
El Segundo	Terminal One	Tankers and ATBs	N/A
Port of Long Beach	Cruise Ship Terminal	Cruise Ships	$25,050,000
Port of Los Angeles	SA Recycling	Bulk Carriers	(combined with POLA)

Section 3 Description of Port/Wharf Modification

3.1 Port of Stockton – Berth 5 & 6 of the East Complex

3.1.1 Summary of Port

Located along the San Joaquin Delta, approximately 75 miles from San Francisco Bay, the Port of Stockton is an important California port for the import and export of bulk products by sea. In 2014, the Port handled nearly 4.1 million metric tons in waterborne tonnage, setting it apart as the leading bulk/break-bulk port in the State. It now exports more than 2.3 million tons of American products annually, and imports more than 1.8 million tons of products with an estimated cargo value of $1.5 billion.

Figure 2 Location of the Port of Stockton, East and West Complexes

Encompassing an area of nearly 4,000 acres, and with over seven million square feet of covered storage, the Port of Stockton is the second largest inland freshwater port in the western United States. The Port possesses more than 60 miles of railroad track and 12,000 linear feet of dock space. It has multiple storage and handling facilities for dry and liquid bulk materials, as well as facilities and equipment to handle a wide variety of break-bulk, project, and containerized cargoes.

The Port's marine terminals are divided into two primary berthing "complexes" –the East Complex and West Complex– offering 15 deepwater ship berths, collectively, many of which are equipped with on-dock rail for cargo load and discharge operations (Reference 6). Also located within the broader port district are a numbr of independently-owned and operated terminals, including as the Penny-Newman bulk cargo terminal which handles liquid and dry feed (grain) products.

The Port of Stockton is called primarily by Panamax-size bulkers and tankers. In 2014, port-wide discharge volumes at the Port of Stockton totaled 1.7 million metric tons. Figure 3 indicates ballast water discharges at the Port of Stockton.

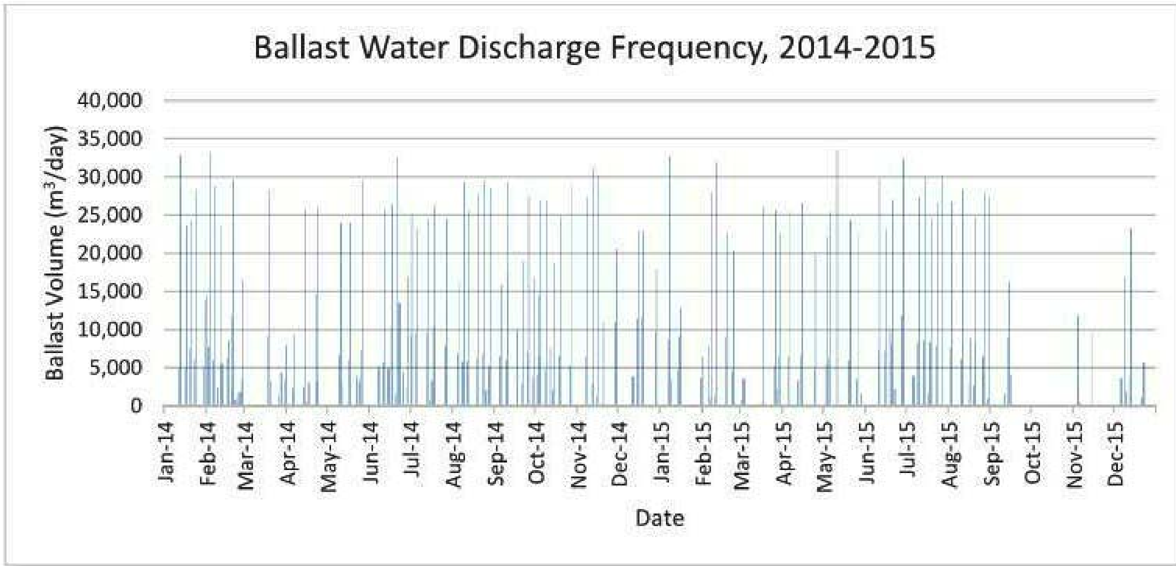


Figure 3 Ballast water discharges, 2014-2015 at Port of Stockton

The Port of Stockton was selected as a case study for this project because it represents a California bulk cargo port with a diverse suite of terminals and cargo operations. The bulk carrier vessel type, which the study was required to evaluate, calls the Port of Stockton most frequently, though it many other vessel types call as well. They are one of few facilities located relatively near to a POTW (existing WWTP), which satisfied a project goal to evaluate the potential for discharge of ballast water to local POTWs for potential treatment. The Port of Stockton is also located in a unique estuarine environment with a fresh/brackish water mix, and receives significant annual discharge volumes of both fresh and marine (salt) ballast water. It sees some of the largest ballast water discharge flowrates of any facility in the State of California. Table 5 provides the case study characteristics and approach.

Table 5 Port of Stockton case study summary

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

The design basis assumed for the Port of Stockton is provided in

Table 6. Port of Stockton ballast water discharges are tightly linked to cargo load rates, which occur daily and in high volumes. Due to this tight pattern of frequent and consistantly high volumes, the design basis is set at the maximum rates with a small margin. Often, there are multiple consequtive days with high volume discharges, resulting in as much as 98,000 tons in a single seven-day period.

Table 6 Port of Stockton design basis

Discharge Rate	Max. (m3/hr)	90% (m3/hr)	Design (m3/hr)	Flange (mm)	Hose (mm)
	2,819	2,600	2,800	600	300
Discharge Volume	**Period** (days)	**Max.** (m3)	**90%** (m3)	**Design** (m3)	**Vessel Types**
	1	33,570	29,500	34,000	Bulk carriers

3.1.2 Marine Vessel Support Requirements

The above design basis identifies the support requirements for marine vessels calling at this terminal.

The ship geometry inputs uses a combination of Panamax and Handy sized bulk carriers to capture the typical range of vertical distances from dock apron to the main deck where the ballast water shore presentation flange would be located. Containerships were also considered for the inputs. Panamax vessels are large, though not uncommon, in terms of likely ship calls at this terminal, and as such are representative, with some conservatism. The assumed point of discharge for the ballast water from the ship will be located on the main deck of the ship and located between 5.40m and 14.80m above the waterline.

The design assumed a 95th percentile discharge rate from the ship is 2800m^3/hr with a resulting pressure at the flange ranging from 100kPa to 340kPa. This pressure from the ship's presentation flange is adequate to prime the ship to shore connection, but not adequate to lift the received ballast water to the storage and treatment plant. As such, intermediate dockside lift stations are required to complete the transfer. The details of those lift stations are provided in the Task 4 report (Reference 3).

Figure 4, Cargo Operations (Image, Port of Stockton)

3.1.3 Terminal Operations

3.1.3.1 General Arrangement Plan

The general arrangement plan for the Port of Stockton terminals (Figure 5) identifies the overall geometry of the Port according to berth numbers. The Port of Stockton's East Complex Berths 5 & 6 were selected as the typical wharf construction for the study.

Figure 5 General arrangement plan

This Task 3 report identifies the available options and costs associated with the conveyance of ballast water from the ship's presentation flange to the first booster pump (at a lift station). Due to the size of the Port of Stockton, not every berth and condition will be addressed. This report will focus on Berth 5 and 6, with comments on the remaining berths.

3.1.3.2 Locations of Landside Water Connections

Based on the wharves geometry, the anticipated numerous variety of ships that call upon on the Port, and the variety of cargos at each respective terminal, it is anticipated that berthing of only one ship per berth at any given time can be expected. Therefore, to locate the landside ballast water connection on the edge of the wharves, the location of the ballast water point of connection on the ship needs to be identified. Any potential for the ship to be moved along the wharf to facilitate loading of the product must also be known. If the ship is moved along the berth to facilitate loading or unloading, then the location of the landside ballast water connection will change based on the ship's location. In the case of Berths 5 & 6, the ship will remain stationary at berth and the product loading system will move along the length of the wharf to facilitate loading of the ship. In the case of Berths 5 & 6, a fixed ballast water handling system would be appropriate. However, in the case of Berths 12 & 13, the ship is moved along the wharf at berth in order to facilitate loading. In the case of Berths 12 & 13, a flexible ballast water handling system is appropriate.

If a fixed ballast water handling system is used, then it can be assumed that a minimum length of hose would be needed to facilitate the connection between the ship and the landside ballast water connection. Based on limited berth length and the ship sizes that visit the port, the location of the landside ballast water connection would be loaded within a very narrow area along the wharf.

Therefore, a length of hose of not more than 38 m would be needed to provide a connection from the ship to the landside ballast water connection. Once the exact location of the ship's presentation flange connection is identified for most ships servicing the Port, the exact location of the landside ballast water connection can be located along the edge of the wharf.

3.1.3.3 Conveyance from Ship to Wharf

Conveyance of the ballast water from the ship to the landside ballast water connection will be though the use of two potential methods: a marine loading arm, or a flexible hose connecting the ship to the landside ballast water connection.

The use of a marine loading arm was researched as a viable method of unloading ballast water to the landside (see Figure 6). However, due to operational constraints at Berth 5-6, in which the wharf narrows at the transit shed to less than 10 m clear, and product conveyor systems transiting the length of the ship, there is physically not enough room in which to place the marine loading arms and still maintain operational capability of the wharf and terminal.

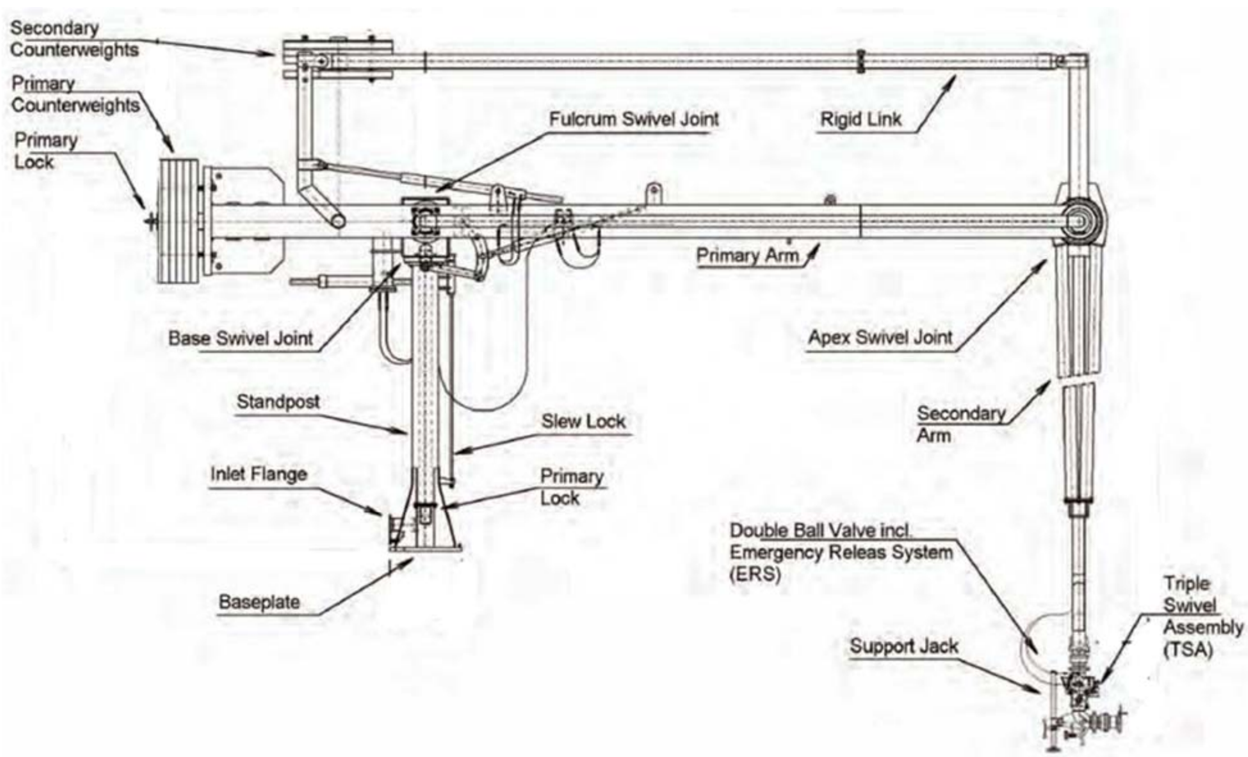


Figure 6 Marine loading arm

Therefore, the flexible hose connection between the ship and the wharf was considered the best method for conveying ballast water to the landside ballast water connection at Berths 5 & 6. Use of a flexible hose system appears to be the most applicable for Berths 2 through 8 and Berths 11 through 13. Berths 9 & 10 appear to be devoid of loading equipment and therefore a marine loading arm may be appropriate at these locations.

The Task 2 report specified the location of the ballast water connection on the ship to be located on the main deck level, approximately 14.8 m above the waterline and 10.0 m above the top of the wharf (Figure 7).

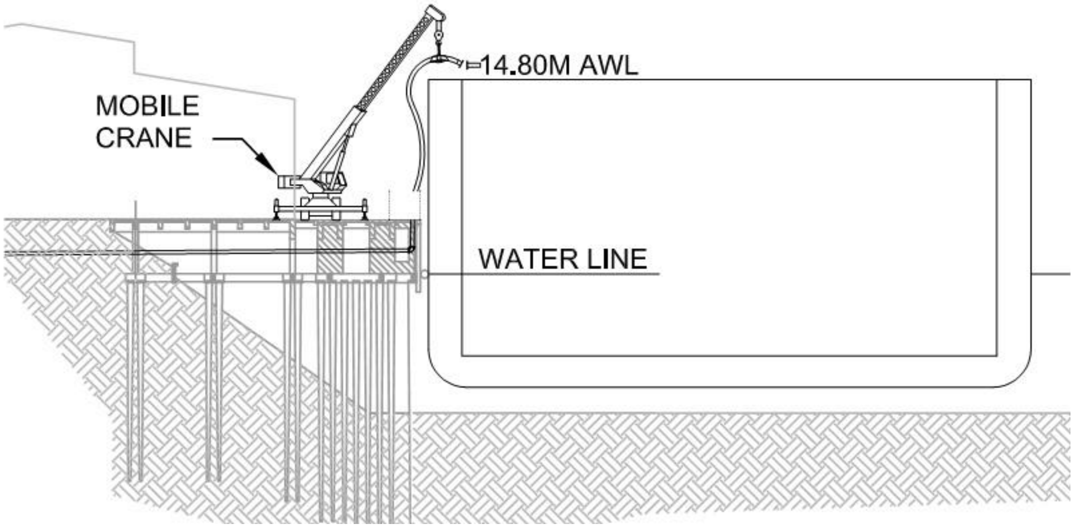


Figure 7 Wharf cross-section and bulk carrier

Based on the anticipated flow of 2,800 m^3/hr, a maximum flow velocity of 12 meters per second, and operational limitations of handling a flexible hose, the minimum calculated hose size of 300 mm in diameter was selected. The flexible hose assembly was identified as a DN300 (300 mm in diameter) smooth bore hose with flanged connection hardware. The hose must meet abrasion and UV resistance requirements. The weight of the hose per meter is estimated to be 32.6 kg/m. The estimated weight of the fittings is 54 kg/fitting. Including end fittings, lifting straps, and 20m of suspended hose, the boom weight is estimated at 1000 kg. The listing of the hose will require a lift of 20 meters vertically and a reach of 5 meters. There are several mobile crane solutions available that can offer such support, including hydraulic, knuckle boom cranes and alike. An example crane is shown in Figure 8.

