SHORE-BASED BALLAST WATER TREATMENT IN CALIFORNIA

TASK 8: COMPARATIVE REVIEW OF BWMS OPERATIONS

PREPARED FOR

DELTA STEWARDSHIP COUNCIL
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PREPARED	CHECKED	APPROVED
DAVID W. LARSEN, PE	**ROSS DUNNING, PE**	**KEVIN J. REYNOLDS, PE**
GLOSTEN	KENNEDY/JENKS CONSULTANTS	GLOSTEN

Table of Contents

Executive Summary 1

Section 1 Introduction 4

Section 2 Comparative Review of Shipboard Versus Shore-based Ballast Water Management Operations 5

2.1 Air Quality 5

2.2 Water Quality 8

2.3 Energy Consumption 8

2.4 Port Congestion 9

2.5 Port Operations 11

Appendix A Study Overview and Definitions A-1

Study Overview A-2

Tasks Overview A-2

Definitions A-3

Revision History

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

References

1. *Shore-Based Ballast Water Treatment in California, Task 13: Other Analysis and Findings,* Glosten, 20 September 2017.
2. *Shore-Based Ballast Water Treatment in California: Memorandum on Scale-up of Land-based and Barge-based Alternatives*, Glosten, 6 April 2017.

Executive Summary

The implementation of on-shore ballast water treatment plants, proposed as treatment barges, promise to meet California's Interim Ballast Water Discharge Performance Standards (CA Interim Standards). This is a more stringent standard as compared to the international and federal standards. For example, whereas the federal standard allows up to 10 viable organisms in the greater than 50 micron nominal size class, the CA Interim Standards allow no detectable. From an environmental impact perspective, this is an improvement.

There is, however, an environmental cost associated with meeting the higher standard. Specifically, the on-shore treatment plant requires twenty times the footprint and six times the power as compared to current shipboard treatment plants that are only certified to meet the federal discharge standard. This approach trades the effects of one impact, reduction in potential aquatic invasive species discharged, for another, an increase in air pollution from the larger treatment plants. These impacts are investigated in this report, including:

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

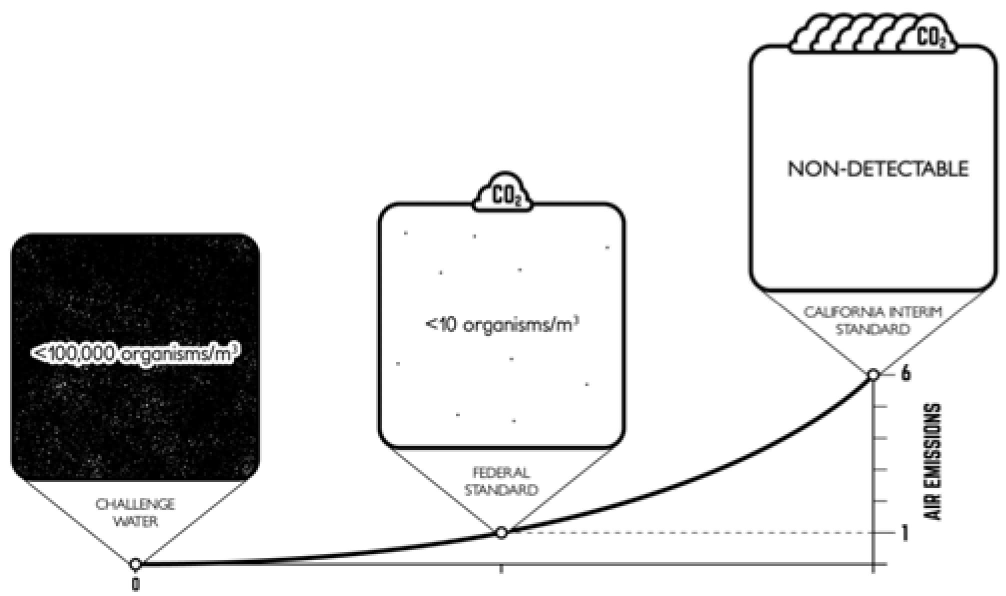

Figure 1 Increasing levels of organism reduction require increasing levels of energy which equates to air emissions

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. 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 can't meet the CA Interim Standards, but simply that they haven't 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 a practical example 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 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 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 1 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%***

Section 1 Introduction

This report is part of an overall coordinated study evaluating the feasibility of using shore-based mobile or permanent ballast water management facilities to meet the CA Interim Standards. This report is presented to the Delta Stewardship Council to meet the objectives of Task 8 – Comparative review of shipboard versus shore-based ballast water management operations. Description of the overall study can be found in Appendix A, along with definitions for terms used in this study.

