Port of Seattle

CRUISE VESSEL BIOMASS MANAGEMENT STUDY

DRAFT PHASE 1A

Data Compilation and Initial Assessment

DRAFT

JANUARY 2, 2009

ENSR | AECOM   kpff   THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community

Table of Contents

Executive Summary 2
Conclusions 5
Methodology 6
Description of Seattle-Alaska Cruise Industry 9
Northwest Cruise Ship Association 10
Memorandum of Understanding between NWCA and State of Washington 10
Alaska Discharge Standards 14
Description of Current Cruise Vessel Wastewater and Biomass Operations 15
Advanced Wastewater Treatment Systems 15
Type II MSDs 18
Characterization of Cruise Ship Biomass 18
Disposal of Cruise Ship Biomass 18
Chemical Properties of Biomass Generated 19
Wastewater Management in Scandinavia 26
Copenhagen Malmö Ports, Denmark 27
Port of Oslo, Norway 27
Port of Helsinki, Finland 28
Port of Stockholm, Sweden 29
Cruise Vessel Wastewater and Biomass Operations 33
Onboard Wastewater Treatment 33
Alternatives to Open-Ocean Discharge of Cruise Ship Biomass 33
Incineration 33
Shore Transfer 33
Existing Shoreside Operations 34
Shore Transfer of Biomass 44
Direct Discharge to Tanker Truck 49
Direct Discharge to Barge 50
Direct Discharge to Piping on Pier 50

Future Methods for Biomass Disposal 49
Conclusion 54
References 56

Figures

Figure 1. Growth in Port of Seattle Cruise Ship Usage from 1999 to 2009 (est.) 9
Figure 2. MOU Boundaries 13
Figure 3. Schematic of biological-chlorination Type II MSD (Source: EPA 2007) .... **Error! Bookmark not defined.**18
Figure 4. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: All Selected Metals 23
Figure 5. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Lowest Concentration Metals 24
Figure 6. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Lowest Concentration Metals 24
Figure 7. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Mid-High Concentration Metals 25
Figure 8. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Highest Concentration Metals 25
Figure 9. Baltic Sea Wastewater Reception Facility Locations 27
Figure 10. Vessel Mooring Lines (Terminal 30) 35
Figure 11. Rendering of T-91 Gangways 36
Figure 12. Crew Gangway (Pier 66) 37
Figure 13. Baggage Loading (Pier 66) 38
Figure 14. Baggage Loading and Crew Gangway 38
Figure 15. Vessel Provisioning (Terminal 30) 39
Figure 16. Utility Connection (Terminal 30) 40
Figure 17. Vessel Shore Power Connection (Terminal 30) 41
Figure 18. Typical Bunker Oil Truck 42
Figure 19. Pier Access (Pier 66) 43

Tables

Table 1. Seattle/Alaska Homeport Industry 12

Table 2. Summary of Washington State Department of Ecology Information Regarding NWCA Cruise Ships, Wastewater Treatment and Biomass Management 17

Table 3. Cruise Ship Chemical Data Summary 20

Table 4. Summary of Cruise Ship and King County Biomass Concentrations 22

Table 5. Wastewater Reception Facilities at Ports in the Baltic Sea 30

Section 1

Executive Summary

Executive Summary

On February 16, 2007, the Port of Seattle Commission passed a motion containing numerous environmental initiatives. The fourth item in this motion states:

> 4. The Commission recognizes the significant economic benefit to the region of having cruise ships homeport in Seattle. The Commission supports the growth of the cruise ship industry in Seattle as well as efforts to enhance water quality and the marine environment. The Commission directs staff to prepare a budget and work program to evaluate the feasibility, environmental impact, cost/benefit and possible funding sources of building additional infrastructure to support the cruise ship industry in Seattle, including proposals to facilitate off-loading of biosolids and hazardous waste. Work program elements will include convening a meeting or series of meetings beginning in the first half of 2007 on this topic, to include relevant Port staff, cruise ship industry officials, Department of Ecology officials, county and city public utilities and health officials, other relevant experts, and community and environmental group representatives.

In April 2007, the King County Council passed a complimentary motion (No. 12498), which directed the King County Wastewater Treatment Division to work cooperatively with the Port of Seattle and other affected agencies to undertake a study of the potential for processing marine cruise industry-generated wastewater through the county's wastewater treatment system. This work culminated in the August 2007 report titled **"Cruise Ship Wastewater Management Report"** prepared by the King County Wastewater Treatment Division.

That study provided several recommendations including identification of the following:

1. There is no identified benefit of channeling wastewater from cruise ships to the regional conveyance and treatment system.
2. The South Treatment Plant could receive and incorporate biomass into the existing treatment process without any expansion or modification of the South Treatment Plant. King County recycles all of its biosolids.

The focus of this King County study was on cruise vessel wastewater, not on biomass.

For the purpose of this study "**biomass**" refers to the partially treated solids residuals from the on-board wastewater treatment process.

As follow-on to the King County study, and with the knowledge that the King County system can receive cruise vessel biomass, Port staff has initiated this Phase 1A Study, to compile data and provide an initial assessment of the physical ability to store on-board, manage, and transfer to on-shore infrastructure the biomass generated by cruise vessels calling at Port of Seattle facilities. The intent of this work is to gain an understanding of the impacts to the vessels on-board infrastructure, pier side operations and facility on-shore infrastructure in order to determine if it is physically possible to store biomass and off-load it at the pier.

Existing Operational Procedures

In April 2004, the Northwest Cruise Association (NWCA), the Port of Seattle and the Washington State Department of Ecology entered into a Memorandum of Understanding (MOU) to formally acknowledge and implement common environmental goals, policies and practices around the management of solid waste, hazardous waste and wastewater within the boundaries of the MOU. The current boundaries of the MOU include Puget Sound, the Strait of Juan de Fuca south of the international boundary with Canada, and three miles from shore on the West side of the State. The MOU does not specifically define the term "biomass".

The majority of cruise vessels operating from Port of Seattle facilities utilize Advance Wastewater Treatment Systems (AWTS's). AWTS's are on-board treatment systems that treat sewage and usually graywater in a combined system. While these systems produce relatively clean effluent, they also produce large amounts of biomass that must be dealt with. The 2007 study conducted by King County estimated that cruise ships generate 35 tons (including water content) of biomass each day. This number is consistent with 15 to 40 tons identified in responses received by the Port of Seattle to questionnaires sent to NWCA member cruise lines.

Sampling accomplished by the EPA and discussed in more detail in Section 2 illustrate that concentrations of nearly all parameters in the cruise ship biomass are well below King County biomass concentrations for metals. Only the four organic constituents were detected in the cruise ship biomass, with phenol slightly exceeding the King County biomass concentration. While there is no ambient water quality criteria for phenols, in both cases the concentrations are below water quality criteria for the consumption of organisms established under EPA's water quality criteria.

Comparison to Scandinavian Operations

A discussion of Cruise Vessels operations in Scandinavia is provided in Section 2. Scandinavian Cruise Vessel operations occur on the Baltic Sea, which has been experiencing eutrophication resulting from high nutrient loading, primarily nitrogen and phosphorus. These conditions differ from North Pacific waters where biomass discharge occurs from Port of Seattle operating cruise vessels.

As described in Section 2, the Baltic Sea ports have invested in numerous dockside waste reception facilities. However, only some of the shipping companies utilize these facilities. Those ships that utilize shore-side wastewater hook-ups have placed the ships wastewater treatment systems on “stand-by”. Thus, a separate biomass waste stream would not be generated and all wastewaters would be landed ashore.

As such, when wastewater off-load does occur, it delivers all wastewater into the upland (municipal) sewage system rather than just delivering the biomass (residual) as proposed at Port of Seattle facilities. Accordingly, the Baltic Sea operations do not represent a direct comparison to proposed activities within Puget Sound. Further, and as identified in the 2007 King County report, there is no identified benefit of channeling wastewater from cruise ships to the regional conveyance and treatment system.

Existing Shoreside Operations

Pier-side activities are significant at facilities accommodating cruise homeport operations such as those provided by the Port of Seattle at Pier 66 and Terminal 91. Pier space is used simultaneously for vessel moorage, cold ironing, utility connection, all necessary crew and passenger embarkation/debarkation, provisioning, luggage transfer, fueling/bunkering as well as providing space for vehicular access. These ongoing activities currently utilize most of the available pier space in order to accomplish all necessary tasks in the short time vessels are alongside Port facilities. A general discussion of each of these operations including identification of their pier operational impact is provided in Section 3. A description of these activities is included because offloading of biomass would need to happen concurrently with these other activities and in the same pier side area.

Alternatives to Open-Ocean Discharge of Cruise Ship Biomass

The two alternatives to open ocean discharge of biomass that are practiced within the cruise industry are incineration and shore transfer. Both operations are discussed in detail in Section 3. Shore transfer alternatives discussed include direct discharge to tanker truck (staged on the adjacent pier), direct discharge to barge (staged opposite the pier on the waterside of the cruise vessel), and direct discharge to piping located on/under the pier.

Shoreside infrastructure improvements necessary to support off-loading biomass at the pier are discussed in Section 3. For each alternative discussed, it is assumed that biomass would ultimately be discharged at off-site King County Wastewater facilities in Renton. This discussion notes that, at a minimum, the following requirements must be met for shore transfer to be practical:

1. Vessels must have the ability to store biomass on board
2. The Biomass must be pumpable

3. The vessels must be configured to pump ashore
4. The vessels must have engineering crew available to oversee the transfer operation
5. The operation must be completed within the time the vessel is in port

The three methods of shore transfer discussed herein would have varying levels of impact to pier side operations and space. Direct discharge to tanker trucks would have the greatest impact and direct discharge to barge would have the least impact.

Conclusions

Based on the data provided herein, the following primary conclusions are apparent, each is described in more detail in Section 4 of this report:

- As currently configured, it is not possible for all vessels to store the entire volume of biomass generated in a week long cruise voyage. Two vessels reported they could store all biomass generated in a week. For the remaining vessels, the storage capacity varied from 47% to 94% of weekly generation (3.3 to 6.6 days of storage capacity). At this time, it is not known on a vessel by vessel basis if adding storage is possible.
- Biomass is pumpable and could potentially be pumped on shore.
- On-shore transfer would have significant impacts to pier side operations. The extent of these impacts would vary by vessel, dock facility, volume of biomass to discharge, and method chosen for transfer to shore facilities. However, it is clear that for at least some of the vessels currently calling at the Port, the requisite disembarkation/embarkation of passengers, bunkering and provisioning, as well as the scheduling demands of an Alaskan itinerary sailing from Seattle, make it unlikely that the vessel could unload all of its biomass during the short time they are alongside Port facilities.
- Further study would be needed for evaluation of the potential environmental impact(s) from off-loading biomass at the pier, including determination of the net environmental benefit/impact of both the off-load operation as well as introduction of this biomass into King County systems.

Methodology

The work provided herein represents on going efforts by the Port of Seattle to address issues identified in the February 16, 2007 Commission motion. Through discussions with Port staff and in recognition of the public attention to this issue, a decision was made to assemble and provide information as it is obtained, rather than wait until all potential studies are complete. As such, the work included herein is intended as the initial part of a potentially larger study that could be required to fully assess the impacts and benefits of alternative means to managing biomass on cruise vessels calling at Port facilities.

This larger study could include the following phases, the scope of each subsequent phase will be evaluated and authorized individually.

- Phase 1A – Data Compilation and Initial Assessment (this report)
- Phase 1B – Engineering Evaluation of On-board Systems and Viable Alternatives
- Phase 2 – Environmental Impacts/Benefits of Potential Implementation

The general intent of each phase identified above is specific:

- Phase 1A and Phase 1B are intended to evaluate the physical impacts to shoreside facilities and on-board infrastructure.
- Phase 2 would be intended to evaluate the environmental benefits and impacts of potential implementation.

In general, this Phase 1A Report has been assembled through review of existing reports and compilation of existing data. Specific existing reports reviewed include Department of Ecology reports documenting prior sampling accomplished on Puget Sound cruise vessels as well as available US EPA reports on cruise vessel on-board treatment systems.

Treatment vendors and cruise ship operators were engaged to understand how waste was being treated and handled by the vessels. A questionnaire was sent to the cruise ships to gather specific information about types of treatment systems employed, disposal practices, and vessel specifics including storage capacity. The vessel operators were also asked if their vessel was equipped with a means of transferring biomass ashore, and if not, whether a retrofit was feasible. A copy of the questionnaire sent to the Cruise Lines is included in the Appendix.

Initial assessment of the impacts to onboard and dock-side infrastructure of alternative biomass off-loading methods is generally based on the professional experience of the Port and Consultant team and their collective knowledge of Pier 91, Pier 66 and vessel infrastructure. Further detail engineering analysis could be accomplished as part of Phase 1B for those alternatives considered viable.

This report has been prepared by KPFF Consulting Engineers, ENSR/AECOM, and the Glosten Associates in cooperation with Port of Seattle staff.

Section 2

Description of Seattle-Alaska Cruise Industry

Current Cruise Vessel Wastewater and Biomass Operations

Characterization of Cruise Ship Biomass

Wastewater Management in Scandinavia

Description of Seattle-Alaska Cruise Industry

The Port of Seattle (POS) has experience significant growth both in the number of vessels calling at the port as well as the number of passengers embarking from the POS.

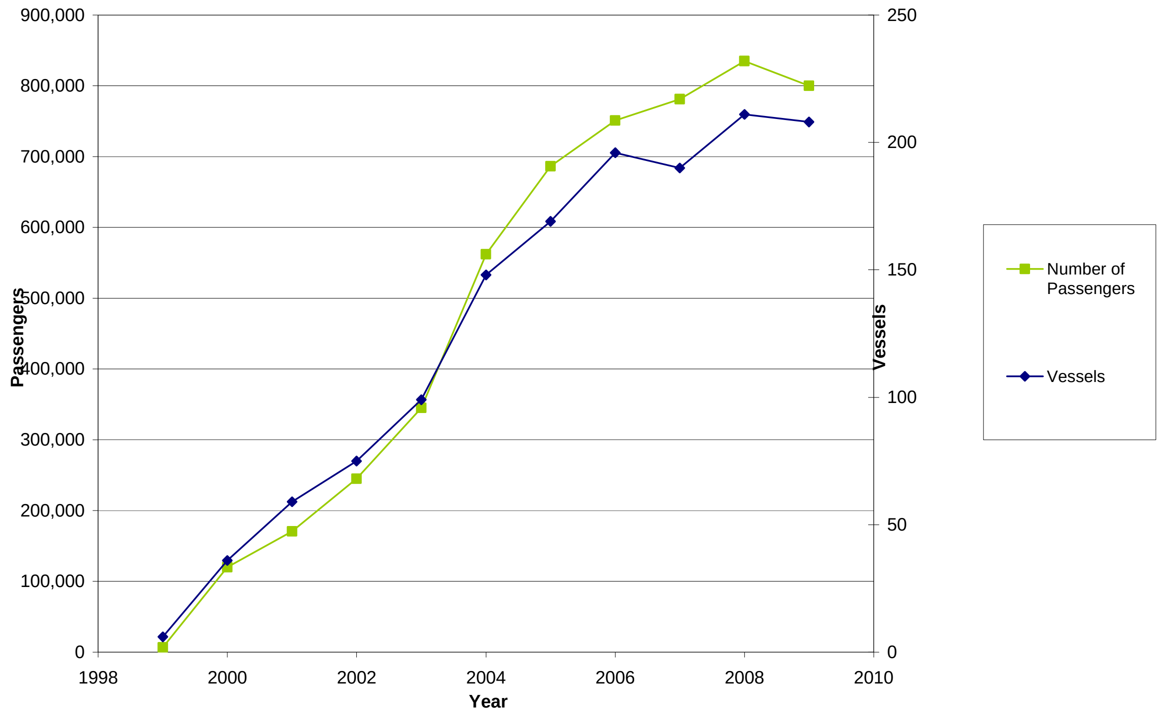

Figure 1. Growth in Port of Seattle Cruise Ship Usage from 1999 to 2009 (est.)

