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DELTA STEWARDSHIP COUNCIL

Kennedy/Jenks Consultants

SHORE-BASED BALLAST WATER TREATMENT IN CALIFORNIA

TASK 15a: SUMMARY REPORT

PREPARED FOR

DELTA STEWARDSHIP COUNCIL
SACRAMENTO, CALIFORNIA

23 APRIL 2018
FILE NO. 15086.01
REV. A

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Revision History

Section	Rev	Description	Date	Approved
All	-	Released as final.	10 April 2018	KJR
All	A	Minor updates to formatting, adding titles to several figures and tables.	23 April 2018	KJR

References

1. *Shore-Based Ballast Water Treatment in California: Memorandum on Scale-up of Land-based and Barge-based Alternatives*, Glosten, Rev. -, 6 April 2017.
2. *Shore-Based Ballast Water Treatment in California, Task 2: Assessment of Retrofitting Vessels,* Glosten, Rev. -, 10 April 2018.
3. *Shore-Based Ballast Water Treatment in California, Task 3: Assessment of Retrofitting Ports and Wharves,* KPFF Consulting Engineers, Rev. -, 10 April 2018.
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5. *Shore-Based Ballast Water Treatment in California, Task 5: Assessment of Treatment Technologies,* Kennedy/Jenks Consultants, Rev. -, 10 April 2018.
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Executive Summary

The Ballast Water Challenge

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 California's Interim Ballast Water Discharge Performance Standards (CA Interim Standards), a more stringent set of standards than the international and US federal standards.

There has been significant development work and widespread commercial installation of ballast water management systems (BWMS) onboard marine vessels themselves. However, there remains significant debate on the ability of shipboard BWMS to reliably meet the CA Interim Standards (see References 15, 18, 21, and 27). As an alternative, shore-based reception and treatment is under consideration as an approach to meet the CA Interim Standards.

Study Approach

This two-year study evaluated the feasibility of implementing shore-based ballast water reception and treatment in California. The study was broken into thirteen separate tasks which are summarized in this report under the five sections shown in Table 1. The reader is encouraged to read the task reports themselves for more in-depth analysis, calculation, and background.

Table 1 Category for each task report in study

Task	Description
Literature Review	
1	Literature search on shore-based ballast water management.
Case Studies	
-	Interim memorandum scaling-up findings in Tasks 2 – 5 to assess the cost and practicality of land-based vs. barge-based alternatives for California.
2	Assess feasibility and required retrofitting of marine vessels to transfer ballast water to shore.
3	Assess modifications to ports and wharves to receive ballast water from marine vessels.
4	Assess shore-based alternatives for conveyance, storage, and treatment of ballast water.
Technical Feasibility	
5	Determine if shore-based treatment technologies could meet the CA Interim Standards.
6	Assess impact of ballast water outfalls and solid waste disposal from shore-based facilities.
7	Summarize pertinent permitting and legal requirements.
8	Comparative review of shipboard vs. barge-based ballast water management operations.
9	Assessment of current practices related to ballast water discharges in California.
Economic Feasibility	
10	Cost analysis of implementation from shipping industry and treatment operator perspectives.
12	Market implications.
Implementation	
11	Implementation timeline.
13	Additional findings, focusing on concept of statewide network of mobile treatment barges.

Study Team

Glosten, a naval architecture and marine engineering consultancy, led the study and provided expertise on marine vessel design and operations. The primary subcontractors were Kennedy Jenks, experts in shore-based wastewater treatment plants, and KPFF, experts in port logistics and design. Additional subcontractors were King and Associates, expert in economics, and Dr. Nicholas Welschmeyer, expert in marine biology and ballast water treatment. This grouping was carefully selected to ensure that team expertise covered the scope of the assessment from marine vessels to ports and wharves to shore-based treatment plants. A peer review process in which each task report was drafted by one entity and peer reviewed by another was implemented to minimize bias based on expertise.

The study was administered by Delta Stewardship Council (DSC). DSC formed an independent expert panel of six members with expertise in wastewater treatment, economics, marine vessel design, and marine biology. The independent expert panel reviewed drafts of all reports, providing written comments that were taken into account for each final task report. DSC hosted three public workshops where the public and the independent expert panel offered comments on the draft task reports.

Feasibility of a Shore-based Solution

A case study approach evaluated five California port locations for implementing a shore-based solution. Studied shore-based solutions included barges, land-based piping systems, new treatment facilities, and using existing publicly owned treatment works. Statewide application of a land-based system of piping, storage tanks, and treatment plants was found to be impractical, as each instance presents unique arrangement, land-use, and permitting challenges. Further, a shore-based barge solution was found to be five to eleven times less costly. A shore-based network of ballast water treatment barges therefore yielded the most cost-effective and practical means to receive, treat, and discharge most ballast water discharges in California to the CA Interim Standards. In practice, it is likely that a few port locations will not use a barge, but will instead develop a land-based solution.

However, verification of this plan first requires prototyping and trialing of the proposed solution. In addition, implementation requires discharge permits to be obtained, the barge network to be built and staffed, and thousands of marine vessels, domestic and foreign, to be outfitted with ballast water transfer stations. An expected four years of development are required before shore-based treatment can start a five-year phase-in period, for a nine-year total implementation timeline.

An estimated twenty-four purpose-built barges would operate in service zones covering the entire state, with capacity to service the estimated 1,556 marine vessel ballast water discharges at an availability rate of 99%. Ballast water would be transferred from the discharging marine vessel to the barge by means of a hose, treating the ballast water as if it was a petroleum product with no leaks or spills allowed.

The proposed treatment barge network is expected to be reliable and to provide the theoretical biological inactivation/removal efficiency to meet the stringent CA Interim Standards. While the benefits are not quantified herein, the reduction in anthropogenic ballast-based invasion risk is expected to scale in direct proportion to the improved efficiency of barge-based ballast treatment relative to achievable shipboard treatment. This invasion risk reduction, however, comes with increased air pollution, port congestion, and potential downtime in cargo transfer rates. The required treatment plant requires six times the energy of shipboard ballast water treatment systems that meet the federal standard. In addition, the tug boats that move the barges also produce air emissions. In the case of the South Coast Air Basin, these shore-based ballast water treatment activities could increase overall harbor craft air emissions by 2.5% to 5%.

The 30-year lifecycle cost of building and operating a network of ballast water treatment barges capable of treating all ballast water discharged into California waters is estimated at $1.45 billion. Marine vessel operators will bear an additional $2.17 billion in costs to retrofit with the new transfer stations along with undetermined labor costs to support the transfer operations.

These costs are likely to be concentrated on a small percentage of marine vessels, have the largest impact on cargo exports, and disproportionately impact remote and low volume ports within California. As an example, under port-specific break-even pricing assumptions, a dry bulk carrier taking on grain exports in Stockton would need to pay an estimated $120,000 in order to offload its ballast water. This additional expense would be passed on directly to cargo exporters in California and points east, potentially diverting cargo to other California or non-California ports, or potentially rendering it non-economical to ship certain agricultural and other price sensitive products. Avoiding such impacts would require establishing policies such as price-sharing or cost-sharing across all California ports.

Next Steps

This study is provided to support policy decisions in California related to the consideration of a shore-based ballast water reception, storage, and treatment network. Should a decision to move towards implementation be made, a detailed program plan is recommended in order to coordinate a complex and interdependent set of tasks. Key tasks include:

- Perform a demonstration project that includes one large and one small treatment barge and at least one low- and one high-transfer-rate marine vessel modification. The project would develop and demonstrate hardware and procedures for making the barge-ship connections, assess the efficacy and costs of the barge treatment plant, and evaluate the barge effluent characteristics.
- Secure permits for the operation of the planned barge network, including study and characterization of the ballast water effluent and solids disposal.
- Develop a ballast water transfer station standard. This might include coordination with the International Standards Institute (ISO) so that vessels may use the same connection in other ports, should other locations also implement this practice.
- Establish requirements and timeline for marine vessels that will discharge ballast water in California to be outfitted with compliant ballast water transfer stations. Such modifications are only practical during a ship's drydocking period, which are typically on a five-year schedule. As such, it will take at least five years from implementation for all vessels to achieve such connections.
- Establish a public-private partnership model to incentivize one or more commercial entities to build and operate a network of treatment barges. This should include close interaction with port facilities on issues of berthing and servicing these barges. This should revisit the zoning of the barges to find an optimal solution.

This study analyzed only the cost side of the cost-benefit balance. Further study might consider the benefit of treating ballast water to the CA Interim Standards as compared to the US federal standard. Such a study might also consider the benefit of a potentially more reliable system, as a system of only twenty-four barge-based treatment plants will likely experience fewer failures than a system of plants dispersed throughout thousands of marine vessels.

Section 1 Definitions

ATB	Articulated Tug Barge
AWL	Height Above Waterline
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, or water outside of 50 nautical miles for coastal voyages, 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.
BWM	Ballast Water Management
BWMS	Ballast Water Management System
BWTB, BWT Barge	Ballast Water Treatment Barge
Capture	Capture is the method by which ballast water is transferred onto or off a marine vessel.
Discharge	Discharge of ballast water is the method by which post-treatment ballast water is disposed of in compliance with applicable standards and regulations.
EPA	Environmental Protection Agency (US, unless otherwise noted)
Filtrate	Water that has been separated from any particulate matter (used to clean ballast water treatment filters).
IMO	International Maritime Organization
ISO	International Organization for Standardization
L	Liter
Lift Station	Means of receiving a liquid, typically from a drain or low-pressure piping, and 'lifting' it with pump(s) to a different location such as a remote tank.
Lightering	Cargo transfer between vessels, commonly practiced to reduce a vessel's draft before entering port.
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
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.
NBIC	National Ballast Information Clearinghouse

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 Pollutant Discharge Elimination System
O&M	Operations and Maintenance (cost)
OCIMF	Oil Companies International Marine Forum
POTW	Publicly Owned [Wastewater] Treatment Works
Residuals	Particulate matter, or dissolved chemicals, 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)
Shipboard Ballast Water Treatment	Ballast water management approaches that do not require support from shore-based infrastructure and are conducted entirely by a vessel's crew.
Shore-Based Ballast Water Management	Ballast water management approaches that require support from shore-based infrastructure in order to meet ballast water management requirements. Such infrastructure may include: means of transferring ballast water to a land-based or another marine vessel facility for storage and/or processing, deployment of shore-based equipment and personnel for onboard treatment approaches, etc.
Slurry	Mixture of filtrate and filter residuals resulting from cleaning ballast water treatment filters.
Slurry Handling	Slurry handling includes activities related to the storage, treatment, and discharge of filtrate and residuals collected from cleaning ballast water treatment filters.
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.
TEU	Twenty-foot Equivalent Unit commonly called a twenty-foot shipping container
TRO	Total Residual Oxidant
UF	Ultrafiltration
USCG	United States Coast Guard
UV	Ultraviolet Light
WWTP	Waste Water Treatment Plant

Section 2 Literature Review (Task 1)

The following three key themes emerged during review of the literature regarding shore-based ballast water reception and treatment feasibility in California.

Shore-Based Reception and Treatment Approaches

The majority of ballast water reception and treatment approaches considered in the past decade are mobile systems – retrofitted marine vessels or truck trailers outfitted with the necessary equipment for capture, treatment, and, in some cases, storage of ballast water. Additional approaches that have been studied include: new land-based treatment and reception facilities, use of existing wastewater treatment plants, and reception and reuse of ballast water. Relevant findings include:

- For a land-based facility, once the ballast water is collected, it may no longer be considered "ballast water," so different effluent restrictions might be applicable.
- The salinity of the ballast water may make using an existing waste water treatment plant impractical. This requires careful review.
- Marine vessel-based or land-based mobile approaches offer significant flexibility to support the port operations of certain locations. Careful consideration of operating and transportation expenses should be considered for this approach.

Port Logistics

Implementing a shore-based treatment approach may negatively impact the logistics of operating a port, varying considerably on the ballast water reception approach and the levels of activity/congestion currently experienced by any given port. Key factors include aligning the marine vessel with the shore-based ballast water transfer station, the method and volume of ballast water to store and treat, and the handling of the treated ballast water effluent and residual slurry. Relevant findings include:

- Further research is needed to understand the extent to which marine vessels discharge ballast water offshore during cargo lightering operations or while transiting to port, and the applicability of regulations on such practices.
- The extent and expense of new port infrastructure will vary greatly depending on the reception and treatment approach and the particulars of the marine vessel ballasting practices for that specific port.
- Ballast water storage facilities can increase port operations flexibility and level ballast water discharge surges, but can significantly increase capital costs.
- Ballast water characteristics, such as salinity or transmittance, could be used in the identification of effective treatment technologies. However, it may not be possible to predict these characteristics as the source of where the ballast water is coming from is not correlated to the port location where the ballast water discharge is taking place.
- It appears to be feasible to dispose of remaining sediments from the treatment process to a landfill, requiring trucks to move the sediment.

Vessel Modifications

Marine vessels intending to use shore-based reception and treatment approaches may require modifications, such as retrofits to piping systems and installation of a universal connection for transfer to shore-based infrastructure. Relevant findings include:

- Vessel modifications can range from tens of thousands to upwards of millions of dollars, depending on vessel type and pre-existing pumps and piping systems.
- A reliable connection between the marine vessel and the shore-based approach is essential to prevent leaks of untreated ballast water.

Section 3 Case Studies

Each year, California's 30+ port locations see approximately 1,500 marine vessel discharge events that total an estimated 12.4 million cubic meters of ballast water. There are an estimated 180 unique ship berths within these ports, and these discharges are from an estimated 800 unique marine vessels of which 415 are calling in California for the first time in at least five years. Each terminal presents unique space and arrangement challenges. There is a significant range of marine vessel characteristics that affect the practicality of transferring ballast water to a shore-based facility. The ballast water itself comes off marine vessels at rates between 350 and 3,400 cubic meters per hour and volumes from less than 10 to more than 40,000 cubic meters.

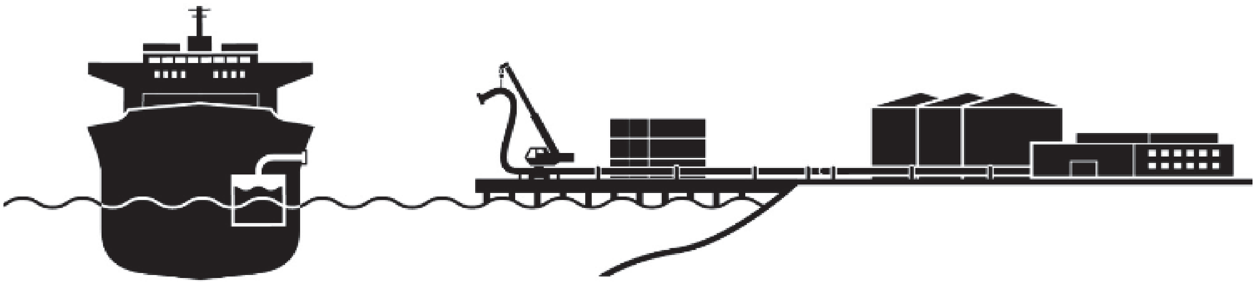


Figure 1 Case studies

A case study approach was implemented in order to develop a set of practical worked examples of transferring ballast water from marine vessels to shore-based facilities for treatment. Five case studies were selected to represent the range of vessel types, berths, and challenges.

Table 2 Case Study Summary

Case Study	Methods Explored	Marine Vessels	Shore Reception Ballast Capacity
Port of Stockton, East Complex	New pipeline to exiting treatment plant	Bulk carriers	34,000 m3/day
Port of Oakland, TraPac Terminal	New pipeline to new on-site treatment plant	Containerships	22,500 m3/day
Port Hueneme, South Terminal Wharf 1	On-site storage with mobile treatment	Car carriers	4,000 m3/day
El Segundo Offshore Marine Terminal	Barge-based reception and treatment	Tankers and ATBs	32,000 m3/day
Ports of LA/LB, SA Recycling and Cruise Terminal	Barge-based reception to off-site treatment	Cruiseships and Bulk carriers	26,400 m3/day

The source data was obtained from the National Ballast Information Clearinghouse (NBIC) (Reference 25), which is a partnership between U.S. Coast Guard and Smithsonian Environmental Research Center. This database was queried multiple times between 2015 and

2018. Data was collected on ballast water discharges in California between 2010 and 2015, inclusive.

3.1 Retrofitting and Outfitting of Marine Vessels (Task 2)

In order to use a shore-based ballast management system, every calling ship must be able to pump its ballast water to a piping connection where shore facilities can receive and process the ballast water. Feasibility considerations include: ballast water flow rates, volumes, and pressures delivered to shore facilities; available vessel deck space and arrangement impacts to make the shore connection; changes and additions to shipboard operational procedures; and costs. Required vessel modifications include: new exterior pipe manifolds, piping of ballast water to the manifold, and relocation of equipment that interferes with the new transfer station.