This report (Task 8) provides a comparative review of shipboard vs. barge-based ballast water management operations, including a qualitative assessment of impacts to local air and water quality, energy consumption, coastal land-use, port congestion, and port operations.

Section 2 Comparative Review of Shipboard Versus Shore-based Ballast Water Management Operations

2.1 Air Quality

2.1.1 Retention

For the limited number of vessels able to retain their ballast water aboard while within the 24-nautical-mile boundary of the US Contiguous Zone, there will be little to no change to air quality from existing vessel operations. That is because there will be little or no change in the power required by these vessels compared to their existing operations. Modest changes in propulsion power from the additional vessel displacement are not considered in this evaluation.

Any ballasting required by these vessels would happen outside the 24-nautical-mile boundary of the US Contiguous Zone, subject to EPA/IMO regulations. Air quality issues outside the 24-nautical-mile boundary are not considered in this evaluation.

2.1.2 Shipboard Ballast Water Management

Instantaneous shipboard BWMS power requirements are commonly as high as 100 kW for a 2,000 m3/hr system[1], and treatment durations of up to 10 hours are required for a large ship. This results in a net power requirement of up to 1 MWh. For vessels moored pierside, there are two typical methods for generating power: (1) shipboard diesel generators or (2) alternate marine power (AMP), aka cold ironing.

Many berths in California ports are fitted with alternate marine power (AMP), allowing vessels to plug in to shore power and shut down their diesel generator engines while in port. If a vessel operating a BWMS is able to use AMP, there will be no increase in the vessel air emissions from shipboard ballast water management, because no increase in shipboard power will be realized. There will likely be an increase in air emissions at the public utility district (PUD) level from the increased power necessary to operate the BWMS, depending on the PUD's sources of power. PUD emissions are expected to be considerably lower per kilowatt hour than shipboard generated power.

If the vessel is unable to use AMP and must power the BWMS with shipboard generated power, air emissions from the vessel will increase compared to using AMP. This is because shipboard power is typically generated with diesel generators. The air emissions from the diesel generators will depend on power levels and EPA/IMO certification level, but are expected to be higher on a kilowatt hour basis than PUD generator power.

The actual air emissions will vary greatly from vessel to vessel and will depend on: BWMS size and power requirements, shipboard generator EPA/IMO emission certification level, and quantity of ballast water to be treated. With loads up to 1 MWh, the overall increase in air emissions due to ballast water management may be significant. A few example emissions amounts for shipboard BWMS operation are given in Table 2 and Table 3 for comparison purposes. Table 2 gives the emission limits for an EPA Tier 2, Category 2 marine diesel engine (less than 10 years old) and the resultant emissions for the estimated 100 kW of additional electrical load on the engine to operate a shipboard BWMS. Table 3 gives the same data for a new engine/ship complying with EPA Tier 4 limits. Emissions could be much higher than these examples for older ships.

[1] Hyde Guardian Gold HG2000G

Table 2 Emissions for EPA T2 - Category 2 Engine

EPA Emission Limits (grams/KW hr)			Resulting Emissions for 100 kW of power (kg/hr)		
CO	NOx+HC	PM	CO	NOx+HC	PM
5	9.8	0.5	30	58.8	3

Table 3 Emissions for EPA T4 - Category 2 Engine

EPA Emission Limits (grams/KW hr)			Resulting Emissions for 100 kW of power (kg/hr)		
CO	NOx+HC	PM	CO	NOx+HC	PM
5	2	0.04	30	12	0.2

Note: Shipboard ballast water management discussions are limited to IMO compliant and/or USCG type approved systems. These systems have lower effluent discharge requirements than the CA Interim Standards. It is not certain that existing IMO and USCG approved systems will comply with the CA Interim Standards or be able to be modified to comply with the CA Interim Standards.