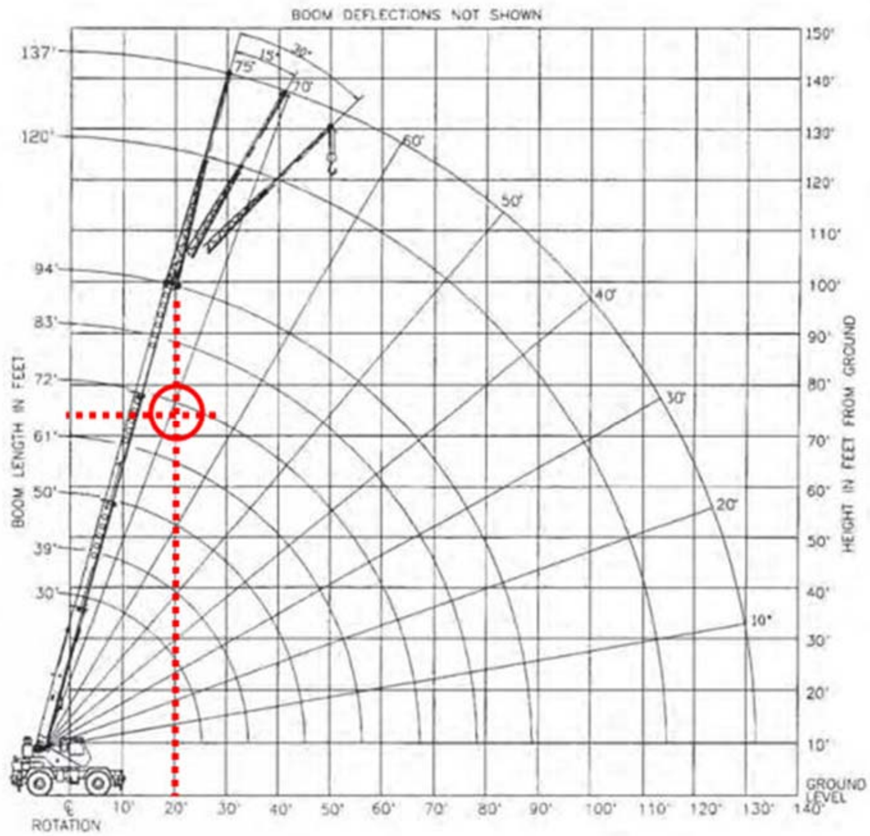


Figure 8 Example crane diagram

Note that the hose can be constructed of either a single length or multiple shorter lengths to equal an overall length of up to 38 m.

The crane used to lift the hose to the ship presentation flange connection will be required to lift the hose into place and to allow the connection of the hose to the ship's presentation flange. Once the hose is connected to the ship's presentation flange, and to the landside ballast water connection, the mobile crane will leave the area to allow ship loading/unloading operations to commence without interference from the mobile crane.

The location of the landside ballast water connection will be located as close to the edge of wharf as possible in order to avoid operational obstructions (see Figure 9 and Figure 10). Due to the geometry of the wharf as shown in Figure 9 and the operational constraints of the bulk loading crane need to transit past the landside ballast water connection on the wharf, the location of the landside ballast water connection will be located on the seaward side of the waterside crane rail. This location will present some challenges from an operational as well as a ship-mooring standpoint. The location of the landside ballast water connection will need to be clear of the passing bulk-loading crane. Therefore the location of the landside ballast water connection will be located on the waterside edge of the wharf. Fall protection or a platform will need to be constructed for the operators to safely make the connection of the ballast water hose to the landside ballast water connection (see Figure 10).

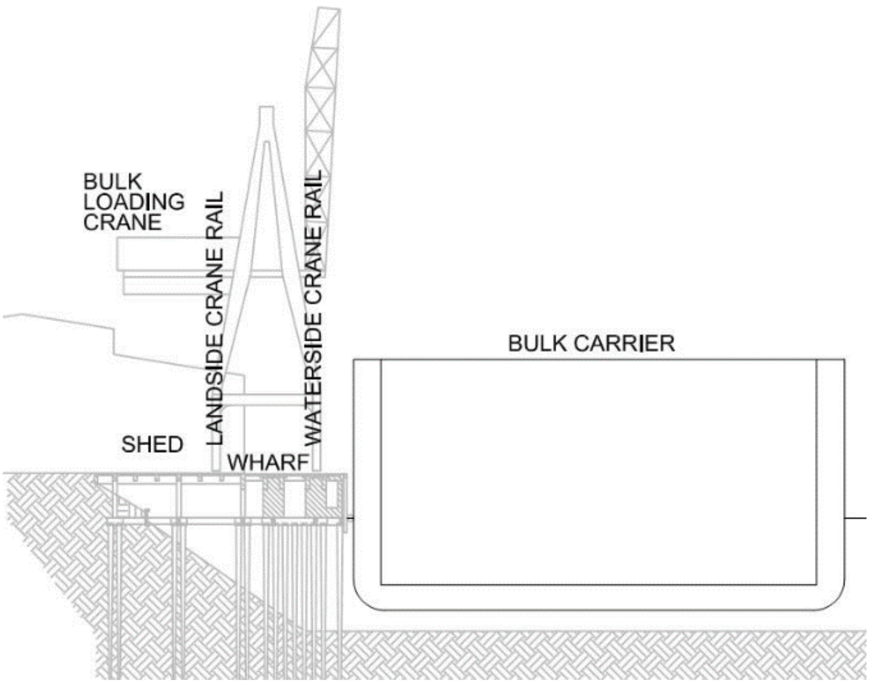


Figure 9 Wharf cross section

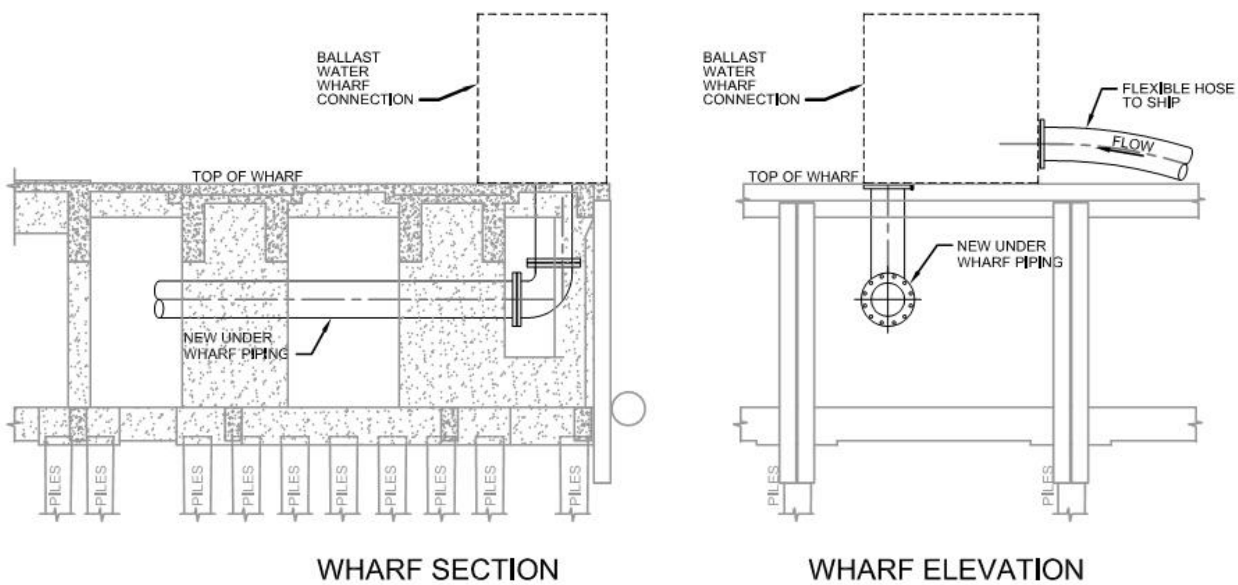


Figure 10 Landside ballast water connection

The location of the landside ballast water connection will need to take into account the mooring lines crossing the landside ballast water connection. Mooring bollards and fenders are positioned along the edge of the wharf and will be obstructions to locating the landside ballast water connection. Therefore, the landside ballast water connection will need to be placed away from both the mooring bollards, the fenders, and take into consideration the crossing mooring lines. This study will not identify the exact location of the landside ballast water connection. However, potential interferences and solutions must be considered during the placement of the exact location.

3.1.3.4 Landside Lift Stations

Pumping of the ballast water from the ship will be through the use of ship's pumps that will elevate the ballast water to the ship's presentation flange hose connection located on the main deck. From this location, the ballast water will flow under a combination of gravity and siphon through the flexible hose to the landside ballast water connection along the wharf. The landside ballast water connection shall be located within 30 m of the ship's point of connection. The piping from the landside ballast water connection will be routed under the wharf, and landside to the lift station.

Based on initial estimates of piping pressure, flow rates, and length of run, it is anticipated that a landside booster pump (at a lift station) will be required to convey the ballast water from the ship to the treatment plant or rail connection through the use of a force main.

The lift stations will be located in an area on the terminal to provide pumping pressure to convey the ballast water to the storage or treatment plant. See Figure 11 for the potential site of the ballast water booster pump/lift station location. The booster pump/lift station location will be identified in order to minimize impacts to the terminal operations (outside of drive aisle) and minimize the loss of terminal storage. Examples include locating the station within a single parking stall 8'x20' or adjacent to existing fixed facilities such as buildings or light poles. Discussions of the lift station will be made in the Task 4 report, Reference 3.

Figure 11 Booster pump/lift station location

3.1.4 Cost Estimate

Based on the specifications above, the cost of modifying the Port of Stockton facility wharf Berths 5 & 6 for a ballast water connection and piping to the lift station (but not including the costs of the lift station) was determined to be $1,650,000. This estimate assumes that the modification of the wharf will be completed during off hours and will have no impact to the terminal operations. In addition, new or repurposed terminal equipment is assumed to be used to lift the connecting hose to the ship.

Table 2 Summary of Port of Stockton Berths 5 and 6 wharf modification cost estimate

Location	Ballast Capacity (m^3)	Modification	Cost
Port of Stockton	34,000	Wharf Modifications (Berths 5 & 6)	$50,000
		Piping between wharf and lift station	$510,000
		Purchase of modification of yard equipment for the movement of piping connection from the wharf to the ship	$500,000
		Regulatory Review	$250,000
		Engineering	$110,000
		Contingency of 20%	$230,000
		Total	**$1,650,000**

3.2 Port of Oakland – Berth 30-33, Tra Pac Terminal

3.2.1 Summary of Port

TraPac, Oakland is a dedicated container-only terminal located in the Port of Oakland, Outer Harbor Channel at Berth 30 and 32. Presently, TraPac handles four to five vessel calls per week (Reference 8), mostly Panamax-sized.

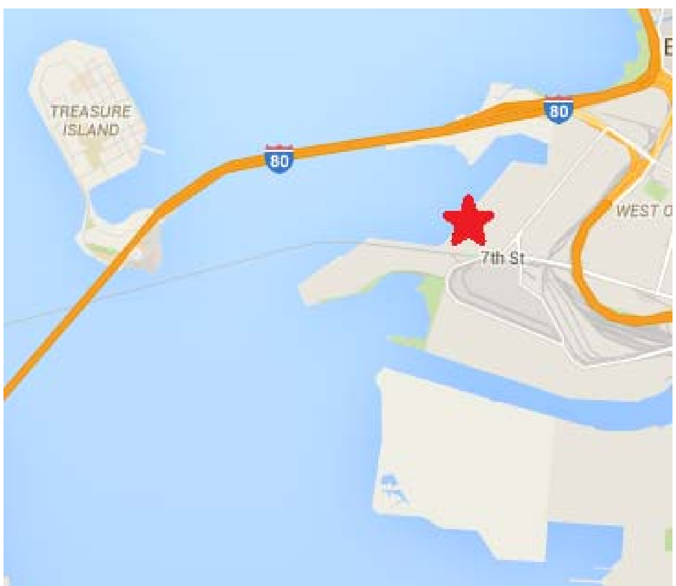


Figure 12 Location of TraPac Terminal

The terminal area encompasses approximately 66 acres. The berth area is 2,100 feet long and has six working lanes beneath four post-Panamax container gantry cranes. Currently, the yard is set up to accommodate a combination of wheeled and grounded operations, but is designed to allow for conversion to higher density grounding if required.

Ballasting operations at TraPac are typical of container terminals that see a net import of cargo. The vessel offloads cargo, and takes on ballast water to compensate for weight changes. In the TraPac case, there were only five ballast water discharges over a 24-month period that saw an estimated 500 vessel calls (one ballast discharge per 100 vessel calls). Discharges are indicated by Figure 13 below.

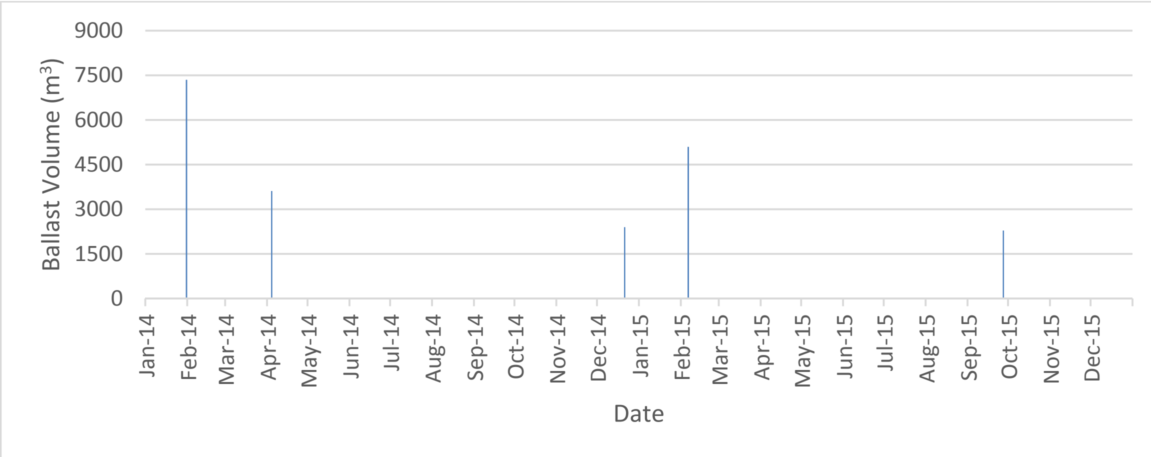


Figure 13 Ballast water discharges, 2014-2015 TraPac Terminal

TraPac Terminal was selected as a case study for this project because it represents a major California container import/export terminal that, in contrast to the other case study ports, receives regular and frequent calls from a single vessel type (i.e. containerships). Despite the frequency of vessel calls and the size of the vessels themselves, ballast water discharge events at TraPac are sporadic and the volumes relatively small. TraPac is also centrally located with available space to accommodate storage and treatment facilities with the potential to serve adjacent terminals. Table 7 gives the case study characteristics and approach.