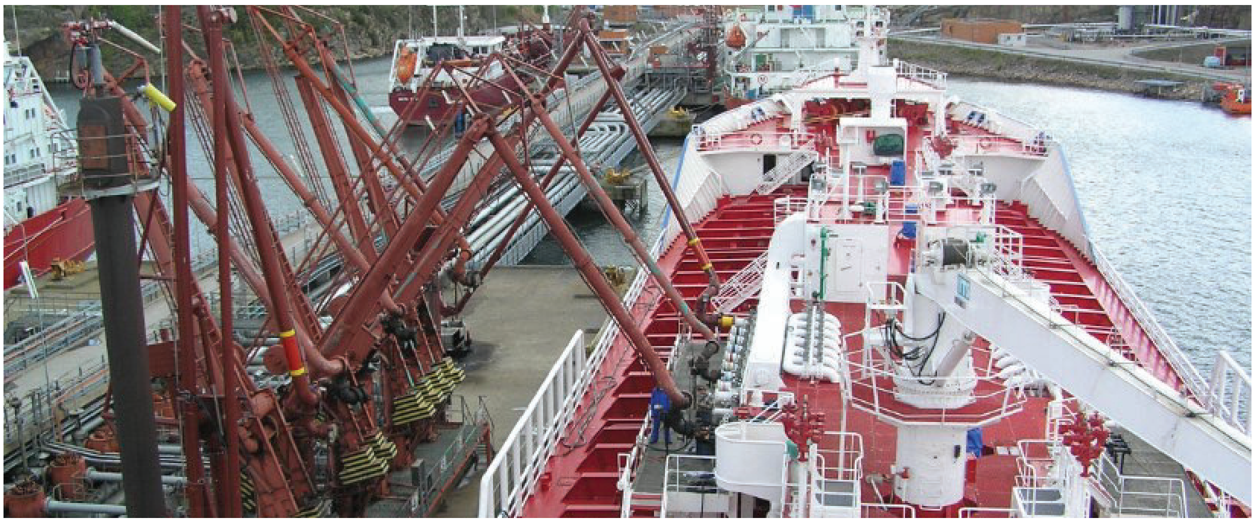


Figure 2 Brofjorden, Sweden marine terminal. Loading arms are similar in size to that needed for SA Recycling's ballast water handling operations, but smaller than required for Stockton or El Segundo case studies. (source Marcus Bengtsson, wikicommons)

3.1.1 General Modifications and Operational Considerations

The offloading of ballast water from a marine vessel to a shore-based facility requires an external connection. As outlined in Figure 3, below, such a connection can be made at a main deck manifold, at a side port similar to those used on passenger cruise ships and car carriers, or at a hull fitting similar to existing overboards. However, existing overboards are impractical as a connection cannot be effectively sealed to prevent leaks.

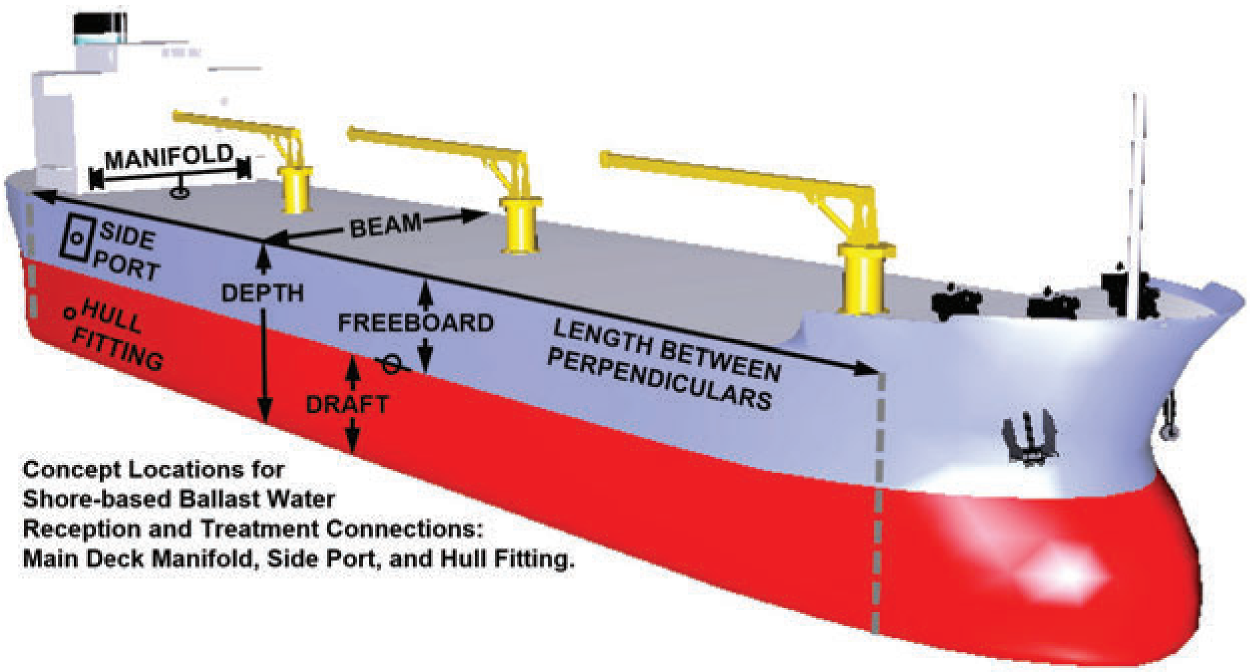
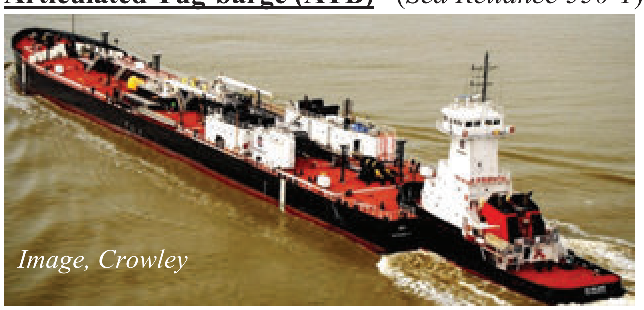


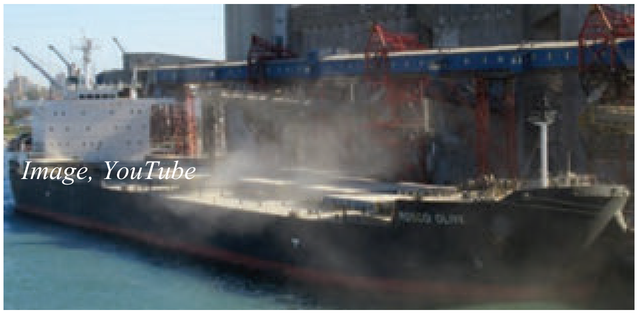
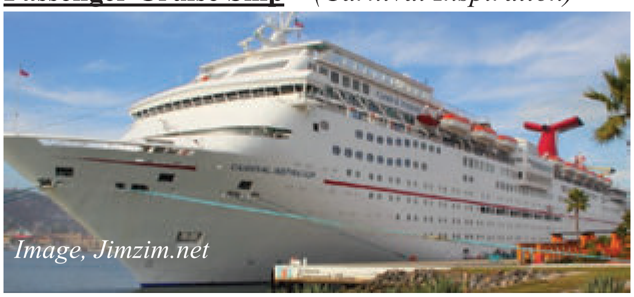
Figure 3 Marine vessel particulars used in analysis, and concept locations for ballast water shore connection fittings

3.1.2 Vessel Types

The vessel modifications required to transfer ballast water to shore-based treatment or conveyance systems for six different vessel types as detailed in Table 3 below. These images are typical for these vessel types, and are vessels that have discharged ballast water in their respective case study locations within the last few years.

Table 3 Vessel type examples in assessment

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

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

The ballast water discharge characteristics were determined for each of these vessels types, particular to those that call at specific case study locations that are representative of California in general. The assessment assumes no reduction of the vessel types' ballast rates, and requires modifications in order to support operations at any port of call in California or elsewhere that might consider shore-based ballast water treatment.

3.1.3 Methods

The specific marine vessels that discharged ballast water in each of the case study locations were identified using the NBIC database (Reference 25). The particulars of these vessels were then located in the ABS Record® database (Reference 16). These vessels were then analyzed in terms of vessel type and ballast water volumes. A model was then developed for each vessel to estimate likely range of arrangements and ballast water hydraulic characteristics. This was then used to estimate a 90% range of operations in terms of discharge volumes and rates to be used in developing case study solutions for reception, storage, and treatment. These totals were then cross-referenced to all ballast water discharges over the last five years in California to ensure that the range of vessel types and ballast water discharges were covered in the case studies.

The resulting arrangement and hydraulic models were then used to develop retrofitting specifications for each vessel type to support offloading of ballast water. A cost estimate was then developed for each.

3.1.4 Summary of Findings

Outfitting marine vessels for ballast water transfer to shore-based facilities is highly dependent on the marine vessel's arrangements and the rate of ballast water discharges. The retrofitting cost required for marine vessels to enable offloading of ballast water to shore-based reception facilities is estimated in Table 4 below. In many cases it will be very challenging to fit a new ballast water transfer station on marine vessels that are already full of equipment. The transfer operation is similar to the transfer of liquid petroleum products which have existing standards and procedures that can be adopted for ballast water.

Table 4 Modification costs by vessel type and size

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

3.2 Retrofitting of Ports and Wharves (Task 3)

The concept explored in the case studies is the refitting of California ports and wharves with the ability to connect a hose to each marine vessel and a network of piping and pumps to transfer the received ballast water to a treatment plant. In addition, the concept of using a barge to make the connection and reception was explored. The case study ports/terminals are highlighted in the table below.

Table 5 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

3.2.1 Methods

Data for this assessment was collected from the NBIC database (Reference 25) and compared to the particulars of the specific vessels that called at these locations using the ABS Record® (Reference 16).

Each of the subject terminals and ports were researched for available vacant space and locations 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 those ports. Reported vessel discharge data were then examined to estimate the practicality and cost of any new infrastructure required on-shore. The assessment includes:

- 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.

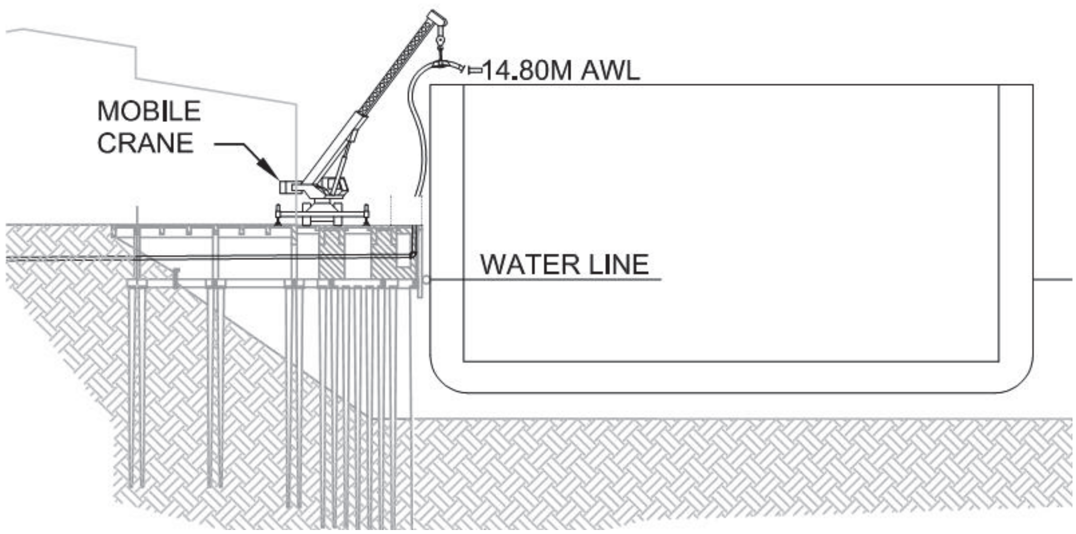


Figure 4 Example wharf cross-section with bulk carrier

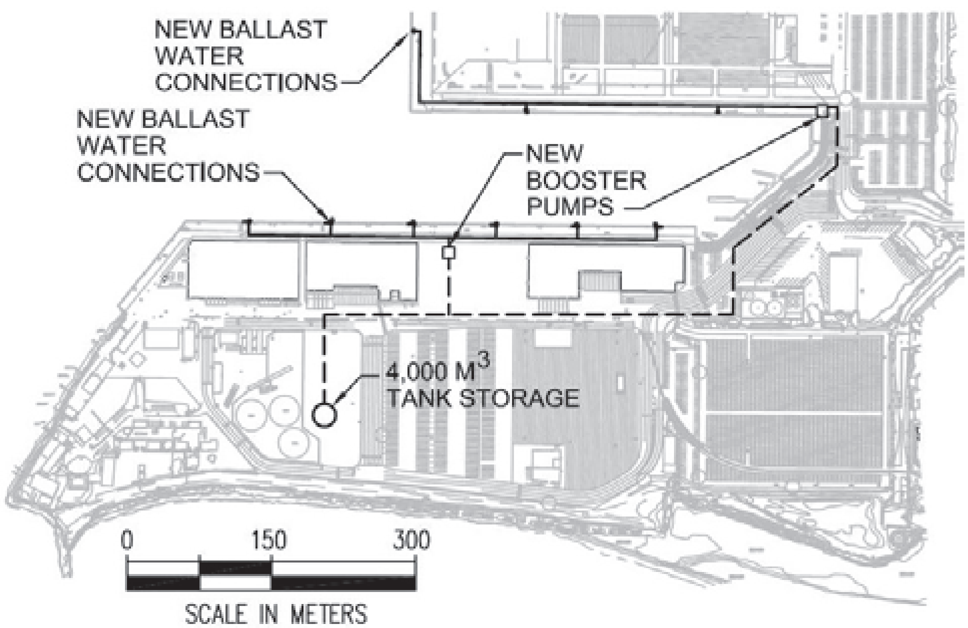


Figure 5 Example wharf arrangement plan

3.2.2 Ship-to-Ship Offloading of Ballast Water

Ship-to-ship (STS) offloading of ballast water to a treatment barge was found to be practical based on the common precedents 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).

On the low end of existing transfer rates would be cruise ship and car carrier ballast water discharges which are similar to existing marine vessel bunkering operations. On the high end would be ballast water transfers at the El Segundo case study of 34,000 cubic meters at a rate of 3,400 cubic meters per hour, which is similar to some tanker cargo transfer rates. The below table provides visual images of typical STS arrangements.

Table 6 Ship-to-ship transfer examples

STS Example	Description
Tug and Barge Servicing Marine Vessel 	Tug and barge servicing marine vessel with hoses. Likely 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.
Ship-to-ship Transfer 	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.

3.2.3 Summary of Findings

After examining the technical, logistical, and economic aspects of both a barge-based solution and a land-based solution at various CA ports a barge-based solution was determined to bebemore practical and cost-effective than a land-based solution at all but a few ports. The land-based solutions faced logistical and challenges associated with existing mooring lines, the movement oftrucks and cargo handling equipment and, most importantly, competing space for the needed piping network. Further, there are certain off-shore terminal locations where only a barge-based solution is practical. It should, however, be noted that there will be some exceptions. In some ports there is little room for barges to tie-up alongside marine vessels, making a land-based connection necessary.

Cost estimates for each case study location are summarized in Table 7 below. These costs are limited to the specific locations noted which weresometimes just a few berths within a larger complex. The costs include modifying wharves and routing pipelines to convey the ballast water to the storage and treatment facilities assessed in Tasks 4 and 5 (References 4 and 5).

Table 7 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 POLB)

3.3 Shore-based Treatment Facilities (Task 4)

The received ballast water, whether it is transferred to a land-based piping network or a barge-based facility it will requirestorage and treatment in order to meet the CA Interim Standards. The various options were accomplishing this were studied for each case study location.

For each option the study addressed technical and engineering challenges, and developed estimates of costs for construction and ongoing operation and maintenance of ballast water pump stations, pipelines, and new stationary, barge-based and truck-based WWTPs. The Stockton case study examined the technical and economic feasibility of using an existing municipal Publicly Owned Treatment Works (POTWs) for treatment of ballast water, and the modifications estimated to be necessary. Finally, reuse of ballast water was considered.