2.1.3 Barge-based Ballast Water Management

Barge-based ballast water management from a network of treatment barges is likely to significantly impact air quality when compared to the other ballast water treatment alternatives, for three reasons: (1) barge-based BWMS will be meeting a significantly higher effluent standard, which requires additional power to achieve, (2) barge-based power generation will be required to operate the BWMS and (3) the treatment barges will need to be deployed to the ships, typically by diesel powered tug boats, which requires power.

Barge-based BWMS able to meet the CA Interim Standards are anticipated to need instantaneous power requirements of up to 600 kW and treatment duration times of up to 10 hours to treat large ships.[2] At 6 MWh, this is up to 6 times the power requirements of IMO compliant BWMS.

The treatment barges will also not be able to take advantage of AMP (shore based power), since they are going to be moored on the outside of the ship being treated. This means that the barges will need to utilize onboard generators (typically diesel powered) to produce the power necessary for the BWMS to operate. Since the barges are anticipated to be new, the diesel generators should meet the latest EPA Tier 3 or Tier 4 emission standards, depending on generator size, mitigating the impacts to some extent. Table 4 gives the emission limits for a EPA Tier 3, Category 1 marine diesel engine that could be used on the barges, and the resultant emissions for the estimated 600 kW of additional electrical load on the engine to operate the barge-based BWMS.

[2] Based on a 0.25kW/m^3 power consumption, extrapolated from Task 5 of this report.

Table 4 Emissions for EPA T3 - Category 1 Engine

EPA Emission Limits (grams/KW hr)			Resulting Emissions for 600 kW of power (kg/hr)		
CO	NOx+HC	PM	CO	NOx+HC	PM
5	5.8	0.12	180	208.8	4.32

The third factor negatively impacting air quality is the fact that tugboats will likely be required to deploy the barges to the locations of the ships needing the ballast water management. Tugboat propulsion and electrical power generation are both typically diesel powered. Tug power levels would be on the order of 2 MW per hour, based on a 4,000 HP tug with a 200 kW diesel generating plant operating at about 50% power output. Air emissions from the tugs would be highly variable and depend on EPA emission standards for the tug's diesel engines as well as the running time of the tugs. New tugs would meet EPA Tier 4 emission requirements, while older tugs may not meet any EPA emission standard. Operational times for the tugs would depend on factors such as deployment distance and port activity levels. A few example emissions amounts for tug operation are given in Table 5 and Table 6 for comparison purposes. Table 5 gives the emission limits for an EPA Tier 2, Category 2 marine diesel engine (less than 10 years old) and the resultant emissions for the engine operating with 2,000 kW of load. Table 6 gives the same data for a new tug meeting EPA Tier 4 requirements. Emissions could be much higher than these examples for older tugs.

Table 5 Emissions for EPA T2 - Category 2 Engine

EPA Emission Limits (grams/KW hr)			Resulting Emissions for 2000 kW of power (kg/hr)		
CO	NOx+HC	PM	CO	NOx+HC	PM
5	9.8	0.5	600	1176	60

Table 6 Emissions for EPA T4 - Category 2 Engine

EPA Emission Limits (grams/KW hr)			Resulting Emissions for 2000 kW of power (kg/hr)		
CO	NOx+HC	PM	CO	NOx+HC	PM
5	2	0.04	600	240	4.8

Table 7 gives a range of the total annual estimates of air emissions based on 12.856 MMT of ballast water to be treated annually from 1,755 annual port calls. The best-case scenario is based on all engines in the treatment barges and tugs being EPA Tier 4 certified. The worst-case scenario is based on all engines on the treatment barges being EPA Tier 3 and all tug diesel engines being EPA Tier 2.

Table 7 Total Annual Emissions Estimates for Barge-Based BWMS

Best Case All Engines EPA Tier 4 (MT)			Worst Case Engines Mix EPA Tier 2 & 3 (MT)		
CO	NOx+HC	PM	CO	NOx+HC	PM
34	14	0.3	34	53	2.2

Alternate, lower-emission means of powering the barges and tugs, such as LNG, CNG, hybrid, or battery have not been considered, due to their increased capital and lifecycle costs. Alternate fuels or energy sources may be possible, but are beyond the scope of this feasibility study.