Table 7 TraPac Terminal case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
2	Port of Oakland/TraPac Terminal	Containerships	New pipeline	New onsite tank	New onsite WWTP

The design basis assumed for TraPac Terminal is given in

Table 8. The TraPac, Oakland facility is used to design reception from ship to shore and intermediate ballast water storage. The adjoining facility details are 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.

Table 8 TraPac Terminal design basis

Discharge Rate	Max. (m^3/hr)	90% (m^3/hr)	Design (m^3/hr)	Flange (mm)	Hose (mm)
Port of Oakland/Trapac	750	750	750	300	200
Adjoining facilities reception	2,400	1,500	1,500	400	N/A
Total for processing plant	3,150	2,400	2,400	500	N/A
Discharge Volume	**Period** (days)	**Max.** (m^3)	**90%** (m^3)	**Design** (m^3)	**Vessel Types**
Port of Oakland/Trapac	1	7,500	7,500	7,500	Containerships. Basis for reception facility.
Adjoining facilities reception	1	15,000	13,500	14,000	Basis for piping works to treatment plant.
Total for processing plant	1	22,500	21,000	22,500	Basis for treatment plant sizing.

3.2.2 Marine Vessel Support Requirements

The above design basis identifies the support requirements for marine vessels calling at this terminal. These requirements consider the 95% case of ballast operations for vessels that called between 2014 and 2015. In addition, the ports and wharves modifications consider the containership identified in the Task 2 report, Reference 2.

A 6,300 TEU containership was used for ship geometry inputs. This size vessel is large, though not uncommon, in terms of likely ship calls at this terminal, and as such is considered representative, with some conservatism. The assumed point of discharge for the ballast water from the ship is on the main deck, and assumed to be located approximately 20 meters above the waterline of the ship's highest point above the water.

The assumed discharge rate from the ship is 750 m^3/hr. The assumed pressure at the point of discharge is zero MPA. This pressure from the ship's presentation flange is adequate to prime the ship to shore connection, but not adequate to lift the received ballast water to the storage and treatment plant. As such, intermediate dockside lift stations are required to complete the transfer to the point of storage and/or treatment. The booster pump/lift station will be located in the container yard approximately 50 m landside of the ship.

3.2.3 Terminal Operations

3.2.3.1 General Arrangement Plan

The general arrangement plan for the TraPac terminal (Figure 14) identifies the overall geometry of the terminal along with the anticipated ship location, points of connection, wharf piping, booster pump/lift station location, piping between the booster pump/lift station and the treatment facility.

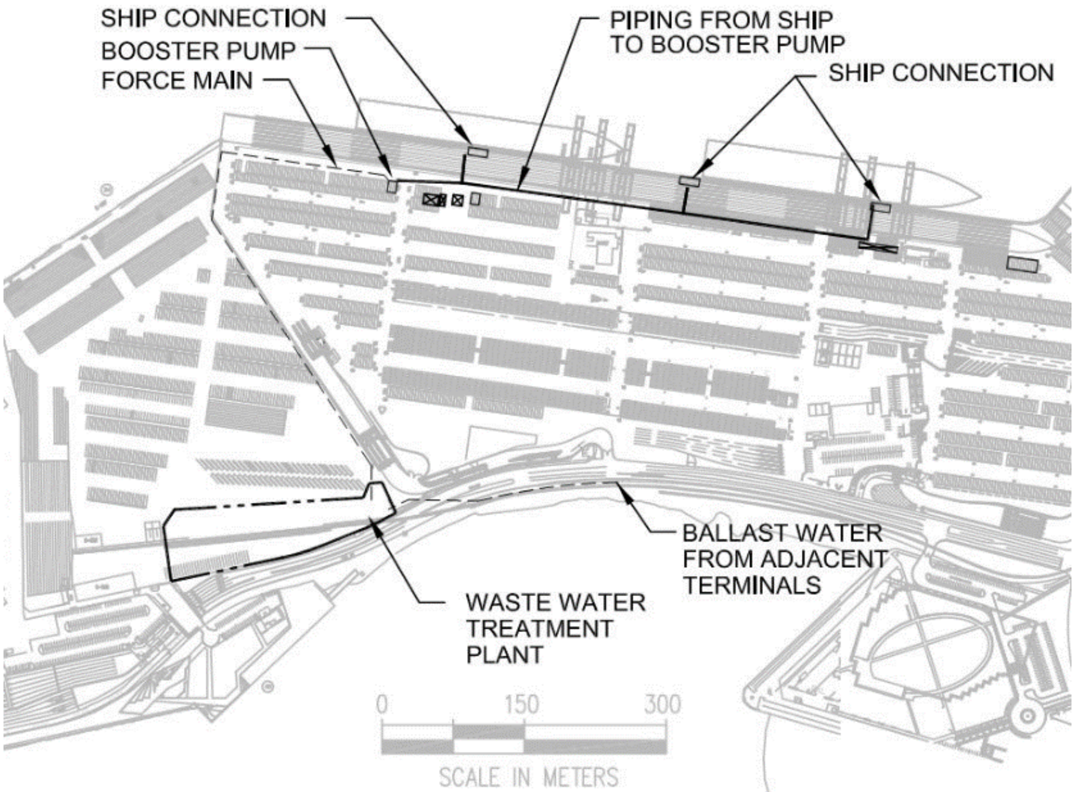


Figure 14 General arrangement plan

This report will identify the available options and costs associated with the conveyance of ballast water from the ship's presentation flange to the first booster pump/lift station.

3.2.3.2 Locations of Landside Water Connections

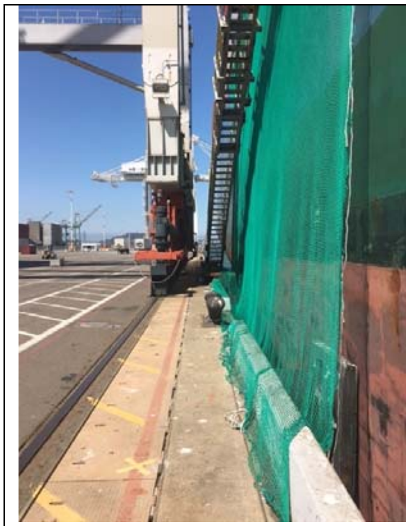
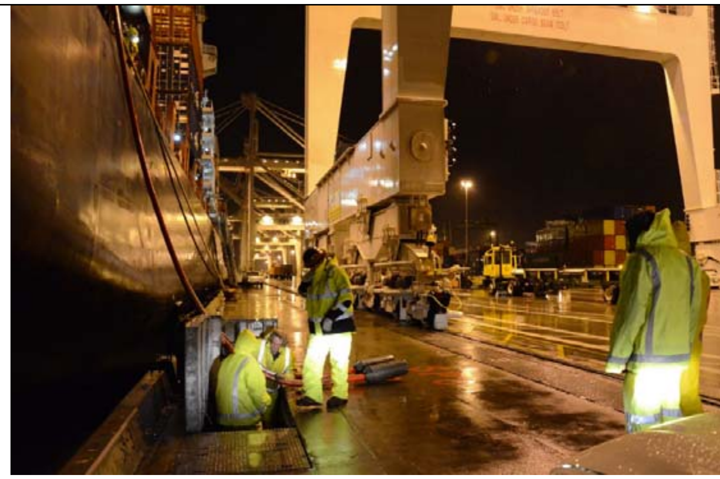
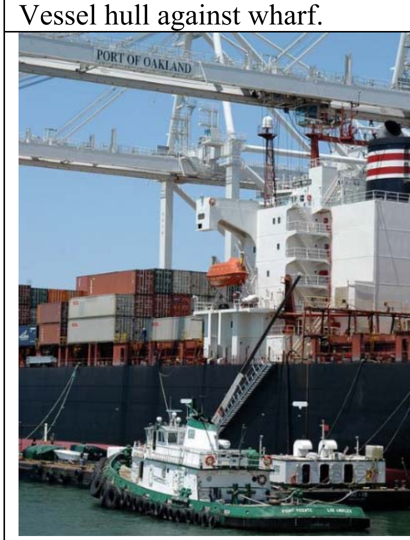
Based on the wharf geometry at the TraPac terminal, the facility allows for the berthing of as many as three ships at any given time. It is important to locate the landside ballast water points of connection along the edge of the wharf at points where the ships will consistently have access to these connections. Recently, larger terminals (more than 50 calls per year) in California have been mandated to reduce emissions while at berth. One method to meet the regulations is to provide electrical power to ships. At the TraPac terminal, three shore power outlets were installed along the edge of the wharf. To locate the ballast water connection on the edge of the wharf, the point of connection on the ship needs to be identified, and a minimum length of hose that would be needed to facilitate the connection between the ship and the landside ballast water connection must be assumed. Using the shore power outlet model of connecting the ship to the shore utilities, we assumed a hose connection length of not more than 38 m in order to provide some flexibility for ship berthing. It is also assumed that, for the purposes of this study, the landside ballast water connection would be within close proximity of the shore power outlets for ease of connections between the shore and the ship. Once the exact location of the ship's presentation flange connection is identified for most ships servicing the Port of Oakland, the exact location of the landside ballast water connection can be identified along the edge of the wharf.

3.2.3.3 Conveyance from Ship to Wharf

Conveyance of the ballast water from the ship to the landside ballast water connection will be though the use of two potential methods: a marine loading arm, or a flexible hose connecting the ship to the landside ballast water connection.

The use of a marine loading arm was researched as a viable method of unloading ballast water to the landside. However, due to operational constraints at the wharf in which the container crane will need to transit the length of the ship and cross the location of the proposed marine loading arm, there is physically not enough room in which to place the marine loading arms and still maintain operational capability of the wharf and terminal.

Table 9, TraPac and Oakland Shore Connection Images

 Vessel hull against wharf.	 Hooking up shore-power connection. Gantry crane in this case is further from vessel hull than other images.
 Tug and barge bunkering containership.	 Image showing gantry crane in way of vessel.

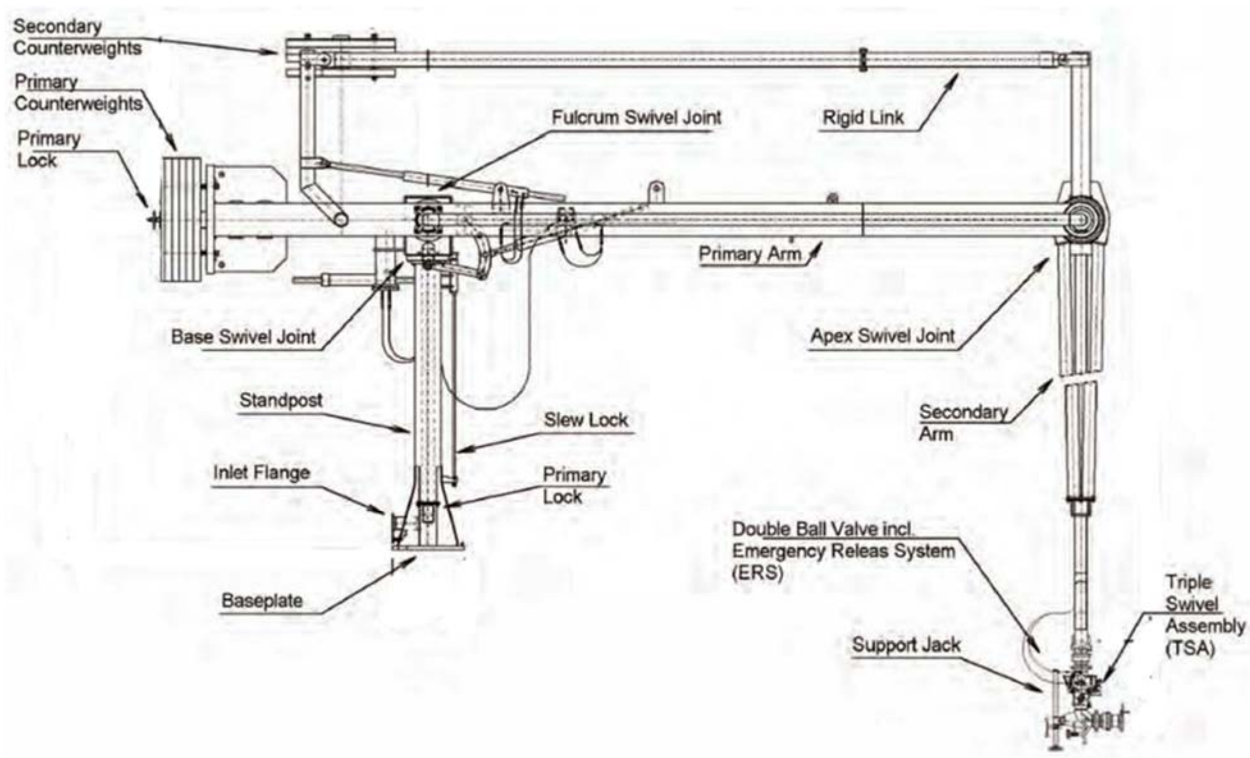


Figure 15 Marine loading arm

Therefore, the flexible hose connection between the ship and the wharf was considered the most acceptable method for conveying ballast water to the landside ballast water connection.

The Task 2 report specified the location of the ballast water connection on the ship to be located on the main deck level, approximately 16.3 m above the waterline and 15.7 m above the top of the wharf (Figure 16).