In the 2008 season, the Port of Seattle will welcome an estimated 211 cruise ship port calls and over 800,000 passengers (Port of Seattle, 2008). This industry has been steadily expanding since its inception in 1999, when only 6 cruise ships and 6,615 passengers left Seattle bound for Alaska. Ports of call for cruise ships in Alaska include:

- Anchorage
- Campbell River
- College Fjord
- Dutch Harbor
- Glacier Bay
- Haines
- Homer
- Hubbard Glacier
- Juneau
- Ketchikan
- Kodiak
- Seward
- Sitka
- Skagway
- Tracy Arm
- Valdez
- Whittier
- Wrangell

The POS operates as a "homeport" and more specifically, what is commonly called in the cruise industry a "turnaround port". This term refers to the fact that the Seattle-Alaska cruises originate from the POS where they disembark and embark passengers as well as provisioning (food, fuel, etc.) for their voyages. **Table 1** below summarizes the Seattle-Alaska cruise industry for 2008 as well as what is planned for 2009. In general, ten ships originate their cruises to Alaska from Seattle, three each on Friday, Saturday and Sunday and one every other

Thursday from two POS dock locations. In 2008, those dock locations were Terminal 30 and Pier 66. In 2009, activities at Terminal 30 will move to Terminal 91.

Northwest Cruise Ship Association

The Northwest Cruise Ship Association (NWCA) is a not-for-profit organization founded in 1986 and was originally intended to provide security services to member lines (Northwest Cruise Ship Association, 2008). Its role has since been expanded to include government relations on legal and regulatory issues. The Association often works with local organizations to mitigate concerns regarding the cruise industry. In addition, it funds economic and environmental studies and works with government agencies on cruise-related issues. Member lines of the NWCA that embark from Seattle include Celebrity, Holland America, Norwegian, Princess, and Royal Caribbean cruise lines.

Memorandum of Understanding between NWCA and State of Washington

In April 2004, the NWCA, the Port of Seattle and the Washington State Department of Ecology entered into a Memorandum of Understanding (MOU) to formally acknowledge and implement common environmental goals, policies and practices around management of solid waste, hazardous waste and wastewater within the boundaries of the MOU. The current boundaries of the MOU include Puget Sound, the Strait of Juan de Fuca south of the international boundary with Canada, and three miles from shore on the west side of the state (see **Figure 2**). The original MOU has amended each year since 2004. The most recent amendment (No. 4) was signed May 19, 2008 (http://www.ecy.wa.gov/programs/wq/wastewater/cruise_mou/FINALamendment4MOU051908.pdf).

The MOU provides the following important definitions for the purposes of this report:

> "blackwater" means waste from toilets, urinals, medical sinks and other similar facilities.
>
> "graywater" includes drainage from dishwasher, shower, laundry, bath, galley drains and washbasin drains.
>
> "residual solids" include grit or screenings, ash generated during the incineration of sewage sludge and sewage sludge, which is solid, semi-solid, or liquid residual generated during the treatment of domestic sewage in the treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary or advanced wastewater treatment processes; and a material derived from sewage sludge.

For "blackwater" and "graywater", all conditions of the MOU apply within "waters subject to this MOU" which include all Puget Sound water areas up to the Canadian border and coastal waters up to 3 miles off the shoreline coast of Washington. For "residual solids", the MOU boundaries are extended to 12 nautical miles from shoreline coast and the entire Olympic Coast National Marine Sanctuary.

The MOU does not specifically define the term "biomass" or "biosolids". For the purposes of this report, "biomass" refers to the partially treated solids residuals from the wastewater treatment process. Ship biomass will typically contain more liquid that shore side produced "biosolids". Cruise ship generated biomass would be considered a subset of the "residual solids" term defined in the MOU.

In the MOU, the cruise industry recognizes Washington's fragile marine environment and commits to help protect the environment. The MOU has established specific requirements for wastewater management and hazardous waste management. In addition, the MOU established an Ecology inspection program allowing inspection of a minimum of one vessel per season to verify compliance with the MOU.

Specific to wastewater, the MOU prohibits discharge of untreated blackwater, untreated graywater and solid waste within waters subject to the MOU and prohibits discharge of oily bilge water if not in compliance with applicable federal and state laws. Discharges of effluent from the treatment of blackwater and graywater are allowed within the boundaries of the MOU if certain reporting, recordkeeping and monitoring requirements are met. However, as stated earlier, the discharge of residual solids is **prohibited** in waters subject to this MOU, within 12 nautical miles from shore and within the entire boundaries of the Olympic Coast Marine Sanctuary.

Table 1. Seattle/Alaska Homeport Industry

2009 (Planned)

Day	Cruise Line	Vessel	Terminal	ETA	ETD	Pax Count	LOA	Itinerary	Arriving From	Next Port
Thursday	Princess	Pacific Princess	T91	0600	1600	670	594	14 Day	Victoria	Ketchikan
Friday	HAL	Zaandam	T91	0700	1700	1432	778	7 Day	Victoria	Juneau
Friday	Royal Caribbean	Rhapsody of the Seas	T91	0700	1600	1998	916	7 Day	Victoria	Juneau
Friday	Celebrity	Infinity	P66	0600	1600	2050	965	7 Day	Victoria	Juneau
Saturday	HAL	Amsterdam	T91	0700	1700	1380	781	7 Day	Victoria	Juneau
Saturday	NCL	Norwegian Star	P66	0600	1600	2240	965	7 Day	Prince Rupert	Ketchikan
Saturday	Princess	Golden Princess	T91	0600	1600	2600	950	7 Day	Victoria	Juneau
Sunday	HAL	Westerdam	T91	0700	1600	1916	936	7 Day	Victoria	Juneau
Sunday	NCL	Norwegian Pearl	P66	0600	1600	2380	965	7 Day	Victoria	Juneau
Sunday	Princess	Star Princess	T91	0600	1600	2600	950	7 Day	Victoria	Ketchikan

2008

Day	Cruise Line	Vessel	Terminal	ETA	ETD	Pax Count	LOA	Itinerary	Arriving From	Next Port
Friday	HAL	Amsterdam	T30	0600	1600	1380	781	7 Day	Victoria	Juneau
Friday	Royal Caribbean	Rhapsody of the Seas	T30	0600	1600	1998	916	7 Day	Prince Rupert	Juneau
Friday	Celebrity	Infinity	P66	0600	1600	2050	965	7 Day	Victoria	Juneau
Saturday	HAL	Oosterdam	T30	0600	1600	1848	936	7 Day	Victoria	Juneau
Saturday	NCL	Norwegian Star	P66	0600	1600	2240	965	7 Day	Prince Rupert	Ketchikan
Saturday	Princess	Golden Princess	T30	0600	1600	2600	950	7 Day	Victoria	Juneau
Sunday	HAL	Westerdam	T30	0600	1600	1916	936	7 Day	Victoria	Juneau
Sunday	NCL	Norwegian Pearl	P66	0600	1600	2380	965	7 Day	Victoria	Juneau
Sunday	Princess	Star Princess	T30	0600	1600	2600	950	7 Day	Victoria	Ketchikan

Notes:
ETA - Estimated Time of Arrival
ETD - Estimated Time of Departure
Pax Count - Passenger Count
LOA - Length Overall

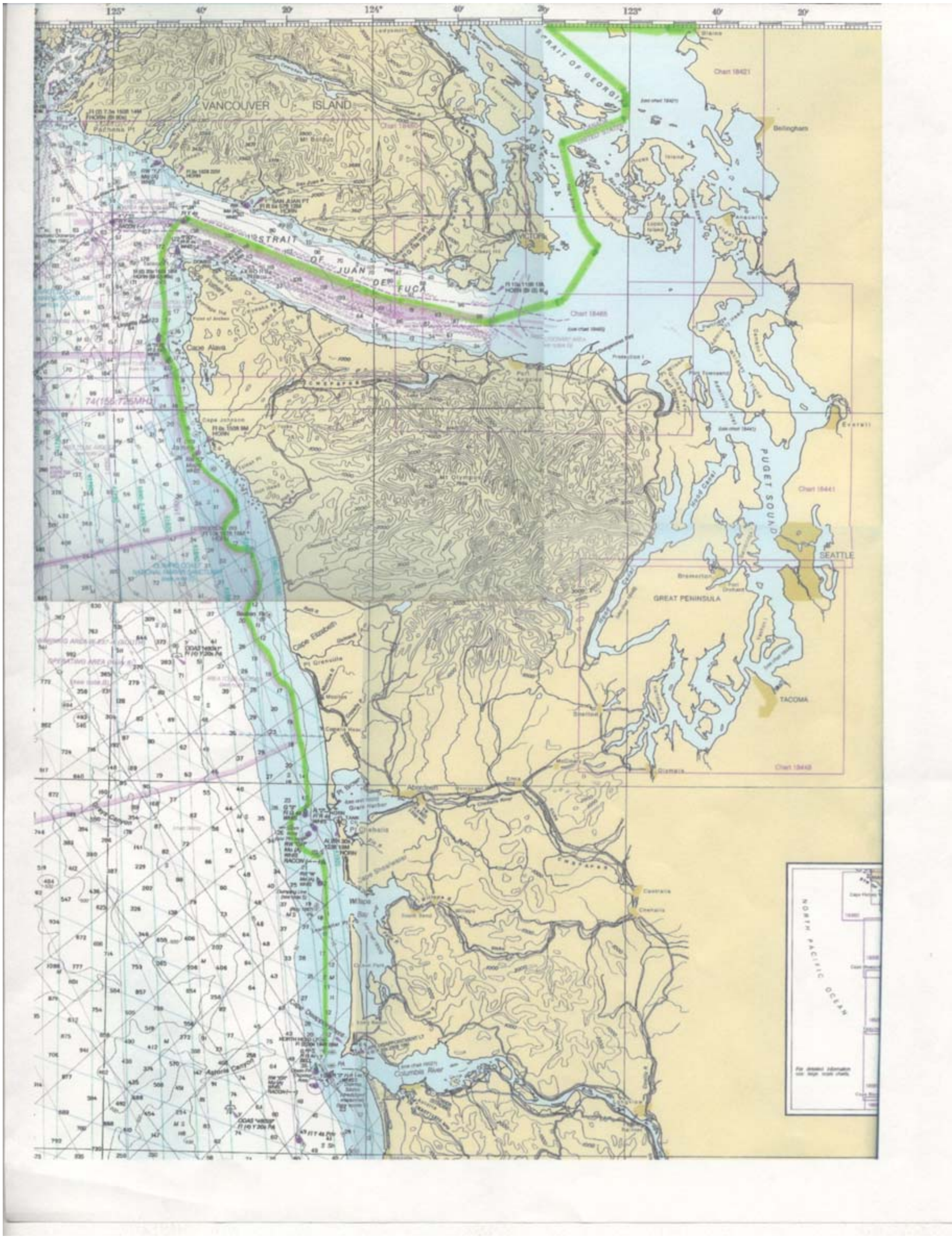

Figure 2. MOU Boundaries

Alaska Discharge Standards

Cruise ships that travel in Alaska waters are subject to rigorous state and federal regulations regarding discharge of wastewater. Specific to federal rules, "Title XIV—Certain Alaskan Cruise Ship Operations" applies to large commercial passenger vessels only, which are defined as those vessels having more than 500 passengers. Effluent standards are set for blackwater only and allows continuous discharge if secondary treatment standards are met and compliance is demonstrated through semi-monthly sampling. Federal law closed former "donut holes".

"Donut holes" were areas greater than three nautical miles from shore but within Alexander Archipelago that provided an unregulated location for ships to discharge raw sewage. The US Coast Guard enforces the federal law. EPA is authorized to create additional standards at its discretion. EPA has begun the process of evaluating current cruise ship wastewater discharge requirements in Alaska.

Beginning in 2008, vessels carrying 250 or more passengers were required to obtain a permit to discharge in Alaskan waters (Alaska DEC, 2008). The new permit includes increased reporting to DEC and more stringent effluent limitations for several water quality parameters, especially copper.

All large vessels under the federal program (500+ passengers) pay a third party sampler and laboratory to take at least two samples of effluent per season. The U.S. Coast Guard requires large cruise ships that have been certified for continuous discharge to sample twice per month. Small vessels can use their crew members only after they prove to the DEC that their crew members have appropriate background and training to perform wastewater sampling.

DEC approves the protocol and procedures used by the industry samplers and the laboratory and also conduct audits of the third party sampler or crew member. In addition, the DEC (or its contractor) takes its own wastewater samples in Southeast and Southcentral Alaska.

Due to the overlap of the state and federal law, large cruise ships have one of three options for their wastewater discharge:

1. Vessels may hold their wastewater and only discharge it once they are outside of Alaska waters (roughly 3 nautical miles from shore but excluding former "donut holes"). The wastewater from these vessels is excluded from the State-required sampling regime and effluent standards.

2. Vessels may discharge their wastewater only when the vessel is at least 1 nautical mile from shore and traveling at least 6 knots. The gray and blackwater must meet the strict effluent limits.

3. Vessels may operate advanced wastewater treatment systems that meet the stringent requirements that enable them to be certified by the U.S. Coast Guard for continuous discharge.

Most large cruise ships operate under option 1 or 3. Vessels typically only operate under condition 2 while they are seeking certification from the U.S. Coast Guard for continuous discharge (option 3).

For a list of large cruise ships that have been allowed to continuously discharge as well as those that hold wastewater, see http://www.dec.state.ak.us/water/cruise_ships/index.htm.

Description of Current Cruise Vessel Wastewater and Biomass Operations

There are primarily two types of wastewater treatment systems on board cruise ships: Advanced Wastewater Treatment Systems (AWTSs) and Type II Marine Sanitation Devices (MSDs). Only one of the cruise vessels homeporting in Seattle in 2009 had MSD, however, both systems are described below to provide a brief synopsis of the major operational features of each treatment system.

Advanced Wastewater Treatment Systems

AWTS's are treatment systems that treat sewage and usually graywater in a combined system. EPA's Draft Cruise Ship Discharge Analysis states, "These systems generally provide improved screening, biological treatment, solids separation (using filtration or flotation), disinfection (using ultraviolet light), and sludge processing as compared to traditional Type II MSDs." According to EPA, 23 of 28 large cruise ships traveling in Alaskan waters were equipped with AWTS's as of 2006 (EPA, 2007). While these systems produce relatively clean effluent, they produce large amounts of biomass that must be dealt with. A 2007 study conducted by King County estimated that cruise ships generate 35 tons (including water content) of biomass each day. This number is consistent with the 15-40 metric tons of biomass per day that was reported by respondents to the questionnaire issued for this study.