2.2 Water Quality

2.2.1 Retention

For the limited number of vessels able to retain their ballast water aboard and refrain from discharging within the 24-nautical-mile boundary of the US Contiguous Zone, there will be no change to water quality from existing non-ballasting vessel operations because no ballast water is discharged.

2.2.2 Shipboard Ballast Water Management

Presently shipboard ballast water management systems are either IMO compliant and/or USCG type approved systems. These systems have lower effluent discharge requirements than the CA Interim Standards. It is uncertain and unlikely that existing IMO and USCG approved systems will be sufficient to meet the CA Interim Standards, and it is expected that additional treatment stages would be necessary if they were to. This will require additional equipment and most importantly additional space. In short, it is unlikely that existing IMO and/or USCG type approved systems will be able to be modified to comply with the CA Interim Standards, especially within the space constraints on existing ships.

2.2.3 Barge-based Ballast Water Management

Based on the evaluation by the study team, our opinion is that a network of treatment barges is expected to be the only way to comply with the CA Interim Standards when ballast water discharge in California receiving waters is required.

2.3 Energy Consumption

2.3.1 Retention

For the limited number of vessels able to retain their ballast water aboard and refrain from discharging within the 24-nautical-mile boundary of the US Contiguous Zone, there will be no change to energy consumption from existing vessel operations.

2.3.2 Shipboard Ballast Water Management

For shipboard ballast water management, energy consumption will increase in comparison to existing vessel operations, but is expected to be lower than barge-based ballast water management. If the vessel is able to use AMP, the increase in energy consumption will be at the public utility district (PUD) level from the increased power necessary to operate the BWMS. If the vessel is unable to use AMP and must power the BWMS with shipboard generated power, energy consumption for the vessel will increase over existing vessel operations.

The actual increase in energy consumption will vary greatly from vessel to vessel and will depend on ballast water management system size and power requirements, and quantity of ballast water to be treated. As discussed above, with instantaneous BWMS power requirements as high as 100 kW and treatment times up to 10 hours for a large ship, i.e. 1 MWh, the increase in energy consumption may be significant.

Note: Shipboard ballast water management discussions are limited to IMO compliant and/or USCG type approved systems. These systems have lower effluent discharge requirements than the CA Interim Standards. It is not certain that existing IMO and USCG approved systems will comply with the CA Interim Standards or be able to be modified to comply with the CA Interim Standards.

2.3.3 Barge-based Ballast Water Management

Overall energy consumption will be highest for barge-based ballast water management from a network of treatment barges when compared to the other ballast water management options. There are two reasons for this. First, as discussed above, the barge-based ballast water management method is achieving a higher level of effluent water quality than current shipboard systems are capable of, requiring up to six times more energy (power) for additional treatment stages when compared to the shipboard systems. The second reason for higher energy consumption is the energy consumption necessary to deploy the barge fleet to the ships needing ballast water management services – i.e. the energy necessary to power the tugs deploying the barges.

Actual energy consumed by the tugs would be highly variable and would depend on factors such as deployment distance, weather conditions, and port activity levels.

Barge power levels are estimated to be up to 600 kW for up to 10 hours – i.e. 6 MWh, for treating a large ship. Tug power levels to deploy and retrieve the barges are estimated to be on the order of 2 MW/hr, based on a 4,000 HP tug with a 200 kW diesel generating plant operating at about 50% power output.

2.4 Port Congestion

2.4.1 Retention

For the limited number of vessels able to retain their ballast water aboard and refrain from discharging within the 24-nautical-mile boundary of the US Contiguous Zone, there will be no change to port congestion, as there is expected to be no increase in the time required for vessel loading/unloading operations.

2.4.2 Shipboard Ballast Water Management

For shipboard ballast water management there would be no change to port congestion, as there is expected to be no increase in the time required for vessel loading/unloading operations.