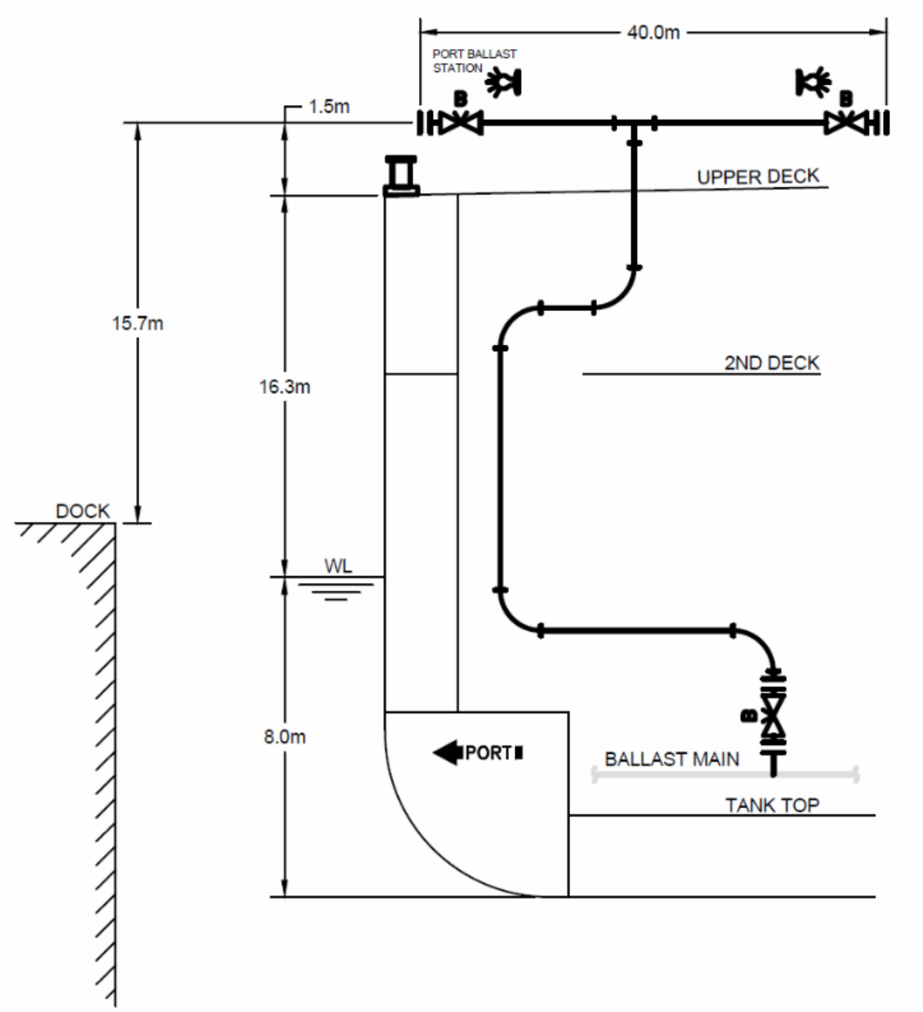


Figure 16 Piping diagram for a representative Panamax containership

Based on the anticipated flow of 750 m^3/hr, a maximum flow velocity of 12 meters per second, and operational limitations of handling a flexible hose, a minimum calculated hose size of 200 mm in diameter was selected. The flexible hose assembly was identified as a DN200 (200 mm in diameter) smooth bore hose with flanged connection hardware. The hose must be capable of sustaining 260 kPa pressure and meet abrasion and UV resistance requirements. The weight of the hose is estimated to be 15.7 kg per meter. The estimated weight of the fittings is 27 kg per fitting. Including end fittings, lifting straps, and 20m of suspended hose the boom weight is estimated at 500 kg, with a required lift of 20 meters vertically and reach of 5 meters. There are several mobile crane solutions available that can offer such support, including hydraulic, knuckle boom cranes and alike. The example shown in Figure 17 is a 30 ton rough terrain crane.

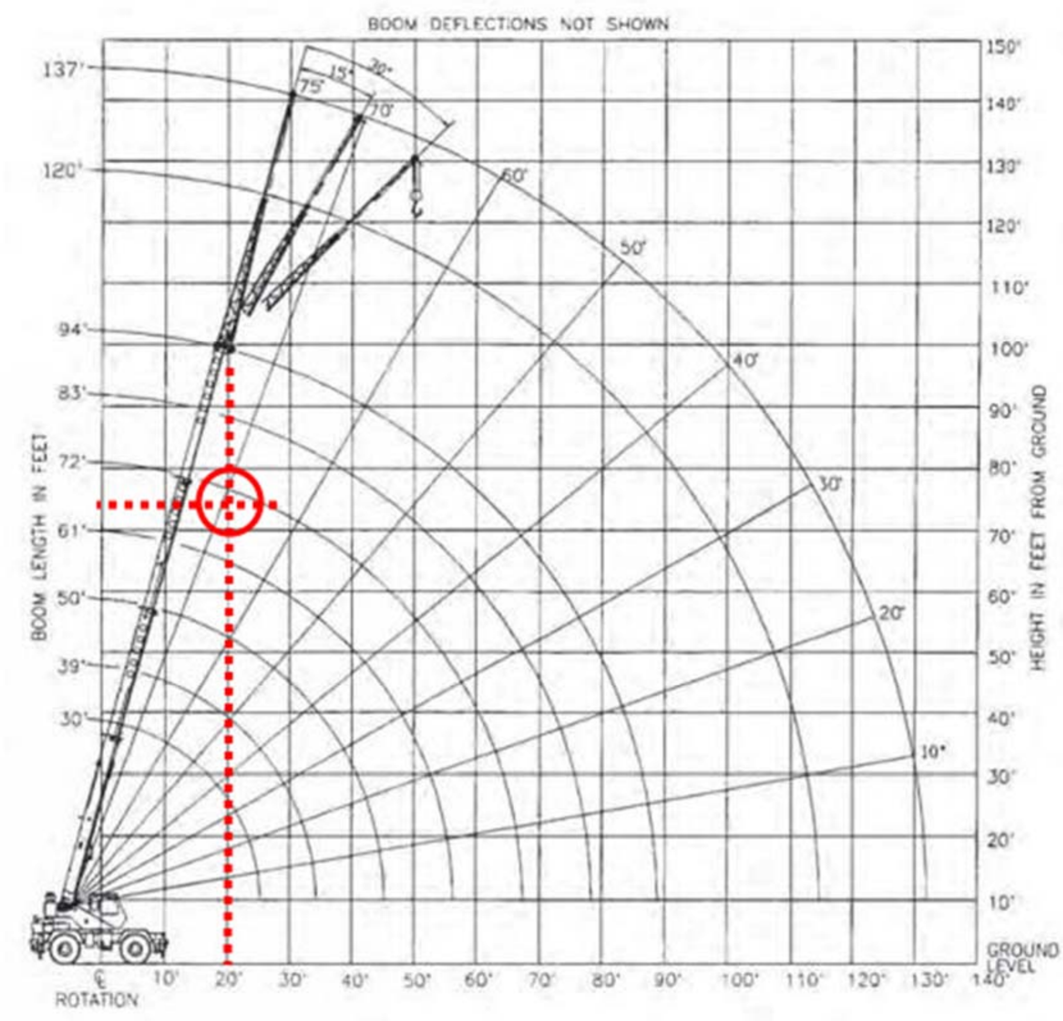


Figure 17 Crane diagram

Note that the hose can be constructed of a single hose length or multiple shorter hose lengths to equal an overall length of up to 38 m.

The crane used to lift the hose to the ship presentation flange connection will be required to lift the hose into place and to allow the connection of the hose to the ship's presentation flange. Once the hose is connected and secured to the ship's flange, and to the landside ballast water connection, the mobile crane will leave the area to allow ship loading/unloading operations to commence without interference from the mobile crane. In addition, under the current longshore contract, the crane will not be allowed to stay on the wharf while the longshore workers are performing loading/unloading operations.

The location of the landside ballast water connection will be seaward of the waterside container crane rail (Figure 18). Due to the geometry of the wharf and the operational constraints of the container cranes needing to transit past the ballast water connection on the wharf, the location of the landside ballast water connection will be on the seaward side of the waterside crane rail. This location will present some challenges from an operational as well as a ship mooring standpoint that will require additional modifications to the wharf.

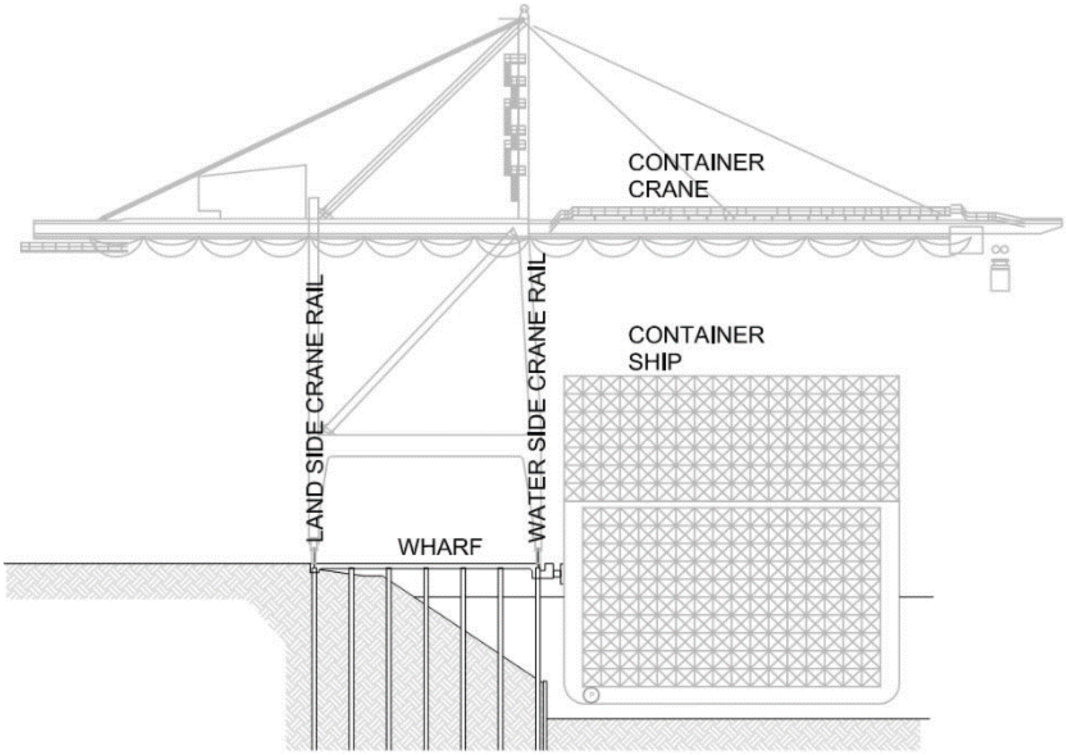


Figure 18 Wharf cross section

The location of the landside ballast water connection will need to be clear of the passing container cranes as well as clear of the power trench that supplies power to the container cranes. The location of the landside ballast water connection will be located on the waterside of the edge of the wharf. A platform will need to be constructed for the operators to safely make the connection of the ballast water hose to the landside ballast water connection while still allowing for compression of the mooring fenders (Figure 19and Figure 20). Similar platforms have been constructed at the Port of Long Beach Pier F facility for the installation of a shore power outlet (Figure 21). A similar platform could be constructed to provide a safe working area for crews to connect the ballast water hose to the landside ballast water connection.

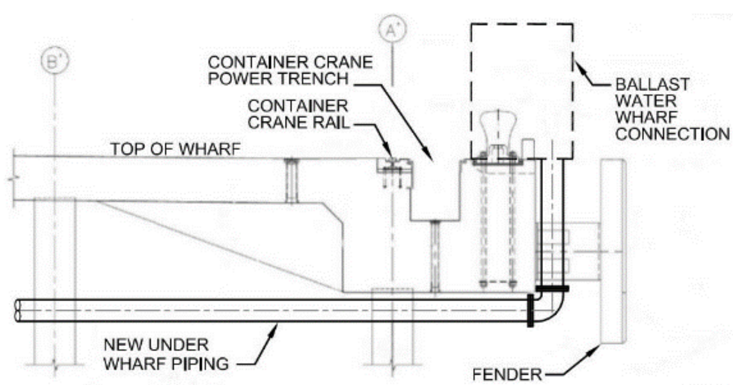


Figure 19 Wharfside connection

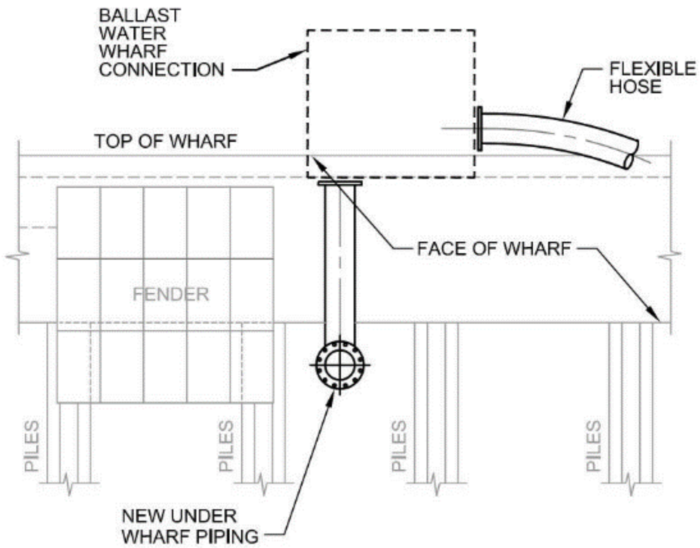


Figure 20 Wharf connection – front elevation

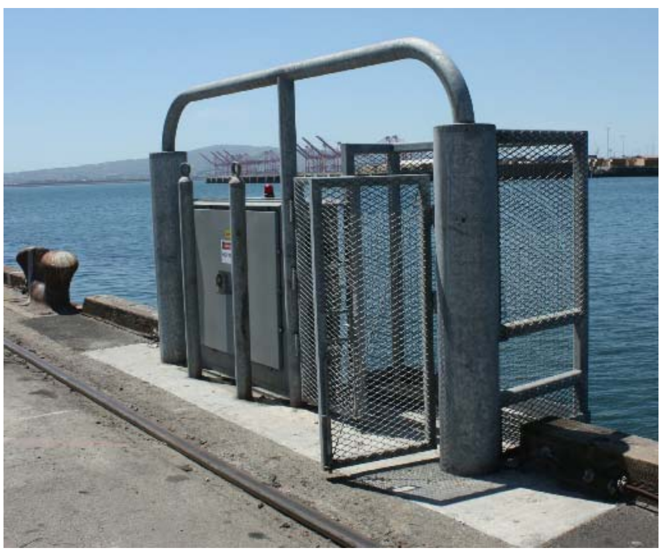


Figure 21 Wharf connection – platform

Location of the landside ballast water connection will need to take into account the mooring lines crossing the landside ballast water connection. In addition, mooring bollards are spaced 21.95 m on center along the edge of the wharf, and fenders panels are placed at 10.97m on center along the edge of the wharf. Therefore, the landside ballast water connection will need to be placed clear of both the mooring bollards and the fenders. This study will not identify the exact location of the wharf side ballast water connection. However, potential interferences and solutions must be considered during the placement of the exact location.

Figure 22 shows the potential relationship of the hose connection between the ship and the wharf at the two extreme ballasting and tidal conditions. Considering terminal operations and the potential for container cranes to gantry the length of the ship, provisions will need to be made on the ship for the attachment and support of the discharge hose from the ship. These provisions can include additional bits and cleats on the main deck, located outboard and above the point of connection of the ballast water discharge line.