There are several types AWTS's produced by different companies that vary slightly in their operational characteristics. These include Hamworthy's Membrane Bioreactor system, ROCHEM's ROCHEM LPRO and Bio-Filt® systems, Zenon's ZeeWeed® MBR system, the Scanship Treatment System, and the Hydroxyl CleanSea® system. **Table 2** shows the different systems utilized on cruise ships that have called at Port of Seattle terminals since 2004 based on an inspection report prepared by the Department of Ecology.

Modern AWTS's for cruise ships have several stages. First the black and grey water is combined; next there is a screening process that removes large solids and non-biodegradable material. The water then enters a biological reactor where it is broken down by bacteria. Following the bioreactor it is necessary to clarify (remove solids) the water. The two main methods applied on cruise ships are ultrafiltration (UF) and dissolved air floatation (DAF). Ultrafiltration involves pumping water through a semi permeable membrane under high pressure. The solids are left on one side and the clarified water passes through the membrane. The DAF method involves dissolving air into the wastewater under pressure then allowing the air to come out of solution at a lower or ambient pressure. When the air comes out of solution it forms tiny bubbles that adhere to the suspended solids and carry them to the surface where they can be skimmed. The last step of treating the clarified water is to sterilize it, typically with ultraviolet light before discharging it overboard.

Table 2. Summary of Washington State Department of Ecology Information Regarding NWCA Cruise Ships, Wastewater Treatment and Biomass Management

Cruise Line	Ship	Total Persons on Board	WW Treatment System		Residual Solids Disposal Technique	Number of Port Calls 2004	2005	2006	2007	2008	Ecology Inspected
			Blackwater	Graywater							
Carnival Cruise Line	NONE										
Celebrity Cruises	Mercury	2779	Biopure/Rochem	Mixed with BW	Solids are sent to BW and GW holding tank and discharged >12 nm (2005 report). Solids are removed, strained and incinerated (2006 & 2007 reports).	12	22	26	16	11	2005; 2006; 2007
	Summit	3409	Hamann/Lazarus	None			2	1	1		
	Infinity	2880	Zenon	Mixed with BW						21	
	Millennium	2034	Unknown	Unknown						4	
Crystal Cruises	NONE										
Holland America Line	Amsterdam	2027	Unknown	Unknown	Strained solids collected and off-loaded in Victoria.	24	20		20	19	2007
	Noordam	2718	Rochem Bio-filtration	Rochem LPRO	GW solids incinerated; BW solids discharged at >12 nm.				21		2007
	Ooesterdam	2648	Rochem Bio-filtration	Rochem LPRO	GW solids incinerated; BW solids discharged at >12 nm. 2007 report states that solids are vibrated out and sent to incineration	21	21	21	21	23	2005; 2006; 2007
	Zaandam	2107	Zenon	Mixed with BW		1	1	22	1	1	
	Zuiderdam	2648	Rochem Bio-filtration	Rochem LPRO					1		
	Volendam	2079	Zenon	Mixed with BW			1	1		2	
	Westerdam	2648	Rochem Bio-filtration	Rochem LPRO	GW solids incinerated; BW solids discharged at >12 nm.			21		21	2006
	Ryndam	1860	Zenon	Zenon				1			
	Statendam	1854	Zenon	Zenon				0			
	Veendam	1854	Zenon	Zenon	Sludge from Zenon system is collected and discharged > 12 nm. Screened solids are collected and landed ashore in Vancouver about once a month.	1	2	2			2006
Norwegian Cruise Line	Norwegian Pearl	4230	Scanship	Mixed with BW	sludge sent to sludge tank and discharged >12 nm or is dried and incinerated.				20	22	2007
	Norwegian Star	4000	Scanship	Mixed with BW	>12 nm out or dried and incinerated; 30% incinerated and 70% discharged	17	20	21	22	21	2005; 2006
	Norwegian Sun	2952	Scanship	Mixed with BW	screened solids and sludge held in sludge tank (14S) and discharged >12 nm.	1	1	20	0		2006
	Norwegian Dream	2448	Scanship	Mixed with BW	sludge sent to 2 holding tanks and discharged >12 nm.		12				2005
	Norwegian Spirit	3600	Scanship	Mixed with BW	sludge sent to sludge tank and discharged >12 nm or is dried and incinerated.	20	18				2005
	Norwegian Wind	2428	Scanship	Mixed with BW		1					
Princess Cruises	Golden Princess	3660	Hamworthy Bioreactor	Mixed with BW	Sludge from Hamworthy system MBR's is discharged at >12 nm, while screened solids are incinerated.				21	21	2007
	Sun Princess	2820	Hamworthy Bioreactor	Mixed with BW	Sludge from Hamworthy system MBR's is discharged at >12 nm, while screened solids are incinerated.		1	20	21		2006
	Star Princess	3800	Unknown	Unknown						21	
	Dawn Princess	2850	Hamworthy Bioreactor	Mixed with BW	Sludge from Hamworthy system MBR's is discharged at >12 nm, while screened solids are incinerated.	1		20			2006
	Diamond Princess	3908	Hamworthy Bioreactor	Mixed with BW	Screened solids bagged and incinerated	20	21				2005
	Saphire Princess	3908	Hamworthy Bioreactor	Mixed with BW	Screened solids bagged and incinerated	16	21				2005
Regent Seven Seas Cruises	Seven Seas Mariner	1200	Hamworthy Bioreactor	Mixed with BW		1				1	
Royal Caribbean International	Radiance of the Seas	3360	Unknown	Unknown					1		
	Serenade of the Seas	2950	Scanship	Mixed with BW					2	2	
	Vision of the Seas	3200	Hydroxyl	Unknown	Sludge is either incinerated or landed ashore in Victoria for treatment and land application (2006); Sludge from BW system is either incinerated or landed ashore for treament and land application (trucked by Emerald Services to King County Metro Station) (2007)			17	19		2006; 2007
	Rhapsody of the Seas	3381	Unknown	Unknown						17	
Silversea Cruises	Silver Shadow	740	Unknown	Unknown		3					

** SOURCE: Washington State Department of Ecology http://www.ecy.wa.gov/programs/wq/wastewater/cruise_mou/previouscruiseseasons.html

Type II MSDs

Only a limited number of Cruise vessels calling at Port of Seattle facilities utilize Type II MSD's. Most Type II MSDs use biological treatment and chlorination for the treatment of sewage. Some cruise ships with Type II MSDs use only maceration (breaking up of solids into small pieces) and chlorination when treating their sewage and do not utilize biological treatment (EPA 2007). A screen is sometimes included for removal of grit and other debris. Type II MSDs are used only to treat blackwater. Vessels utilizing Type II MSDs must hold their untreated graywater on board until they are within an area where discharge is permitted.

Type II MSDs using biological-chlorination work similarly to municipal wastewater treatment systems. **Figure 3** shows a simplified schematic of a biological-chlorination Type II MSD.

Excess biological mass (referred to hereafter as "biomass") after the clarification step in Type II MSD systems is typically recycled back into the bioreactor, meaning that biological mass is typically discharged in the treated effluent. However, according to the Washington State Department of Ecology (Ecology), visual inspections of Type II MSDs indicate some removal of biomass from the tanks occurs. The volume is typically less that the AWTS and the materials is either incinerated, discharged (outside of 12 nm), or it is contained (usually by drum) and landed ashore for disposal. Also, one or two times per year, a Type II MSD may undergo a thorough cleanout generating a larger volume of residual solids requiring disposal.

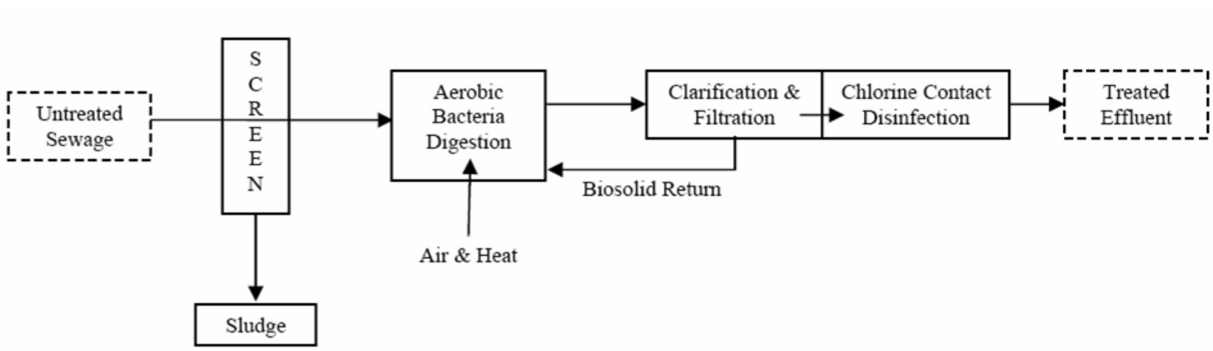

Figure 3. Schematic of biological-chlorination Type II MSD (Source: EPA 2007)

Characterization of Cruise Ship Biomass

Disposal of Cruise Ship Biomass

In accordance with the MOU, Ecology conducts routine inspections of the cruise ships and prepares an inspection report. Narrative summaries of residual solids disposal techniques are summarized in **Table 2**. Based on the Ecology information, the cruise ships incinerate their residual solids or discharge them at a distance of 12 nm from shore at vessel speeds no less than 6 knots. It is important to note that neither Washington State law nor the MOU have any jurisdiction over the current biomass management practice, which is fully compliant with all applicable laws and regulations.

Chemical Properties of Biomass Generated

Data on the physical and chemical characteristics of biomass from four cruise ships were collated from EPA reports from 2006 (EPA 2006a-d) and raw data files obtained directly from the EPA authors of the reports. A summary of the biomass data from these reports are presented in **Table 3**. These were compared to the biomass data contained in the 2008 report of two King County, Washington, treatment facilities (see **Table 4**) (King County 2008).

Data from the King County Wastewater Treatment Division represents data from both the West Point Treatment Plant (WPTP) and the South Treatment Plant (STP) at Renton. Both plants receive wastewater from numerous cities and industries in King County. The plants provide secondary wastewater treatment with anaerobic digestion of all solids followed by a dewatering process. The materials sampled are the treated biosolids prior to being beneficially recycled in forestry agriculture, soil reclamation and compost (King County 2008).

Note, due to the unavailability of percent solids data for the *Norwegian Star*, the data from that ship has not been used in the determination of average concentrations. In all cases, the percent solids information was used to determine a mg/kg concentration so that the variation in the solids content of the biomass could be normalized. This is an important factor as organic constituents as well as most metals tend to absorb to solids particulate and this methodology also results in a conservative assumption regarding constituent concentrations in the biomass materials. Data is also presented in mg/l for full comparison of the sample data.

Table 3. Cruise Ship Chemical Data Summary

		Island Princess Samples collected Aug 28 - Sept 2, 2004		Oosterdam Samples collected Sept 18-23, 2004		Veendam Samples collected June 20-25, 2004		Cruise Ship Average**	
Pathogen Indicators									
E. Coli	MPN/100mL	<1.14	NA	<1.35	NA	ND (1.00)	NA	ND	NA
Enterococci	MPN/100mL	<1.21	NA	ND(1.00)	NA	<1.14	NA	ND	NA
Fecal Coliform	CFU/100mL	<3.20	NA	<1.82	NA	ND (1.00)	NA	ND	NA
		mg/kg	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg	mg/L
Classical Pollutants									
Alkalinity		47,424	806	**35,700**	500	38,400	499	40,508	602
Ammonia As Nitrogen (NH3-N) (s)		2,348	40	9,730	136	5,870	76	5,983	84
Available Cyanide		--		35	0	**0.0769**	0	18	0.247
Biochemical Oxygen Demand		--	--	--	--	297,692	3,870	297,692	3,870.00
Chemical Oxygen Demand (COD)		843,091	14,333	23,700	332	1,140,000	14,820	668,930	9,828.12
Chloride		65,574	1,115	17,900	251	4,800	62	29,425	476
Hardness (s)		96,019	1,632	--	--	3,785	49	49,902	841
Nitrate/Nitrite (NO2-N+ NO3-N)		14	0	595	8	75	1	228	3
Sulfate		9,543	162	114,000	1,596	30,600	398	51,381	719
Total Kjeldahl Nitrogen (TKN) (s)		32,845	558	90,000	1,260	98,100	1,275	73,648	1,031.22
Total Organic Carbon (TOC)		159,836	2,717	290,000	4,060	5,810	76	151,882	2,284.25
Total Phosphorus		10,129	172	13,700	192	11,800	153	11,876	172
Total Dissolved Solids (TDS)		74,941	1,274	NA	NA	NA	NA	74,941	1,274.00
Total Suspended Solids (TSS)		925,059	15,726	NA	NA	NA	NA	925,059	15,726.00
Total % Solids		1.7%		1.4%		1.3%		1.5%	
Total Metals									
Aluminum, Total		570	10	1,600	22	808	11	993	14
Antimony, Total		**0.22**	0.004	**0.15**	0.002	1.30	0.017	0.56	0.008
Arsenic, Total		**0.21**	0.004	0.40	0.006	0.58	0.008	0.40	0.006
Barium, Total		8	0.136	271	4	120	2	133	2
Beryllium, Total		ND	ND	ND	ND	ND	ND	ND	ND
Boron, Total		50	0.858	45	1	60	0.7750	52	0.753
Cadmium, Total		1.47	0.025	0.50	0.007	0.40	0.0052	0.79	0.012
Calcium, Total (s)		18,588	316	7,340	103	10,154	132	12,027	184
Chromium, Total		16.59	0.282	18.10	0.253	4.93	0.064	13.21	0.200
Cobalt, Total		1.53	0.026	**0.02**	0.0003	0.61	0.008	0.72	0.011
Copper, Total (s)		1,259	21	493	7	325	4	692	11
Iron, Total		1,206	21	987	14	3,369	44	1,854	26
Lead, Total		18.76	0.319	10.90	0.153	4.60	0.060	11.42	0.177
Magnesium, Total (s)		12,118	206	2,340	33	3,031	39	5,829	93
Manganese, Total		103	2	40	1	75	1	73	1
Mercury, Total (s)		**0.000500**	0.00001	0.25	0.004	**0.00200**	0.00003	0.08	0.001
Molybdenum, Total		5.59	0.095	3.99	0.056	2.81	0.0365	4.13	0.062
Nickel, Total		18.24	0.310	13.70	0.192	18.00	0.2340	16.65	0.245
Selenium, Total (s)		4.06	0.069	2.68	0.038	1.98	0.0257	2.91	0.044
Silver, Total		3.06	0.052	3.96	0.055	2.32	0.0301	3.11	0.046
Sodium, Total (s)		41,000	697	9,810	137	10,923	142	20,578	325
Thallium, Total		ND	ND	ND	ND	ND	ND	ND	ND
Tin, Total		4.53	0.077	24.20	0.339	3.97	0.05160	10.90	0.156
Titanium, Total		0.29	0.005	10.90	0.153	0.55	0.00710	3.91	0.055
Vanadium, Total		16.00	0.272	2.34	0.033	1.68	0.02180	6.67	0.109
Yttrium, Total		0.35	0.006	0.08	0.001	**0.00854**	0.00011	0.15	0.002
Zinc, Total (s)		1,824	31	1,530	21	456	6	1,270	19
Organics									
Acenaphthene		--		ND	ND	ND	ND	ND	ND
Acenaphthylene		--		ND	ND	ND	ND	ND	ND
Anthracene		--		ND	ND	ND	ND	ND	ND
Benzene		--		ND	ND	ND	ND	ND	ND
Benzo(a)anthracene		--		ND	ND	ND	ND	ND	ND
Benzo(a)pyrene		--		ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthene		--		ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene		--		ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthene		--		ND	ND	ND	ND	ND	ND
Bis(2-chloroethoxy)methane		--		ND	ND	ND	ND	ND	ND
Bis(2-Chloroethyl)ether		--		ND	ND	ND	ND	ND	ND
Bis(2-ethylhexyl) phthalate		--		4.21	0.059	1.56	0.0203	2.89	0.040
Bromodichloromethane		--		ND	ND	ND	ND	ND	ND
Bromoform		--		ND	ND	ND	ND	ND	ND
Bromomethane		ND		ND	ND	ND	ND	ND	ND
Butyl benzyl phthalate		--		ND	ND	ND	ND	ND	ND
Carbon tetrachloride		--		ND	ND	ND	ND	ND	ND
Chlorobenzene		--		ND	ND	ND	ND	ND	ND