3.3.1 Methods

Preferred ballast water storage and treatment system layouts, with associated rough order of magnitude (ROM) construction costs for ballast water conveyance, storage, and treatment were developed considering available facility footprints, ballast water discharge rates and frequencies, and the case study-specific goals identified previously. In general, the evaluation included:

- Assessment of instantaneous ballast water discharge flow rates necessary to size pump stations and pipelines required to meet facility and vessel-specific operational needs.
- Consideration of daily maximum discharge rates for each facility to size ballast water equalization tanks and treatment equipment.

- Consideration of facility-specific operational areas dictating the space available for storage and treatment equipment.
- Assessment of the adequacy of the Port of Stockton regional municipal wastewater treatment plant for treatment of ballast water flows and to achieve specified water quality goals.
- Development of rough order of magnitude (ROM) cost estimates for ballast water conveyance, storage, treatment, discharge, and anticipated ongoing operation and maintenance (O&M).

3.3.2 Ballast Water Storage and Treatment Approaches

Two ballast water treatment approaches were evaluated for construction of new facilities. The first approach, applicable at the Port of Oakland TraPac facility and the ballast water facility serving SA Recycling and the Long Beach Cruise Terminal, would employ permanent shore-based tanks for ballast water flow equalization and a centralized ballast water treatment facility equipped with coagulation, flocculation, sedimentation, membrane filtration, and chlorine contact basins.

The second approach utilizes smaller truck- and barge-based treatment systems using membrane filtration and UV disinfection as the primary unit treatment processes. At Port of Hueneme, shore-based permanent storage tanks serviced by truck-based treatment would be employed and at El Segundo flow equalization and storage would be provided on a barge also housing treatment equipment.

A third treatment approach including modification of a POTW adding necessary equipment to meet the CA Interim Standards was considered for the Port of Stockton.

3.3.2.1 Sizing Storage and Treatment Facilities

Wastewater treatment plants use storage to manage surges in influent flow (e.g. while ballast water is being discharged) and maintaining treatment during interim lower flow periods (e.g. between discharge events). As a general rule, assuming adequate space is available, increasing storage capacity and reducing the size of treatment equipment reduces cost and the total area needed for treatment. To evaluate if increasing storage resulted in lower cost and smaller footprints for ballast water treatment, the storage volume, footprint, and capital costs were assessed over a range of treatment times (defined as time needed to treat a port’s daily ballast water discharge volume).

Footprint and capital costs decrease with increasing storage and treatment times. The smallest footprint and capital cost for all ports studied is based on this finding of a 24-hour treatment cycle, rather than sizing for treating on a 12-hour daily work schedule. Thus, the storage and treatment equipment capacities for each shore-based case study were selected to treat the maximum daily discharge over a 24-hour period unless described otherwise.

3.3.2.2 Reuse and Recycling of Ballast Water

It may be feasible in some locations to reuse and recycle ballast water. This is generally applicable in locations where the volume of ballast water being discharged by one group of marine vessels is similar to the volume being taken-up by other marine vessels. An example of this would be a container terminal where an arriving ship could discharge 2,000 tons of ballast water to a holding tank. That water is then later transferred to a second ship, either at the same berth or one nearby, that needs to take-on that 2,000 tons of ballast water.

This operation has some practical applications in a limited set of locations and circumstances.. This study has not developed an estimate of how frequently this type of operation might take place because including this option would not significantly alter study findings due to the following:

- The cost for the transfer stations, piping, and storage tanks to receive the ballast water will be the same for reception and reuse as it would for reception and treatment.
- It would be unusual for the amount of ballast water to be discharged from marine vessels to be the same as the amount needed from other vessels to be taken up. As such, a treatment plant would be needed to make up this difference in mass balance. While the plant would be smaller, there would still be significant costs.
- Reuse and recycle would require that marine vessels that are taking up ballast water would have to have a ballast water transfer station. This would be a significant cost on these vessels. In addition, the number of transfers of ballast water to shore-based facilities would effectively double in order to include both ballast water discharges and ballast water uptakes.

Reuse and recycling should remain a consideration, but would not likely result in a significant state-wide reduction in costs.

3.3.3 Summary of Findings

ROM estimated costs for construction of conveyance, storage, and treatment equipment are provided in Table 8 below.

Table 8 Ballast water conveyance, storage, and treatment summary

Case Study	Conveyance & Treatment Approach	Max Daily Discharge (m^3)	Storage Required (m^3)	Capital Cost ($M)
Stockton, East Complex	New pipeline to POTW & new onsite or offsite tank	34,000	NA	>$50
Oakland, TraPac Term.	New pipeline to new onsite WWTP	22,500	13,600	$28.4
Port Hueneme, South Terminal Wharf 1	Onsite storage & mobile shore-based treatment	4,000	4,000	$10.0
El Segundo Marine Terminal	Offload to mobile, marine vessel-based storage & treatment	32,000	19,300	$29.4[6]
LA/LB, SA Recycling & Cruise Terminal	Offload to mobile marine vessel & new offsite WWTP	26,400	6,800	$12.7[7]

Section 4 Technical Feasibility

A shore-based network of ballast water treatment barges may provide a practical means to receive, treat, and discharge most if not all ballast water discharges in California to the CA Interim Standards. However, verification of this plan first requires prototyping and trialing of the proposed solution.

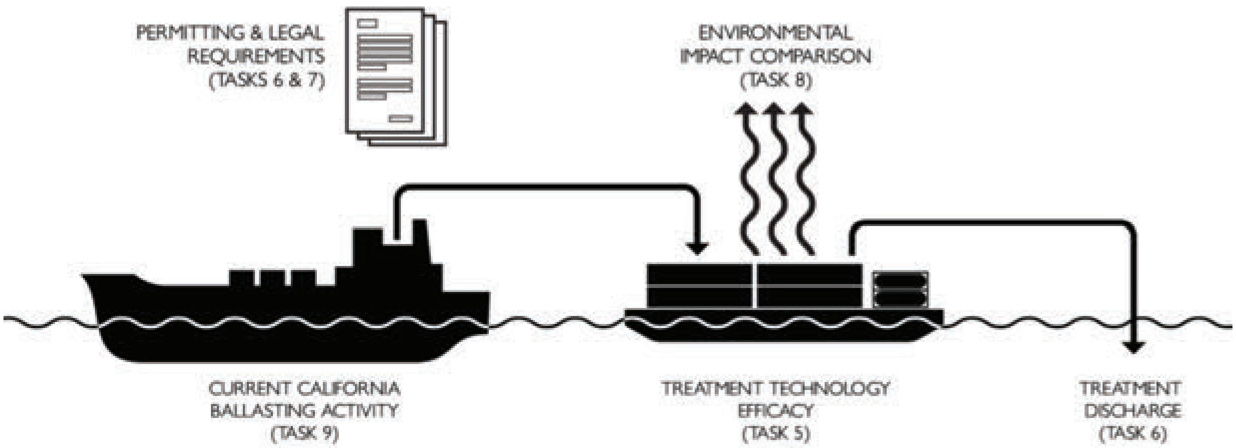


Figure 6 Assessing technical feasibility

The most significant unproven aspect is the ability of shore-based treatment plants to meet the CA Interim Standards, which prohibits the discharge from vessels of any detectable organisms over 50 microns in nominal dimension and includes stringent restrictions on smaller organisms and pathogens. Existing technologies have been identified and practically paired together that, from theoretical performance specifications, should meet this standard. They have been evaluated for placement aboard barges and sized to suit the required storage and treatment rates. A robust prototyping and trial period of not less than two years will be required to implement these concepts.

The effluent from the treatment barge, also known as the outfall, will be cleaner in terms of organisms and contaminants than the existing untreated ballast water discharges from marine vessels. From a practical perspective, these discharges will be in the same location in which they were collected, as it is not practical to receive and move the ballast water. It is expected that an NPDES permit can be obtained for these discharges, but this requires study and evaluation as part of the permit process.

As noted in the case studies section, it is possible to make the transfer connection between marine vessels and shore-based reception facilities. However, federal preemption would likely prevent California from requiring marine vessels to be outfitted with the needed ballast water transfer stations/equipment. Instead, California should consider supporting an international standard that would detail these requirements and look at enforcement of its interim standard with transfer to a reception facility as a viable alternative for marine vessels.

The shore-based network of ballast water treatment barges is a practical means to potentially meet the CA Interim Standards, which is more stringent than federal and international standards. This however, will increase the associated air pollution by six-times in comparison to treating the ballast water on the marine vessels themselves. For example, air emissions from harbor craft in the South Coast Basin would increase by an estimated 2.5% to 5% when implementing the barge-based ballast water treatment network.

There are very few vessels that cannot practically change their existing operations in order to offload ballast water to a ballast water treatment barge. There are in fact many examples of marine vessels that discharge ballast water while underway. However, most of these are elective for purposes of convenience. In the handful of non-elective discharges, the treatment barges can be used to meet the marine vessels and service these discharges.

With the focus on a barge-based ballast water treatment approach, the question of how treatment barges would be deployed must be addressed. This study recommends a zone approach, by which California State waters are subdivided into a number of smaller operating zones, with a dedicated fleet of treatment barges assigned to each zone. These implementation details are explored in detail in Section 6 below.

4.1 Treatment Technology Efficacy (Task 5)

Ballast water treatment technologies (physical, mechanical, and chemical), whether on shore or on barges, must be capable of removing or inactivating organisms to a level below the stringent concentration limit set forth in the CA Interim Standards.

There are standardized treatment approaches that should be able to achieve the CA Interim Standards, though it is noted that additional bench-scale and in-field testing will be required to verify the validity, performance, and reliability of the treatment approaches described.

4.1.1 Scope

All types of treatment technologies potentially available for shore-based reception facilities that could meet the CA Interim Standards were evaluated including how the efficacy of such systems can be measured. Work completed for each technology included:

- Description of the technology and its current state of development,
- Summary of any testing performed relative to ballast water treatment,
- Discussion of potential efficacy relevant to the CA Interim Standards,
- Methods for determining compliance of the effluent with the standard.

4.1.2 Summary of Findings

The CA Interim Standards present challenges in terms of detecting and verifying compliance. For microorganism (≤50 µm), the CA Interim Standards provide ballast water discharge levels in absolute concentrations. In contrast, the CA Interim Standards for larger organisms (>50 µm) state that those organisms must be undetectable in discharged water. This non-quantitative standard will present problems in enforcement since the total detected organism count will depend on the volume of sample analyzed. If the volume analyzed is too small the chances of 'no detection' will be quite high; California must restate, quantitatively, the sampling conditions expected for determination of organisms >50 µm.

Three physical methods (coagulation/flocculation/sedimentation, dual-media filtration, and membrane filtration), one mechanical method (UV disinfection), and three chemical methods (ozone disinfection, sodium hypochlorite disinfection, and electrochlorination disinfection) of ballast water treatment were studied in this report. The initial processes of coagulation/flocculation/sedimentation are routine in freshwater treatment of sewage and wastewater treatment. Here it is assumed that the frequent presence of gelatinous marine zooplankton such as jellyfish, larvaceans, salps and ctenophores would be compatible with the initial coagulation step without fouling the mechanical devices; however, this remains to be tested. The efficacy of each technology and combination of technologies to meet the CA Interim Standards was determined primarily using estimated log zooplankton (microorganisms > 50 µm), protist (50 µm ≥ microorganism > 10 µm), bacteria, and virus inactivation values. It was estimated 5-log removal of zooplankton, protists, and bacteria and 7-log removal of viruses would be required to meet the CA Interim Standards.

It was determined that the most effective method combination for ballast water treatment was coagulation, flocculation, and sedimentation followed by membrane filtration and UV or chemical disinfection. The microorganism log removal values for the individual treatment processes and treatment combinations are summarized in Table 9.

Coagulation, flocculation, and sedimentation offer negligible microorganism removal; however, they were included because they improve microorganism removal by dual-media and membrane filtration and provide a means to manage residual waste streams produced during filter backwashes. There is little information on the removal of zooplankton and protists by dual-media membrane filtration; however, 5-log removal by both technologies was assumed in this study due to the large size of zooplankton and protists compared to the size of particles removed in dual-media and membrane filtration. This would need to be confirmed through field testing. Membrane filtration was given credit for 3-log bacteria removal as demonstrated by Guastalli et al. (Reference 22); membrane filtration was not given credit for virus inactivation. Based on the available literature, it was found that the treatment trains including UV and chemical disinfection can achieve the required bacteria removal (5-log) but do not achieve the required virus inactivation (7-log).

The lower virus inactivations, 2- and 4-log for UV disinfection, were reported for UV doses of 100 and 190 mJ/cm^2. UV log virus inactivation has a linear relationship with the UV dose, which is a function of the UV lamp irradiance intensity and contact time (Reference 28). The EPA (Reference 28) provides tables summarizing UV dose requirements to achieve specific log virus inactivation. These UV doses are for fresh water, but should be applicable to ballast water since UV disinfection is not particularly affected by salinity, pH, or other water quality parameters not related to organic matter or suspended solids. By extrapolating from the EPA UV dose requirement table, the estimated minimum required dose to achieve 7-log virus inactivation would be 310 mJ/cm^2.

Table 9 Removal of regulated ballast water organism size class by proposed treatment steps and treatment trains

Physical Treatment		**Mech./Chem. Treatment**	**Total System Removal**
Coag./Floc./Sed. **Removal:** Org. > 50 µm = Low 50 ≥ Org. > 10 = Low Bacteria = Negligible Virus = Negligible	**Membrane Filtration** **Removal:** Org. > 50 µm = 5-log 50 ≥ Org. > 10 = 5-log Bacteria = 3-log Virus = Negligible	**UV Disinfection** **Removal:** Org. > 50 µm ≈ Low 50 ≥ Org. > 10 ≈ Low Bacteria = 2-log [1] Virus = 2-log, 4-log [2]	**Treatment Train: Coag./Membrane/UV** Org. > 50 µm = **5-log** 50 ≥ Org. > 10 = **5-log**. Bacteria = > **5-log** [1] Virus = **2-log, 4-log** [2]
		Chemical Disinfection **Removal:** Org. > 50 µm ≈ Low 50 ≥ Org. > 10 ≈ Low Bacteria = > 4-log [3] Virus = 1-log [4]	**Treatment Train: Coag./Membrane/Chem.** Org. > 50 µm **= 5-log** 50 ≥ Org. > 10 = **5-log** Bacteria = > **7-log** [3] Virus = **1-log** [4]

[1] Removal achieved at a UV dose of 60 mJ/cm^2
[2] 2-log and 4-log removal based on UV doses of 100 and 190 mJ/cm^2
[3] Removal based on a TRO ≥ 5 mg/L and HRT ≥ 10 hours
[4] Removal based on a TRO = 8.1 mg/L and HRT = 4 minutes

Similar to UV disinfection, virus inactivation for chemical disinfection can be improved by increasing the dose. A common way to calculate the chemical disinfection dose is to multiply the chemical concentration at the end of treatment by the treatment time – this is referred to as "Ct". The Ct used by Liltved et al. (Reference 23) to achieve 1-log virus inactivation was approximately 32 mg-min/L as chlorine. This Ct is almost 100 times lower than the Ct used to achieve the 4-log bacteria removal (Ct = 3,000 mg-min/L). Increasing the Ct by two orders of magnitude will definitely increase the virus inactivation, but testing of the ballast water would be required to determine if a Ct = 3,000 mg-min/L is sufficient, or if a higher Ct is required. Although more testing is required, it is likely 7-log virus inactivation should be achievable using UV and chemical disinfection at higher doses than have previously been tested.

The treatment technology selections given in the Task 5 report (Reference 5) were based on the case studies used in Tasks 2 – 4 (References 1, 3, and 4), choosing technology configurations based on the capital cost, footprint, energy demand, chemical cost, and other design constraints at each port. Implementation on barges requires assessment in terms of footprint, and will require further testing to confirm efficacy when shifting this technology from land.

A summary of the compiled design parameters is provided in Table 10.