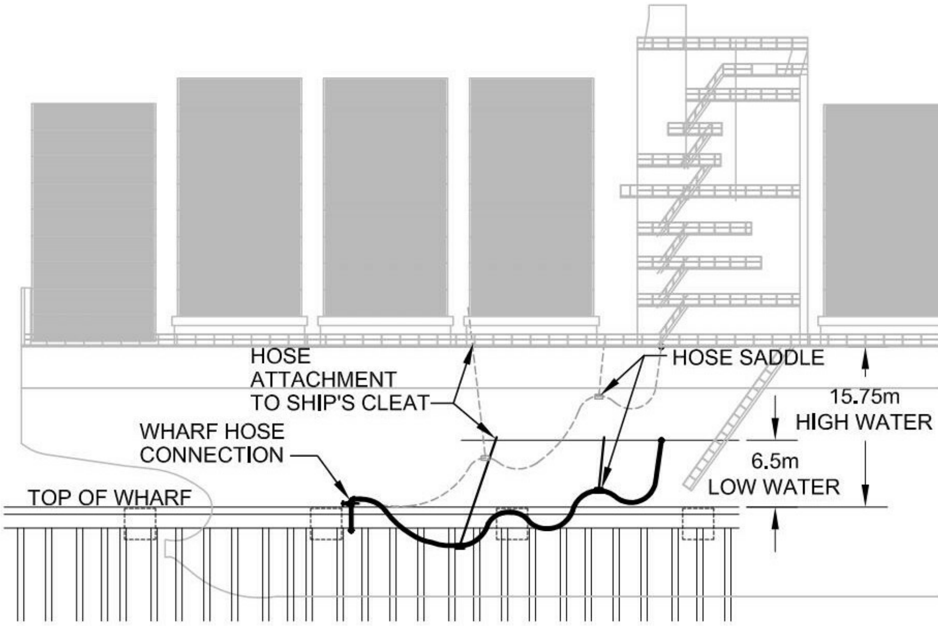


Figure 22 Flexible hose ship connection

3.2.3.4 Landside Lift Station

Pumping of the ballast water from the ship will be through the use of ship's pumps that will elevate the ballast water to the ship's presentation flange hose connection located on the main deck. From this location the ballast water will flow under a combination of gravity and siphon through the flexible hose to the landside ballast water connection along the wharf next to the shore power outlets. The landside ballast water connection will be located within 30 m of the ship's point of connection. Piping from the landside ballast water connection will be routed under the wharf, and landside to the lift station.

Based on initial estimates of piping pressure, flow rates, and length of run, it is anticipated that a landside booster pump (at a lift station) will be required to convey the ballast water from the ship to the treatment plant through the use of a force main. Discussions of the lift station will be made in the Task 4 report (Reference 3).

The lift stations will be located in an area on the terminal to provide pumping pressure to convey the ballast water to the storage or treatment plant. The booster pump/lift station location will be identified in order to minimize impacts to the terminal operations (outside of drive aisle) and minimize the loss of terminal storage area. Examples of pump/lift station locations include locating the pump within a single parking stall 8'x20' or adjacent to existing fixed facilities such as buildings or light poles.

3.2.3.5 Conveyance From Lift Station To Storage / Treatment Plant

Conveyance from the booster pump/lift station will be through the use of a force main and will terminate at either a storage tank or the treatment plant, depending on the allowable treatment rate of the plant. If the treatment plant's rate of treatment cannot match the rate of discharge from the ship, then a storage facility (tank) will be required to accept the surge storage volume.

3.2.4 Cost Estimate

Based on the specifications above, the cost of modifying the Port of Oakland facility for a ballast water connection and piping to the treatment plant was determined to be $1,690,000. This estimate assumes that the modification of the wharf will be completed during off hours and will have no impact to the terminal operations. In addition, new or repurposed terminal equipment is will be used to lift the connecting piping to the ship.

Table 2 Summary of Port of Oakland wharf modification cost estimate

Location	Ballast Capacity (m^3)	Modification	Cost
Port of Oakland	7,500	Ballast transfer connection stations	$150,000
		Purchase of modification of yard equipment for the movement of piping connection from the wharf to the ship.	$500,000
		Piping from wharf to lift station	$790,500
		Regulatory review	$250,000
		Engineering	$150,000
		Contingency 20%	$290,000
		Total	**$2,130,000**

3.3 Port of Hueneme – South Terminal Wharf 1

3.3.1 Summary of Port

The Port of Hueneme is located approximately 60 miles north of Los Angeles, near the city of Oxnard. Port of Hueneme handles approximately $9 billion in cargo annually, mainly from Ro-Ro vessels, refrigerated cargo and general cargo ships, and small containerships. The port has ~120 acres of available land area, as well as a ~30-acre Naval facility, and six wharves (Reference 9).

Figure 23 Port of Hueneme

The Port of Hueneme received nearly 1,500 ship calls over the four-year period between June 2012 and June 2016. During this same period, there were 34 ballast water discharge events totaling 40,280 metric tons. These discharges ranged from 75 tons to 6,972 tons per ship call, with discharge rates estimated between 150 and 2,000 metric tons per hour. The majority of the discharges in this four year period were from containerships (12 discharges totaling 10,097 metric tons), followed by tankers (7 discharges totaling 7,178 metric tons). This constitutes a broad range of ballast water discharge volumes and flow rates. Additionally, ballast water discharges at the Port of Hueneme are sporadic. Discharges over 2,000 metric tons in volume have only occurred three times in the past four years.

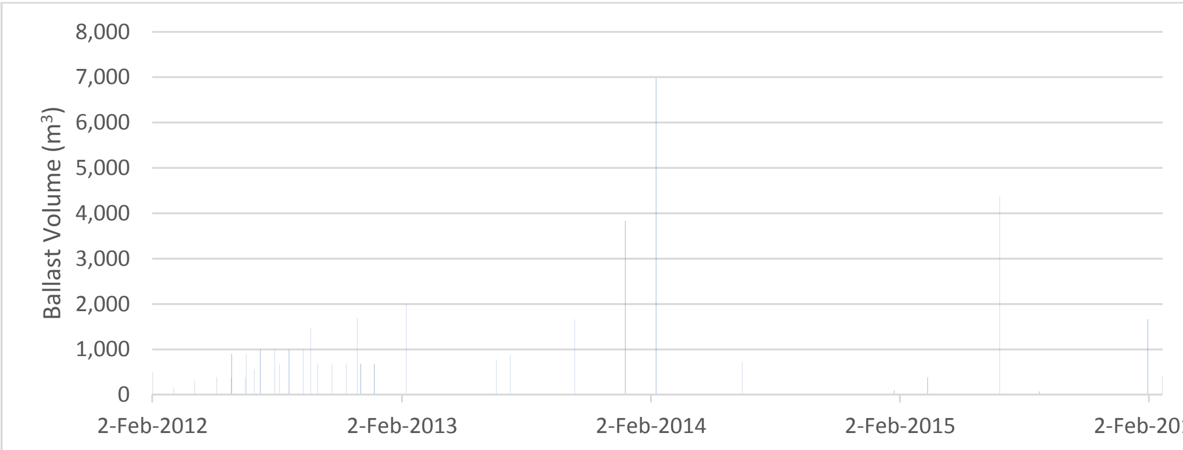


Figure 24 Ballast water discharges, 2012-2015 at Port of Hueneme

The Port of Hueneme was selected as a case study for this project because it represents a smaller scale California port with regular but (comparatively) less frequent calls from multiple vessel types, including Ro-Ro ships. Due to its limited land area, the Port of Hueneme also faces terminal space constraints that merit consideration in this study, in addition to the variability in ballast water discharge frequency and volumes, described above. The comparatively low ballast water treatment requirements at this terminal make it well suited to mobile truck-based treatment. For the purposes of the evaluation, it is assumed that storage capacity would be provided at one location to accommodate the design flow rate and volume.

Table 10 gives the case study characteristics and approach.

Table 10 Port of Hueneme case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
3	Port of Hueneme/South Terminal Wharf 1	Automobile Carriers	Onsite storage	New onsite tank	Mobile shore-based treatment

The design basis for the Port of Hueneme is given in Table 11. 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 on a 20 day period based on 12 year data, typically seeing no more than 4,000 tons of ballast discharge. For the rare, every five years, higher volumes, an additional barge or other means would be required.

Table 11 Port of Hueneme design basis

Discharge Rate	Max. (m^3/hr)	90% (m^3/hr)	Design (m^3/hr)	Flange (mm)	Hose (mm)
	900	250	350	200	150
Discharge Volume	**Period** (days)	**Max.** (m^3)	**90%** (m^3)	**Design** (m^3)	**Vessel Types**
	20	11,000	4,000	4,000	Various. Base ship connection on car carriers

3.3.2 Marine Vessel Support Requirements

The above design basis identifies the support requirements for marine vessels calling at this terminal. These requirements consider the 90% case of ballast operations for vessels that called between 2012 and 2016. In addition, the ports and wharves modifications consider the break bulk ship identified in Task 2, Reference 2.

An automobile carrier ship was used for ship geometry inputs. This size of vessel is large, though not uncommon, in terms of likely ship calls at this terminal, and as such is representative with some conservatism. The point of discharge for the ballast water from the ship is assumed to be located on the side of the ship approximately 3.90m to 7.20m above the waterline of the ship at the highest point above the water.

Our assumed discharge rate from the ship is 350m^3/hr. The assumed pressure at the point of discharge is zero MPA. This pressure from the ship's presentation flange is adequate to prime the ship to shore connection, but not adequate to lift the received ballast water to the storage and treatment plant. As such, an intermediate dockside lift station will be required to complete the transfer to the point of storage and/or treatment. The booster pump/lift station will be located in the container yard adjacent to the storage tanks.

3.3.3 Terminal Operations

3.3.3.1 General Arrangement Plan

The general arrangement plan for the Port of Hueneme (Figure 25) identifies the overall geometry of the terminals along with the anticipated points of connection, wharf piping, booster pump/lift station location, piping between the booster pump/lift station and the treatment facility.

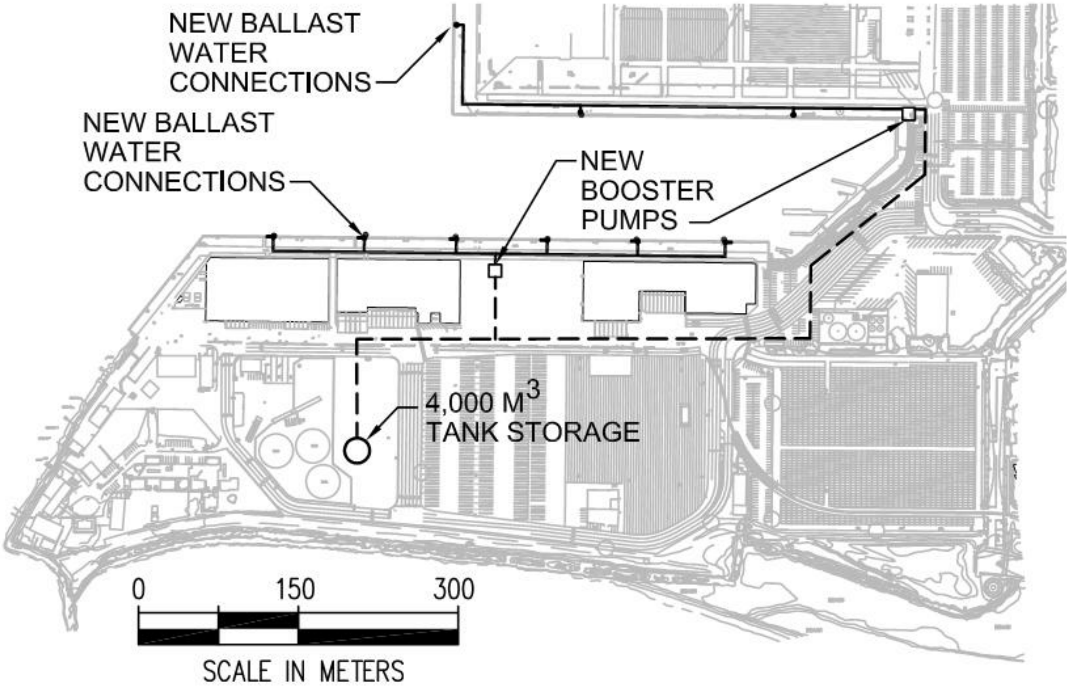


Figure 25 General arrangement plan

This report will identify the available options and costs associated with the conveyance of ballast water from the ship's presentation flange to the first booster pump/lift station.

3.3.3.2 Locations of Landside Water Connections

Based on the wharf geometry and the terminal tenant agreements, the wharves permit the berthing of multiple ships at any given time. Therefore, it is important to locate the landside ballast water connection on the wharves at a point where the ships will consistently have access to the point of connection. Recently, larger terminals (more than 50 calls per year) in California have been mandated to reduce emissions while at berth. One method to meet the regulations is to provide electrical power to ships. Six shore power outlets were installed along the edge of the Port of Hueneme southern wharf. The general arrangement places the landside ballast water connection in close proximity to the shore power outlets in order to provide a uniform utility connection location for the maintenance personnel and the ship crews. Based on the shore power outlet model of connecting the ship to the shore utilities, we assumed a hose length of not more than 38 m to provide some flexibility for ship berthing. It is also assumed that, for the purposes of this study, the ballast water connection would be within close proximity of the shore power outlets for ease of connections between the shore and the ship. Once the exact location of the ship's presentation flange connection is identified for most ships servicing the Port of Hueneme, the exact location of the landside ballast water connection can be located along the edge of the wharf.

3.3.3.3 Conveyance from Ship to Wharf

Conveyance of the ballast water from the ship to the landside ballast water connection will be though the use of two potential methods: a marine loading arm, or a flexible hose connecting the ship to the landside ballast water connection.

The use of a marine loading arm was researched as a viable method of unloading ballast water to the landside. However, due to operational constraints at the wharf in which the mobile harbor cranes will need to transit the length of the ship and cross the location of the proposed marine loading arm, and the narrowness of the wharves between the warehouses and the edge of the wharf, there is physically not enough room in which to place the marine loading arms and still maintain operational capability of the wharf and terminal.

In addition, due to the variety of ships that call on this port at any given time, the opportunity to place a marine loading arm in the exact location in which to consistently connection to the ship is virtually impossible. Therefore, the flexible hose connection between the ship and the wharf was considered the best method for conveying ballast water to the landside treatment.

The Task 2 report specified the location of the ballast water connection on the ship to be located on the main deck level, approximately 10.2 m above the waterline and 5.9 m above the top of the wharf (Figure 26).