Note: Shipboard ballast water management discussions are limited to IMO compliant and/or USCG type approved systems. These systems have lower effluent discharge requirements than the CA Interim Standards. It is not certain that existing IMO and USCG approved systems will comply with the CA Interim Standards or be able to be modified to comply with the CA Interim Standards.

2.4.3 Barge-based Ballast Water Management

Implementation of barge-based ballast water management from a network of treatment barges will increase the tug/barge traffic at California ports and would be expected to increase congestion in the busiest ports. This could happen in a myriad of ways. First, there will be tugs deploying and retrieving the fleet of ballast water treatment barges among the vessels requiring ballast water management services in the various harbors. It is anticipated that the tugs will not stand by the treatment barges during operations, but drop them off and then return for the barges upon completion of ballast water treatment operations. In areas such as San Francisco Bay and Port of Los Angeles/Port of Long Beach, with multiple ballast water discharge events per day, this will result in a significant increase in port traffic, which may lead to an increase in port congestion.

In smaller ports with modest vessel traffic, the uptick in vessel traffic related to barge-based ballast water management may not increase congestion adversely.

Second, in physically constrained port berths, having a treatment barge moored outside the vessel in the navigable waterway may restrict or at least slow down other vessel traffic, resulting in an increase in port congestion. For descriptive purposes, Figure 2 and Figure 3 show how a treatment barge could look moored to a vessel at the Port of Stockton or Port of Long Beach, respectively. The treatment barge extends significantly into the available navigable waterway. To navigate a large ship past a deployed treatment barge may require slower speeds and/or additional assist vessels. In open ports with wide channels, the barge-based BWMS may not increase port congestion adversely.

Lastly, port congestion may increase should there occasionally be a need to wait for an available treatment barge, if a barge is not available when needed.

Figure 2 Large treatment barge moored alongside a vessel at Port of Stockton

Figure 3 Large treatment barge moored alongside a vessel at Port of Long Beach

2.5 Port Operations

2.5.1 Retention

For the limited number of vessels able to retain their ballast water aboard and refrain from discharging within the 24-nautical-mile boundary of the US Contiguous Zone, there will be no change to port operations, as there is expected to be no increase in the time required for vessel loading/unloading operations.

2.5.2 Shipboard Ballast Water Management

For shipboard ballast water management there would be no change to port operations, as there is expected to be no increase in the time required for vessel loading/unloading operations.

2.5.3 Barge-based Ballast Water Management

The treatment barges are intended to be operated in parallel with vessel cargo operations to minimize potential impact on vessel port stays and port operations. In further research on the feasibility of a barge-based ballast water management system, it will be important to obtain concurrence from representatives of all personnel potentially impacted by ship operations and treatment barge operations as to the validity of this assumption.

Beyond cargo operations, barge-based ballast water management is expected to impact port operations in the following ways:

Vessel scheduling. Arriving vessels in each port with a need to process ballast water will need to be scheduled and the schedules coordinated with the treatment barge fleet. While the sizes and quantity of barges in the proposed barge-based ballast water management system described in Reference 1 have been based on a 99% availability with one barge out of service, there is still a chance that a treatment barge may not be available exactly when needed. It is also possible to have scheduling issues, breakdowns with the supporting fleet of tugs, labor issues, etc. These would be new challenges for both ports and ship owners to deal with.

Fuel bunkering. Presently, many vessels bunker from a tank barge that moors alongside while the vessel is berthed in port. While some vessels may be able to have multiple barges moored alongside simultaneously performing different operations, most will not. Barge-based ballast water management operations will likely interfere with these dockside barge-based bunkering operations. The net result may include increased pierside time for vessels to allow sequential bunkering and ballast water management to take place, or the vessels needing to go to an anchorage to bunker either before or after the vessel's dockside time.

Barge-based emission controls. Similar to bunkering challenges, vessels utilizing barge-based emission control methodologies for compliance with dockside emission requirements will have to assess whether it is feasible to have multiple barges moored alongside simultaneously. If it proves unfeasible, the vessel owners will need to make potentially costly changes to the vessels emission control strategies.

Treatment barge mooring and maintenance. Port operations will need to determine where to moor the treatment barges when not in use. Ideally this would be in locations that are easily accessible for performing maintenance and repairs on the treatment barges and onboard systems.

Appendix A Study Overview and Definitions

Study Overview

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

In response, there has been significant development work and commercial installations of ballast water management systems (BWMS) onboard marine vessels themselves. However, there is a lack of data to determine if shipboard BWMS are capable of meeting the CA Interim Standards. Therefore, shore-based ballast water reception and treatment is under consideration as an approach to meet the CA Interim Standards.

This study evaluates the feasibility of shore-based ballast water reception and treatment in 13 separate tasks, beginning with a review of shore-based treatment research, followed by a series of detailed analyses, including: permitting and legal requirements, detailed cost estimates, timeline to implementation, and market implications.

Tasks Overview

Tasks 6 through 13 are submitted together to discuss the practical implementation of shore-based ballast water reception and treatment throughout California state waters, accomplished by a "network" of six (6) independently operating fleets of mobile treatment barges (see Table A-1).

During the course of this study, following completion of Tasks 2-5 and the comparative scale-up exercise described in Reference 2, this approach was deemed most technically, operationally, and financially feasible of the five approaches that were evaluated (i.e. new onsite treatment facility, new offsite treatment facility, existing wastewater treatment facility, shore-side mobile treatment, mobile marine vessel-based treatment).

Table A-1 Tasks 6 through 13

Task	Description
6	Assessment of construction related to outfalls for treated ballast water discharges, and provision for disposal of solids as needed.
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.
10	Cost analysis.
11	Implementation timeline.
12	Market implications.
13	Other analysis and findings. Introduces the concept of a statewide network of mobile treatment barges for the provision of ballast water reception and treatment services across the state, and forms the basis for assessments and analyses in Tasks 6-12.

Definitions

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

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

Ro-ro	Roll-on/roll-off (vessels designed to carry wheeled cargo such as car, trucks, trailers, and equipment)
RWCF	Regional Wastewater Control Facility (e.g. City of Stockton, CA)
Shipboard Ballast Water Treatment	Ballast water management approaches that do not require support from shore-based infrastructure and are conducted entirely by a vessel's crew.
Shore-Based Ballast Water Management	Ballast water management approaches that require support from shore-based infrastructure in order to meet ballast water management requirements. Such infrastructure may include: means of transferring ballast water to a land-based or another marine vessel facility for storage and/or processing, deployment of shore-based equipment and personnel for onboard treatment approaches, etc.
Slurry	Mixture of filtrate and filter residuals resulting from cleaning ballast water treatment filters.
Slurry Handling	Slurry handling includes activities related to the storage, treatment, and discharge of filtrate and residuals collected from cleaning ballast water treatment filters.
SOLAS	International Convention for Safety of Life at Sea
Storage	Storage of ballast water includes provision of space and containment for ballast water, either pre-or post-treatment.
STS	Ship-to-Ship. Transfer from one marine vessel to another.
TDS	Total Dissolved Solids
TEU	Twenty-foot Equivalent Unit
TOC	Total Organic Carbon
Transfer	Ballast water transfer considers the logistics and equipment required to capture the ballast water from the marine vessel and transport to a reception and treatment facility.
Transport	Transport is the method by which ballast water is moved post-capture from marine vessels to remote, non-mobile reception and treatment facilities – either land-based or otherwise.
Treatment	Treatment includes the various methods to process ballast water such that it is suitable for discharge in compliance with applicable standards and regulations.
Treatment Approach	A general method for implementing ballast water treatment. Treatment approaches may include mobile systems, land-based facilities, shipboard systems, etc.
Treatment Technology	Specific techniques for removal or inactivation of organisms in ballast water (e.g., UV disinfection, filtration, ozonation, etc.)
TRO	Total Residual Oxidant
TSS	Total Suspended Solids
UF	Ultrafiltration
UKC	Underkeel Clearance
UL	A global independent safety consulting and certification company (formerly Underwriters Laboratories).
USCG	United States Coast Guard
UV	Ultraviolet Light
UVT	UV Transmittance
VLCC	Very Large Crude Carrier

WWTF	Waste Water Treatment Facility
WWTP	Waste Water Treatment Plant