Table 10 Summary of treatment process design parameters and cost and footprint estimates

PHYSICAL TREATMENT		
Coagulation, Flocculation, and Sedimentation		
Parameter	Units	Value
Capital Cost [1, 2]	$	= 24 (Q) + 75,000 [3]
Chemical Cost	$/dry ton	485
Chemical Dose	mg/L	20
HRT [4], Floc Basin	minutes	10 – 40
Depth, Floc Basin	m (ft)	3.5 – 4.5 (11.5 – 14.8)
HRT, Settler [5]	minutes	10 – 20
Depth, Sedimentation	m (ft)	3.4 – 5 (11.5 – 16.4)
Sludge Production	lbs ferric chloride/mgd	= [(Dose)(0.66)(8.34)] + [(Turbidity)(1.3)(8.34)]
Dual-Media Gravity Filtration		
Filtration Rate	m^3/m^2-h (gal/ft^2-min)	8 – 15 (3 – 6)
Water Recovery	%	94 – 98
Capital Cost[2]	$	= 64 (Q) + 380,000 [3]
Footprint	m^2/1000 m^3-day (ft^2/mgd)	30 – 50 (1,200 – 2,100)
Energy Demand	kWh/m^3 (kWh/1000 gal)	0.05 (0.2)
Membrane Filtration		
Flux	L/m^2-hr (gal/ft^2-day)	40 – 80 (24 – 47)
Water Recovery	%	88 – 94
Capital Cost [2]	$	Lower Limit = 59 (Q) + 830,000 [3] Upper Limit = 105 (Q) + 1,000,000 [3]
Footprint	m^2/1000 m^3-day (ft^2/mgd)	20 – 35 (840 – 1,500)
Energy Demand	kWh/m^3 (kWh/1000 gal)	0.2 – 0.4 (0.75 – 1.5)

MECHANICAL TREATMENT		
Ultraviolet Disinfection		
Parameter	Units	Value
Equipment Cost [6]	$	= 13 (Q) + 96,000 [3]
Footprint	ft^2	Q < 17 mgd = 84 (Q) + 350[3] Q > 17 mgd = 40 (Q) + 1220[3]
Energy Demand	kWh/m^3 (kWh/1000 gal)	0.2 (0.8)
CHEMICAL TREATMENT		
Ozone Disinfection		
Parameter	Units	Value
Equipment Cos t[7]	$/1000 m^3 ($/mgd)	65,000 (245,500)
Energy Demand	kWh/kg (kWh/lb)	22 – 26 (10 – 12)
Chemical Dose [8]	mg/L-h	0.7 – 1.3
HRT[4]	hours	10
Chlorine – Sodium Hypochlorite Disinfection		
Equipment Cost [9]	million $	= 0.006 (L) + 0.27 [10]
Chemical Cost [9, 11]	$/$m^3$ ($/gal)	160 – 264 (0.6 – 1.0)
Chemical Dose [12]	mg/L	20
HRT[4]	hours	24
Electrochlorination Disinfection		
Equipment Cost [9]	million $	= 0.0011 (L) + 4.0 [10]
Energy Demand	kWh/kg (kWh/lb)	4 (1.8)
Chemical Dose [13]	mg/L	15
HRT[4]	hours	12

[1] Capital cost is only for high-rate plate settler
[2] Capital cost calculation is in 2013 dollars
[3] Flow (Q) is in m^3/day
[4] Hydraulic retention time (HRT)
[5] Detention is for high-rate plate settler
[6] Capital cost calculation is in 2004 dollars
[7] Equipment cost estimate is in 1999 dollars
[8] Chemical dose estimated assuming a 10-h retention time and 4-log bacteria removal
[9] Capital cost estimate is in 2015 dollars
[10] Load (L) = flow rate x chlorine dose x 8.34. The units for the flow rate is million gallons per day (MGD) and the units for the chlorine dose is in mg/L.
[11] Chemical cost is estimated for a 12.5% sodium hypochlorite solution
[12] Chemical dose estimated assuming a 24-h retention time
[13] Chemical dose estimated assuming a 12-h retention time

4.2 Treatment Discharges (Task 6)

Marine vessels currently discharge ballast water into California water while alongside docks during cargo operations, at anchorages, and while underway. The “outfalls” from these marine vessel ballast water discharges are pipe terminations at the skin of the vessel’s steel hull where ballast water is discharged to the receiving waters.

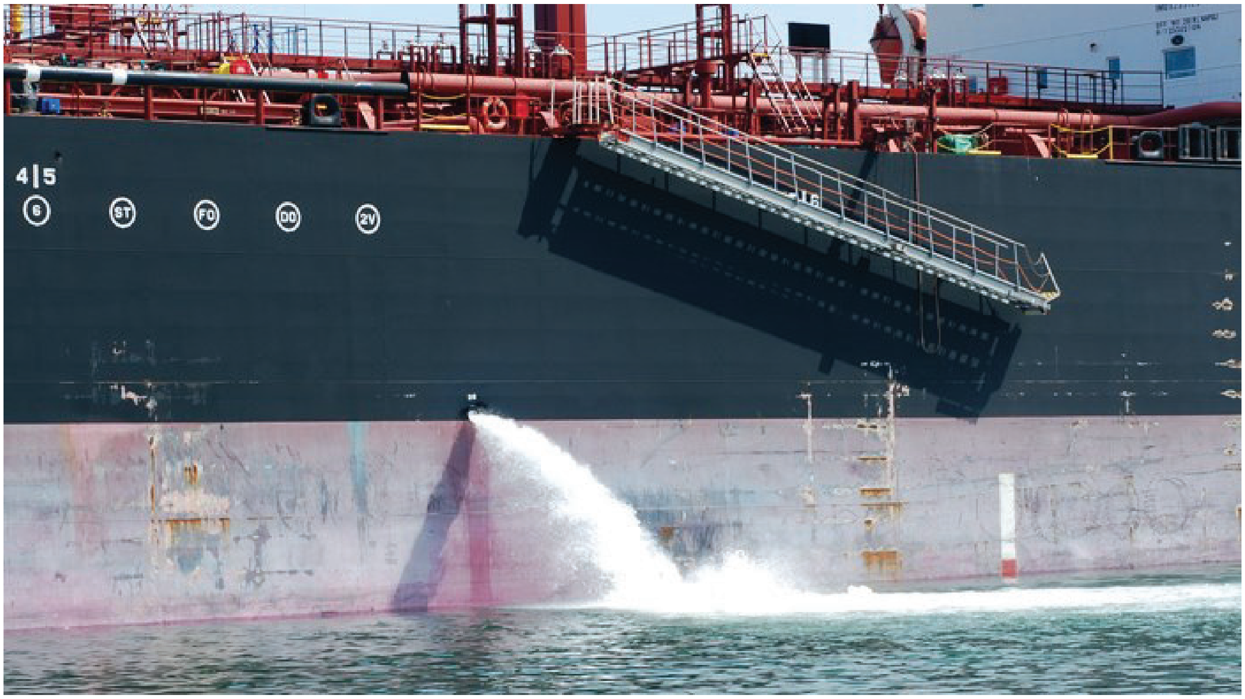


Figure 7 Overboard discharge from tankship at deep water line; the vessel is light and in ballast, so the overboard is above water line; if fully laden with cargo, the overboard would be at the water line

A treatment barge network is proposed as a practical means to receive these discharges and process them to meet the CA Interim Standards. Ballast water would first flow into the treatment barges for processing, after which it would be discharged into the receiving waters. Marine vessels would continue to be able to discharge ballast water alongside docks and at anchorages once connected to the treatment barge; underway discharges, however, would no longer be practical. Table 11 provides a range of ballast water discharge volumes and rates from typical vessel types, along with the typical overboard distance above or below the waterline, and Table 12 shows proposed treatment capacities for the three proposed barge sizes.

Table 11 Summary of interface height by vessel type for shore-based ballast connections

	Ballast Water		**Overboard (typical) Distance above water line**	
	Capacity	**Rate**	**Deep Draft**	**Light Draft**
Vessel Type	*(m3)*	*(m3/hr)*	*(m)*	*(m)*
ATB Tanker	20,000	1,700	-1.70	3.80
Tankers	41,000	3,400	-0.70	8.30
Bulk Carriers	33,000	2,800	-1.20	7.20
Containerships	42,000	2,300	-2.90	5.40
Cruise ships	4,000	300	3.00	3.60
Car Carriers	13,000	700	3.00	6.10

Table 12 Standardized barge designs for service in California

	Small Barge	**Medium Barge**	**Large Barge**
Ballast Volume	10,000 m^3	20,000 m^3	35,000 m^3
Treatment Plant, Rate	721 m^3/hr	1,450 m^3/hr	2,570 m^3/hr
Surge Capacity, Volume	2,789 m^3	5,502 m^3	9,297 m^3

The treatment barge method would not substantially change outfall volumes, discharge rates, geographic locations, water depths, or velocities from current operations. The discharges will have been filtered, having passed through the concept treatment plant envisioned for the treatment barges, shown in Figure 8. Most suspended solids will be removed, and the living biological organism loading will be reduced according to the log reduction expectations introduced earlier.

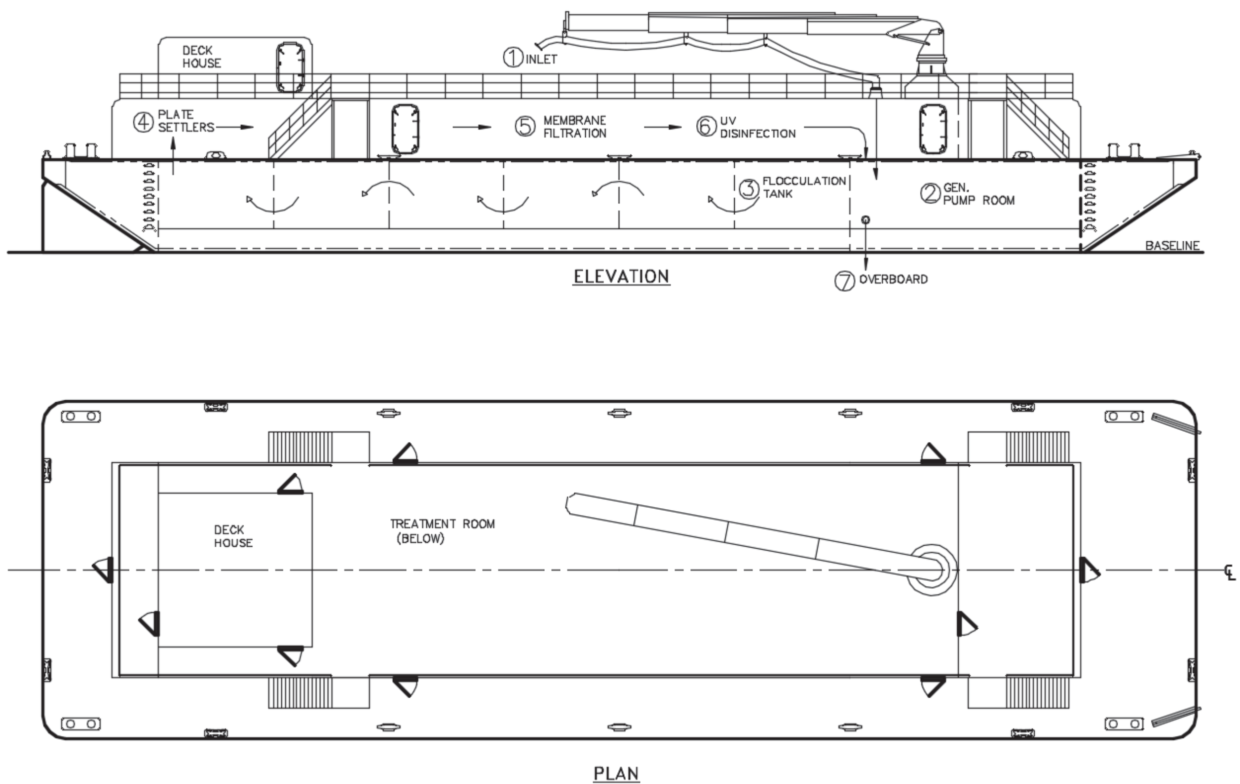


Figure 8 Notional treatment barge design

One result of the barge treated discharge is that the majority of the suspended solids entrained in the ballast water discharged to the treatment barge will have been filtered, collected, and need disposal. This includes particulate organic and inorganic material; in other words, large and tiny debris from living and non-living sources. The treatment process will collect no significant portion of dissolved materials; salt, for example, will not be collected in the process. Undissolved solids will be collected through coagulation, flocculation, and then settling. During coagulation, additional material is added to the water being treated in order to increase particulate binding. The settled solids will then be concentrated, producing a slurry of 20% solids and 80% seawater. Table 13 shows expected slurry volumes and disposal costs for varying levels of treated ballast volume; a ballasting event of 10,000 metric tons, for example, is expected to produce ~2 metric tons of slurry with a disposal cost of ~$710. Once separated from the seawater, solids would be transferred to a tank truck and disposed at a landfill permitted for such operations.

Table 13 Predicted solids production

	Treated Ballast Volume	Typical Slurry		
		Slurry Volume	Disposal Cost	Truck Loads
	(metric tons)	(metric tons)	($)	(#)
Small Barge	10,000	2	$710	0.1
Medium Barge	20,000	4	$1,420	0.3
Large Barge	35,000	7	$2,485	0.5
Zone 1 (annual production)	1,940,000	388	$137,740	25.9
Zone 2 (annual production)	1,770,000	354	$125,670	23.6
Zone 3 (annual production)	2,540,000	508	$180,340	33.9
Zone 4 (annual production)	1,110,000	222	$78,810	14.8
Zone 5 (annual production)	5,420,000	1,084	$384,820	72.3
Zone 6 (annual production)	30,000	6	$2,130	0.4
Statewide (annual production)	12,810,000	2,562	$909,510	170.8

The resulting solids are not expected to contain pollutants in excess of levels acceptable for non-specialized landfills. There will be no concentration of salt or other dissolved materials from the treatment process. Most of the material will be a mixture of organic and inorganic debris, combined with coagulants added during treatment. The resultant solids are not expected to be of high caloric value, so standard landfill disposal is recommended over disposal into digesters for methane production.

Ships may uptake ballast water in contaminated port locations, for example at a foreign port with less stringent environmental controls. In these cases, hydrophobic contaminants may be contained in the ballast water and therefore concentrated in the resulting ballast treatment solids. As such, the solids should be monitored for special disposal. Furthermore, it is possible that with additional monitoring of outfalls from marine vessels or treatment barges, the community will become aware of additional existing contaminants common in ballast water discharges. While the treatment barge can collect suspended solid contaminants, it may not be feasible for the treatment barge to remove dissolved pollutants. This should be considered in the development of the NPDES permit.

4.3 Permitting and Legal Requirements (Task 7)

Marine vessels discharging ballast water in California will be required to meet the CA Interim Standards. These standards are one thousand times more stringent in the "<50 µm and ≥ 10 µm" size class than the International Maritime Organization (IMO), US Coast Guard, and US EPA ballast water discharge standards. In the "≥ 50 µm" size class, the CA Interim Standards are unique in allowing no detectable living organisms. They are also the most stringent for the indicator microbes *E.coli*, intestinal *enterococci*, and *Vibrio cholera*.

This study identifies shore-based technologies that should be able meet the CA Interim Standards; however, these technologies require twenty times the footprint and six times the power of technologies used onboard marine vessels to treat ballast water to the IMO ballast water treatment standards. Given marine vessel space and power constraints, it is not generally practical to install such shore-based technologies onboard the marine vessels themselves.

This study proposes a network of land-based treatment barges as a technically feasible alternative that could receive ballast water from discharging marine vessels and treat it to the CA Interim Standards. The conceived series of barges would support the required tankage, machinery space footprint, and available power on the barge itself.

Once the ballast water is transferred to the treatment barge, it will likely be regulated as industrial wastewater under the National Pollutant Discharge Elimination System (NPDES). The permitting process for the ensuing treatment is expected to last between two and three years and require significant study. Key issues include solids management, outfalls, and seawater discharges into freshwater systems. Possible stances and purviews of regulatory agencies in this process are outlined in the table below.

Table 14 NPDES agency purviews and stances

Authority	Legal and Permitting
US Coast Guard and IMO	Ballast water transfer to a treatment barge is an acceptable alternative. Treatment barge must be NPDES permitted and meet USCG/IMO discharge standards.
State Lands Commission	Transfer to a treatment barge does not relieve the requirement to meet the CA Interim Standards.
US EPA	Each treatment barge will require an NPDES permit.
State Water Board	Regional Water Boards will issue, if suitable, permits for the barges operating within their boundaries, based on studies of impacts on those regions.

Practical implementation of a network of treatment barges requires outfitting marine vessels with a standardized ballast water transfer connection and ballast water transfer station. However, California may be preempted from regulating this vessel design aspect given established US Coast Guard efforts in this area. If California enforces the CA Interim Standards and treatment barges are the only practical solution, then such a standardized connection would be a de facto requirement for marine vessels expecting to discharge ballast water into California waters.

The implementation of a shore-based network of treatment barges will require a permitting process. Risks include freshwater ports not receiving the required discharge permits for salt water discharges, required changes to barge outfalls and treatment plants causing schedule delays, and cost overruns due to unforeseen permitting obstacles. That noted, there is a known permitting process, and if diligently executed there is a reasonable expectation of success.

4.4 Environmental Impact Comparison (Task 8)

The implementation of on-shore ballast water treatment plants, proposed as treatment barges, may be able to meet California's Interim Ballast Water Discharge Performance Standards (CA Interim Standards). These are more stringent standards than other international and federal standards. For example, whereas the federal standard allows up to 10 living organisms in the greater than 50 micron nominal size class, the CA Interim Standards allow no detectable living organisms. From an environmental impact perspective, this is a reduction in the risk of invasive species invasions.

While meeting these more stringent CA discharge standards have environmental benefits in terms of reducing threats from marine bio-invasions therethere are some environmental cost associated with meeting them,. Specifically, the on-shore treatment plants/barges requires twenty times the footprint and six times the power of current shipboard treatment plants that are only certified to meet the federal discharge standard. To some extent, therefore, employing shore-based treatment approaches that can meet more stringent CA discharge standards involves trading off one impact, reduction in potential aquatic invasive species introductions, for another, increased air pollution from larger treatment plants. The importance of these trade-offs with respect to each treatment method can be established by examining:

- Treatment effectiveness (reduction in introduced organisms and pathogens form ships' ballast water).
- Energy consumption and expected air emissions.
- Port operations and port congestion.

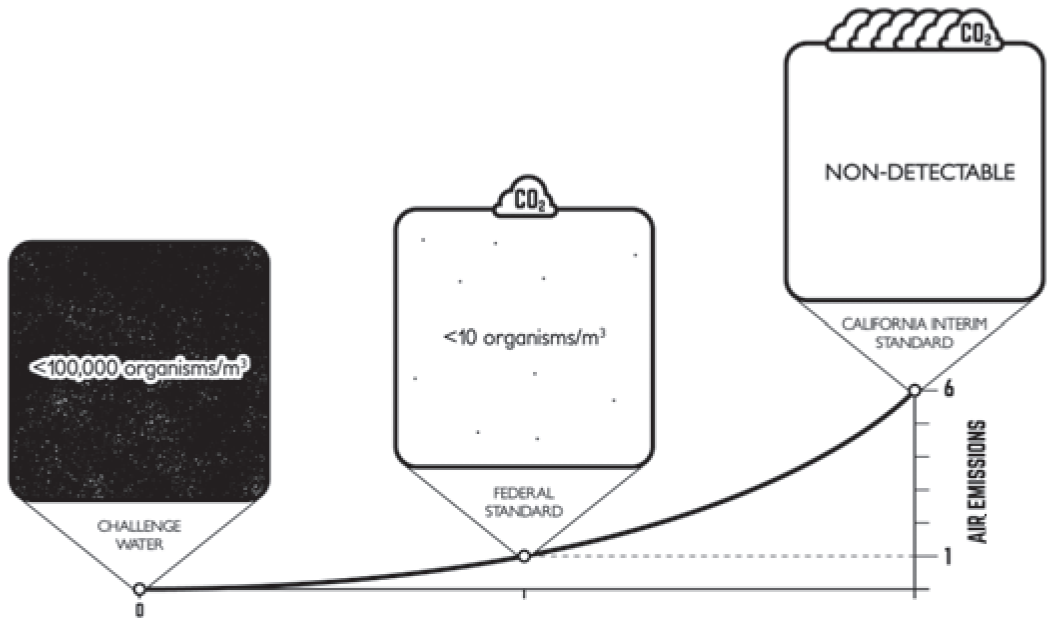


Figure 9 Increasing levels of organism reduction require increasing levels of energy which equates to air emissions

Onboard Retention of All Ballast Water

Onboard retention is a completely effective means of eliminating risk of aquatic invasive species from marine vessel ballast water. In fact, between 2010 and 2015 on average 84% of vessels filing ballast water reports indicated that they did not discharge any ballast water in California. While most of this may be due to California being a cargo discharge port (where ballast water is generally taken-up), it indicates that the great majority of vessels do in fact retain their ballast water in California. In fact, onboard retention to the extent practical is already mandated in the EPA Vessel General Permit that applies to all marine vessels calling in California.

However, there are certain vessels that cannot practice onboard retention. Highly ballast-dependent vessels such as tankers and bulk carriers do not have the ability to retain all ballast water onboard and conduct normal cargo operations. Consequently, onboard retention is not considered a viable statewide solution for all marine vessels.

Shipboard Ballast Water Management

Shipboard ballast water management systems are currently limited to those designed and tested to meet the international and federal ballast water discharge standards. This does not mean that they cannot meet the CA Interim Standards, but simply that they have not been evaluated for such compliance.

In general, these systems are based on shore-side technologies which are compacted into the small footprints and reduced power configurations to meet the space and power limitations on board marine vessels. The major advantage of such an approach is that there is no impact to harbor or port logistics, such as tying up a barge and passing a hose. Further, when compared to the barge-based system, the energy consumption is much less.

Shore-Based Ballast Water Management

The practical implementation of shore-based ballast water management is with the proposed treatment barges. These barges are able to accommodate large and high-powered treatment plants that are not feasible onboard the marine vessels themselves. However, these barges have environmental impacts that include:

- Increased air emissions from the larger ballast treatment plant, and the deployment of diesel powered tug boats to move and handle the barges.
- Increased port congestion due to movement and storage of the treatment barges, as well as constriction of waterways where the treatment barges are secured alongside vessels at berth.

Port Emissions Example

The ports of Los Angeles and Long Beach offer practical examples when considering port emissions impacts. The shore-based treatment plant is estimated to require 0.25 kilowatt-hours (kW-hrs) per metric ton of ballast water treated, and the proposed treatment barge Zone 5 (LA/LB) would see 5.42 million tons of ballast water treated each year. This computes to 1.3 million kW-hrs annually. Further, it is estimated that tug boat service calls in Zone 5 (mostly due to servicing Pacific Area Lightering (although outside of California jurisdiction) and El Segundo Marine Terminal) would total 915 shifts of an average of nine miles. This accounts for an estimated 3.7 million kW-hrs expended from tugs, totaling a combined annual 5.0 million kW-hrs.

Marine harbor craft in California generally meet the EPA Tier 3 emissions requirements, see the below figure. Assuming that the affected marine engines all run at the Tier 3 limit, we can expect a significant port wide contribution to pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbon (HC), and particulate matter (PM). The below table provides a rough estimate of the contribution based on the 2016 Port of Los Angeles Inventory of Air Emissions. Some future considerations might relieve these estimates, including: use of alternative fuels such as LNG, decreases in treatment plant energy based on prototype trials, and scheduling of barge movements to reduce tug shifting distances.

Table 15 Shore-based ballast treatment, contribution to South Coast Air Basin harbor craft emissions

		CO	NOx+HC	PM
Tier III Engines	(gram/kW-hr)	5	5.8	0.14
Estimated Emissions				
Harbor craft, total	(MT)	486.6	828.5	26.7
Shore-based ballast treatment	(MT)	24.80	28.77	0.69
Contribution	***(%)***	***5.10%***	***3.47%***	***2.60%***

4.5 Current California Ballasting Activity (Task 9)

One concern with respect to the feasibility of implementing shore-based ballast water reception and treatment in California is how to serve vessels that discharge ballast water while underway in State waters. Vessels that have a legitimate need to discharge while making way present an obvious challenge for ballast water collection and treatment using barges or other shore-based infrastructure.

Specific to California, little prior research on the topic of underway discharges has been performed; thus, the frequency, average volumes, and any discernable patterns in underway discharges in California waters are not widely known.

4.5.1 Report Scope

Using publicly available data from the National Ballast Information Clearinghouse (NBIC) (Reference 25), this section assesses current ballast water discharge practices from marine vessels in California, with focused discussion on vessels that discharge while underway, rather than at berth.

Although California state jurisdiction extends only three nautical miles offshore, underway discharges occurring at any location shoreward of the outer limit of the US Contiguous Zone (24 nm offshore) were included in the assessment. This was decided in light of the recent 2012 Supreme Court decision in *PMSA v. Goldstene*, which granted individual states, California in particular, the power to enact "conditions of entry" relative to shipping activities outside their territories, to the outer limit of the 24 nautical mile US Contiguous Zone (Reference 17). The resulting dataset was used to characterize underway discharge activity in California over a five-year period.

To meet the goal of preventing the introduction of aquatic invasive species and harmful pathogens into California waters, methods capable of effectively minimizing or eliminating underway discharges were investigated. In doing so, a clear distinction between "elective" and "non-elective" underway discharges is made – i.e. vessels that *opt* to discharge vs. vessels that *must* discharge.

Ultimately, a feasible option for minimizing or eliminating such discharges into California waters is identified, taking potential impacts to vessel schedule integrity and port and marine terminal operations into consideration.

4.5.2 Methods

Underway discharges between 0 and 24 nautical miles offshore were extracted from NBIC data for a five-year period from 2011-2015. For purposes of this study, an underway discharge event is defined as one indicating a discharge amount >0 and a location recorded in the NBIC database as geographic coordinates (latitude and longitude), rather than the placename of one of California's seaports or a designated anchorage/lightering area. Key assumptions were made in distinguishing between elective and non-elective underway discharges. An **elective** underway discharge can be described as one that is either:

A. Conducted for convenience (e.g. to reduce crew workload), to maintain or minimize impact to vessel schedule integrity, to minimize impact to marine terminal or shoreside facility operations, or to realize certain operating efficiencies;

B. Conducted to trim the vessel for routine cleaning, maintenance, or other operational purposes not critical for vessel safety;

C. Conducted for the safe operation or navigation of the vessel, but the crew has some discretion in the timing of the discharge (i.e. the discharge can be deferred or conducted in advance of an event or specific portion of the voyage without compromising vessel safety).

A **non-elective** underway discharge can be described as one that must be conducted for the safe operation or navigation of the vessel, the timing of which the crew has limited ability to control (i.e. the discharge cannot practically be deferred or conducted in advance of an event or a specific portion of the voyage).

4.5.3 Summary of Findings

Currently, all six vessel types considered in this study discharge ballast water while underway; however, the frequency of such discharges in California waters is quite low. During the period 2011-2015, there were 53 individual underway ballast water discharge events attributable to 32 unique vessels. The average discharge volume associated with these events is also low, just 700 MT. All 53 discharge events were less than 3,000 MT. Discharge events and volumes per vessel type are indicated in the table below.

Table 16 Underway discharges between 0 and 24 nautical miles from shore by vessel type (NBIC, 2011-2015)

Type	Count	Volume (MT)
Tanker	9	12531
Container	8	13490
Bulker	5	8670
Other	5	333
General Cargo	2	2288
Passenger	2	323
Combo	1	161

The below table shows the total number of non-elective underway discharges during the period 2011-2015 by zone.

Table 17 Number of non-elective underway discharges in California by Zone (2011-2015)

Zone Designation	Service Area	Non-elective Underway Discharges
Zone 1	San Francisco Bay (North Part) and Humboldt Bay	1
Zone 2	San Francisco Bay (South Part) and Monterey Bay	5
Zone 3	Carquinez Strait and Suisan Bay	4
Zone 4	Stockton	0
Zone 5	Los Angeles/Long Beach and Vicinity	1
Zone 6	San Diego	0
TOTAL		**11**

With prudent planning, the practice of discharging ballast into coastal waters while a vessel is making way can be eliminated by: a) avoidance (i.e. not discharging); b) discharging outside the 24-nautical-mile boundary of the US Contiguous Zone; or, c) discharging in port, where oceangoing vessels could be serviced by treatment barge, as described in the Task 13 report (Reference 13).

Both elective and non-elective discharges related to normal vessel operations can take place in port or beyond 24 nautical miles without compromising vessel safety. Emergency deballasting is the only form of non-elective underway discharge that cannot necessarily be avoided, conducted outside 24 nautical miles, or deferred until arrival in port. Such cases are allowed under state and federal safety exemptions. The expected frequency of such events cannot be determined from the data available but is estimated at <1 per year in waters between 0 and 24 nautical miles offshore.

Based on this conclusion, this study proposes that underway discharges be planned in advance to the extent practicable and, whenever they cannot be practically avoided or conducted outside 24 nautical miles, conducted in port at designated anchorages or “Deep Water Service Stations” (DWSS).

Ballast water capture and treatment operations at a DWSS would be virtually equivalent to bunkering operations at anchor, as shown in the below figure. Barges would be dispatched to vessels at pre-arranged times and secured alongside in the same manner as for vessels at berth. The processes for connection, capture, and treatment of ballast would also be similar.

Figure 10 Open-hatch gantry ship, *Star Florida* engaged in bunkering operations in Vancouver Harbor, British Columbia.

If implemented for each zone, DWSS would provide a suitable and practical means of eliminating current underway discharge practices in California, both for inbound and outbound vessels. The few vessels requiring this practice would experience schedule impacts, but the system would not cause disruptions to normal operations at marine terminals, or appreciably contribute to marine traffic in port or other port congestion issues.

It should be noted that planning and conducting ballasting operations at specified locations may result in unintended or undesirable outcomes. These outcomes may include vessels sailing in a less-than-optimal loading condition during transits from offshore waters to port (or vice versa), or vessel schedule delays associated with conducting ballasting operations in port that had previously been conducted while underway.

The barge-based system proposed herein will not prevent those few discharges that must be conducted immediately for the safety of the vessel and crew. In these instances, the capabilities of the vessels' onboard BWMS must be deemed sufficient. However, considering the apparent infrequency of underway discharges in California, and the ability to foresee and plan for the majority of these instances, the implementation of a shore-based ballast water management system utilizing treatment barges is well-suited to assist in minimizing or eliminating these discharges in California waters.

Section 5 Economic Feasibility

The 30-year lifecycle cost of building and operating a network of ballast water treatment barges (treatment barges) capable of treating all ballast water discharged into California waters is estimated at $3.63 billion. This overall lifecycle cost includes a one-time capital investment of $552 million to build the barges and an estimated $55.3 million in average annual operating costs over a 30 year time horizon A separate ongoing investment of $127 million will be required every year to outfit marine vessels that are newly entering the California market with the ballast transfer stations that are required to use the barge network.

The cost of building and operating a network of treatment barges will need to be passed on, in some way, to ship operators who use the network. These costs could be reflected in fees charged per treatment service or per ton of ballast water treated or per unit of cargo, or be worked into port charges in some other way. And, these costs and fees could vary widely among California ports, resulting in increased inter-port competition among California ports. On the other hand, these fees could be managed on a state-wide basis to even out fees charged at high cost/low volume and low cost/high volume California ports to reduce impacts on inter-port competition.

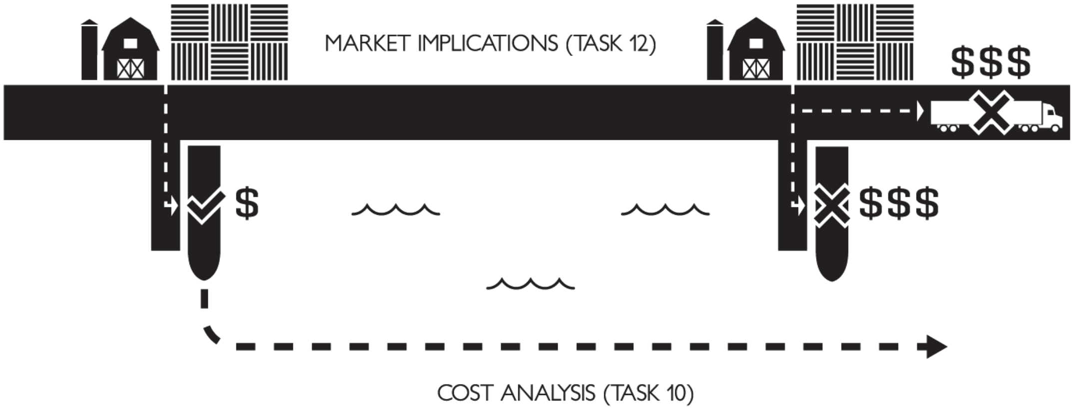


Figure 11 Economic feasibility

In some cases costs to ship operators may be passed back to shippers (exporters) who may be able to pass them forward to buyers (importers), In many case, however, this will not be possible and costs charged to ship operators (see Table 16) will directly affect their profitability and could be high enough to affect their decisions about using certain California ports, or using any California ports. The calculated costs to support a network of treatment barges, when considered in relation to the elasticity of market demand for shipping goods through California ports suggests that the market implications of ships using treatment barges could have significant and measurable state-wideeconomic impacts.. It is expected that the direct effects will be most felt by a small percentage of marine vessels, on exported rather than imported cargo, and at smaller and more remote ports. These effects will be the result of the likely diversion of some cargo to larger California ports and/or non-California ports, or rendering it non-economical toexport certain agricultural and other price sensitive products.