		Island Princess Samples collected Aug 28 - Sept 2, 2004		Oosterdam Samples collected Sept 18-23, 2004		Veendam Samples collected June 20-25, 2004		Cruise Ship Average**	
Pathogen Indicators									
E. Coli	MPN/100mL	<1.14	NA	<1.35	NA	ND (1.00)	NA	ND	NA
Enterococci	MPN/100mL	<1.21	NA	ND(1.00)	NA	<1.14	NA	ND	NA
Fecal Coliform	CFU/100mL	<3.20	NA	<1.82	NA	ND (1.00)	NA	ND	NA
		mg/kg	mg/L	mg/kg	mg/L	mg/kg	mg/L	mg/kg	mg/L
Chloroethane		--		ND	ND	ND	ND	ND	ND
Chloroform		ND		ND	ND	ND	ND	ND	ND
Chloromethane		--		ND	ND	ND	ND	ND	ND
Chrysene		--		ND	ND	ND	ND	ND	ND
cis-1,3-Dichloropropene		--		ND	ND	ND	ND	ND	ND
DI-N-BUTYL PHTHALATE		--		ND	ND	ND	ND	ND	ND
DI-N-OCTYL PHTHALATE		--		ND	ND	ND	ND	ND	ND
DIBENZ(A,H)ANTHRACENE		--		ND	ND	ND	ND	ND	ND
Dibromochloromethane		--		ND	ND	ND	ND	ND	ND
Diethyl phthalate		--		ND	ND	ND	ND	ND	ND
Dimethyl phthalate		--		ND	ND	ND	ND	ND	ND
Ethylbenzene		--		ND	ND	ND	ND	ND	ND
Fluoranthene		--		ND	ND	ND	ND	ND	ND
Fluorene		--		ND	ND	ND	ND	ND	ND
Hexachlorobenzene		--		ND	ND	ND	ND	ND	ND
Hexachlorobutadiene		--		ND	ND	ND	ND	ND	ND
HEXACHLOROCYCLOPENTADIEN		--		--	--	ND	ND	ND	ND
Hexachloroethane		--		ND	ND	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene		--		ND	ND	ND	ND	ND	ND
Isophorone		--		ND	ND	ND	ND	ND	ND
Methylene chloride		ND		ND	ND	ND	ND	ND	ND
N-Nitroso Di-n-propylamine		--		ND	ND	ND	ND	ND	ND
N-NITROSODIMETHYLAMINE		--		--	--	ND	ND	ND	ND
N-NITROSODIPHENYLAMINE		--		--	--	ND	ND	ND	ND
Naphthalene		--		ND	ND	ND	ND	ND	ND
Nitrobenzene		--		ND	ND	ND	ND	ND	ND
Pentachlorophenol		--		ND	ND	ND	ND	ND	ND
Phenanthrene		--		ND	ND	ND	ND	ND	ND
Phenol		--		27.14	0.380	64.80	0.842	45.97	0.6112
Pyrene		--		ND	ND	ND	ND	ND	ND
Tetrachloroethene		0.87	0.015	**0.00250**	0.000035	0.20	0.0025	0.36	0.00579
Toluene		--	--	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene		--	--	ND	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene		--	--	ND	ND	ND	ND	ND	ND
Trichloroethene		--	--	**0.00250**	0.000035	0.08	0.0011	0.04	0.0005687
Trichlorofluoromethane		--	--	ND	ND	ND	ND	ND	ND
Vinyl chloride		--	--	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane		--	--	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane		--	--	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane		--	--	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane		--	--	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene		--	--	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene		--	--	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene		--	--	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane		--	--	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane		--	--	ND	ND	ND	ND	ND	ND
1,3-Dichlorobenzene		--	--	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene		--	--	ND	ND	ND	ND	ND	ND
2,2'-Oxybis(1-chloropropane)		--	--	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol		--	--	ND	ND	ND	ND	ND	ND
2,4-Dichlorophenol		--	--	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol		--	--	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol		--	--	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene		--	--	ND	ND	ND	ND	ND	ND
2,6-Dinitrotoluene		--	--	ND	ND	ND	ND	ND	ND
2-Chloroethyl vinyl ether		--	--	ND	ND	ND	ND	ND	ND
2-Chloronaphthalene		--	--	ND	ND	ND	ND	ND	ND
2-Chlorophenol		--	--	ND	ND	ND	ND	ND	ND
2-Nitrophenol		--	--	ND	ND	ND	ND	ND	ND
3,3'-Dichlorobenzidine		--	--	ND	ND	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol		--	--	ND	ND	ND	ND	ND	ND
4-Bromophenyl phenyl ether		--	--	ND	ND	ND	ND	ND	ND
4-Chloro-3-methylphenol		--	--	ND	ND	ND	ND	ND	ND
4-Chlorophenyl phenyl ether		--	--	ND	ND	ND	ND	ND	ND
4-Nitrophenol		--	--	ND	ND	ND	ND	ND	ND

**averages taken of detected values and half the detection limit for non-detected values
-- not reported by EPA
ND - non-detect
NA - not available
MPN - most probable number
CFU - colony forming units
Bold values are half the detection limit for non-detect values (used for averaging)

Table 4. Summary of Cruise Ship and King County Biomass Concentrations

	West Point Biosolids Generation 2007 Average (mg/kg)	South Plant Biosolids Gereration 2007 Average (mg/kg)	Treatment Plant Average* (mg/kg)	Treatment Plant Average* (mg/L)	Cruise Ship Average** (mg/kg)	Cruise Ship Average** (mg/L)	Cruise Ship Average as % of treatment plant Average (mg/kg)
Classical Pollutants							
Alkalinity	--	--			40,508	602	
Ammonia As Nitrogen (NH3-N) (s)	9,300	12,100	10,700	2,675	5,983	84	56%
Available Cyanide	--	--			18	0.247	
Biochemical Oxygen Demand	--	--			297,692	3,870	
Chemical Oxygen Demand (COD)	--	--			668,930	9,828	
Chloride	--	--			29,425	476	
Hardness (s)	--	--			49,902	841	
Nitrate/Nitrite (NO2-N+ NO3-N)	--	--			228	3	
Sulfate	--	--			51,381	719	
Total sulfur	11,200	11,100	11,150	2,788	NA	NA	
Total Kjeldahl Nitrogen (TKN) (s)	59,400	70,800	65,100	16,275	73,648	1,031	113%
Total Organic Carbon (TOC)	--	--			151,882	2,284	
Total Phosphorus	18,200	22,500	20,350	5,088	11,876	172	58%
Total Potassium	1,700	2,200	1,950	488	NA	NA	
Total Dissolved Solids (TDS)	--	--			74,941	1,274	
Total Suspended Solids (TSS)	--	--			925,059	15,726	
Total Solids	0.27	0.22	0.25		0.01		6%
Total Metals							
Aluminum, Total	--	--			993	14.197	
Antimony, Total	--	--			1	0.008	
Arsenic, Total	6.36	6.21	6.29	2	0.40	0	6%
Barium, Total	252	221	237	59	133	1.83	56%
Beryllium, Total	ND	ND			NA	ND	
Boron, Total	16	14	15	4	52	0.753	346%
Cadmium, Total	2.95	3.32	3.14	1	0.79	0.012	25%
Calcium, Total (s)	--	--			12,027	183.59	
Chromium, Total	41	45	43	11	13	0.200	31%
Cobalt, Total	--	--			1	0.011	
Copper, Total (s)	523	522	523	131	692	11	133%
Iron, Total	18,300	19,200	18,750	4,688	1,854	26.039	10%
Lead, Total	101	48	75	19	11	0.177	15%
Magnesium, Total (s)	6,150	8,140	7,145	1,786	5,829	93	82%
Manganese, Total	741	440	591	148	73	1.095	12%
Mercury, Total (s)	1.42	1.19	1.31	0	0.08	0.001	6%
Molybdenum, Total	10	11	11	3	4	0.06	38%
Nickel, Total	31	28	29	7	17	0.245	57%
Selenium, Total (s)	6.92	7.25	7.09	2	2.91	0.044	41%
Silver, Total	17	11	14	4	3	0.046	22%
Sodium, Total (s)	--	--			20,578	325	
Tin, Total	--	--			11	0.156	
Titanium, Total	--	--			4	0.055	
Vanadium, Total	--	--			7	0.109	
Yttrium, Total	--	--			0	0.002	
Zinc, Total (s)	940	912	926	232	1,270	19	137%
Organics	Mean of two 2007 sampling events	Mean of two 2007 sampling events					
Acetone	2.24	2.41	2.32	1			
alpha-chlordane	0.03	0.07	0.05	0			
Anthracene	0.81	ND	0.81	0			
Benzo(a)anthracene	0.99	ND	0.99	0			
Benzoic Acid	ND/9.37	ND					
Bis(2-ethylhexyl) phthalate	90	101	96	24	3	0.04	3%
Carbon Disulfide	0.04	ND/0.037	0.04	0			
Chrysene	1.19	ND	1.19	0			
Coprostanol	1635	1566	1601	400			
Fluoranthene	1.99	ND/0.905	1.99	0			
Fluorene	ND/0.63	ND					
Phenanthrene	2.88	ND/1.21	2.88	1			
Phenol	7.52	14.30	10.91	3	45.97	0.61	421%
Pyrene	2.63	ND/0.95	2.63	1			
Tetrachloroethene	--	--			0.36	0.01	
Toluene	0.02	0.03	0.02	0			
Trichloroethene	--	--			0.04	0.0006	
1,4-Dichlorobenzene	1.89	2.08	1.98	0			
2-Butanone (MEK)	0.45	0.66	0.56	0			
Aroclor 1248	ND	ND					
Aroclor 1254	ND	ND					
Aroclor 1260	ND	ND					

-- not reported
NA - not available
ND - non-detect
*averages taken of detected values only, because the detection limit was not reported.
**average exclude Norwegian Star data

As shown by **Table 4** and **Figures 4 through 8**, concentrations of nearly all parameters in the cruise ship biomass are well below King County biomass concentrations for metals. Only the four organic constituents were detected in the cruise ship biomass, with phenol slightly exceeding the King County biomass concentration. While there is no ambient water quality criteria for phenols, in both cases the concentrations are below water quality criteria for the consumption of organisms established under EPA's water quality criteria.

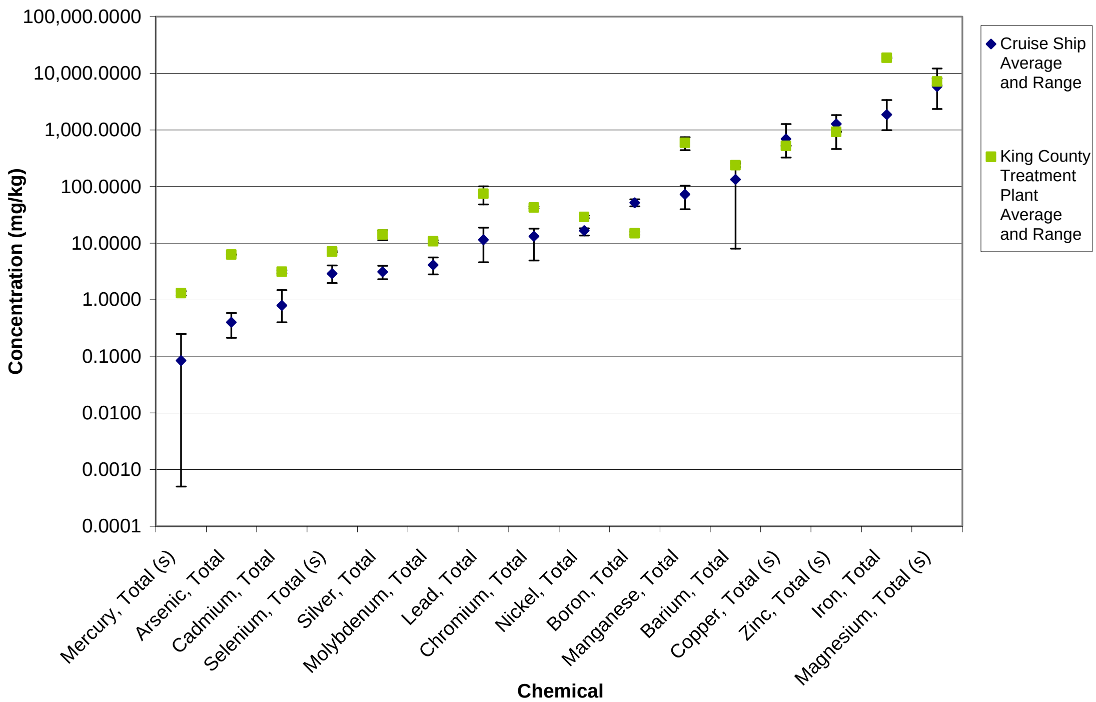

Figure 4. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: All Selected Metals