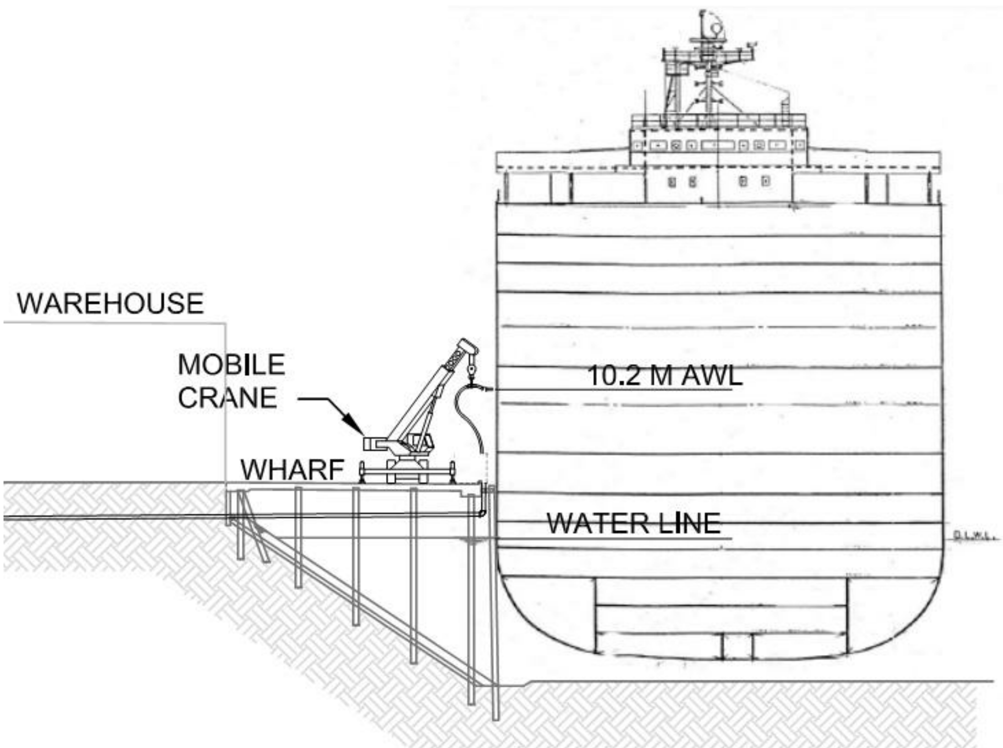


Figure 26 Piping diagram for a representative Ro-Ro ship

Based on the anticipated flow of 350 m^3/hr, a maximum flow velocity of 12 meters per second, and operational limitations of handling a flexible hose, a minimum calculated hose size of 150 mm in diameter was selected. The flexible hose assembly was identified as a DN150 (150 mm in diameter) smooth bore hose with flanged connection hardware. The hose must be capable of sustaining 180 kPa pressure and meet abrasion and UV resistance requirements. The weight of the hose per meter is estimated to be 9.8 kg/m. The estimated weight of the fittings is 20 kg/fitting. Including end fittings, lifting straps, and 20m of suspended hose the boom weight is estimated at 350 kg, with a required lift of 10 meters vertical and reach of 5 meters. There are several mobile crane solutions available that can offer such support, including hydraulic, knuckle boom cranes and alike. An example crane is shown in Figure 27.

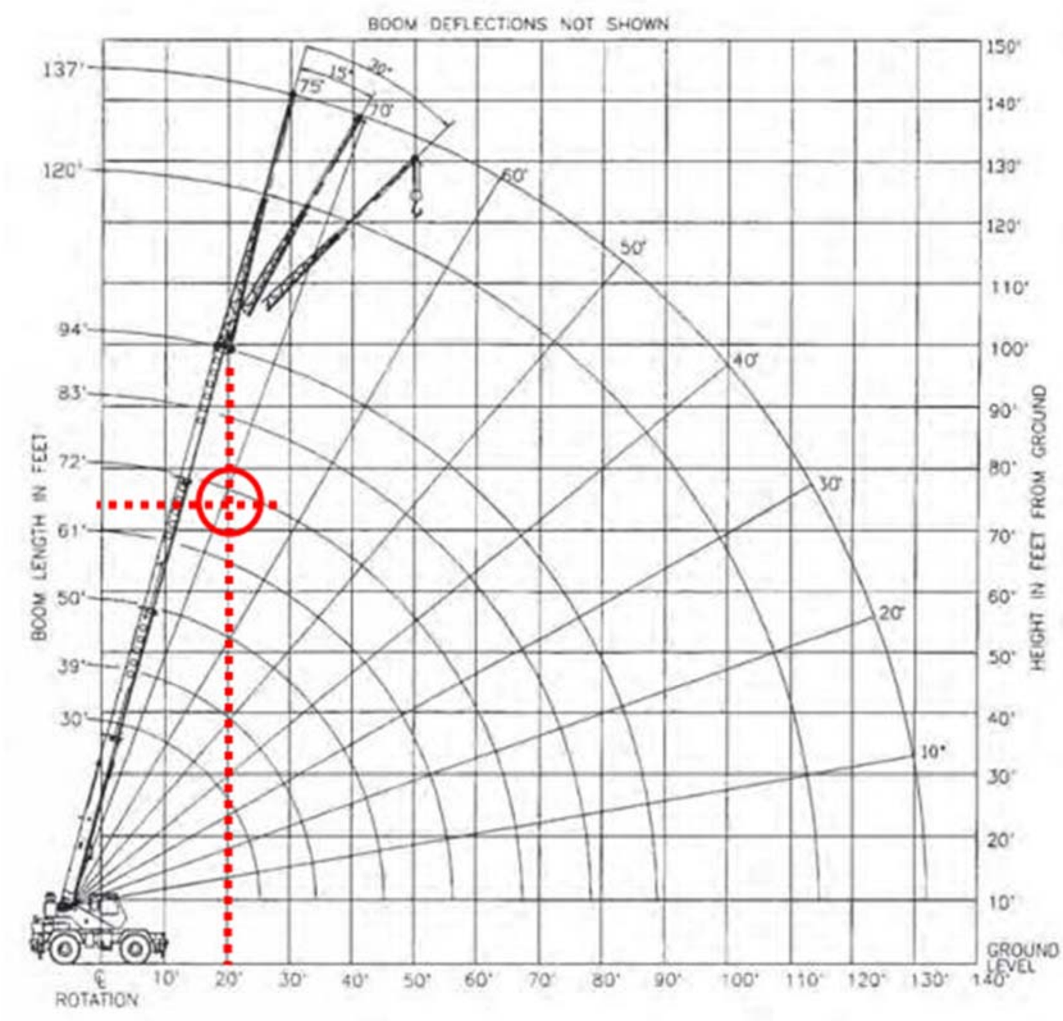


Figure 27 Crane diagram [to be updated with different crane]

Note that the hose can be constructed of a single hose length or multiple shorter hose lengths to equal an overall length of up to 38 m.

The crane used to lift the hose to the ship presentation flange connection will be required to lift the hose into place and to allow the connection of the hose to the ship's presentation flange. Once the hose is connected to the ship's flange, and to the landside ballast water connection, the mobile crane will leave the area to allow ship loading/unloading operations to commence without interference from the mobile crane. In addition, under the current longshore contract, the crane will not be allowed to stay on the wharf while the longshore workers are performing loading/unloading operations.

The location of the landside ballast water connection will be located near the waterside edge of the wharf (Figure 28). Due to the geometry of the wharf and the operational constraints of the mobile harbor cranes transiting past the landside ballast water connection, the location of the landside ballast water connection will be on the waterside edge of the wharf. This location will present some challenges from an operational as well as a ship mooring standpoint.

The location of the wharf side connection will need to be clear of the passing mobile harbor cranes. The wharf is narrow and warehouses constrain the width of the wharf to 20 m. Due to the narrow width of the wharf and a narrow fendering system along the edge of the wharf, a below deck connection of the landside ballast water connection may be an option. The hose connecting the ship to the landside ballast water connection is 150 mm in diameter and is more easily handled by crews then hoses of larger diameter. Therefore, the below deck connection may be an option.

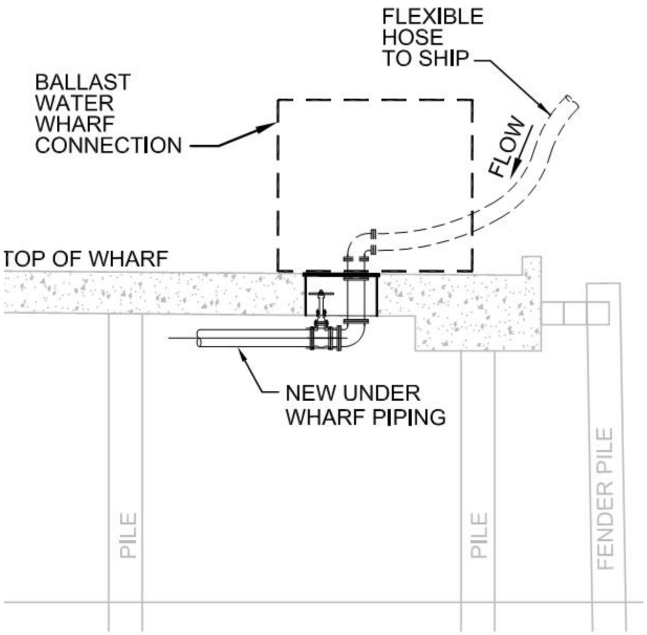


Figure 28 Wharf side connection

Location of the wharf side ballast water connection will need to take into account the mooring lines crossing the wharf side ballast water connection. Mooring bollards are located along the edge of the wharf with approximate spacing of 18.2 m on center. In addition, the fender piles are placed at 2.6 m intervals along the edge of the wharf. Therefore, the landside ballast water connection will need to be placed away from both the mooring bollards and the fenders, and take into consideration the crossing mooring lines. This study will not identify the exact location of the wharf side ballast water connection. However, potential interferences and solutions must be considered during the placement of the exact location.

Due to the location of the point of connection on the ship at low water when heavily ballasted (-1.3m below the wharf deck) and the existing fender pile system at the wharves, modification of the fenders is anticipated in key areas to allow the full tidal range of movement with no resulting damage to the point of connection and the fenders. However, due to the low probability of occurrence of an extreme low tide with a heavily ballasted ship and/or laden ship, the potential for damage to the connection is slight. In order to prevent damage, the discharge hose will need to be monitored and coordinated by the terminal managers.

Figure 29 shows the potential relationship of the hose connection between the ship and the wharf and the two extreme ballasting and tidal conditions. Considering terminal operations and the potential for the mobile harbor cranes to traverse the length of the ship, provisions will need to be made on the ship for the attachment and support of the discharge hose from the ship to the landside ballast water connection. These provisions can be additional bits and cleats on the main deck, located outboard, and above the point of connection of the ballast water discharge line.

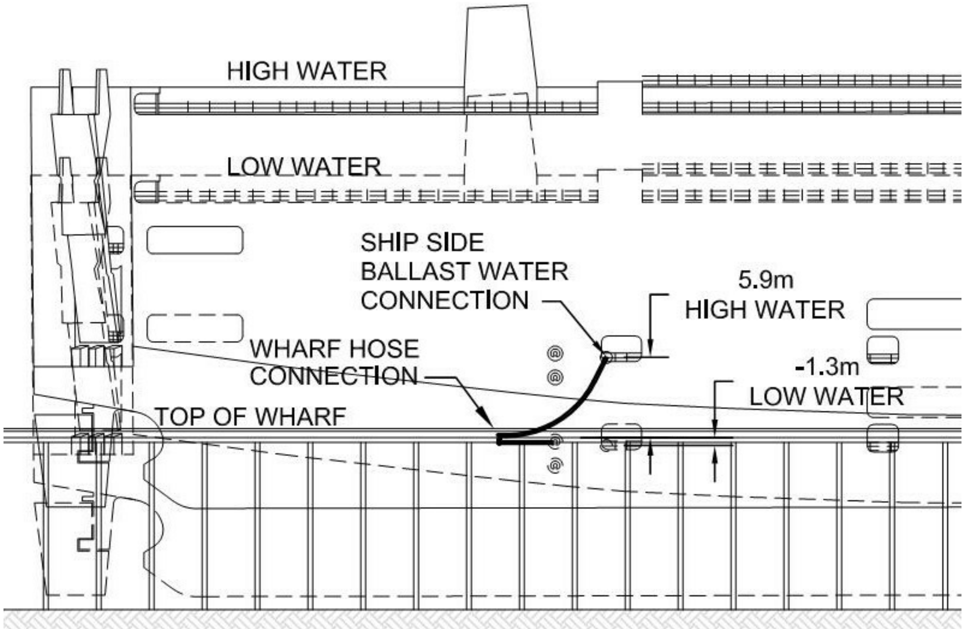


Figure 29 Flexible hose ship connection [to be updated to show crane]

3.3.3.4 Landside Lift Station

Pumping of the ballast water from the ship will be through the use of ship's pumps that will elevate the ballast water to the ship's presentation flange hose connection located on the main deck. From this location, the ballast water will flow under gravity and siphon, through the flexible hose to the landside ballast water connection located next to the shore power outlets and within 30 m of the ship's point of connection. From the landside ballast water connection the piping will be routed under the wharf and landside to the lift station.

Based on initial estimates of piping pressure, flow rates, and length of run, it is anticipated that a landside booster pump (at a lift station) will be required to convey the ballast water from the ship to the treatment plant through the use of a force main. Discussions of the booster pump/lift station will be made in the Task 4 report, Reference 3.

The booster pumps/lift station will be located in an area on the terminal to provide pumping pressure to convey the ballast water to the onsite storage tank. The booster pump/lift station location will be identified in order to minimize impacts to the terminal operations (outside of drive aisle) and minimize the loss of terminal storage. As an example, the booster pump/lift station could be located within a single parking stall 8'x20' or adjacent to existing fixed facilities such as buildings or light poles.

3.3.3.5 Conveyance from Lift Station to Storage Tank

Conveyance from the lift station will be through the use of a force main and will terminate at the onsite storage tank awaiting treatment and discharge. The booster pump/lift station will receive the ballast water from the ship and will lift the water into the top of the storage tanks. One 4,000 m^3 tank will be constructed to contain the maximum discharge of the ships until a treatment vehicle can arrive and treat the ballast water for discharge. For the purposes of this study, the storage tank will be tentatively located in "570 Lot" on the southern terminal near the existing tank farm facility. Based on previous geotechnical investigations, the soils in this area are hydraulically sand placed fill. Due to the nature of hydraulically placed fills during seismic events, liquefaction, lateral spreading, and differential settlement can be anticipated. Therefore, it may be assumed that the tank foundation may need to be increased in thickness or the soils will need to be improved in the form of stone columns in order to reduce or eliminate the potential for liquefaction.

3.3.4 Cost Estimate

Based on the specifications above, the cost of modifying the Port of Hueneme wharf facility for a ballast water connection, piping to the storage tanks, and tank foundations and/or ground improvements was determined to be $1,970,000. This estimate assumes that the modification of the wharf will be completed during off hours and will have no impact to the terminal operations. In addition, it is assumed that new or repurposed terminal equipment will be used to lift the connecting piping to the ship.

Table 2 Summary of Port of Hueneme wharf modification cost estimate

Location	Ballast Capacity (m^3)	Modification	Cost
Port of Hueneme South Terminal	4,000	Wharf modifications	$120,000
		Purchase of modification of yard equipment for the movement of piping connection from the wharf to the ship.	$350,000
		Piping from wharf to lift station s	$800,000
		Regulatory review	$250,000
		Engineering	$200,000
		Contingency 20%	$250,000
		Total	**$1,970,000**

3.4 El Segundo Marine Terminal – Wharf 1

3.4.1 Summary of Port

El Segundo Marine Terminal facility is an offshore import/export facility for liquid bulk petroleum products, operated by Chevron U.S.A. Products Company. The terminal is located in an open, unsheltered offshore mooring in Santa Monica Bay, directly offshore of Dockweiler State Beach in El Segundo.

Figure 30 Location of El Segundo Marine Terminal

The Terminal has two berths, defined by two seven-point conventional buoy moorings systems. Berth No. 3 is approximately 7,200 feet offshore, and Berth No. 4 is approximately 8,100 feet offshore (Reference 3). Cargo is transferred to and from the onshore facility through a network of submarine hoses and pipelines. The terminal is maintained and operated 24 hours a day, 7 days a week.