5.1 Cost Analysis (Task 10)

Costs could be shared and passed along to ship operators and shippers in many different ways. Table 18 provides a summary of what costs will be borne by the shipping industry directly, and then the additional costs for operating the treatment barge network. It then uses only the treatment barge network to estimate cargo shipment unit costs.

Table 18 Comparative costs

Who Pays	Metrics
Shipping Industry (costs directly on the marine vessels)	$2.17 billion 30-year lifecycle cost $127 million annual investment in outfitting marine vessels $7.6 million annual operating costs on marine vessels themselves *Excludes fees from treatment barge operator
Treatment Barge Operators (additional cost of operating the barge network)	$1.45 billion 30-year lifecycle cost (in addition to the $2.17 billion above) $552 million to invest in treatment barges $55.3 million annual operating costs for treatment barges, including tugs *Excludes treatment barge profit
Ship Operator, Single Marine Vessel (marine vessel PLUS barge network costs)	$152,633 to $308,893 one-time cost to outfit ballast transfer station $36,751 to $118,321 cost for barge per ballast water discharge event 10 to 20 hours of personnel time per ballast water discharge event *Excludes treatment barge profit
Cargo Shipment (only considering barge network costs)	$2.18 cost per metric ton of bulk cargo, such as grain or petroleum $18.68 per shipping container TEU $11.30 per automobile $46.38 per passenger *Excludes shipping industry costs *Excludes treatment barge profit

5.1.1 Marine Vessel Outfitting and Operations

The cost of outfitting marine vessels with ballast transfer stations and the cost of operating them were detailed in the Task 2 report (Reference 1) and are summarized below. Operating costs include the cost of personnel required to operate and maintain transfer stations and fuel to power pumps to move the ballast water through the transfer stations.

Table 19 Marine Vessel Refit and Operating Costs

		Containership	Bulkers	Tankers	Passenger	RoRo	Others	**California**
Life Cycle Cost	***(Million USD)***	**191.3**	**1,250.2**	**528.3**	**18.8**	**39.6**	**144.6**	**2,173**
Capital Expenses	*(Million USD/yr)*	11.3	73.6	30.8	1.0	2.4	8.3	**127**
Operating Costs	*(Million USD/yr)*	0.59	4.10	2.03	0.16	0.03	0.66	**7.6**

*Excludes barge network costs.

5.1.2 Treatment Barges, Capital Expenses

Cost estimates were developed for treatment barges in three distinct size categories that align with various marine vessel discharge volumes and rates. The average capacity of barges in each category is paired to the maximum practical ballast water volume that a typical barge in each category can receive and process over a ten-hour discharge period.

Table 20 Standardized barge designs for service in California

BWTB Design	Small Barge	Medium Barge	Large Barge
Service Capacity			
Ballast Volume	10,000 m^3	20,000 m^3	35,000 m^3
Particulars			
Length	200 ft	240 ft	280 ft
Breadth	62 ft	74 ft	84 ft
Summary Totals			
Treatment Plant, Rate	721 m^3/hr	1,450 m^3/hr	2,570 m^3/hr
Surge Capacity, Volume	2,789 m^3	5,502 m^3	9,297 m^3
Cost, Barge and Outfitting	$6,273,599	$10,192,858	$15,451,111
Cost, Treatment Plant	$4,609,943	$7,009,470	$9,883,075
Cost, Total	$10,883,542	$17,202,328	$25,334,186

5.1.3 Treatment Barge, Lifecycle Costs by by Zone

Estimates of the lifecycle costs of operating the treatment barge network are provided in Table 21. Lifecycle costs are presented in 2018 dollars using a discount rate of 6% and assuming annual cost inflation of 2.5% and annual fuel cost escalation of 3%. Approximately one-third of lifecycle costs are associated with the procurement of the barges themselves; the remaining two-thirds of lifecycle costs are associated with operating the barge networks.

Table 21 Zone lifecycle costs

	Zone 1 SF North	Zone 2 SF South	Zone 3 Carq. Suisun	Zone 4 Stockton	Zone 5 LA/LB	Zone 6 San Diego	Totals
Lifecycle Cost (million USD)	228.6	224.1	254.8	159.7	534.7	51.4	1,453.3
Operating Costs (million USD/ year)	8.0	8.2	9.6	4.6	23.2	1.5	55.3

*These costs do not include marine vessel refitting with transfer station, or marine vessel personnel to support these operations from the marine vessel side.

5.1.4 Cargo Metrics, Unit Costs

Cargo metrics are provided in the tables below, with the caveat that location-specific assumptions must be considered carefully in order to understand actual cargo-throughputs and impacts. This first table provides unit costs by zone location based on reasonable assumptions regarding port-specific cargo metrics. Notice that San Diego is an outlier because there are so few discharge events and such low discharge volumes that the unit costs of providing treatment from a dedicated barge at that port are extremely high.

Table 22 Zone cargo metrics

		Zone 1 SF North	Zone 2 SF South	Zone 3 Carq. Suisun	Zone 4 Stockton	Zone 5 LA/LB	Zone 6 San Diego
Discharges, Number	*(#/yr)*	236	236	259	88	915	28
Discharges, Volume	*(MT million/ year)*	1.94	1.77	2.54	1.11	5.42	0.034
Volume per Discharge, Average	*(MT/disch)*	8,220	7,500	9,807	12,614	5,923	1,214
Est. Cost per Discharge	*($/disch)*	61,593	60,295	62,282	116,414	36,751	118,321
Est. Cost per Volume	*($/MT)*	7.49	8.04	6.35	9.23	6.20	97.44

These costs do not include the marine vessel costs, which are assumed to be borne by the ship operators. Including these costs would increase the costs presented here by an average of about 150%. The costs presented also do not include any profit for the treatment barge operators who may need to charge significantly more than costs to compensate for significant investment risks. If they are not able to reduce or share some of these risks (e.g., via state or shipper financed revenue insurance) their expected return on investment could increase to the cost per discharge and cost per volume estimates presented here.

5.2 Market Implications (Task 12)

The 30-year lifecycle costs of building and operating a network of ballast water treatment barges (treatment barges) capable of treating all ballast water discharged into California waters is estimated at $3.63 billion. While it is not possible to predict how these costs will be passed on to ship operators as fees, or how ship operators will respond, the following sections attempt to put these costs and associated fees and possible shipping industry responses into perspective.

5.2.1 Marine Vessel Operator Perspective

A marine vessel calling in California must already be outfitted with a USCG compliant sanitary system, be prepared to burn low sulfur fuel oil and, in some cases (containerships and cruise ships) be ready to plug into shore power once at the dock. Operators of these vessels are now preparing to install on-board ballast water treatment systems that have an installed cost ranging from $500,000 to $3,500,000. An additional one-time investment of $152,633 to $308,893 to outfit a ballast transfer station in order to be able to discharge ballast water at California ports is not likely to dissuade marine vessel operators that routinely call in California. It will, however, decrease the pool of vessels that are qualified to call in California ports. Please note that this amount only considers the refit cost, and not the cost to use the ballast barge network.

5.2.2 Cargo Shipments

Treatment barge costs passed along to a marine vessel will, in many cases, be equivalent to the cost of several marine vessel transit days. Those additional days in transit could allow the marine vessel to reach an alternative cargo loading port location where these fees are lower or do not exist. For example, under logical assumptions regarding treatment costs and cargo-throughput, a dry bulk carrier taking on grain in Stockton is estimated to need to pay the treatment barge operator a break-even price of $120,000 to offload ballast water. However, that bulk carrier only costs $12,000 per day to operate. That would allow the ship operator to lower costs by steaming up to 10 additional transit days to pick-up cargo either in an alternative

California port where the treatment barge service cost less, or to a port outside of California where there would not be a similar fee.

There could be many customer-related, cargo-related or logistical reasons why ship operators' demand to use a particular California port might be relatively "inelastic" with respect to port costs. For example, it might only be possible to ship certain agricultural products out of the nearest port to avoid spoilage. If these were low margin products, unavoidable increases in treatment-related shipping cost at nearby California-based ports could make the cargo export unprofitable.

Table 23 Cost of barge network in comparison to marine vessel day rates

		Ballast Cost	Day Rate	Time	Market Impact	Alternative Action
Vessel Type	**Zone**	($/call)	($/day)	(days)		
Car Carrier	2	60,295	35,000	1.7	Low/None	
Car Carrier	6	118,321	35,000	3.4	Moderate	Divert to another port
Containership	1	61,593	35,000	1.8	Low	Divert to another port
Containership	5	36,751	35,000	1.1	None likely	
Cruiseship	5	36,751	120,000	0.3	None likely	
Bulker	4	116,414	12,000	9.7	High	Divert to another port
Bulker	5	36,751	12,000	3.1	Moderate	Divert to another port
Tanker	3	62,282	16,000	3.9	Mixed	If discretionary, divert
Tanker	5	36,751	16,000	2.3	Mixed	If discretionary, divert

Table 24 Treatment costs as percentage of cargo value

		Ballast Cost	Cargo Value	Percentage	Market Impact
		($)	($)	(%)	
Automobile	*(CEU)*	11.30	35,000	0.03%	Low
Container	*(TEU)*	18.68	100,000	0.02%	None
Passenger	*(trip)*	46.38	800	5.80%	Moderate
Wheat	*(m.ton)*	2.18	440	0.50%	Low
Crude Oil	*(m.ton)*	2.18	390	0.56%	Low

CEU is car equivalent units.

5.2.3 Panama Canal Costs

The expansion of the Panama Canal raised concerns that California would be bypassed for discretionary mid-west cargos. Reports claim that US west coast ports are losing Asia container market share to US gulf and east coast ports (Reference 24). One barrier that can keep discretionary cargo moving through west coast ports are Panama Canal tariffs. However, treatment barge costs at California ports could approach 60% of Panama Canal tariff rates for tankers and bulkers, and 10% of the tariff rates for containerships.

5.2.4 Concentration of Costs and Demand Elasticity

The costs of implementing a shore-based network of treatment barges is likely to be concentrated on a small percentage of marine vessels that discharge, have the largest impact on cargo exports, and disproportionately impact remote and low volume ports.

- In a given year, there are ~9,500 ship visits in California, but only ~1,500 ballast water discharges. In the five-year period from 2011 to 2015 all ~7,500 discharges were from only ~2,300 unique vessels. As such, the cost of shore-based treatment will be concentrated on a relatively small number of marine vessels.
- Most ballast water discharges are associated with cargo exports, not cargo imports, because. ballast water is discharged as export cargo is loaded. As such, the costs to support the shore-based network will be disproportionately born by U.S. cargo exports rather than U.S cargo imports.
- The per cargo unit cost for the treatment barge is the cost of the service divided by the units of cargo moved. For example, a single service call would cost $118,321 in San Diego which would only be spread over a single 1,400 TEU cargo move resulting in $84.52 per TEU. The higher number of service calls and higher volume of cargo moving through Long Beach, on the other hand, results in $2.55 per TEU. In other words, remote and low volume ports will see a disproportionate economic impact. This could be offset by establishing a price-sharing or cost-sharing policy across all California ports.

Market implications are difficult to predict in a quantitative manner. A 2007 study (Reference 20) suggests that elasticity of demand for shipping discretionary cargo through the ports of LA/LB is “unitary” with respect to shipping costs, i.e. a 10% increase in shipping costs at these ports decreases cargo volume throughput by 10%. It also suggests that local cargoes that are not discretionary have a demand elasticity of 0.3 meaning that the same 10% increase in cost would only reduce volume by 3%.

The 2007 study combined with the calculated costs to support a network of treatment barges suggests that the market implications are significant, i.e. will have a measurable effect. Further, that effect will be most felt by a small percentage of marine vessels, on exported cargo, and at smaller and remote ports.

Section 6 Implementation

A network of ballast water treatment barges is proposed as the most practical means to implement shore-based ballast water reception, storage, and treatment. The proposed concept estimates that twenty-four purpose-built barges would operate in service zones covering the entire state, with capacity to service the estimated 1,556 marine vessel ballast water discharges at an availability rate of 99%. In practice, it is likely that a few port locations will not use a barge, but will instead develop a land-based solution.

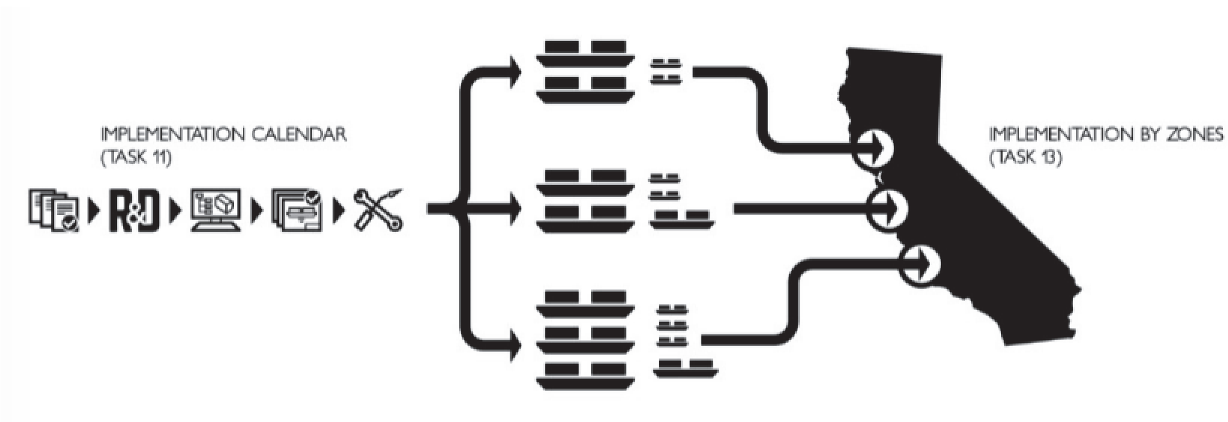


Figure 12 Treatment barge network implementation

A phased-in implementation schedule is recommended that would have the first shore-based ballast water reception, storage, and treatment barge system in place six years after the start of the program and nine years to fully implement. This schedule reflects the need for:

- Treatment barge prototyping, pilot projects, set-up of public-private partnership(s) PPP(s), design/build contracting and, finally, the delivery of operational treatment barges.
- Development of standards and procedures for marine vessel ballast water transfer stations, communication of the guidance and requirements, and outfitting of marine vessels with ballast water transfer stations over a five-year phase-in period.
- Ballast discharge study and permitting, followed by phasing in the treatment barge network over a three-year period starting in year 7.

The following sections first present the implementation timeline, and then provide a summary of the concept barge network.

6.1 Implementation Timeline (Task 11)

Full implementation of the barge-based treatment option is estimated to take place nine years from initial research and development of the barge-based treatment technologies, as shown in Figure 13. The first six years will be occupied with the study of ballast water discharges, building and pilot testing of treatment barge prototype(s), development of transfer station standards, communication of requirements to marine vessels, development of the PPPs, and contracting for the design/build of the treatment barges. Years 7, 8, and 9 will be occupied with phasing in the treatment barge network.. Importantly, Year 1 starts only after budgets and plans have been put into place.

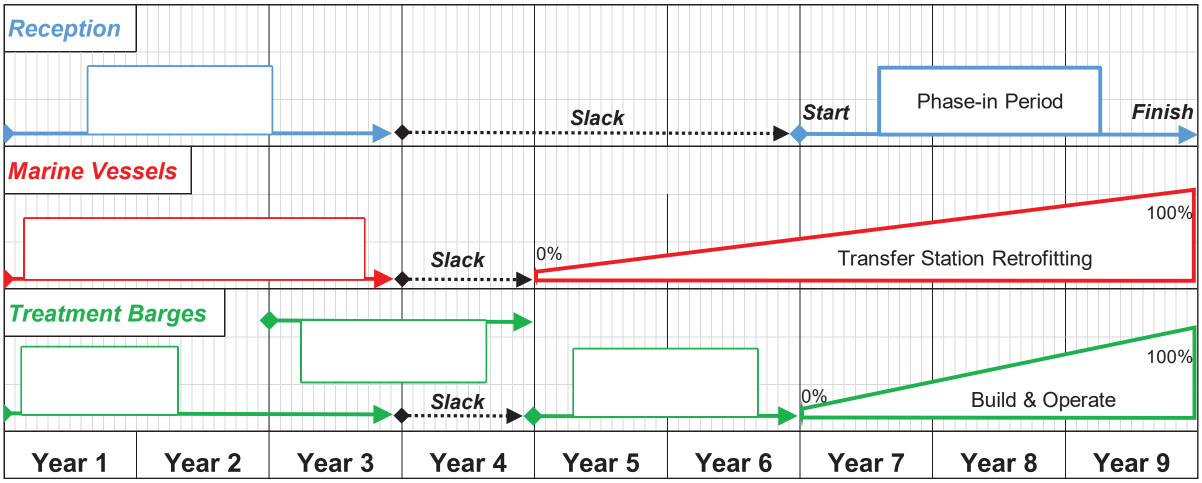


Figure 13 Overall implementation timeline

The treatment barge implementation timeline starts with a three-year process for prototyping and pilot testing. This would include not only confirming the treatment plant efficacy, but also testing and demonstrating the transfer station connections with marine vessels included in the pilot project. A two-year period is expected to set-up the PPP needed to oversee the construction and operation of the barge network. The PPP could then contract for a design/build program which would be expected to start production of the barges within two years. Delivery of the barges would be expected over the following three-year period. One year of schedule slack is allowed for the prototyping to be completed, such that lessons learned are included in the design/build contract(s).

Three years are scheduled for the development of the transfer station standard and communication of the requirements to the marine vessel community. One year is provided as slack for the take-up of those requirements, with marine vessels expected to start arriving in California with transfer stations at the beginning of year 5. The phase-in would take five years, with all vessels arriving with transfer stations by the end of year 9.

Three years are planned for ballast water discharge study and permitting, with completion expected by end of year 3. This early completion will assist with ensuring that the vessel design and PPP agreements incorporate any permitting requirements. The first shore-based ballast water reception, storage, and treatment is expected to start in year 7 with the entire network online by end of year 9.

6.2 Concept for Implementation by Zones (Task 13)

The study team proposes a statewide network of mobile treatment barges for receiving and treating ships' ballast water to the CA Interim Standards. This "barge-based" method is one approach to shore-based ballast water reception and treatment. Shore-based approaches are different than vessel-based approaches where the treatment plants are located onboard the marine vessels (ships) that are carrying ballast water. In the case of mobile treatment barges, the treatment equipment would be located on shore-based mobile barges and not the marine vessels that carry ballast water into port.

Scale-up of Land-based and Barge-based Alternatives (Reference 1) found the barge-based alternative to be significantly more economical than land-based alternatives (i.e. fixed treatment plants) in terms of capital, operating, and life-cycle costs. That analysis applied the findings and data from the Task 2-5 work efforts (References 1, 3, 4, and 5, described above) to two different California port districts. In addition to a clear cost advantage, the barge-based alternative offers more technical certainty and fewer financial risks than than the shore-based alternatives, The study Public Review Panel concurred with this assessment and directed that further shore-based analysis focus solely on the barge-based alternative.

With the focus on a barge-based ballast water treatment approach, the question of how treatment barges would be deployed must be addressed. This study recommends a zone approach, by which California State waters are subdivided into a number of smaller operating zones, with a dedicated fleet of treatment barges assigned to each zone. Having barges dedicated to individual zones simplifies management of vessel operations and ensures quality of service in localized areas as well as the flexibility to temporarily or permanently reallocate treatment capacity among operating zones

One example of how a barge network could be designed involves dividingthe state into six (6) discrete network service areas or “zones,” follows:

- Zone 1 – San Francisco Bay (North Part) and Humboldt Bay
- Zone 2 – San Francisco Bay (South Part) and Monterey Bay
- Zone 3 – Carquinez Strait and Suisan Bay (including the Port of West Sacramento)
- Zone 4 – Stockton
- Zone 5 – Los Angeles/Long Beach and Vicinity
- Zone 6 – San Diego

Zone boundaries are shown in Figure 14 and Figure 15 below.

While other network configurations could ultimately prove more favorable or economical, this configuration is presented as a workable solution. Further research beyond the scope of this study could be performed to develop an optimized network design that involves other treatment barge allocations and different operating zones.

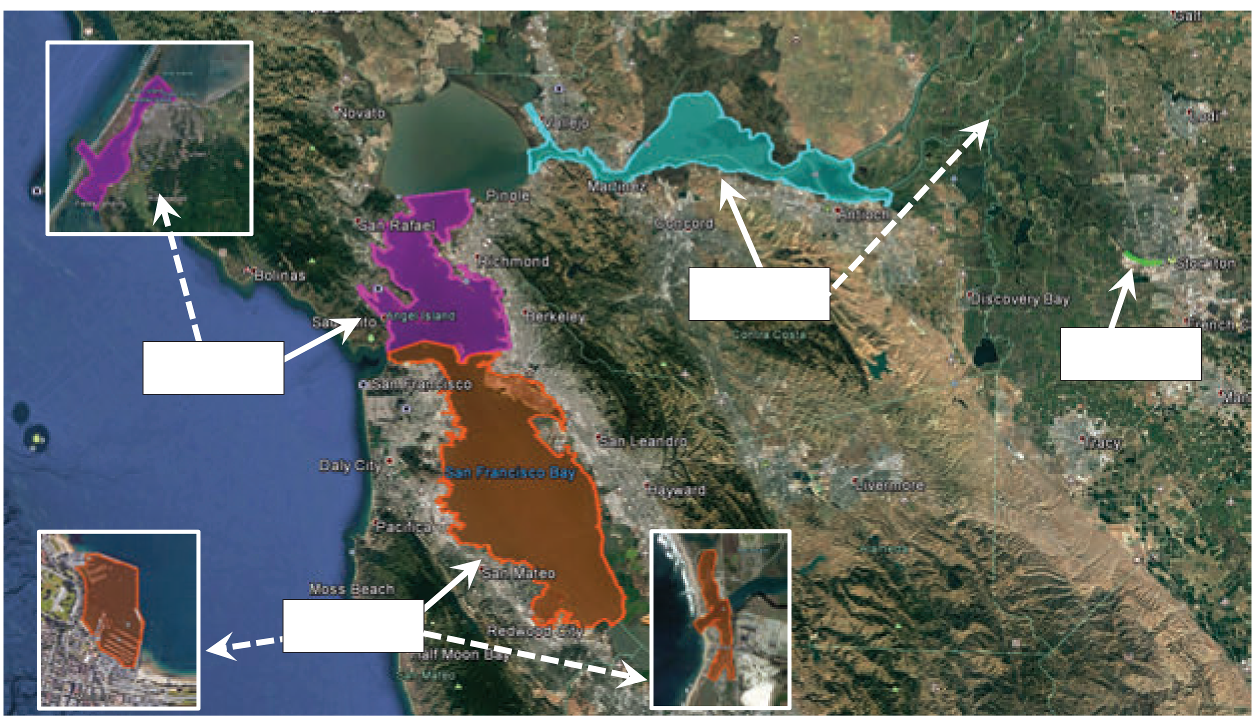


Figure 14 Google Earth capture showing barge network Zones 1-4, with their respective “satellite” areas overlaid

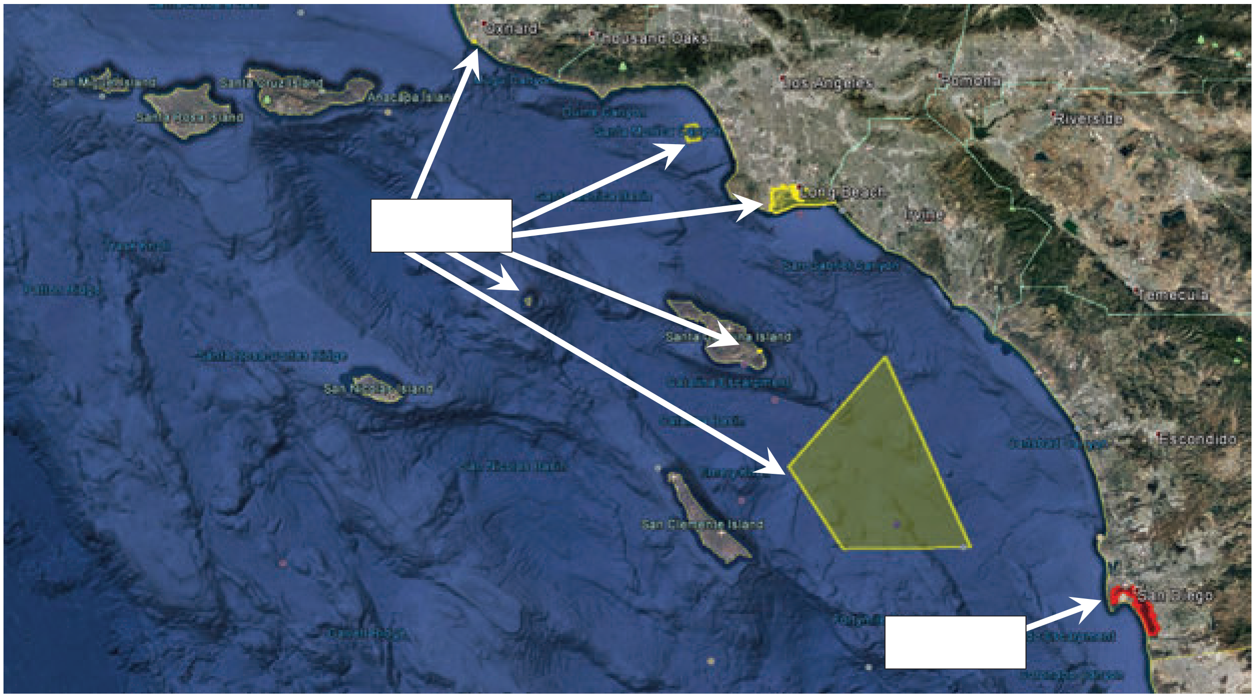


Figure 15 Google Earth capture showing barge network Zones 5 and 6

More detailed description and rationale for these zone designations is provided in the Task 13 report (Reference 13).

Ballast water treatment services in each zone would be provided by a dedicated and independently operated fleet of tank barges fitted with ballast water treatment systems on the main deck capable of meeting the CA Interim Standards, i.e. ballast water treatment barges (treatment barges).

Within their respective zones, treatment barges would be dispatched directly to marine vessels, at berth or at anchor, expecting to discharge ballast water. These barges would be pushed, towed, or otherwise transported by towing vessels (tugs), and secured alongside near a ballast transfer station outfitted on the vessel's main deck (see Task 2 report, Reference 1). A flexible hose would then be lifted by a deck crane on the barge and subsequently connected to a presentation flange at the vessel's ballast transfer station for the capture of untreated ballast water. During de-ballasting operations, ballast water would flow into the treatment barge tanks and, from there, a system of pumps would draw it to the barge's main deck for treatment before discharging overboard.

This operation is analogous to ship bunkering operations; and though it would constitute a new operation for ships' crews to manage, the general process would be very similar. Additional training would consist of education on the practice of off-loading ballast water and, in some cases, handling hoses of significantly larger sizes than those used for bunkering operations. Additional procedures and, potentially, more barge operators maybe needed in cases where ballast transfers would take place simultaneously with cargo operations. Shipboard modifications described in Task 2 would still be required, as with any shore-based treatment approach. The barge network would come online over a three-year period, as marine vessels are constructed and outfitted with suitable ballast transfer stations.

Three standard treatment barge concept designs have been developed for use across all six zones, summarized in Table 25. These barge sizes correspond to the range of ballast water discharge volumes and flow rates in California waters. Employing multiple barge sizes instead of just one standard barge design reduces the overall cost of the statewide fleet, as utilizing smaller barges (whenever they can serve all expected ballast water discharges) reduces capital expenses and vessel horsepower/capability requirements.

Table 25 Standardized barge designs for service in California

Treatment Barge Design	Small Barge	Medium Barge	Large Barge
Service Capacity			
Ballast Volume	10,000 m^3	20,000 m^3	35,000 m^3
Particulars			
Length	200 ft	240 ft	280 ft
Breadth	62 ft	74 ft	84 ft
Summary Totals			
Treatment Plant, Rate	721 m^3/hr	1,450 m^3/hr	2,570 m^3/hr
Surge Capacity, Volume	2,789 m^3	5,502 m^3	9,297 m^3
Cost, Barge and Outfitting	$6,273,599	$10,192,858	$15,451,111
Cost, Treatment Plant	$4,609,943	$7,009,470	$9,883,075
Cost, Total	$10,883,542	$17,202,328	$25,334,186

Across the six California treatment zones, there is variation in the size and composition of individual treatment barge fleets. Using some combination of the standardized barge designs introduced above, each fleet is structured to suit the average frequency and volume of ballast water discharges that occur in their respective zones at an availability rate of 99%. The composition of treatment barge fleets is summarized below in Table 26. Methods for determining treatment barge fleet composition and detailed information on each zone/fleet is described briefly in the following section, and in detail in the Task 13 report (Reference 13).

Table 26 Treatment barge zone summary

Zone Designation	Service Area	Small Barges (10,000 m^3 service)	Medium Barges (20,000 m^3 service)	Large Barges (35,000 m^3 service)	Total Barges
Zone 1	San Francisco Bay (North Part) and Humboldt Bay	1	1	2	4
Zone 2	San Francisco Bay (South Part) and Monterey Bay	2	-	2	4
Zone 3	Carquinez Strait and Suisun Bay	1	1	2	4
Zone 4	Stockton	-	1	2	3
Zone 5	Los Angeles/Long Beach and Vicinity	3	1	3	7
Zone 6	San Diego	2	-	-	2
TOTALS		**9**	**4**	**11**	**24**

Implementation of a treatment barge network in California requires a business model that balances the competing needs of: a) supporting existing commerce patterns, and b) ensuring investment of significant capital and time into this new and uncertain market. If the resulting fees to vessel operators are too high or imbalanced, it could cause noticeable increases in shipping costs (particularly for bulk exports), the diversion of marine commerce away from California in general, or a shifting of vessel activity from small or remote California ports to larger ones with lower overall port call costs. Investment capital and time is at risk due to the potential for political pressure to delay or even cancel implementation, and dependence on the marine vessels themselves to install specialized ballast transfer stations to support ballast water transfer operations. These delay risks, of course, also have environmental costs in terms of the amount of undertreated ballast water that may be discharged into California waters.

A public-private partnership (PPP) is a general framework where one or more private companies could work with the state of California and various port districts to balance these competing needs. Under the Design, Build, Operate (DBO) variation, California could finance the capital investment with private companies designing, building, and operating a fleet of service barges in one or more zones. Ownership of the barges and assets would depend on the terms of the financing. The PPP would require a licensing agreement that offers private operators exclusive access to the respective zone(s) they service. This would protect the joint investment and provide California a mechanism to control fees and potentially support disadvantaged port locations.

6.2.1 Methods

In developing a feasible zone approach, a statewide assessment was conducted, broken into four main aspects:

1. Develop a defensible method for dividing the state into discrete ballast water treatment zones.
2. Determine the geographical boundaries of each zone, as well as any "satellite" areas to be served.
3. Determine design basics for a minimum number of treatment barge models needed to efficiently serve all vessel types (i.e. basic dimensions, ballast water storage capacity, and ballast water treatment capacity).
4. Use data to determine the total number and appropriate "mix" of treatment barges needed to provide adequate service for each zone.

Once the zones were defined, vessel arrivals and ballast tank detail data were downloaded from the NBIC website in the form of comma-separated values (CSV) files for vessels arriving in California for years 2011 to 2015. The ballast tank detail data only were used to characterize ballast water discharge activity in California.

Ballast water discharge activity was analyzed for each of the six zones (presented in detail in the Task 13 report, Reference 13), including:

- Distribution of annual average ballast water discharge by discharge location (port)
    - Average annual amount
    - Average number of events per year
- Average annual discharge amount by vessel type
- Average number of discharge events per year as a function of discharge amount.
- Annual daily frequency of discharge events

Ballast water discharge activity within a zone was defined as all discharges that had discharge locations reported at ports or anchorages within the zone, regardless of arrival port and ballast water management.

The ballast tank detail data records reflect the tank-by-tank discharge activity reported on each ballast water management report submitted. This level of granularity was not required for the analysis performed here. To consolidate the tank-by-tank data into single discharge events, each record was assigned a unique identifier composed of the vessel's IMO number, discharge date, and an identification number associated with the discharge location. A ballast discharge event was then defined as a group of records with the same unique identifier.

Within the different treatment zones, there is variability in BWT demands, depending on the type of marine terminals present and the frequency of vessel calls/cargo operations at those terminals. The data analysis identified that three standardized barge designs, based on the following 10-hour treatment capacities, could service all California ports:

- 10,000 MT/12-hour treatment capacity.
- 20,000 MT/12-hour treatment capacity.
- 35,000 MT/12-hour treatment capacity.

Three nominal treatment barge designs were developed to suit these three capacities. The design concept seeks to minimize impacts to existing operations (allowing marine vessels to maintain their current discharge frequencies, locations, and flow rates) and treat ballast water to the CA Interim Standards

The fleet composition for each zone was based on the statistics of discharge events per day, which occurred within the zone boundary, as a function of discharge volume. The barge fleet in each zone was determined such that there is a 99% probability of barge availability with one barge out of service. Consideration was given to the distribution of discharge events per discharge amount when determining how many barges of each capacity should be assigned to each zone. It was noted that the highest capacity barges are able to handle all discharge amounts up to 35,000 MT.

A variety of operating and governance models were researched and evaluated in the context of the state's competing needs of: a) supporting existing commerce patterns; and, b) ensuring investment of significant capital and time into this new and uncertain market.

6.2.2 Summary of Findings

The use of treatment barges offers an effective means of servicing all ports and outport locations in California. These barges can be effectively dispersed throughout port districts to ensure vessels can offload ballast water at their current ballast water discharge rates, with minimal disruption to normal operations. Additionally, a statewide network of treatment barges offers a high degree of reliability, maximized by the following features:

- Barge machinery and equipment will be designed to robust marine standards to increase component reliability.
- Redundancy of systems, machinery and equipment on each barge to reduce downtime due to mechanical failure.
- Redundancy in the number of barges assigned to each zone.

  The operational redundancy goal was for a 99% probability of barge availability in each zone, with one barge out of service.

- Barge mobility allows inter-zone asset sharing.

The mobility of the barges means that a towing vessel and transit time between zones are the only requirements for asset sharing between zones.

These features, together with proper fleet composition, help ensure certainty and convenience for ship operators.

The adaptability of the barge-based network is also high due to the mobility of barges. As described above, three standard barge designs are proposed to meet system demands as represented by the NBIC data. Should the future demands of individual zones change, barge assets can be easily moved between zones, either temporarily or permanently. Should demand increase significantly in one or more zones, additional barges can be constructed and entered into service.

The scalability of the barge-based network is also high. As individual barges are constructed, they can be placed into operation immediately without having to wait for fixed infrastructure.

Simultaneous operations with cargo operations would present standard types of safety risks and other challenges that would have to be managed with strict adherence to established safety protocols and procedures. Crew training programs and spill contingency plans would also have to be developed and maintained over time.

The collection and disposal of filtrate presents additional challenges. The de-sedimentation and filtration processes will result in solid and slurry wastes that must be collected and disposed so as to not impact or present risks to the environment. This waste cannot be discharged into the harbor or dumped offshore, as it must be assumed to contain harmful aquatic organisms and pathogens. This material must be collected, dried, and sent to shore-side landfills.

Though there are several commercial approaches to implementing such a network of barges, a concession, granted for a limited time on a per-zone basis, is suggested as a means to promote effective service and pricing. A public-private partnership model should be considered as a means of incentivizing private investment in the barge network, while meeting the State's dual objectives of protecting the environment and promoting commerce. Further research is needed to determine an optimal network design and sustainable business model.

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Appendix B Internal References

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Shore-Based Ballast Water Treatment in California, Task 6: Outfalls for Treated Ballast Water Discharge, Glosten, Rev. -, 10 April 2018.

Shore-Based Ballast Water Treatment in California, Task 7: Permitting and Legal Requirements, Glosten, Rev. -, 10 April 2018.

Shore-Based Ballast Water Treatment in California, Task 8: Comparative Review of BWMS Operations, Glosten, Rev. -, 10 April 2018.

Shore-Based Ballast Water Treatment in California, Task 9: Current BW Discharge Practices, Glosten, Rev. -, 10 April 2018.

Shore-Based Ballast Water Treatment in California, Task 10: Cost Analysis, Glosten, Rev. -, 10 April 2018.

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Shore-Based Ballast Water Treatment in California, Task 13: Other Analysis and Findings, Glosten, Rev. -, 10 April 2018.

Shore-Based Ballast Water Treatment in California, Task 15a: Summary Report, Glosten, Rev. -, 10 April 2018.

Appendix C Independent Expert Panel Comments: Response for DSC Review

Task/Comment	Comment	Response
Task 2 - Retrofitting of Vessels	*Contractor shall assess retrofitting of existing vessels and outfitting of new vessels to allow discharge of ballast water through vessel-to-shore connections. The transfer of ballast water to shore facilities faces several practical challenges: ballast water pumps on board the marine vessels typically do not have adequate lift to move the ballast water up to the main deck; the ballast water tends to be moved during the cargo loading period; and the ballast water flow rates may require large piping that are not easily located. Further, such connections require hoses or articulated piping systems that can handle vessel motions and tidal changes when connected to another marine vessel or to shore.*	
2.1	Pumps	Updated to reflect consistent velocity rating. Updated booster vs. lift station terms.
2.2	Hydraulics	Updated controls arrangement discussion.
2.3	Ballasting Rates	Updated controls between ship and shore discussion, including affect of piping losses.
2.4	Hoses	Updated safety discussion on hoses and mooring lines, and compatibility of hose to ship connections.
2.5	Datasets	The data provided assumes continued discharges that are similar in rate and volume. The effects of future discharges are expected to increase based on trend for larger ships. This will require some conservatism in the final estimates of the handling equipment. This conservatism is provided in these calculations.
2.6	Cost estimates	A range of costs for each vessel type will be considered as a new scope item. The costs selected herein are representative of each group of vessels, and therefore useful for cost estimating, i.e. some less and some more cost, in general around the estimate.
Task 3 - Retrofitting of Ports/Wharves	*Contractor shall identify, summarize, and assess retrofitting of ports and wharves needed for receiving ballast water from the following vessel types that call on California and that will need to transfer to on-site reception and treatment facilities, taking into account the need to minimize the disruption of normal port and vessel operations: automobile carriers, bulk carriers, container ships, passenger cruise ships, tank ships, and articulated tug-barges..* *The contractor shall identify and summarize the available methods of transferring ballast water from marine vessels to shore-based or marine vessel-based reception and/or treatment facilities. The contractor shall identify which of these methods appears to be most feasible for the identified case studies. In some cases, such as Los Angeles/Long Beach, a combination of methods may be recommended. The contractor shall develop the concept of the required network, identify the potential impacts on port and vessel logistics, and cost the modifications.*	
3.1	Ship to shore conveyance	Not sure how to incorporate these aspects. Updated to note these trends in the report.
3.2	Logistical considerations	Noting in report that existing structures do continue to undergo changes to meet commercial and practical demands, such as changing services, trade, and vessel types.
3.3	Permitting	This is deferred to the permitting task report.
Task 4 - Treatment Plants/Facilities	*Contractor shall assess shore-based treatment plants and facilities needed to process ballast water. Construction at California's ports of dedicated shore-based ballast water treatment plants/facilities using the most cost-effective methods of treatment needed to meet California's interim performance standards, and including the construction of water storage facilities with appropriate capacity to minimize the disruption of normal port and vessel operations and minimize the overall cost of treatment. In determining the most cost-effective overall approach, the study should consider on a case-by-case basis (1) whether it would be more cost-effective for a port or terminal that receives a small quantity of ballast water to construct storage only at the site (that is, no treatment plant) and periodically ship the stored ballast water to a treatment plant located elsewhere, and (2) whether it would be more cost-effective to build storage and/or treatment in or on a barge moored at a port or terminal rather than on land. If ballast water storage or treatment is, for any reason, not feasible in port areas, or if alternative options are more cost-effective, the report shall discuss alternative options for nearby storage and treatment. This analysis should also compare the feasibility and use of dedicated treatment facilities vs. use of existing municipal or industrial wastewater treatment systems and/or outfalls.* *This assessment shall be closely coordinated with Task 3, port/wharves modifications, and in consideration of practical logistics to provide concepts relevant to the case studies. In making the assessment, the following shall be considered:* *• Use of storage facilities, land or vessel based,* *• Transfer of ballast water to remote locations for processing,* *• Barge-based as compared to land-based facilities, and* *• Use of existing versus new water treatment plants.* *Following the initial assessment, the selected concept for each case study shall be developed including footprints, costs, and schedule.*	
4.1	Cost estimates	Updated design life considerations in the cost estimate task report to accommodate 30 years. Discuss permitting use and lost opporunity costs in report.
4.2	Permitting	Panel concurrence, no change requested.
4.3	Recycling and reuse	Discussion on reuse of ballast water incorporated.
4.4	Lift stations	Coordination added to Task 2, relative to ship to shore operations.
Task 5 - Treatment Technologies	*Contractor shall assess applicable types of treatment technologies available for shore-based reception facilities that can meet California's interim performance standards and how the efficacy of such systems can be measured. Current testing guidelines and protocols have been challenged to definitively determine if the developed technologies have been consistently meeting the established standard. This challenge comes more sharply into focus when considering the California treatment standard that is significantly more stringent.*	
5.1	Non-detect limits	Added to report.
5.2	Literature	Studies considered are adequate.
5.3	Pathogen control	Consideration of virus removal added.
5.4	DBP formation	Added to report.
5.5	Monitoring	Added to report.
5.6	Technology Selection	Will incorporate in report.
5.7	Coagulation Chemistry	Will incorporate in report.
5.8	Reuse vs. Discharge	Will incorporate in report.
5.9	Permitting	Permitting is covered in Task 7.
Task 6 - Outfalls	*Contractor shall provide an assessment on construction of outfalls for treated ballast water discharges, and provision for disposal of solids as needed.*	
6.1	Port Logistics	Task 13 addresses the port logistics aspects discussed in this comment. This includes the transit time of the barges between service locations and the frequency of vessel ballast water discharges. It also includes the "rush hour" effect, specifically how often multiple ships will be discharging on a single day. We suggest that all aspects of this comment are addressed in Task 13.
6.2.1	Alternate Power	The environmental burden is discussed generally in Task 8. The impact of alternative power sources (LNG, etc.) will added to this discussion.

Task/Comment	Comment	Response
6.2.2	Near-Term & Future Scenarios	The proposed scenarios are not in the project scope. Aspects related to a two-phase treatment (onboard pretreatment plus shore-based) can be reviewed and reported in a new short section that considers the primary current shipboard technologies. Please confirm and an estimate will be provided.
6.3.1	Treatment Validation	Discussion is included in Task 5 report.
6.3.2	Solids Disposal	Will incorporate a range of potential values in report. Relevant references identified in Task 1 - Literature Review.
Task 7 - Permitting and Legal	*Contractor shall provide a review and analysis report on applicable existing, environmental, water quality, and ballast water management laws (state, federal, international) and their regulation of the discharge of ballast water treated by shore-based facilities into receiving ports. This analysis should include a review of the legal liability for vessel discharge compliance using shore-based reception and treatment facilities. The review should also include a brief overview of the potential for shore-based treatment facilities to handle other (non-ballast) vessel discharges.*	
7.1	Permitting - Land-Based Disposal	Unable to predict future regulatory changes or permitting requirements. Not in project scope.
7.2	Permitting - Shoreside Recep Facilities	Will incorporate discussion on permitting shoreside facilities for reception of filtrate/solids.
7.3	Permitting - General Permit	Will expand explanation of EPA Vessel General Permit in report.
Task 8 - Shipboard vs. Shore-based	*Comparative review of potential impacts of shipboard ballast water treatment versus discharge to shore-based reception facilities versus retention of all ballast water onboard the vessel. Impacts shall include, but not be limited to, air quality, water quality, energy consumption, coastal land-use, port congestion and port operations.*	
8.1	Energy Estimate Sources	Will add source information to report.
8.2	Air Quality Information	Will expand discussion on air quality in report.
Task 9 - Current Discharge Practices	*Contractor shall assess the annual number of vessels that would need to discharge ballast while underway in California waters rather than at port and the amount of ballast water needing such discharge, and effective methods capable of minimizing or eliminating such discharge into California waters, including changes in equipment, use of different vessels or ports, other operational adjustments, use of barges or other vessels to receive the discharge, or other approaches.* *Contractor shall identify the number of vessels and their ballasting characteristics. Identify subject vessels through research on past ballast water discharges using the National Ballast Information Clearinghouse database and relevant current information.*	
9.1	Discharge Patterns	Discharge patterns and trends are not included in the scope. An analysis of such trends can be performed as additional scope. Please confirm and an estimate will be provided.
9.2	Discharge Trends	
9.3	Interviews - Contextual Info	Scope was already exceeded in conducting stakeholder inteviews. Any relevant contextual information not included in the report will be added.
9.4	Deep Water Service Stations Info	An assessment as per the panel's request can be provided as a new scope item. Please confirm and an estimate will be provided.
Task 10 - Cost Analysis	*Contractor shall conduct a cost analysis of shore-based facilities versus upgrading shipboard systems as technologies or methodologies improve over time to meet California's interim performance standards. This analysis should take into account ballast water management requirements by other state, federal, and international agencies and regulatory bodies. Cost analysis shall include, but not be limited to, land acquisition, equipment (capital costs and operation and maintenance), labor, and the need to acquire relevant regulatory approvals. Costs shall be calculated on the basis of costs to the shipping industry (ship owners or ports) to comply, and costs to the state regulatory agencies to implement.*	
10.1	Monetization - Invasive Mitigation	Such an assessment is not part of the project scope, i.e. estimating the cost benefit of reduced environmental harm. This would be a very valuable assessment, and would certainly help the reader understand the "benefit" portion of the cost analysis. That noted, this would be a significant effort. We are unsure if we should estimate this, or this be part of a separate project.
10.2	Provide Spreadsheet/Calcs	Spreadsheet will be provided as an enclosure with the final report.
10.3	Economic Model Parameters	The panel's requested multiparameter analysis is outside of the feasibility level cost analyis scope. We can provide such an assessment including a sensitivity and uncertainty analysis. Please confirm and we will provide an estimate.
Task 11 - Implementation Timeline	*Contractor shall conduct an estimate of the time needed to fully implement shore-based ballast water reception and treatment facilities needed to meet California's interim performance standards (including land acquisition, permitting, design and construction of facilities and retrofitting of vessels) compared to overcoming challenges currently encountered by shipboard treatment systems that so far have been incapable of meeting California's interim standards. Contractor shall develop an implementation timeline. The timeline shall be delivered as a GANTT chart using MS Project. It shall include details and major milestones.*	
11.1	Treatment System Certification	Will expand discussion on treatment system comissioning and certification in report.
11.2	Stakeholder Input	Will update GANTT chart and report.
11.3	Permitting Process	This discussion is included in Task 7 - Permitting and Legal.
Task 12 - Market Implications	*Contractor shall conduct an analysis of shipping market implications of complying with California's interim performance standards through the use of shore-based ballast water reception and treatment facilities with respect to the competitive environment in which vessels call at California ports (i.e. taking into account competition from other West Coast, Gulf Coast, east coast and international ports).*	
12.1	Reference Citations	Will add reference citations to report.
12.2	Examples of Influencing Market Fluctuations and Trends	Will incorporate in report.
Task 13 - Other Analysis & Findings	*Contractor shall conduct any other analyses or findings not covered by the above tasks and related to shore-based ballast water treatment to meet California's interim performance standards. Issues to be considered include reliability, adaptability, safety, ease of maintenance or repair, contingency planning, training and qualifications of system operators, certainty and convenience to ship operators, and the effort and cost to a regulatory agency to monitor and enforce the level of compliance and effectiveness.*	
13.1	Optimization of Statewide System	The panel's comments on optimizing the statewide system are well noted. We suggest that a discussion on optimizing can be added within the existing scope, and still serve the panel's objective. If this is suitable, we will proceed on that path. If an optimization is needed, please confirm and an estimate will be provided.
13.2	Risk Analysis/SWOT	A risk analysis methodology and/or SWOT analysis are not in scope. We suggest that a discussion on how other methods of breaking the network into pieces could be effective, without actually doing these assessments. If this is suitable, we will proceed on that path. If these assessments are needed, please confirm and an estimate will be provided.