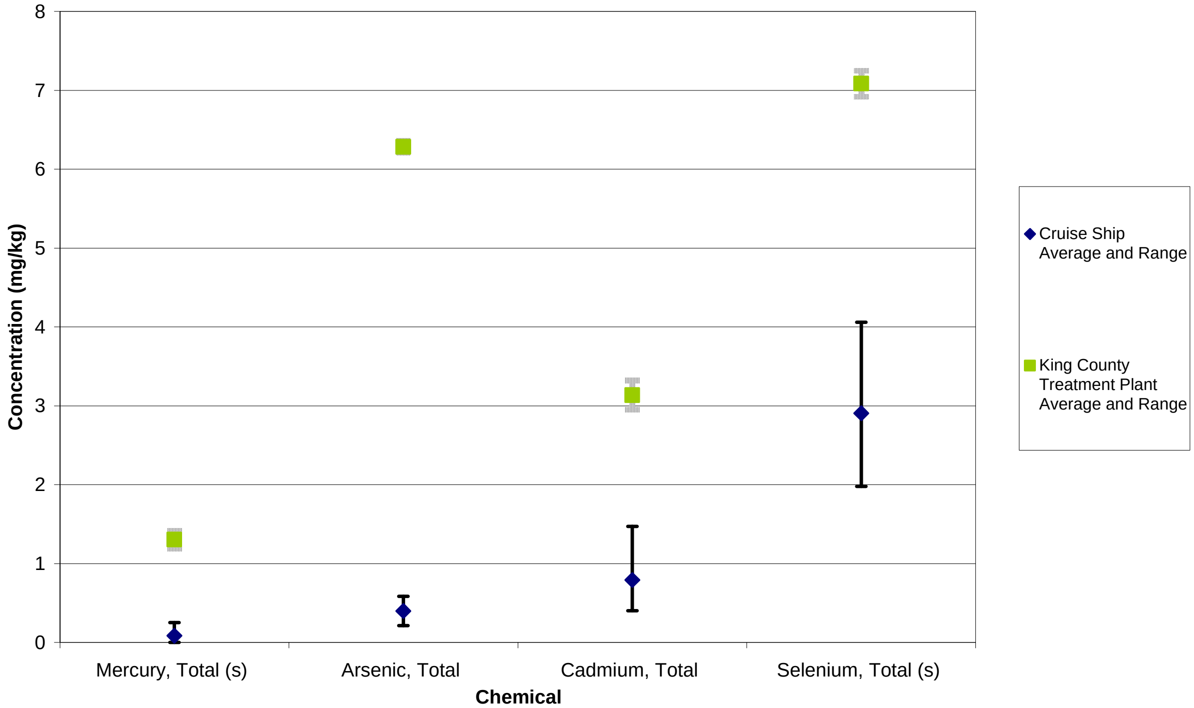

Figure 5. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Lowest Concentration Metals

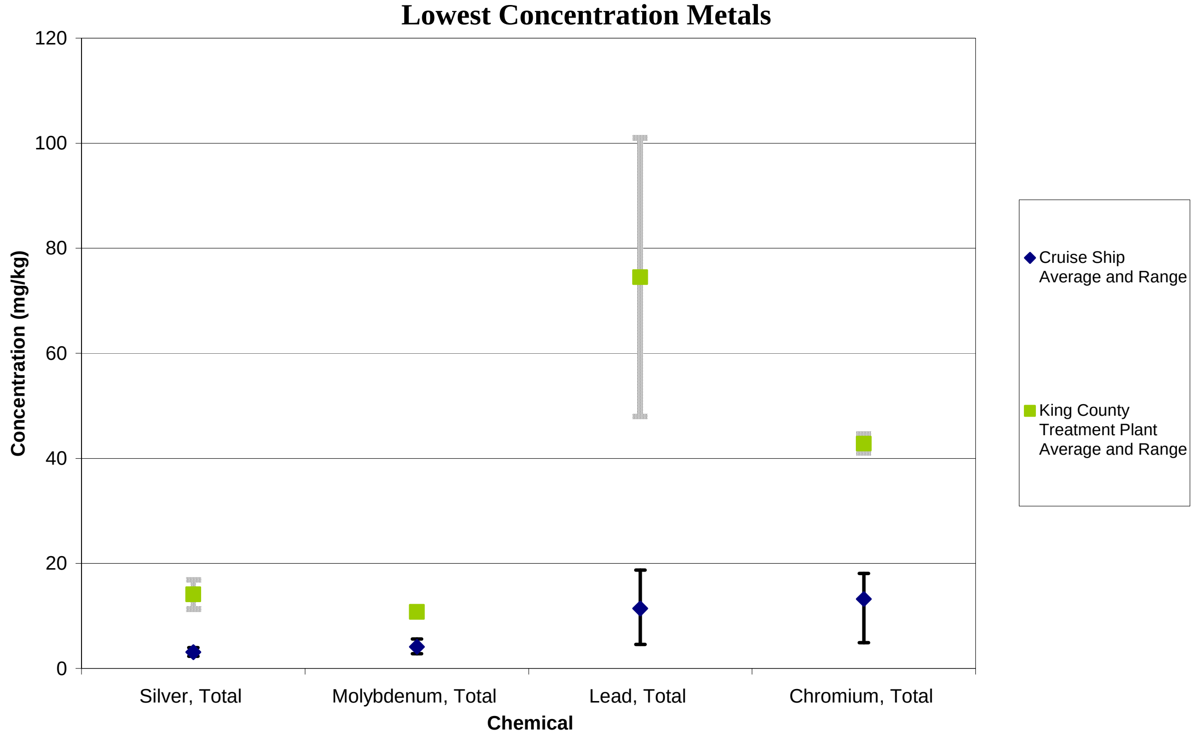

Figure 6. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Lowest Concentration Metals

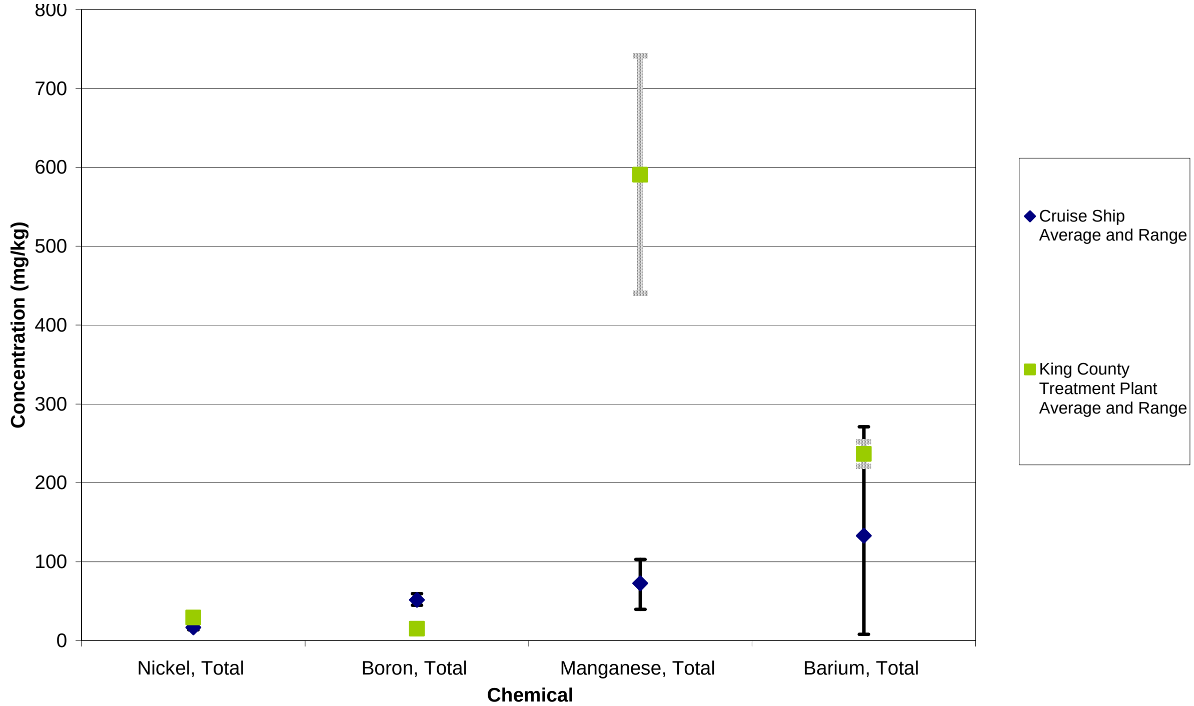

Figure 7. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Mid-High Concentration Metals

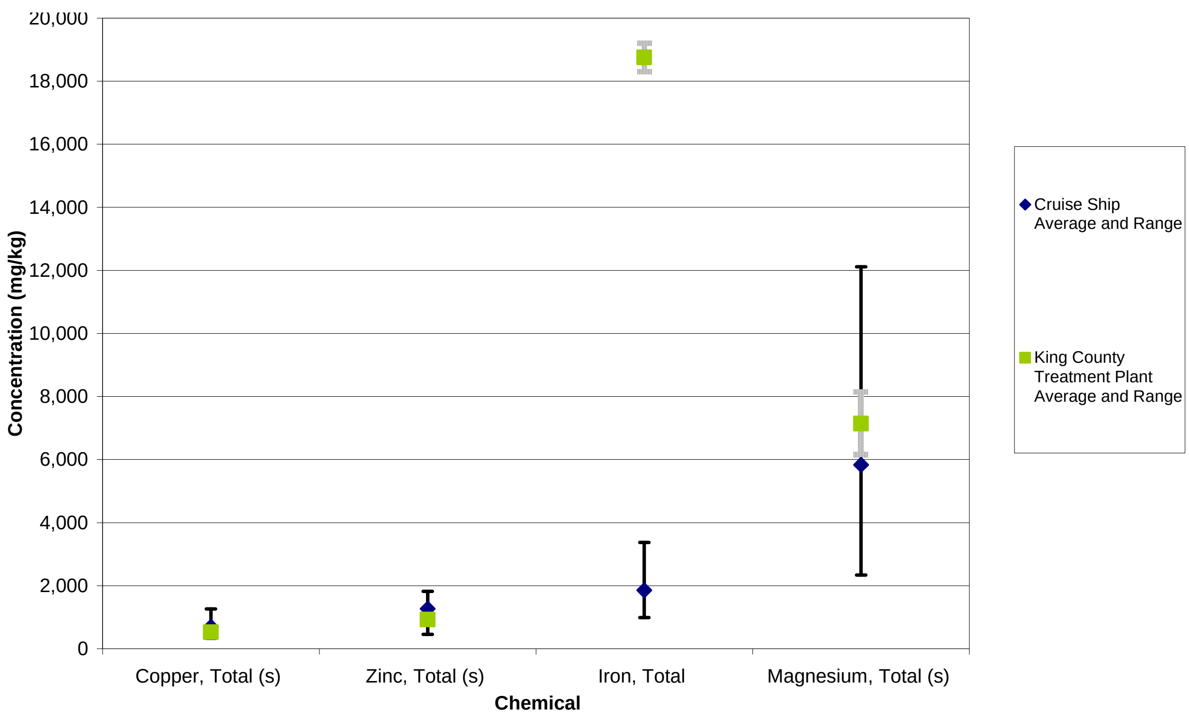

Figure 8. Chemical Comparison of Cruise Ship Biosludge and Treatment Plant Solid Waste: Highest Concentration Metals

Wastewater Management in Scandinavia

Much like the Alaskan cruise industry, growth of the Scandinavian cruise industry has greatly increased over the past decade. The Baltic Sea has been experiencing eutrophication resulting from high nutrient loading, primarily nitrogen and phosphorus. The most visible sign of this environmental problem has been the massive blue green algae blooms visible along the shorelines of the Baltic Sea. Municipal treatment systems in at least parts of Baltic Area include treatment to remove these nutrients, while treatment plants in King County do not.

Note that Cruise vessels sailing from Port of Seattle facilities currently discharge biomass in North Pacific waters (no discharge of biomass occurs within the Puget Sound) at distances greater than 12 nautical miles from shore at vessel speeds in excess of 6 knots. Further it is noted that the population, physical and environmental characteristics of the Northern Pacific waters differ from those of the Baltic Sea.

The Baltic Sea can be characterized as a relatively shallow, enclosed body of water with minimal tidal exchange surrounded by dense population. A report on the estimated nutrient load originating from ship's wastewater into the Baltic Sea found that approximately 0.05% of the total nitrogen and 0.5% of the total phosphorus load could be attributable to ship's wastewater (Hanna-Kaisa Huhta et al, 2007). Note, this study addresses wastewater from all ships and assumed no wastewater treatment. The rise in maritime traffic in the Baltic is primarily attributable to tankers and cargo ships. Albeit small, discharges of phosphorus and nitrogen from ship wastewater are readily controlled when compared to atmospheric depositions or nutrient inputs from land-based sources. Due to the "no special fee" system in this area, the Baltic Sea ports have invested in numerous waste reception facilities (see **Figure 9** and **Table 5**). The "no special fee" system was developed to encourage ships to deliver waste ashore and to avoid undesirable waste streams between ports, thereby encouraging a sound sharing of waste burden. However, only some of the shipping companies utilize these facilities. Those ships that utilize shore-side wastewater hook-ups have placed the ships wastewater treatment systems on "stand-by". Thus, a separate biomass waste stream would not be generated and all wastewaters would be landed ashore.

Additional information on management of wastewater was collected as part of this study via e-mail correspondence with the Copenhagen Malmö Ports in Denmark, The Port of Oslo in Norway and the Port of Helsinki, Finland and Port of Stockholm, Sweden as described below. In all instances, no distinction was made in the management of wastewater versus the management of biomass. As stated earlier, ships that plan to discharge wastewater on-shore typically do not operate their wastewater treatment systems and thus no biomass is produced.

An additional information request regarding total off-load time, logistical shore-side considerations (i.e., number of tanker trucks on the dock, etc.), and odor mitigation and system reliability have been requested. Only limited information from the Port of Stockholm has been received at the time of this publication and is provided below.

Copenhagen Malmö Ports, Denmark

Copenhagen Malmö Ports in Denmark utilize tanker trucks to collect wastewater from cruise ships. After collection, the wastewater is pumped via pump station and sewer system to the local municipal wastewater treatment facility (e-mail correspondence with Leif Kurdahl of Copenhagen Malmö Ports). Ships can transfer waste to the tankers with no special fee if they meet the following conditions:

1. The ship can deliver the sewage at the shipside at a pump capacity of 50 m^3 per hour.
2. Tankers can obtain unhindered access to and from the place of collection without delay
3. The ship is fitted with a standard flange

Copenhagen Malmö Ports charge a fee for disproportionately large amounts of waste (i.e. more than 130 liters per person per day since the last port of call).

Port of Oslo, Norway

In Norway, the general rule is to discharge wastewater no less than 300 meters away from shore (Correspondence with Lisbeth Petterson, Port of Oslo). However, there are several protected areas in Norwegian waters that have more restrictive dumping rules (usually 12 nautical miles from shore). Despite the overall less restrictive dumping rules, the Port of Oslo does offer means of onshore disposal of cruise ship wastewater. The wastewater is collected via tanker truck and then delivered to a local municipal treatment facility, but the exact method by which the waste is collected is unclear. The Port of Oslo finances this service by charging all vessels a waste fee, regardless of whether or not waste is disposed of onshore. This waste fee also covers collection and disposal of garbage, recyclables, varnish waste, and bilge water (as long as the amount of waste generated is considered reasonable given a ship's size and time at sea).

Figure 9. Baltic Sea Wastewater Reception Facility Locations

Port of Helsinki, Finland

The Port of Helsinki, Finland also has facilities for cruise ships to pump their wastewater to municipal treatment systems (e-mail correspondence with Vuorivirta Kaarina of Port of Helsinki). The Port of Helsinki recently extended its program for cruise ships wastewater management in June 2008 (Voss, 2008). In order to make on-shore discharge possible, the Port of Helsinki built sewers and receiving bays at all cruise terminals and ferry docks that connect to the city's sewer system and have a receiving capacity of approximately 100m³/hr through port-provided wastewater hoses.