El Segundo Terminal sees approximately 214 tank vessel calls annually (2014 and 2015 data). The vessels are generally Handymax, Aframax, and Suezmax size tankers; but less frequent calls by articulated tug-barge units (ATBs) and very large crude carriers (VLCCs) also occur. Vessels discharged ballast water 95 times over a 24-month period (1/1/2014 – 12/31/2015), averaging less than one (1) discharge per week. The discharge volumes range from 122 to 53,819 m^3, with 95% of discharge volumes being less than 18,250 m^3 and 75% less than 9,250 m^3.

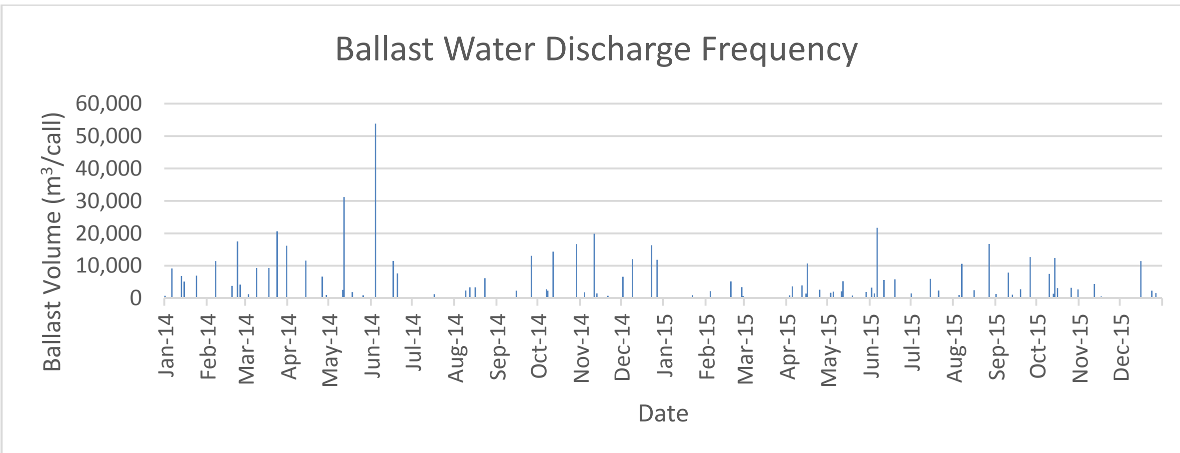


Figure 31 Ballast water discharges, 2014-2015 at El Segundo Terminal

The El Segundo Marine Terminal was selected as a case study for this project because it represents a California liquid bulk import/export terminal with regular calls from two vessel types (tankers and ATBs) that vary considerably in size and carrying capacity. This terminal is unique in that it is an offshore mooring with no dock infrastructure, and thus no direct access to the facility ashore. The El Segundo Marine Terminal is also the site of some of California's largest ballast water discharges, in terms of discrete discharge events by a single vessel. Table 12 gives the case study characteristics and approach.

Table 12 El Segundo case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
4	El Segundo Marine Terminal	Tank Ships; ATBs	Offload to mobile marine vessel	Mobile marine vessel	Mobile, marine vessel-based treatment

The design basis assumed for the El Segundo Marine Terminal is given in Table 13. El Segundo vessel ballast water discharge rates are closely coordinated to cargo loading rates, which are generally impractical to slow. 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 accomodation.

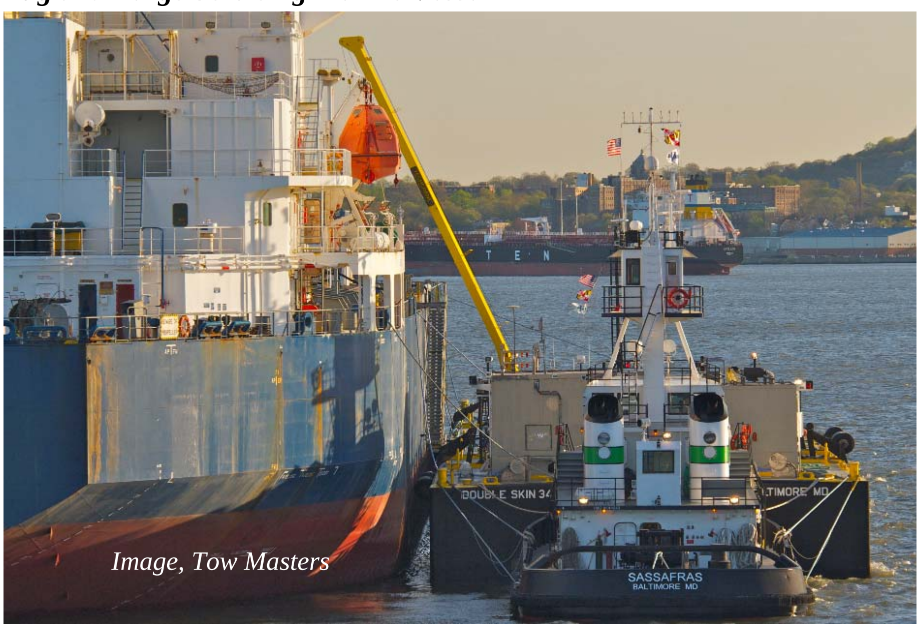
Table 13 El Segundo design basis

Discharge Rate	Max. (m³/hr)	90% (m³/hr)	Design (m³/hr)	Flange (mm)	Hose (mm)
	5,000	3,400	3,400	600	300
Discharge Volume	**Period** (days)	**Max.** (m³)	**90%** (m³)	**Design** (m³)	**Vessel Types**
	1	53,819	32,000	32,000	Tankers.

3.4.2 Ship-to-Ship Offloading of Ballast Water

Ship-to-ship (STS) transfers are commonly performed in the liquid petroleum trade. The standard procedures and requirements for such transfers are guided by documents such as the "Ship-to-Ship Transfer Guide (Petroleum)," that are put forward by the International Chamber of Shipping and Oil Companies International Marine Forum (OCIMF). The design basis for Ballast water transfers of 34,000 cubic meters at a rate of 3,400 cubic meters per hour is similar to some tanker cargo transfer rates. These are very significant volumes and rates. The below table provides visual images of typical arrangements.

Table 14, Ship-to-ship transfer examples.

STS Example	Description
Tug and Barge Servicing Marine Vessel 	Tug and barge servicing marine vessel with hoses. Likley a fuel bunkering operation at flow rates near to 800 cubic meters per hour. The flow rates, barge size, and hose size are too small for case study service.

<table>
<tr>
<td>Ship-to-ship Transfer

</td>
<td>Ship to ship transfer with hose. A lightering transfer where cargo is transferred from one vessel to the other.

Hose similar to case study size, in range of 200 to 300 mm, supporting flow rates up to 3,500 cubic meters per hour.</td>
</tr>
<tr>
<td>Ship-to-ship Transfer

</td>
<td>Ship to ship lightering transfer with hoses. Very high transfer rates, reaching as much as 5,000 cubic meters per hour.

Hoses are used to support hoses during transfer and account for vessel relative motions and draft changes.

The scale of large and small vessels is approximately what would be required to receive offloaded ballast water.</td>
</tr>
</table>

Vessel outfitting details are provided in the ATB and Tanker sections of the Task 2 report. The reception vessel details are provided in the El Segundo case study section of the Task 3 report.

3.5 Port of Long Beach Cruise Terminal and Port of Los Angeles SA Recycling (Berth T118)

3.5.1 Summary of Port

Taken together, the twin ports of Los Angeles and Long Beach constitute the busiest port complex in the US. Two separate terminals were examined in this study – the SA Recycling facility in the Port of Los Angeles (Terminal Island, Berth T118), and the Long Beach Cruise Terminal in the Port of Long Beach.

SA Recycling is a full-service ferrous and non-ferrous metal recycler and processor operating multiple facilities in California and six other states. The Terminal Island facility in Los Angeles is both a processing facility and export terminal, servicing one or two vessel arrivals per month, on average.

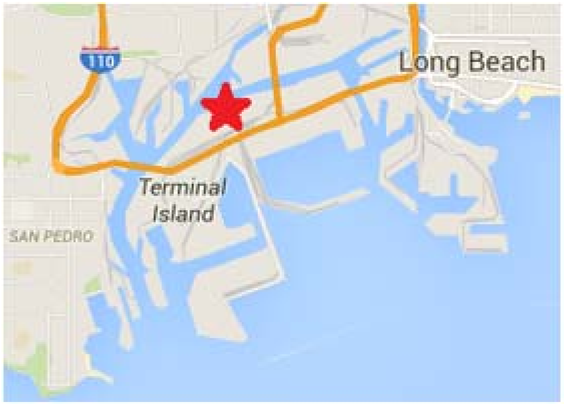


Figure 32 Location of SA Recycling Terminal

Vessel sizes are typically Panamax in the 50-60k deadweight ton range. Cargo operations normally occur over a consecutive five-day period, with export volumes around 45k metric tons per vessel call (see Figure 33). There were 27 ballast water discharges at this terminal in a 24-month period from 2014 – 2015.

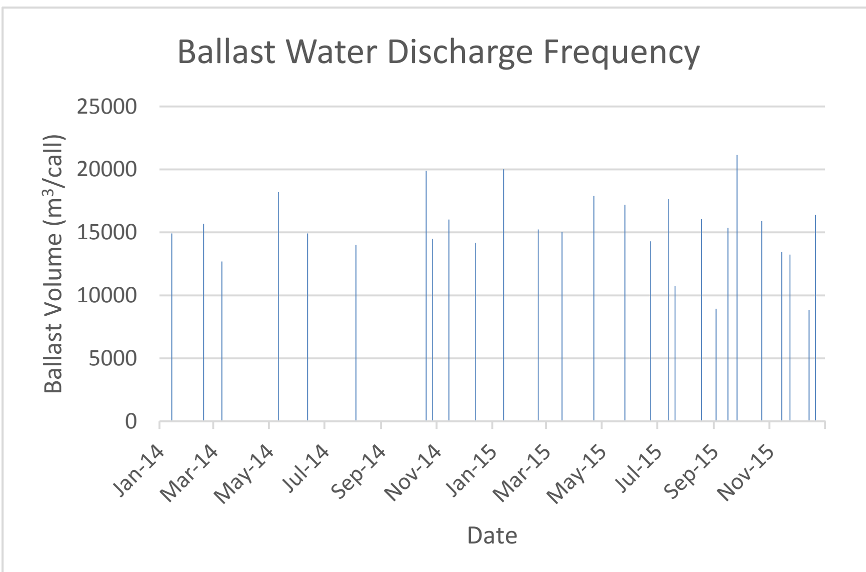


Figure 33 Ballast water discharges, 2014-2015 at SA Recycling Terminal

Owned and operated by Carnival Corporation, the Long Beach Cruise Terminal is located at the head of Queensway Bay in the Port of Long Beach. It features a single ship berth at the end of a T-shaped pier, approximately 50 meters from shore.

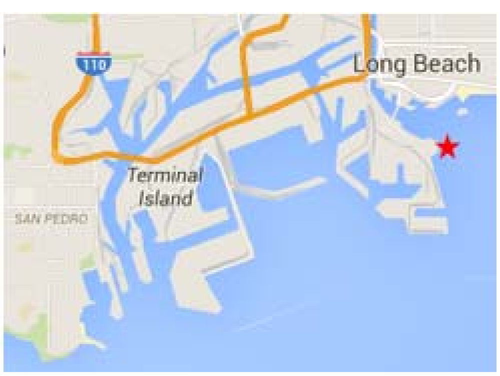


Figure 34 Location of the Long Beach Cruise Terminal

The Cruise Terminal receives roughly 250 vessel arrivals per year - generally one per day, excepting Tuesdays and Wednesdays. The duration of ballast water discharge events on cruise ships is closely related to the duration of fuel oil bunkering operations, rather than the duration of cargo operations as with other vessel types. The average discharge volume per event is 783 m^3, and the total annual volume is 158,000m^3 (see Figure **35**). In a 24-month period from 2014-2015, this terminal saw 483 discharge events.

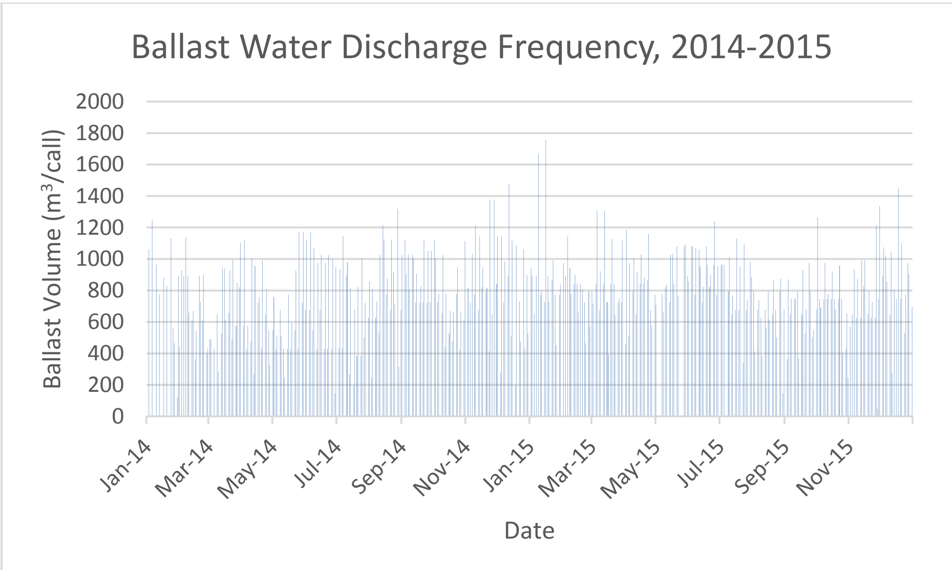


Figure 35 **Ballast water discharges, 2014-2015 at Long Beach Cruise Terminal**

These two terminals at LA/ Long Beach were selected as a case study for this project because they represent two dissimilar terminals in a busy port district, serving two very different vessel types – bulk carriers and passenger cruise ships. They are also physically distant from one another within the port complex, which highlights the challenges associated with conveying water to a shared WWTP. The Long Beach Cruise Terminal sees frequent -almost daily-discharge events characterized by relatively small volumes and lower flow rates. This terminal also represents a unique case in that it sees seasonal fluctuations in vessel activity. In comparison, the SA Recycling facility sees infrequent -monthly- discharge events characterized by relatively large volumes and higher flow rates. Together, these two terminals illustrate the variability in ballast water discharge practices within the LA/Long Beach port district. A ballast water conveyance approach must accommodate the ballast water needs of both terminals. Table 15 gives the case study characteristics and approach.

Note: a large-scale container terminal was intentionally not selected for evaluation in LA/Long Beach since a similar terminal is evaluated in the Port of Oakland case study.

Table 15 Ports of Long Beach case study matrix

Case Study	Port/Terminal	Vessel Type	Conveyance Approach	Storage Approach	Treatment Approach
5	Long Beach Cruise Terminal/ Lost Angeles SA Recycle	Bulk Carriers and Passenger Cruise Ships	Offload to mobile marine vessel	New offsite tank	New offsite WWTP

The design basis assumed for the Port of Long Beach is given in Table 16. SA Recycling Terminal 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 m^3/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 m^3/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 m^3/hr, 50% of ship pumps.

The Cruise Terminal has 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 around of four hour period. 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 m^3/hr to correspond to six-hour processing of larger volumes.

Table 16 Ports of Long Beach/Los Angeles design basis

Discharge Rate	**Max.** (m^3/hr)	**90%** (m^3/hr)	**Design** (m^3/hr)	**Flange** (mm)	**Hose** (mm)
SA Recycling	2,800	2,500	1,400	400	200
Cruise Terminal	500	350	400	200	150
Discharge Volume	**Period** (days)	**Max.** (m^3)	**90%** (m^3)	**Design** (m^3)	**Vessel Types**
SA Recycling	5	21,672	18,000	24,000	Bulk carriers
Cruise Terminal	1	1,800	1,500	2,400	Cruise ships

3.5.2 Marine Vessel Support Requirements

The above design basis identifies the support requirements for marine vessels calling at this terminal. The case study identified these two locations for the off- loading of ballast water to an awaiting barge and then transport of the ballast water to a location within the Port's complex. As a result, the Port of Long Beach's wharves are not anticipated to be modified for the offloading of ballast water to the storage barge. Both the Long Beach Cruise Terminal and SA Recycling will off load the ship's ballast water onto barges to be transported to the Navy Mole where a new ballast water treatment plant will be constructed.

3.5.3 Terminal Operations

3.5.3.1 General Arrangement Plan

The Ports of Los Angeles and Long Beach study incorporates the use of a barge system to receive ballast water from the ships and transport of the ballast water via barges to a new waste water treatment facility (WWTF) within the Ports complex. For the purposes of this study, the tentatively location of the WWTF was identified to be placed on the Navy Mole (Figure 36). The "Navy Mole" is a man-made peninsula that juts in front of the former Long Beach Naval Shipyard and current Pier T Terminal.

Figure 36 Overall map

3.5.3.2 Conveyance from Ship to Barge

Based on the anticipated discharge volumes from the ships, two barges are anticipated to hold 8,000 m^3 of ballast water each. The barges will be moored alongside of the ships using one tug to maneuver the barge into place. At the end of terminal shift, or when the barge is full, the barge will be returned to the barge mooring facility for discharge and processing of the ballast water. If terminal operations require the continued use of a barge, the second barge will be placed alongside of the ship for continued receiving of ballast water.

The anticipated barge size of 8,000 m^3 will have approximate dimensions of 50 m long x 20 m wide and 8 m tall. It is anticipate that the barge will be equipped with onboard pumps to discharge the ballast water cargo to the landside ballast water connection and onto the waste water treatment facility at a rate that the plant can treat and discharge. Due to the limited area on the Navy Mole, it was determined that the barges could act as temporary storage units, metering out the ballast water to the WWTF.

The barges are anticipated to have double hulled construction, for future resale, and will receive the ballast water from the ship on the opposite side of the wharf (Figure 37). The barges will have an onboard diesel generator, electric pump for pumping of the ballast water, articulated crane for handling of the hoses and a piping manifold system for connection to the landside ballast water connection via the mooring facility piping.

Figure 37 Marine operations

3.5.3.3 Barge Mooring Structure

The general arrangement plan for the off shore barge mooring facility (Figure 38) identifies the overall geometry of the barge mooring facility with respect to the waste water treatment facility, along with the anticipated barge locations.

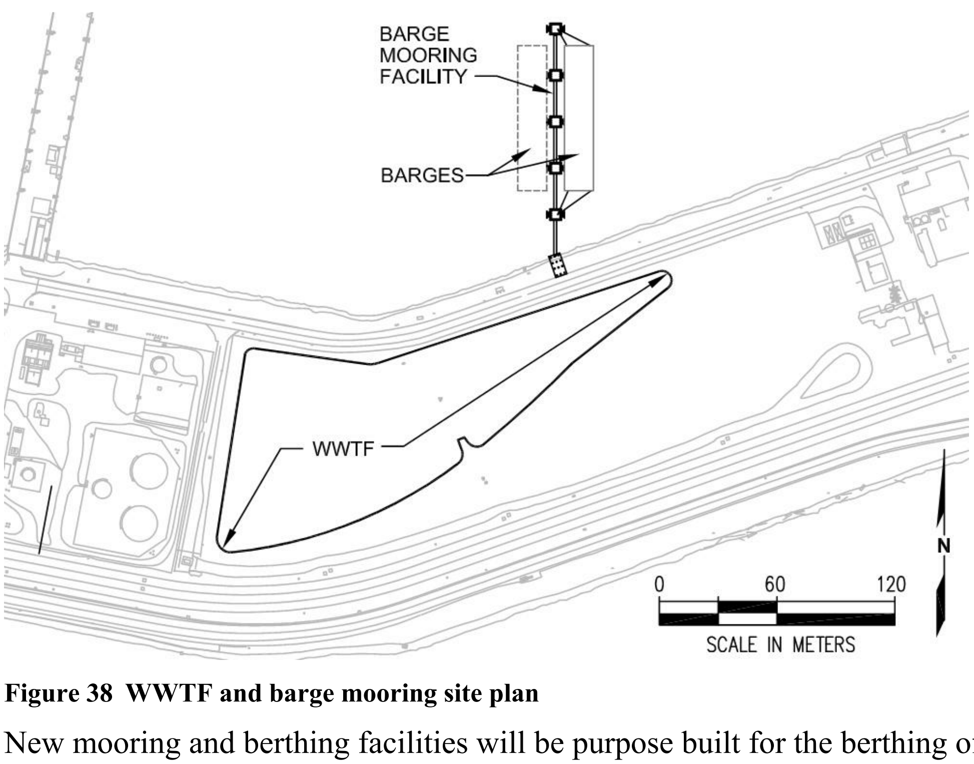


Figure 38 WWTF and barge mooring site plan

New mooring and berthing facilities will be purpose built for the berthing of the ballast water barges. The location of the mooring facility was chosen based on available land at the Port of Long Beach, for its proximity to the terminals, and the equidistance travel between the two terminals of study. The new facility will allow up to two barges to be moored in place for the offloading of the ballast water to the shore based waste water treatment facility.

The barge mooring facility geometry consists of the construction of five mooring dolphins equally spaced from the shoreline. Access to the mooring dolphins will be through a 1.5 meter wide pedestrian bridge structure constructed of aluminum Figure 39.

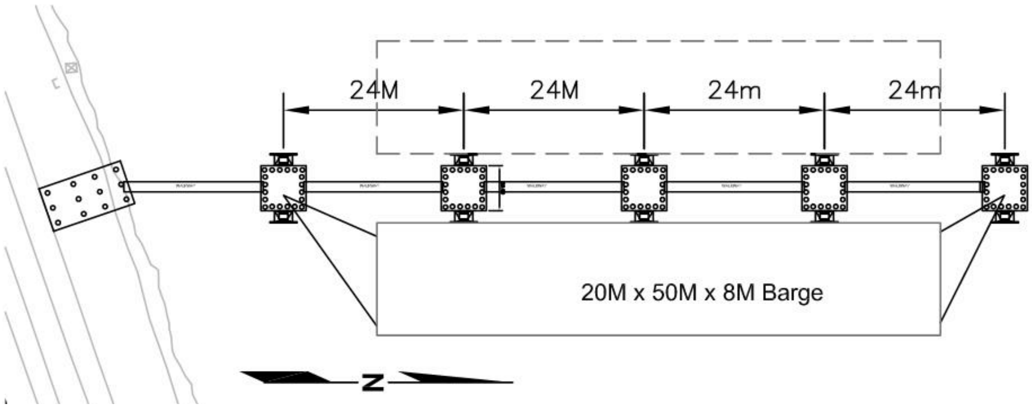


Figure 39 Barge mooring facility site plan

A mooring dolphin is a man-made marine structure that extends above the water level and is not connected to shore. Dolphins are usually installed to provide a fixed structure when it would be impractical to extend the shore to provide a dry access facility, for example, when ships (or the number of ships expected) are greater than the length of the berth/pier.

The mooring facilities will be constructed using the standard materials and practices of construction within the Port of Long Beach and will consist of cast-in-place concrete caps atop of 600mm octagonal precast concrete piles. Based on previous experience in the Port of Long Beach, the concrete piles will be driven to a tip elevation of -24m MLLW (Mean Lower Low Water). The tops of the mooring dolphins will be located at elevation +4.5m MLLW.

The mooring dolphin equipment will include mooring bollards (for securing the barges to the mooring dolphins), fender piles (for berthing of the barges against the mooring dolphins), and marine unloading arms (for the conveyance of the ballast water from the barges to the mooring dolphins). Fender piles were chosen over fender panels as a mooring option due to the deep draft of the barges and shallow freeboard (Figure 40).

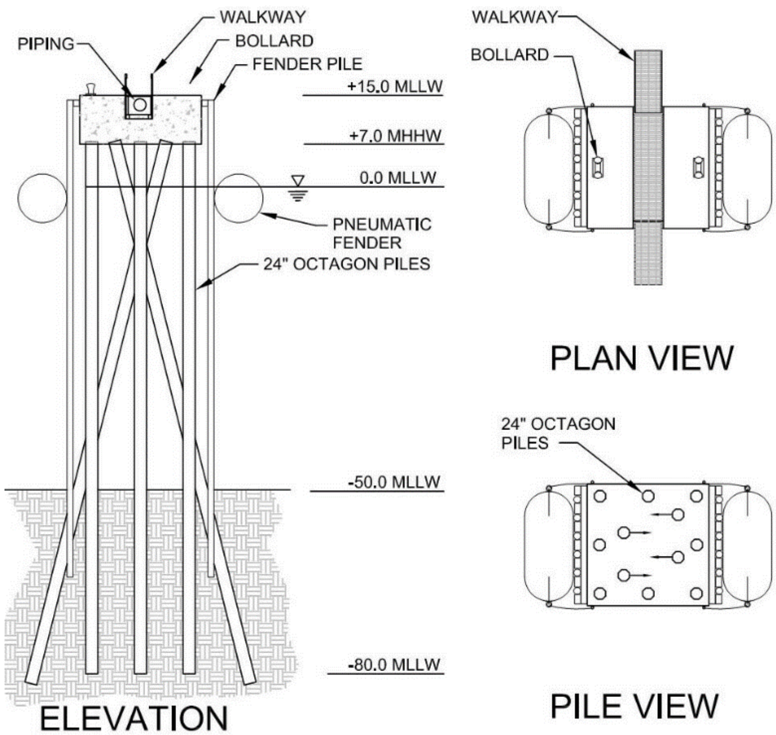


Figure 40 Barge mooring facility dolphin

3.5.3.4 Conveyance from Barge to Lift Station

Conveyance of the ballast water from the barges to the landside ballast water connection will be though the use of two potential methods: marine loading arm, or a barge-based flexible hose connecting the barge to the landside ballast water connection.

The use of a marine loading arm was researched as a viable method of unloading ballast water to the landside. The marine loading arms have limited movement and therefore requires that the ship, or barge, must be located at the same mooring location every time for the marine loading arm to be effective. Since the barges mooring facility is a dedicated facility, the barges are the same size, and the barges will be mooring at the same location each time the use of a marine loading arm is the best method for unloading of the ballast water. In addition, the marine loading arm requires a large area in which to be located and operate and the mooring facility can accommodate these requirements.

The barges will be equipped with flexible hoses and cranes for the taking on ballast water from the ships. Utilizing the barge-based crane and hoses for unloading operations of the ballast water from the barge to the mooring dolphins is equally effective as the marine loading arm and can be used as a substitute method for the unloading of the ballast water.

Based on the anticipated flow of 1,400 m3/hr, a maximum flow velocity of 12 meters per second (OCIMF maximum flow rate), and operational limitations of handling a flexible hose, the minimum calculated hose size of 200 mm in diameter was selected. The flexible hose assembly was identified as a DN200 (200 mm in diameter) smooth bore hose with flanged connection hardware. The hose must be capable of sustaining 190 kPa pressure and meet UL abrasion and UV resistance requirements.

Piping from the marine loading arm to the waste water treatment facility will be by way of steel piping below the 18.3 m long interconnecting walkways between the dolphins. The piping will terminate at the wastewater treatment facility and lift station location.

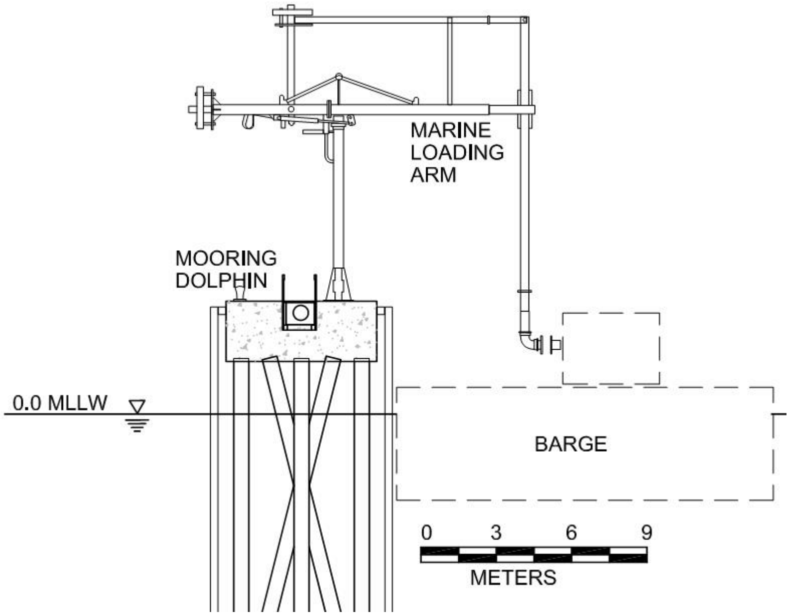


Figure 41 Hose handling crane on dolphin

3.5.3.5 Landside Lift Station

Pumping of the ballast water from the barges to the WWTF will be through the use of barges' onboard pumps that will elevate the ballast water to the barge's presentation flange connection located on the main deck. From this location, the ballast water will be pumped under pressure to the landside lift station.

Based on initial estimates of piping pressure, flow rates, and length of run, it is anticipated that a landside lift station will be required to convey the ballast water from the barge to the treatment facility through the use of a force main. Discussions of the booster pump/lift station will be made in the Task 4 report, Reference 3.

3.5.4 Cost Estimate

Based on the specifications above, the cost of constructing the mooring facility at the Port of Long Beach Navy Mole for ballast water treatment was determined to be $25,050,000. This estimate assumes that construction of the new mooring facility will not impact adjacent terminal operations.

Table 17 Summary of Ports of Long Beach/Los Angeles wharf modification cost estimate

Location	Ballast Capacity (m^3)	Modification	Cost
Port of Long Beach – Cruise Terminal	24,000	Ballast Transfer Connection Stations, Marine Loading Arms (Each)	$1,000,000
Port of Long Beach - SA Recycling		Mooring Facility.	$6,660,000
		Piping from Mooring Facility to WWTF	$420,000
		Equipment: Barges ($5,650,000 Each)	$11,300,000
		Regulatory Review	$250,000
		Engineering	$1,550,000
		Contingency 20%	$3,870,000
		Total	**$25,050,000**

Appendix A Cost Estimates