Prior to 2008 the City of Helsinki enacted a separate charge for wastewater discharged into the city sewer system. However, the Port recently formed a five-year agreement with Helsinki Water (Helsingin Vesi) to pay only a fixed fee regardless of the amount of water discharged, enabling them to lower their prices and encourage cruise companies to use the system. The long-term plan is to charge a standard fee for cruise vessels to discharge wastewater on shore, and then at the end of the season to reward the ship or company with the biggest increase in wastewater pumped into the system with a discount on their discharge fees (Voss, 2008).

Port of Stockholm, Sweden

Like all ports in the Baltic Sea, the Port of Stockholm, Sweden is regulated by maritime EU rules and regulations that include a general port fee. The port has chosen to include the waste disposal service in the general port fee to encourage proper handling of wastewater (e-mail correspondence with Melissa Feldtmann). It should be noted that ships in the Baltic do maintain the right to discharge their wastewater and biomass in international waters (>12 nm from shore). The Port of Stockholm does not use trucks to offload the ships but has a sewage system in place with a number of connections points which transfer the wastewater to munciple treatment facilities. Tank trucks are used very rarely in this port.

While the Port of Stockholm reports a high level of reliability with their wastewater reception facilities, they have had continuous problems with hydrogenated sulphur compounds in the wastewater forming into sulphuric acid. This mist above the water surface at the port eats away and corrodes the upper parts of the sewage pipes requiring a lot of maintenance. The port is working with the ships to find solutions to minimize the production of hydrogenated sulphur in the wastewater tanks in the ships. The port also must maintain a lot of different fittings to be able to connect to the ships as there are not a standard fitting requirement at this time. The Port of Stockholm has also had odor complaints around wastewater off-loading operations. The specific frequency of odor complaints was not reported.

Table 5. Wastewater Reception Facilities at Ports in the Baltic Sea

Finland	**Reception facility**
Hanko	ROPAX ships pump sewage straight into the sewer network. Ro-Ro ships can pump sewage to a tank truck
Helsinki	Eteläsatama: 17 waste water reception points. Länsisatama: 9 waste water reception points. Sörnäisten satama: 1 waste water reception point. Other harbour parts: totally 24 waste water reception points. The waste water reception points are for passenger ships. The port of Helsinki arranges waste water reception for cargo ships using the tank truck if needed.
Inkoo Shipping	Ships can pump sewage to a tank truck.
Kaskinen	Ships can pump sewage to a tank truck.
Naantali	Ships can pump sewage to a tank truck; there are waste stations for solid waste.
Oulu	Ships can pump sewage to a tank truck.
Pori	Ships can pump sewage to a tank truck; Ekokem Oy Ab collects oily waste.
Rauma	Ships can pump sewage to a tank truck.
Sköldvik	Ships can pump sewage toa tank truck.
Turku	Silja and Viking Line ships pump the sewage straight into the sewer network. Other domestic traffic has a possibility to use a tank truck by Hans Langh Oy.
Uusikaupunki	There are waste wells near the pier where ships can pump sewage. Ships can also pump sewage to a tank truck.
Vaasa	In the passenger port there is a reception pipeline at ro-ro piers1&2. Ships can also pump sewage to a tank truck.
Denmark	
Copenhagen	Sewage is pumped to the tank trucks and is then discharged into the municipal waste water plant (biological and chemical waste water treatment).
Frederikshavn	Black water is pumped to the tank trucks and grey water is discharged into the Frederikshavn's sewer network.
Rönne	Black water and grey water are pumped to the tank trucks. Part of the grey water is discharged into the sewer network.
Århus	Private company collects sewage from ships.
Germany	
Sassnitz	No reception facilities for waste water. Sewage is pumped to the tank truck from a local waste disposal company.
Latvia	
Ventspils	Sewage is transported to JSC Ventbunkers for treatment.
Riga	Sewage is transported to Riga Municipal Waste Water Treatment Plant.
Poland	
Gdansk	Sewage is discharged into the sewer network from the tank trucks (WUKO) and after that there are several treatment plants: mechanical-biological sewage treatment plant in Port Północny, sewage treatment plant KOS 2x3 in Basen Górniczy, sewage treatment plant Bioclere at Przemysłowe Berth.
Gdynia	Sewage is pumped to the tank trucks.
Sweden	

Halmstad	Reception facilities only for oil sludge and bilge water.
Helsingborg	The passenger ships discharge sewage into the sewer network; other ships pump sewage to the tank truck.
Kalmar	Local waste management company collects the sludge from ships. It is transported by trucks to a terminal situated in the harbour.
Landskrona	Waste water is pumped into the sewer network.
Oskarshamn	No reception facilities.
Oxelösund	The type of reception facility is not described.
Sölvesborg	Sewage is pumped to the tank trucks.
Umeå	No reception facilities.

Waste water reception facilities in the ports in the year 2005 based on the inquiry results (Huhta et al., 2007).

Section 3

Cruise Vessel Wastewater and Biomass Operations

Alternatives to Open-Ocean Discharge of Cruise Ship Biomass

Existing Shoreside Operations

Shore Transfer of Biomass

Future Methods of Biomass Disposal

Cruise Vessel Wastewater and Biomass Operations

Onboard Wastewater Treatment

Cruise vessels calling on the Port of Seattle utilize a variety of AWTS systems. Some systems combine blackwater and graywater for treatment, and some have separate systems for treating each.

The biomass is separated from the wastewater and stored using different methods. Some systems discharge the biomass to a storage tank where it is later discharged outside the 12 nautical mile boundary. Some vessels dewater the solids and incinerate them onboard.

All five major operators calling at the Port of Seattle completed the survey. The survey provided specific information on vessel operations, systems and capacities for eleven vessels that they operate although only ten had AWTS systems onboard. There was not an opportunity to ask follow up questions to the information provided.

Alternatives to Open-Ocean Discharge of Cruise Ship Biomass

The two alternatives to open ocean discharge of biomass that are practiced within the cruise industry are incineration and shore transfer.

Incineration

Before the biomass can be incinerated it must be dewatered and dried. This requires special equipment for conveying the waste, as well as heat for drying. The incineration of biomass consumes fuel for drying and incineration. Vessels incinerating biomass are also incinerating even larger volumes of solid combustible garbage. The ash from the biomass is a small percentage of the total ash volume and completely mixed with the other ash.

Half of the 12 vessels in the survey are incinerating residual solids, but only three vessels are incinerating all biomass, and one vessel is incinerating 50-75% of their biomass. The other two vessels only incinerate ‘screened solids’ (the coarse debris that is initially screened off and bagged). All three lines that incinerate biomass transfer the ash to shore for disposal.

Shore Transfer

This method involves the transfer the biomass from the on board storage tanks to a shore facility for treatment. There are several methods by which shipboard waste can be conveyed to a shore based treatment facility including the following:

- **Direct Discharge to Tanker Truck -** This alternative would involve pumping biomass from onboard storage tanks directly to tanker trucks positioned on the pier. Vessel to tanker discharge would occur through flexible hoses.
- **Direct Discharge to Barge -** This alternative would include positioning a tanker barge on the off-shore side of the cruise vessel and direct discharge via flexible hose

connections to the on-board vessel infrastructure. Following completion of discharge from the Cruise vessel to the barge, the barge would need to be moved to a separate pier where off loading of the barge to a shoreside tanker truck would occur prior to disposal of the biomass at an upland facility.

- **Direct Discharge to Piping on Pier -** This operation would allow discharge from the vessel via flexible hose to supplemental deck mounted pumps which would be connected to under-pier piping through access ports in the pier deck. Discharged biomass would be pumped via the under-pier piping to a remote storage facility where the biomass can be stored and ultimately delivered to tanker trucks for off site disposal.

Specific issues associated with each of these shore transfer scenarios are discussed later in this section.

Existing Shoreside Operations

Many pier side activities occur during cruise homeport operations. Pier space is used simultaneously for all of the following operations to support the efficient and timely turn-around of the vessel during the relatively short time at pier.

Placement of the vessels at each pier requires coordination between facility owner, facility operations, longshore staff, and vessel operator. This process results in a detailed vessel docking plan unique to each vessel and port facility.

In addition, the specific location where a vessel can be berthed at facilities is controlled by the vessel size, location of the pier-mounted mooring bollards, location of the shore-power connection, and the gangway access location. For vessels calling at Terminal 91, the shore-power connection controls the mooring location of the vessel as this hardware is fixed to the pier and requires the vessel be moored at a specific location in order to be connected to the shore-power services. This varies by vessel.

Pier side operations include the following activities (many of these are illustrated at existing Port of Seattle facilities in **Figures 10 through 19)**.

- **Vessel Mooring and Fendering:** Cruise vessels require a number of mooring lines fixed to the pier to adequately secure the vessel in the wind conditions that occur at both Pier 66 and Terminal 91. Typically, this includes vessel moorage to as many as 10 different pier mounted mooring bollards. Generally, these lines are cast from the extreme bow and stern sections of the vessel. Pier side impacts from line handling operations are generally limited to the time preceding vessel arrival and departure where longshore crews require unrestricted access to the pier to set the lines. Due primarily to tidal fluctuations and risks to dock personnel, it is not possible to access the vessel within the span of the various mooring lines for the duration of the vessels time alongside the pier.

Figure 10. Vessel Mooring Lines (Terminal 30)

- **Passenger Debarkation and Embarkation:** As many as 3,000 passengers can arrive for debarkation on the cruise vessels serving both Pier 66 and Terminal 91. A similar amount of passengers embark onto the vessel during the approximately 7 hour unload/loading period. The gangways used to transit this many passengers must also allow for dock-side vehicular movement, adjust for vessel movement and tides, and be fully ADA compliant. The result is a gangway structure with a substantial pier footprint and commensurate operational impact.

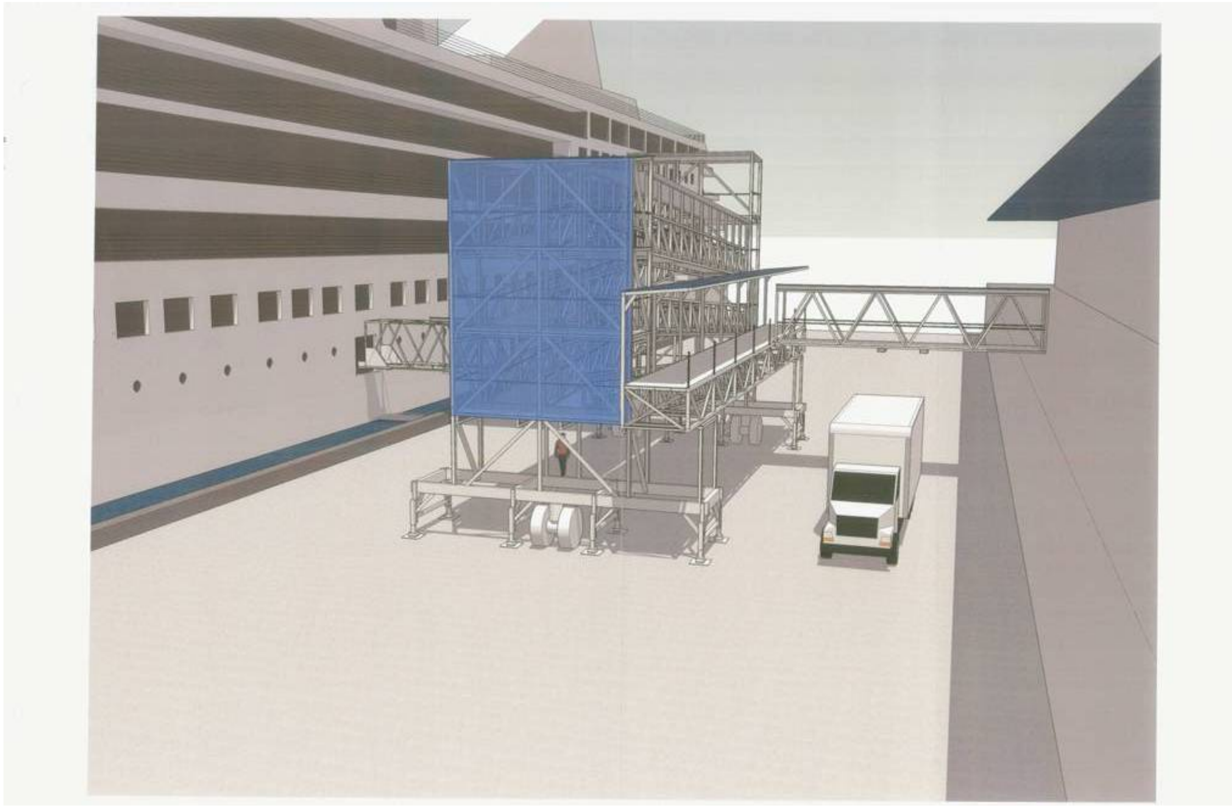

Figure 11. Rendering of T-91 Gangways
Courtesy PND Engineers, 2008

- **Crew Debarkation and Embarkation:** Unlike the passenger loading gangway, the crew gangway is more modest and takes up substantially less dock area. Accordingly, the crew gangways offer substantially less clearance underneath and do not accommodate pier traffic under the gangways. Crew gangway systems in Seattle typically include a gangway connection from the vessel to a platform located on the pier and then a second gangway from the platform to the dock surface. USCG regulations require that the crew gangway is in place and operational prior to commencement of any fueling or bunkering activities.

Figure 12. Crew Gangway (Pier 66)

Luggage Unloading and Loading: Luggage movement occurs by forklift and baggage handling carriage from the first floor of the cruise building to the vessel luggage ports. Individual luggage carriages are moved by the forklifts to a point on the pier within reach of mobile cranes and loaded onto loading cages which are lifted overside of the pier and positioned such that the luggage carriage can be removed from the cage and onto the vessel through a shell door.

Figure 13. Baggage Loading (Pier 66)

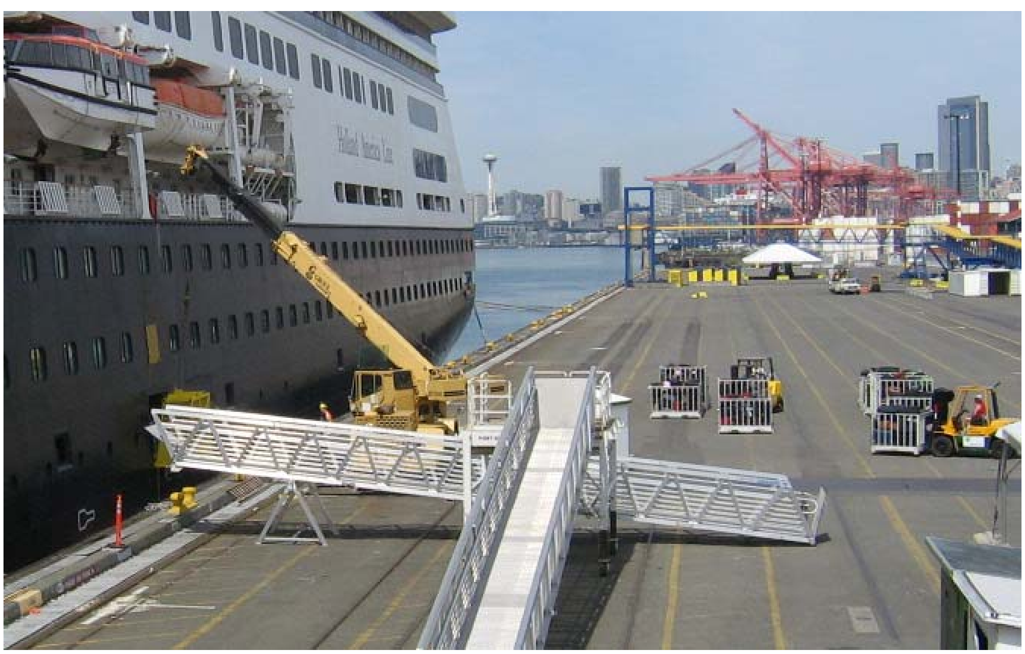

Figure 14. Baggage Loading and Crew Gangway

(Note: Crew gangway shown prior to final placement on vessel. Terminal 30 North berth not occupied at time this photo was taken.)

- **Provisioning:** All of food, beverage, spare parts and sundries necessary to serve passengers and crew (up to 4,000 people for a full week) must be loaded in similar fashion to the luggage during the vessel call. In addition, all or some of the used expendables, garbage, and recycle wastes from the prior week's excursion are off loaded at the pier. These products are delivered and received on the pier space adjacent to the vessel by delivery trucks of varying sizes. All material is moved through the vessel access ports, via crane to deck, then by forklift onto the pier for sorting and delivery to waiting trucks for transport off site to appropriate disposal facilities.

Figure 15. Vessel Provisioning (Terminal 30)
(Note: Luggage handling shown, provisioning requires a similar operational area.)

- **Utility Connection:** Typically cruise vessels connect to several utilities including potable water, electrical systems, and communication systems while at berth. These connections are made by flexible hose connections and require monitoring throughout their use. In addition, pier space is required along the pier/vessel interface to connect the various hoses. A typical Cruise vessel will connect to shoreside potable water in four locations and receive water flow for the entire duration of its time at berth.

Figure 16. Utility Connection (Terminal 30)

- **Shore Power Connection:** Typically, Homeporting cruise vessels calling at the Terminal 91 facility will connect to "cold ironing" shore power facilities. This infrastructure includes 4" diameter cables, pier mounted or mobile cranes, and substation infrastructure to supply the high voltage requirements of the vessel. Due to the safety and operational considerations of the high voltage systems, minimum clear distances to this operations are required which impacts the ability to utilize pier area adjacent to the shore power connection.

Figure 17. Vessel Shore Power Connection (Terminal 30)

(Note: Blue hose in foreground is ships potable water utility connection.)

- **Vessel Lube and Bunker Oil:** Vessel lube oil and other miscellaneous machinery oils are received for use on on-board systems and waste-oil products are discharged at the pier through bunker doors via flexible hose connection to tanker trucks and/or flat-bed trucks carrying fuel barrels that are positioned on the pier. This activity is typically not required at every vessel call, however it can occur as frequently as every-other call. Due to the environmental sensitivity of this type of activity, dedicated oversight by trained personnel is required to monitor these operations. Tanker trucks receiving and delivering these products are relatively large (up to approximately 5,000 gallon capacity) and require an approximately 80' by 40' area to operate.

Figure 18. Typical Bunker Oil Truck

- **Vessel Fueling/Bunkering:** Due to USCG and Seattle Fire Department regulations, and due to the large volume of fuel received by the cruise vessels, cruise vessel fueling is accomplished via tanker barge positioned on the off shore side of the cruise vessel. Connection to the vessel occurs at the bunkering port which is typically located at or near the mid-ship location. Connection is made to the vessel by flexible connection and fueling activities can not commence without deployment of a floating boom to contain any spills should they occur.

- **Emergency Vehicle Access:** Seattle Fire Department requires a 20-foot wide vehicular corridor adjacent to the cruise vessel and cruise terminal building to be clear and useable throughout all periods of facility operations. Operational vehicles may transit this access corridor, however, no product, truck, or equipment can be parked, placed or staged in this area that would in any way prohibit use by Emergency responders.

Figure 19. Pier Access (Pier 66)

Note: Limited operation area and width between adjacent trucks for emergency vehicle access to the pier.

- **Miscellaneous Law Enforcement Operations:** A variety of law enforcement agencies have jurisdiction over various aspects of Cruise facility operations including the Port of Seattle Police Department, US Customs and Border Protection, US Coast Guard, and others. Pier side impacts of these requirements include staging of various equipment and vehicles and access to the vessel for routine and emergency need.

Shore Transfer of Biomass

As discussed earlier in this section transfer of the ships biomass to shore is one of the alternatives to open ocean discharge. Some of the issues associated with each scenario for shore transfer are discussed below.

All alternative discharge methods discussed below could have varying levels of impact related to the transfer of the biomass. Potential impacts will be studied as part of future phases of this study and could include:

- Impacts caused by potential spills during off-loading.
- Possible emission of sewage odor in close proximity to boarding passengers, adjacent businesses, and dock workers.
- Noise impacts from discharge pump equipment in close proximity to boarding passengers.

Shoreside infrastructure improvements could be necessary to support off-loading biomass at the pier. For each alternative, it is assumed that biomass would ultimately be discharged at off-site King County Wastewater facilities in Renton.

As a minimum the following requirements must be met for shore transfer to be practical:

1. **Vessels must have the ability to store biomass on board:**

   The vessel will need to have adequate dedicated storage capacity to hold the biomass to be transferred to shore. The typical voyage time is one week. If the vessel does not have enough storage capacity for a full voyage, then the excess biomass must be offloaded at sea (as currently practiced by most carriers), at another port, or incinerated. It should be noted that offloading at ports other than Seattle was not investigated here and is beyond the scope of this study.

   Available biomass storage capacity among the cruise ships varies. Two vessels reported they could store all biomass generated in a week. For the remaining vessels the storage capacity varied from 47% to 94% of weekly generation (3.3 to 6.6 days of storage capacity). At this time it is not known on a vessel by vessel basis if adding storage is possible. However, many of the tanks on board the vessels are flexible as to what can be stored in them but increasing storage would likely require modifications to the vessels.

2. **The Biomass must be pumpable:**

   The waste must have a consistency that will allow it to be pumped, implying a high percentage of water. For the vessels that are incinerating, the biomass must be dewatered after it is generated. Once it is dewatered it generally cannot be pumped by conventional means so shore transfer must occur before dewatering. The vessels surveyed reported that, prior to dewatering, the biomass ranged from 80 - 98% liquids and is therefore pumpable.

3. **The vessels must be configured to pump ashore:**

   The vessel needs to be properly configured for transferring the waste ashore. At the very least the vessel will need to have piping of an adequate diameter to the storage tank(s) and a properly configured and sized onboard pump. The vessel must also have piping manifold that is accessible from either the pier or a waterside access break (door) that has the adequate closures, valves, spill containment, etc. that will be required for the operation.

   Of the 10 vessels with an AWTS, 9 report that they have at least some ability to transfer biomass to shore. However, more information is needed to understand specific modifications that may be required in order to support regular and consistent shore-side transfer.

4. **The vessels must have engineering crew available to oversee the transfer operation:**

   At least one operating engineer must be available to supervise the transfer operation. Depending on how the ships systems are configured, or what type of shore transfer will be done, other crew may also be required to operate pumps, open and close valves, maintain radio contact with shore side personnel, monitor tank levels, monitor pump discharge pressures, etc.

   The survey did not cover the questions of crew availability, due in part to the fact that the demands on the crew were not known before the survey. The demands on the crew cannot be well understood until a vessel by vessel evaluation of the off-load process can be done. However, it is anticipated that the biomass off-load operations will require additional service time by available crews and/or the need to hire crews specifically to perform and oversee the off-load operations.

5. **The operation must be completed within the time the vessel is in port:**

   The duration of the operation must fit within the allotted time in port. Vessels are in port approximately 10 hours total. However, due to Customs and Border Protection regulations and various operational requirements on arrival and departure such as handling mooring lines, gangway hook up and disconnect, hook up and disconnect shoreside facilities, etc., the available time for unloading and off-loading is approximately 7 hours.

As illustrated in **Figures 3-1 and 3-2**, the existing pier side operations currently utilize most available deck space at both Port of Seattle's cruise facilities at Pier 66 and Terminal 91. At Terminal 91, based on discussions with Longshore and operations staff, it is clear that even without consideration of biomass disposal operations, concerns exist about the relatively limited amount of pier area (which at 90' wide is roughly half that which was available at the former Terminal 30 facility) to accomplish all the currently required operations. Pier 66 operations are further limited by the small 55' wide apron.

The three methods of shore transfer discussed in this section would have varying levels of impact to pier side operations and space. Direct discharge to tanker trucks would have the greatest impact and Direct discharge to barge would have the least impact.

Plotted: Nov 18, 2008 – 1:31pm anavarro Layout: FIGURE 1
M:\2007\107127.1 Cruise Biosolids Study\Drawings\2008-10-30 Port Exhibit\Figure 1.dwg

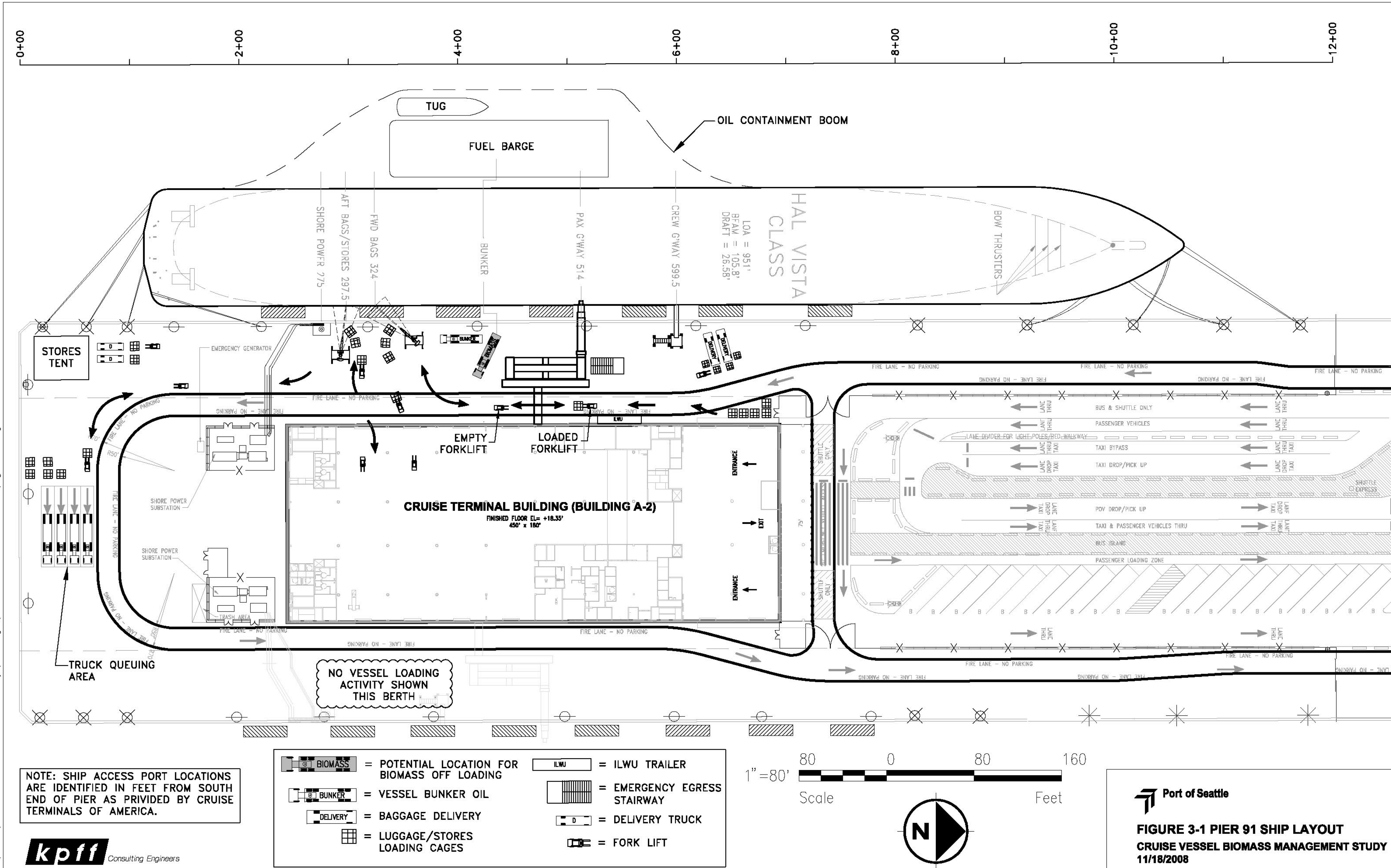

FIGURE 3-1 PIER 91 SHIP LAYOUT
CRUISE VESSEL BIOMASS MANAGEMENT STUDY
11/18/2008

Plotted: Nov 18, 2008 – 1:34pm anavarro Layout: FIGURE 2
M:\2007\107127.1 Cruise Biosolids Study\Drawings\2008-10-30 Port Exhibit\Figure 2.dwg

= BAGGAGE DELIVERY
= VESSEL BUNKER OIL
= FLOWER VAN
= FORK LIFT
= LUGGAGE/STORES LOADING CAGES

NOTE: PHOTO TAKEN FOLLOWING COMPLETION OF LOAD/UN-LOAD OPERATIONS SHORTLY BEFORE VESSEL DEPARTURE.

NOTE: POTENTIAL LOCATION FOR BIOMASS OFF LOADING IS NOT APPARENT.

NOT TO SCALE

kpff Consulting Engineers

Port of Seattle

FIGURE 3-2 PIER 66 SHIP LAYOUT

CRUISE VESSEL BIOMASS MANAGEMENT STUDY

11/18/2008

Direct Discharge to Tanker Truck

Discharging various types of waste from ships to tanker trucks is a common practice in the marine industry. However due to the volume of waste involved in biomass transfer, and the pier side congestion during existing turnaround operations, specific challenges arise that are discussed below. It is anticipated that this alternative for biomass transfer would have the largest impact on existing pier side operations.

Emerald Services of Seattle has been servicing the marine industry with vacuum truck services for a number of years. They are currently located on East Marginal Way where they transfer waste via pipeline directly to the South King County treatment facility. *Emerald Services* has a fleet of 11 ‘large’ vacuum trucks and 12 ‘small’ vacuum trucks. There are approximately 4 trucks with a 6500 gallon capacity, 7 trucks with a 5000 gallon capacity and 12 with a 3000 gallon capacity. All trucks are equipped with vacuum pumps. The large trucks are 50-60 feet long.

The total biomass loads based on all vessels surveyed varied from 15,000 gallons per week to 74,000 gallons per week. The vessels with the two largest weekly generation quantities were 74,000 gallons each. If these are considered outliers and the remaining vessels are averaged, the biomass off-load volume is approximately 35,000 gallons.

Using the information gathered from speaking with *Emerald Services* an analysis was done to determine how a series filling operation would work, and what the likely fill times would be to transfer a weeks worth of biomass from the surveyed vessels.

For all but three of the vessels surveyed, it is possible to unload a full weeks worth of biomass in 7 hours or less with a total of three large trucks using series loading.

The three truck series loading scenario allows for time for hooking up, loading, unhooking, paperwork processing, transit to the unloading location, unloading, transit back to the pier, and waiting in a queuing area to fill again. Using the data provided by the vendor it is estimated that one large truck can be filled continuously, every 70 minutes. One truck is on the pier at all times, and one truck is in waiting at the designated queuing area. The third truck is in transit or unloading. The advantage of this scenario is that only one truck is on the pier for the entire 70 minute loading, however a second truck would need to be staged at a queuing area and then moved into position adjacent to the first truck (prior to the first trucks departure) for the period of time required to connect hoses in order that the 70-minute cycle time be realized.

For the three remaining vessels to be off-loaded in the 7 hour timeframe, it is only possible if two trucks are loaded in parallel on the pier. The vessels cannot currently support this. This scenario doubles the total number of large trucks in the entire operation from three to six. The whole scenario requires two large trucks on the dock at all times, two trucks in the queuing area, and two trucks offloading or transiting. The loading rate is twice what would be required for single truck loading. According to *Emerald Services* the vessels and the trucks are configured with 3" quick disconnect fittings. Two large trucks loaded in one hour would mean an average loading rate of 13,000 gallons per hour or 217 gallons per minute. 217 gallons per minute is not an unreasonable flow rate for a 3" fitting, resulting in velocities of fewer than 10 feet per second. However, loading two trucks in parallel would require modification to existing on-board systems as the vessels are not currently outfitted to support this type of operation. In addition, for this proposed operation to occur, it would be necessary to confirm that the ship's pumps and piping are adequate for this pumping rate.

Direct Discharge to Barge

This alternative would include use of marine barges to remove the biomass using similar methodology to how marine fuels are currently loaded onto cruise vessels. A marine barge would be positioned by tug alongside the cruise vessel, a floating boom would deployed around the tug and barge to contain the off-load operations, and biomass would be transferred to the barge using vessel on-board pumps.

This scenario has the benefit of not impacting pier side operations, however it would require the purchase or lease of barges specifically designed/constructed for this unique use. A complexity of this scenario is that on most vessels the location for biomass transfer and vessel fueling occur at the same "break" or access door in the vessel hull. Due to the size of the barges involved and complexity of marine fueling operations, it would not be possible to simultaneously fuel the vessel from a barge while also removing biomass to a second barge located in close proximity. Accordingly, in order to accomplish simultaneous transfer of fuel (onboard) and biomass (offload), modification to onboard piping systems including potentially creation of a new access break served by biomass piping would be required. It is unknown if regulatory agencies with oversight capacity of marine fueling operations would have any concerns about the simultaneous fueling and biomass off-loading.

Direct Discharge to Piping on Pier

The location of biomass transfer varies by vessel due to the variable access port location where on-board piping systems can deliver biomass to the shore. In order to accommodate this variability of off-load location, it would likely be most efficient if the shore side pumps, required to support off-loading and transfer of biomass product to the remote storage facility, were mounted on a chassis or similar device to allow efficient positioning at any of the unique off-load location required by each vessel. However, the need to service the variable discharge locations on the vessels requires a similar ability to connect to the under-pier piping at several, perhaps many, discrete locations through access points ("manholes") in the pier.

Note that while the Terminal 91 cruise facility is currently in the final stages of construction, the piers structures adjacent to the new building were constructed in 1992 (West side) and 1997 (East side).

Creation of this type of access points through the pier deck requires structural analysis of the pier to ensure all existing and proposed load conditions meet applicable codes. In addition, construction work of this kind is generally expensive as it requires work in the over-water environment and due to the relative inaccessibility of the area under the pier.

Piping to transfer the biomass to an upland facility would be placed under approximately 1,200 to 1,500 lineal feet of pier at both Pier 66 and Terminal 91. At both facilities, it is not anticipated that piping could be placed in upland soils adjacent to the piers. These soil areas already are located below existing building structures or contain the utility infrastructure necessary to support the current operations. At Terminal 91 for example, only approximately 8 feet of soil area exists between the new cruise facility and the pier, and this area currently carries several utilities including storm water, as well as potable and fire water supply to the building.

Under-pier piping of this kind requires thoughtful placement and protection to minimize damage from floating debris which occasionally float under the pier spaces and can damage piping on a rising tide or in wave conditions. Potential environmental issues associated with placement of biomass pipes under the pier where they could be damaged are unknown and would need to be evaluated.

Due to the significant weight of storage tanks, it is not practical to store the biomass on the pier structure itself. Accordingly, it would be necessary to develop storage areas for the biomass in the upland areas adjacent to the cruise piers at either Pier 66 or Terminal 91. The specific location where such storage facility could be placed at either cruise facility is unknown. However, it is anticipated that such a facility would require an area of sufficient size for storage tanks, discharge piping and tanker truck access. It is unlikely that a facility of this size could be placed at Pier 66 due to the relatively small and constrained nature of the site.

The benefit of a direct discharge type of installation would be the smaller pier foot print area required to support the biomass off-loading which would likely have a similar lesser impact (than tanker truck off-loading) on current pier side operations. Disadvantages of this type of installation include the cost to purchase the pumping infrastructure, install the pipes under the piers, and construct the storage facility. In addition, and as noted above, the exposed location of the pipes under the pier increases the risk of potential spills due to damage caused by floating debris.

Future Methods for Biomass Disposal

A significant effort is underway by industry to develop innovative ways to achieve better environmental performance in the disposal of waste from ships.

The company PyroGenesis with support from the US Navy and in cooperation with Carnival Cruise Lines has developed the PAWDS (Plasma Arc Waste Destruction System) as an alternative to shipboard incineration. According to website information the system is scalable and has the option for energy recovery with system capacities ranging from 0.1 to 15m^3/day. The final product is an inert sand like ash which can either be off-loaded in port or disposed of at sea. The system has been in operation on Carnival Cruise Lines *M/S Fantasy* since 2003 and is now solely operated by the vessel crew. The system handles 5m^3/day of waste. PAWDS is currently being marketed as Plasma King Waste Destruction System by Deerberg-Systems.

Scanship Environmental which makes waste treatment and handling systems for a significant portion of the cruise ship market has recently entered into and agreement with ITI Energy Limited whereby Scanship will promote, install and support ITI's marine gasification technology according to a company press release. The agreement covers the full integration and use of ITI's technology with Scanships 'Clean Ship Solutions' system. According to Scanship the system will be on the market soon and will be suitable for new build and retrofit markets. Scanship claims the system will not only produce ultra low emissions but will also produce a gas that can be fed into an internal combustion engine to generate a considerable amount of electricity. More detailed information about this system was not available and it is not known if any pilot projects are underway using the Scanship gasification technology. While this may hold promise for future applications, more data from demonstration projects are needed to determine the viability of the technology.

Section 4

Conclusion

References

Conclusion

Based on the data provided herein, the following primary conclusions are apparent:

- As currently configured, it is not possible for all vessels to store the entire volume of biomass generated in a week long cruise voyage. Two vessels reported they could store all biomass generated in a week. For the remaining vessels the storage capacity varied from 47% to 94% of weekly generation (3.3 to 6.6 days of storage capacity). At this time it is not known on a vessel by vessel basis if adding storage is possible.

  Accordingly, for all vessels that do not currently have sufficient capacity to store the biomass generated during a full week voyage, the available alternatives include:

  - biomass off-shore disposal as currently allowed,
  - mid-voyage transfer to other (not-in-Seattle) on-shore facility at other Port's-of-call,
  - or, modification of the existing on-board treatment, transfer and storage systems.

  The costs and environmental impact of all of these alternatives are unknown and beyond the scope of this phase of the study.

- Biomass is pumpable and could potentially be pumped on shore.
- On-shore transfer would have significant impacts to pier side operations. The extent of these impacts would vary by vessel, dock facility, volume of biomass to discharge, and method chosen for transfer to shore facilities. However, it is clear that for at least some of the vessels currently calling at the Port, the requisite disembarkation/embarkation of passengers, bunkering and provisioning, as well as the scheduling demands of an Alaskan itinerary sailing from Seattle, make it unlikely that the vessel could unload all of its biomass during the short time they are alongside Port facilities.
- Further study would be needed for evaluation of the potential environmental impact(s) from off-loading biomass at the pier, including determination of the net environmental benefit/impact of both the off-load operation as well as introduction of this biomass into King County systems.

Before proceeding with alternative methods for managing and disposing of biomass, more study is needed both regarding the feasibility and cost of vessel retrofits as well as the environmental benefits or impacts of offloading biomass at the Port of Seattle.

The survey that was sent to Cruise Line operators is a first step in answering some of the questions related to upgrades necessary to the cruise vessels associated with biomass unloading. However, as part of a potential Phase 1B, more detail discussions with each vessel operator could be addressed to reach stronger conclusions about the physical impacts of proposed methods for onboard storage and transfer. Specific questions to be asked within these follow-up interviews include:

The following additional tasks are recommended as part of continued Phase 1B study:

1. Onboard visits of at least three vessels to determine biomass storage capacity, pumping capacity, shore transfer capability and rate(s) etc.
2. Meet with crew to better understand shore transfer and waste treatment operations and vessel system functions.
3. Preliminary engineering cost estimates for modifications of vessels surveyed.
4. Meet with shore side operator terminal operator to discuss impacts and mitigation for on-pier impact(s).
5. Preliminary engineering cost estimates for pier side modifications and additional infrastructure.

Phase 2 would focus on assessment of potential environmental impacts/benefits of alternative methods of biomass disposal and management. It may make sense to complete Phase 2 prior to proceeding Phase 1B.

References

Alaska Department of Environmental Conservation (DEC). "Division of Water, Cruise Ship Program." Accessed September 28, 2008.
http://www.dec.state.ak.us/water/cruise_ships/index.htm

Hamworthy. "Membrane BioReactor Gray and Blackwater Treatment." Accessed September 28, 2008 http://www.hamworthy.com/docGallery/415.PDF

Huhta, Hanna-Kaisa, Jorma Rytkonen & Jukka Sassi. "Estimating nutrient load from waste waters originating from ships in the Baltic Sea Area" Espoo 2007. VTT Tiedotteita – Research Notes 2370. 58 p. + app. 13 p.

Hydroxyl. "Hydroxyl Sea Clean." Accessed September 28, 2008
http://www.hydroxyl.com/products_cleansea.php

King County Department of Natural Resources and Parks Wastewater Treatment Division, 2008. *2007 Biosolids Quality Summary*. Seattle, WA.

MEPC (Marine Environment Protection Committee), adopted 13 October 2006. *Annex 26 Resolution MEPC.159(55), Revised Guidelines on Implementation of Effluent Standards and Performance Tests for Sewage Treatment Plants.* International Maritime Organization.

Northwest CruiseShip Association. "NWCruiseShip.org." Accessed September 28, 2008
www.alaska.nwcruiseship.org/

Port of Seattle. "Cruise Seattle." Accessed September 28, 2008
http://www.portseattle.org/seaport/cruise/

ROCHEM (n.d.). "Clearly Superior in Waste Water Treatment," Accessed September 28, 2008. http://www.rochem.com/Home/home.html

U.S. Environmental Protection Agency. 2006a. *Holland America Veendam Sampling Episode Report*. Washington, DC. ***http://www.epa.gov/owow/oceans/cruise_ships/veendam.html***

U.S. Environmental Protection Agency. 2006b. *Norwegian Star Sampling Episode Report*. Washington, DC ***http://www.epa.gov/owow/oceans/cruise_ships/finalstar.html***

U.S. Environmental Protection Agency. 2006c. *Princess Cruise Lines Island Princess Sampling Episode Report*. Washington, DC. ***http://www.epa.gov/owow/oceans/cruise_ships/island.html***

U.S. Environmental Protection Agency. 2006d. *Sampling Episode Report Holland America Oosterdam Sampling Episode 6506*. Washington, DC.
http://www.epa.gov/owow/oceans/cruise_ships/oosterdam.html

U.S. Environmental Protection Agency. 2007. *Draft Cruise Ship Discharge Assessment Report*. Washington, DC.

U.S. Environmental Protection Agency. *40cfr133.102*. Washington, DC.

Voss, Kelly. "The Port of Helsinki Current Environmental Projects. September 3, 2008" Prepared for the Port of Seattle.

Appendix

Blank Survey – As Sent to Cruise Lines

Port of Seattle

P.O. Box 1209
Seattle, WA U.S.A. 98111

BIOMASS MANAGEMENT STUDY

The Port of Seattle is in the process of studying the feasibility of alternatives to open-ocean discharge of cruise vessel biomass. The first step of this process is to gather information on cruise vessels currently calling at the port. In support of this study, the Port of Seattle is requesting that you please answer the following questions regarding the current methods for handling biomass produced within the vessel. Please return the completed survey to Marie Fritz (fritz.m@portseattle.org) no later than noon on July 16, 2008.

For the purposes of this study, "Biomass" refers to the partially-treated solids residuals from the wastewater treatment process.

1. Cruise line and name of the vessel:

2. Type (make/model) of advanced wastewater treatment system(s) or marine sanitation device (please include schematic of treatment system if available):

3. Identify on-board waste water types that generate flow which enter the AWTS for treatment (gray water, black water, etc.):

4. For each system identified above, provide the approximate quantity of blackwater and graywater generated daily:

5. Identify the storage capacity of untreated wastewater within the vessel:

6. Identify the storage capacity of treated wastewater within the vessel:

7. Identify the daily treatment (process) capacity of the AWTS system (example – gallons or cubic meters per day):

Port of Seattle

P.O. Box 1209
Seattle, WA U.S.A. 98111

8. Identify the daily volume of biomass generated and the volume of biomass generated on a normal cruise evolution (7-days):

9. Estimated consistency of biomass (%liquid, % solid):

10. Identify the capacity of biomass that can be held on-board and the method of storage (dry, wet, in tanks, in containers, etc.):

11. What is the current method of biomass disposal:

12. In a normal cruise evolution (7-day voyage), how often is biomass discharged:

13. Is the point where biomass is discharged determined based on capacity or by vessel location:

14. If the vessel conducts shorter cruises (3-4 days), how often and where is biomass discharged:

15. Has the vessel's biomass ever been sampled for conventional pollutants or any other parameters?

16. Is this vessel currently fitted to store and discharge biomass to a shoreside facility?

17. If "No" to question 16:

a) What would it take to modify the existing on-board systems to allow discharge to a shoreside facility:

b) Is the consistency of the biomass material conducive to pumping to a shoreside facility:

18. If "Yes" to question 16:

a) How is the biomass transferred shoreside (pumped, water-added then pumped, vacuumed, etc.):

b) Identify company that receives the biomass shoreside and (if possible) the location where the biomass is ultimately disposed:

c) How long does it currently take to transfer biomass to the shoreside facilities:

19. If all or portions of the biomass is incinerated:

a) Describe what portion of the biomass is incinerated (screened solids, etc.):

b) How is this biomass transferred to the incinerator:

c) How much time does it take to transfer and incinerate the biomass:

d) How much fuel is consumed in the incineration of the biomass:

e) How is the remnant ash (left over following incineration) typically disposed: