Marinas, Boatyards, and Boat Manufacturers: An account of services, activities, stormwater, and process wastewater in the twenty coastal counties in North Carolina.

NC Division of Water Quality,
Wetlands and Stormwater Branch,
Raleigh, July 2007.

INTRODUCTION

Marinas, boatyard facilities, and boat manufacturers conduct activities and provide services that often include boat ramp access, boat maintenance, boat haul-out services, wastewater dump/pump-out, fueling, pressure washing, sanding, painting, etc. The purpose of this study was to better understand the scope of these commercial activities as well as the current land and adjacent water uses, services, and activities common to these facilities in the 20 coastal counties of North Carolina.

This investigation took place exclusively within the 20 coastal counties as defined in the Coastal Area Management Act (CAMA) (NCEMC 1995). While the focus of this investigation was at the North Carolina coast, it is anticipated that the results and recommendations will have application statewide.

The goals of this investigation were as follows: 1) to better understand the services and activities common to Marinas, Boatyards, and Manufacturers; 2) determine if these facilities are properly covered by the National Pollution Discharge Elimination Systems (NPDES) Stormwater permitting requirements (NCG190000); 3) to understand types/frequency of process wastewater; and 4) to sample process wastewater in order to understand and typify waste streams at marine facilities in North Carolina.

METHODS

An inspection form was developed to characterize current activities, with a particular emphasis on stormwater management and boat repair/maintenance activities, at existing Marinas, Boatyards and Manufacturers (Appendix 1). The development of this inspection form was accomplished from the use of the Clean Marina Checklist (Clean Marina Program), established North Carolina Division of Water Quality (NCDWQ) stormwater inspections forms, and additional NCDWQ staff recommendations.

Service and Activities

A list of 26 services and activities was developed and defined with an emphasis on stormwater management, impervious surfaces, boat repair/maintenance activities and process wastewater common to Docks Only, Marinas, Boatyards, and Manufacturers. The development of this list of services and activities was a prerequisite to differentiate Docks Only, Marinas, Boatyards and Manufacturers. These services and activities were defined as follows:

Definitions.

Services and Activities

1) Transient Slips: Boat slips available for temporary dockage.
2) Permanent Slips: Boat slips that are sold or rented on a monthly or yearly basis
3) Electricity: Electrical access is available for boating uses.
4) Lodging: Facility provides lodging.
5) Restrooms: Site has restroom (wastewater) facilities
6) Restaurant: Facility has a restaurant located onsite.
7) Retail Store: Site has retail store located onsite.
8) Boat Sales: Routine boat sales occur at the facility.
9) Trash Collection: Trash Collection is a service provided onsite.
10) Recycling: Recycling is a service provided.
11) Fish Cleaning Area: Area provided designated for cleaning fish
12) Charter: Renting of boats with or without a captain.
13) Live Aboard: Facility allows permanent live aboard residents.
14) Dry Boat Storage: Facility provides dry boat storage onsite.
15) Engine Repair: Engine repairs routinely occur onsite.
16) Dump Station: Service is provided to boaters to empty portable toilets.
17) Haul Out: Services are provided to lift boats in and out of the water with a travel lift or forklift.
18) Pump Out: Service to pump sewage from boat holding tanks to some form of sewage treatment
19) Hand Wash: After boat is removed from water, hand washing (light rinsing) services are provided or allowed onsite
20) Fuel: Boat fueling station is provided.
21) Boat Ramp: Boat ramp facilities are located at the facility.

22) Sanding: Boat sanding occurs onsite.
23) Sand Blasting: Sand blasting occurs onsite.
24) Painting: Boat painting occurs onsite.
25) Pressure Washing: Washing of boats using a mechanized power washer.
26) Boat Building: Facility builds boats onsite.
Figure 1: depicts the definitions of 26 services and activities associated with Docks Only, Marinas, Boatyards, and Manufacturers.

Docks Only, Marina, Boatyard, and Manufacturer

The facilities were divided into four categories: Docks Only, Marinas, Boatyards, and Manufacturers. The categories were based on services and activities typically offered at commercial and private marine facilities. These categories are defined below.

Docks Only: Table 1 depicts 13 (items 1-13 listed below) services and activities identified for Docks Only facilities. In comparison to the other three categories, Docks Only facilities are best characterized by services and activities that they lack. Dry boat storage, dump and pump stations, haul outs, ramps, maintenance and repair services, sanding, pressure washing, and boat building are not services and activities performed at Docks Only facilities (Table 1).

Marina: Table 1 depicts items 14 through 21 (listed below) as services and activities identified for Marinas. Marinas are distinguished from Docks Only facilities by the services and activities present at the facility. That is, a Marina may have activities and services listed number 1 through 21, but the facility must perform at least one activity from 14 through 21 to be considered a Marina. Dry storage, engine repair, dump and pump services, haul out, hand washing, boat ramp and fueling service are common to Marinas (Table 1).

Boatyard: Table 1 depicts items 22 through 25 as discrete services and activities identified for Boatyards. Boatyards may have activities and services labeled number 1 through 25, but the facility must perform at least one of the activities 22 through 25 to be considered a Boatyard. Sanding, sand blasting, painting, and pressure washing services are common to Boatyards (Table 1).

Manufacturer: Boat building is the activity unique to Manufacturers. Manufacturers may have activities number 1 through 26, but the facility must build boats (item 26) to be considered a Manufacturer (Table 1).

Table 1: Services and Activites

	Services	Docks Only	Marina	Boatyard	Manufacturer
1	Transient Slips	X	X	X	X
2	Permanent Slips	X	X	X	X
3	Electricity	X	X	X	X
4	Lodging	X	X	X	X
5	Restrooms	X	X	X	X
6	Restaurant	X	X	X	X
7	Retail Store	X	X	X	X
8	Boat Sales	X	X	X	X
9	Trash Collection	X	X	X	X
10	Recycling	X	X	X	X
11	Fish Cleaning Area	X	X	X	X
12	Charter	X	X	X	X
13	Live Aboard	X	X	X	X
14	Dry Boat Storage		X	X	X
15	Engine Repair		X	X	X
16	Dump Station		X	X	X
17	Haul Out		X	X	X
18	Pump Out		X	X	X
19	Fuel		X	X	X
20	Boat Ramp		X	X	X
21	Hand Wash		X	X	X
22	Sanding			X	X
23	Sand Blasting			X	X
24	Painting			X	X
25	Pressure Washing			X	X
26	Boat Building				X

The columns of services and activities depicted above are those that may be provided by and used to differentiate Docks Only, Marinas, Boatyards, and Manufacturers.

SAMPLE DESIGN

We compiled a list of facilities in North Carolinas 20 coastal counties (NCEMC 1995) using lists the Small Business and Technology Development Center - Boating Industry Services (SBTDC) marinas and boatyard list (www.ncwaterways.com) as well as the Division of Water Quality (DWQ) list of facilities with a NPDES Stormwater General Permit (NGG190000). From these sources, a total of 282 sites were identified. A systematic random sample design was used to ensure that sampling efforts spatially captured and well represented North Carolina's 20 coastal counties.

The 20 coastal counties were divided into four geographic groups (groups A,B,C,D) representing the following counties:

Group A: Bertie, Hertford, Chowan, Gates, Perquimans, Pasquotank, Camden, Currituck [n=27]

Group B: Washington, Beaufort, Tyrrell, Hyde, Dare [n=59]

Group C: Craven Pamlico, Carteret [n=101]

Group D: Onslow, Pender, New Hanover, Brunswick [n=95]

[Totaling 282 sites]

Once the 282 sites were blocked into geographic groups, the facilities in each group were then randomized as described by Zar (1996). Fifty percent (50%) of the facilities within each block group (A,B,C,D) were identified and investigated (Figure 2).

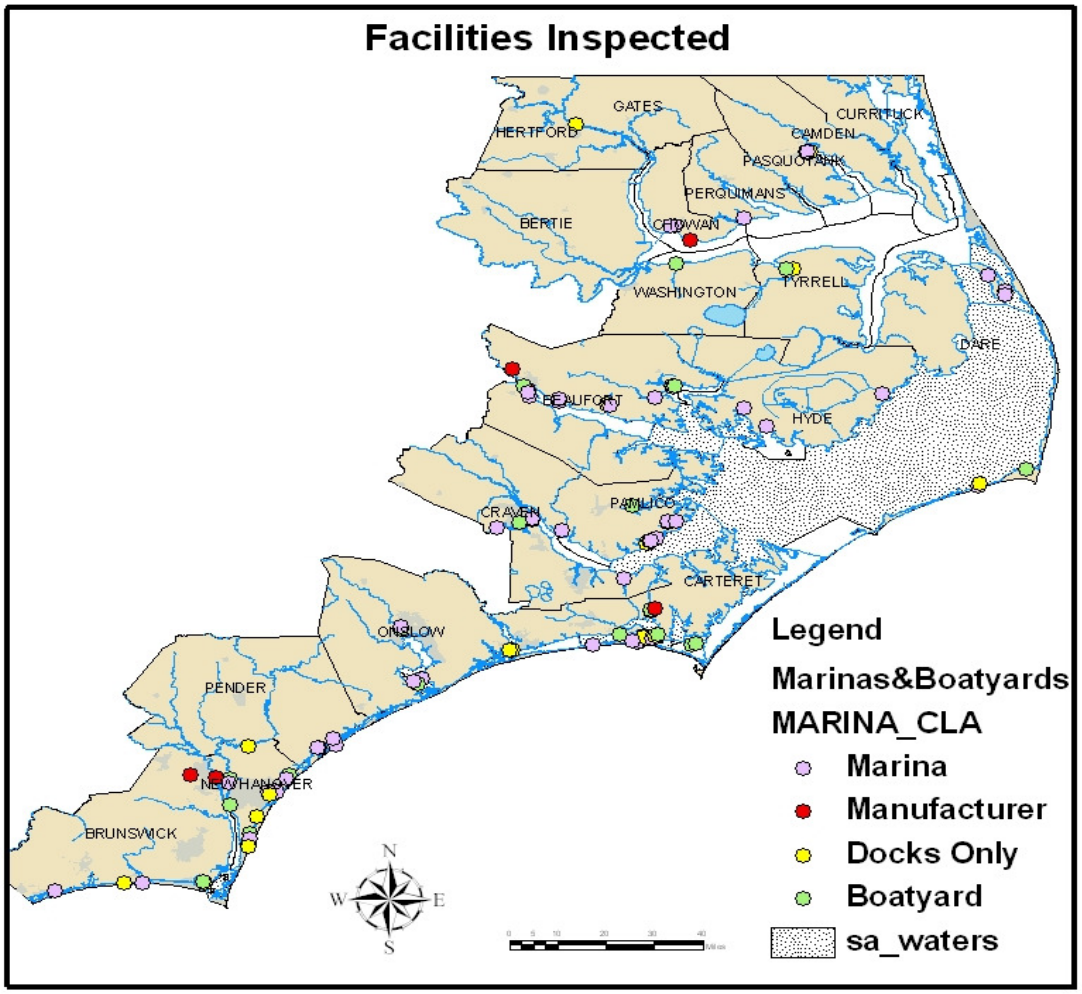

Figure 2. The map depicts locations of Docks Only, Marinas, Boatyards, and Manufacturers inspected during this investigation.

Process wastewater:

During the period between August 2006 and June 2007, DWQ staff undertook efforts to collect wastewater samples from pressure washing and hand washing activities. A total of 20 grab samples were collected and analyzed for aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. The metal analysis was conducted by North Carolina Division of Water Quality, Laboratory Section using US Environmental Protection Agency Methods 200.8, 200.7, and 245.1 (Method Reference a, b, c). Eleven (11) samples were taken from boat pressure washing activities and nine (9) samples were taken from boat hand washing/rinsing activities.

RESULTS

One hundred forty-one (141) sites were visited (50% of total sites) in the 20 coastal counties. Interestingly, 32 sites were observed to no longer exist. This is attributed to errors in the original database, business closures, and land use changes. Many of these facilities are located where redevelopment (or new development) is prolific. Condominiums and new residential single-family houses have replaced this commercial use.

Facility Characteristics: Docks Only, Marina, Boatyard, and Manufacturer.

Of the 141 sites, 109 facilities were still operating and were inspected. These 109 facilities were grouped according to services and activities offered as follows: Docks Only 19% (21), Marinas 51% (56), Boatyards 24% (26), Manufacturers 6% (6) (Figure 3).

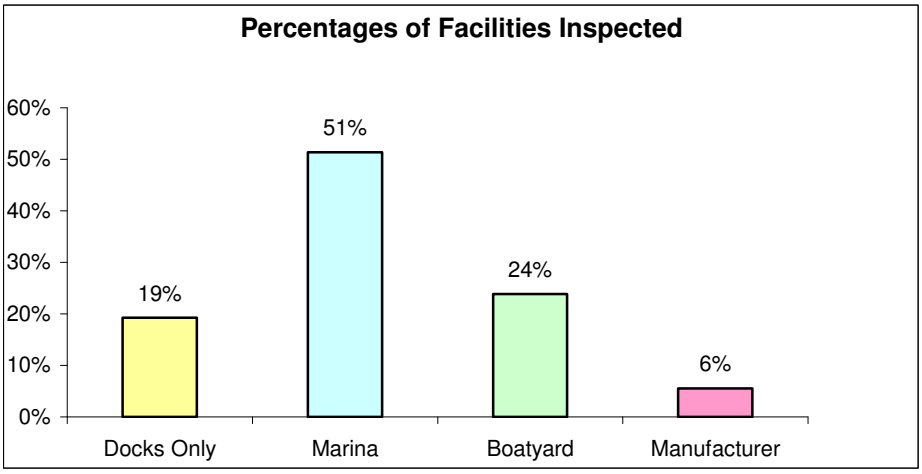

Figure 3. This figure depicts percentages of Docks Only, Marinas, Boatyards, and Manufacturers encountered from 109 facilities inspected during this investigation.

For the 20 coastal counties, NCDWQ estimates 112 active Marinas and 52 Boatyards currently operate in the 20 coastal counties. (Facilities that no longer exist were excluded from the analysis). The Docks Only category has been excluded from the above estimations, because it is likely the original sample dataset did not capture all of the Docks Only facilities. These facilities are ubiquitous and not well represented by the sample dataset. However, Docks Only is a useful category to consider. It is necessary to understand this land/water use in order to meaningfully differentiate Docks Only activities and services from Marinas, Boatyards and Manufacturers.

Docks Only. Thirteen (13) services and activities were identified for Docks Only facilities. None of the Docks Only facilities investigated offered boat sales. Some of the most commonly encountered services and activities include: permanent boat slips, trash collection, electrical access, restroom facilities, transient boat slips, and recycling (Table 2).

Marinas. Twenty (21) services and activities were identified at Marina facilities. Restroom facilities, permanent boat slips, electrical access, trash collection, transient boat slips, boat ramp, recycling, and fueling are activities that are most commonly encountered (Table 2).

Boatyards. Twenty-five (25) services and activities were identified at Boatyard facilities. The most common activities were painting, pressure washing, boat rinse and hand wash services, restrooms, trash collection, sanding, engine repair, boat haul-out services, permanent boat slips, and electrical assess. Boatyards are distinguished from Marinas by conducting sanding, sand blasting, painting, or pressure washing services (Table 2).

Manufacturers. Sixteen (16) services and activities were identified at Manufacturer facilities. Notably fewer services and activities are offered by Manufacturers as compared to Marinas and Boatyards which suggest a markedly different commercial/industrial land/water use. The most frequently encountered services and activities were boat building, sanding, restrooms, trash collection, recycling, and dry boat storage. Manufacturers can be distinguished from other categories due to the unique activity of boat building (Table 2).

Only six manufacturing facilities were encountered during this investigation. This type of facility merits further investigation in order to develop more comprehensive accounts of the services and activities common to Manufacturers.

Table 2: Services and Activities Observed

Services	Docks Only		Marina		Boatyard		Manufacturer	
1)Transient Slips	11	58%	36	65%	13	52%	0	0%
2)Permanent Slips	18	95%	47	85%	19	76%	0	0%
3)Electricity	14	74%	47	85%	18	72%	0	0%
4)Lodging	6	32%	13	24%	2	8%	0	0%
5)Restrooms	14	74%	50	91%	24	96%	6	100%
6)Restaurant	3	16%	14	25%	2	8%	0	0%
7)Retail Store	1	5%	27	49%	16	64%	1	17%
8)Boat Sales	0	0%	3	5%	8	32%	2	33%
9)Trash Collection	16	84%	48	87%	24	96%	6	100%
10)Recycling	11	58%	32	58%	17	68%	6	100%
11)Fish Cleaning Area	4	21%	24	44%	10	40%	0	0%
12)Charter	3	16%	14	25%	5	20%	0	0%
13)Live Aboard	2	11%	10	18%	4	16%	0	0%
14)Dry Boat Storage			13	24%	18	72%	5	83%
15)Engine Repair			4	7%	21	84%	1	17%
16)Dump Station			11	20%	4	16%	0	0%
17)Haul Out			3	5%	21	84%	2	33%
18)Pump Out			20	36%	12	48%	0	0%
19)Fuel			31	56%	10	40%	2	33%
20)Boat Ramp			32	58%	11	44%	1	17%
21)Hand Wash			3	5%	25	96%	4	67%
22)Sanding					22	88%	4	67%
23)Sand Blasting					7	28%	1	17%
24)Painting					25	100%	3	50%
25)Pressure Washing					24	92%	4	67%
26)Boat Building							6	100%

The number of occasions and the respective percentages of each service and activity encountered for Docks Only, Marinas, Boatyards, and Manufacturers.

Boat Slips

Boat slips are commonly encountered and are prominently associated when considering Docks Only, Marinas, and Boatyard facilities. The results reveal that the percentage of Docks Only, Marinas, and Boatyard facilities having permanent boat slips is 95%, 85%, and 76%, respectively. The percentages of Docks Only, Marinas, and Boatyards providing transient slips are 58%, 65%, 52%, respectively. Only one Manufacturer of the six inspected was observed to have slips (Table 3).

The average total number of boats slips encountered for Docks Only is 23.8 slips per Docks Only facility. Marinas have the highest average of slips per facility at 65.1 boat slips. The average number of slips observed for Boatyards is 44.3, nearly double that of Docks Only (Table 3).

Table 3: Descriptive Statistics for Boat Slips

	Mean	Count	Median
Docks Only	23.86	21	20.00
Marina	65.07	56	46.00
Boatyard	44.31	26	26.00
Manufacturer	.67	6	0.00

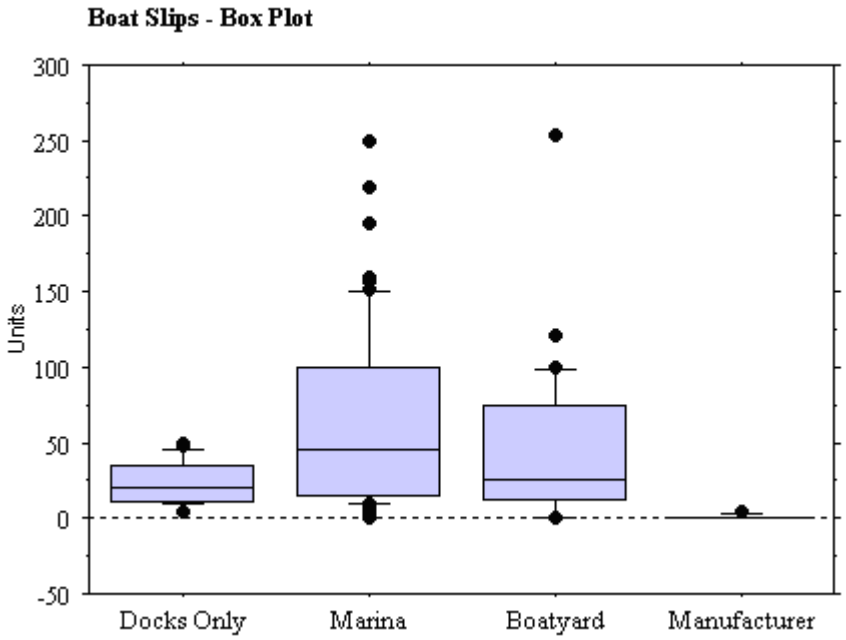

Figure 4. Number of boat slips housed at Docks Only, Marinas, Boatyards, and Manufacturers.

The median number of boat slips for Marinas is 46, nearly twice that of both Docks Only at 20 slips per facility and Boatyards at 26 slips per facility. The number of boat slips housed at a facility may provide a useful indication of the scope and volume of services and maintenance provided by a facility.

Stormwater - NPDES Permit (NCG190000)

The original dataset compilation from which 50% of sites were chosen for inspection included permitted NPDES Stormwater permitted facilities (NCG190000). With the facilities that no longer exist excluded from the analysis, it is estimated that 112 Marinas and 52 Boatyards

currently operate in the 20 coastal counties. Of the 282 sites identified, 51 of these facilities, located in the 20 coastal counties, are currently permitted by an NPDES Stormwater permit (NCG190000).

Land Use and Permeability- Of the 109 facilities inspected, 106 facilities had designated vehicle parking available. These parking areas included paved, gravel, grass, and bare earth lots. Thirty-two (32) facilities had designated hand wash areas. Designated pressure wash areas were observed at 28 facilities. Covered maintenance areas were observed at 33 of the facilities investigated; however, it is noted that many of these sites with covered maintenance areas also have ongoing maintenance in uncovered areas. These maintenance and washing areas include paved, gravel, grass, covered, bare earth or a combination of several areas.

Boats Serviced and Painted

Boatyards and Manufacturers provide maintenance, engine repairs, boat storage, sanding, pressure washing and painting services. Annually, Boatyards and Manufacturers provide service to or produce an average of 200and 224 boats per facility, respectively. Boatyards and Manufacturers respectively paint an average of 67.1 and 39.0 boats per facility annually (Table 4). Docks Only and Marina facilities do not provide these services and are thereby excluded from this analysis. Most manufacturers produce boats with a gel coat and therefore do not paint the boats. Typically bottom paint is later applied at a Boatyard.

Table 4. The number of boats serviced/produced, and painted per facility annually.

	Mean	Count	Median
Boatyard Serviced/ yr	200	24	100.0
Boatyard Painted/ yr	67	24	25.0
Manufacturer Produced/ yr	224	6	139.5
Manufacturer Painted/ yr	39	6	0.0

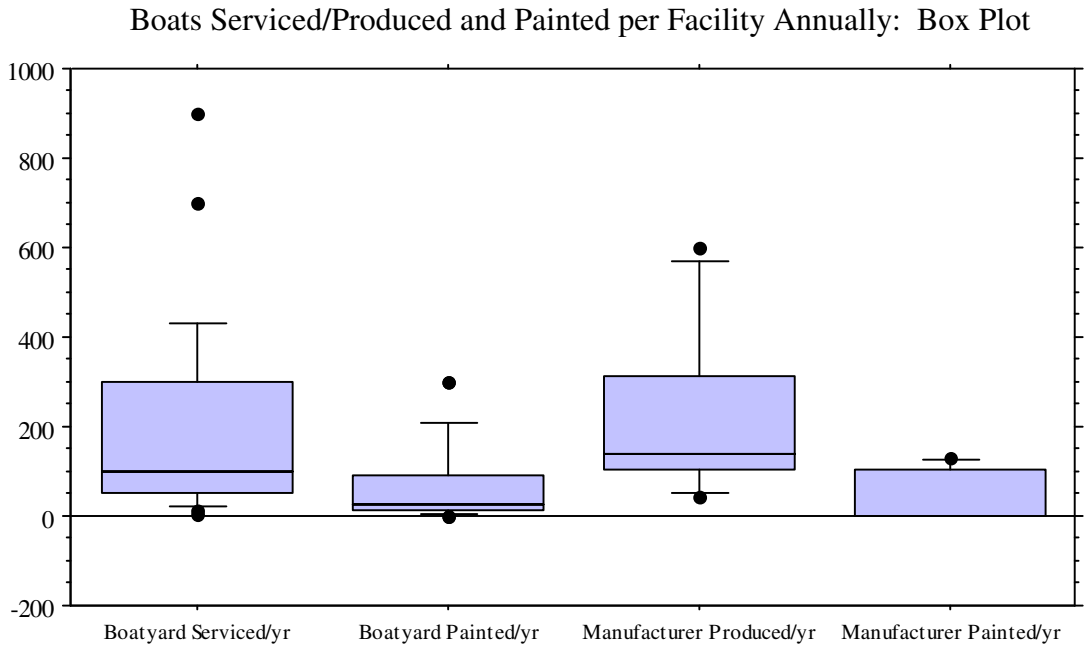

Figure 5. Number of boats serviced/produced and painted per facility, annually.

It is noted that the median number of boats serviced by Boatyards annually is 100 and the median number of boats produced by Manufacturers annually is 140. The median number of boats painted per year by Boatyards is 25. Only six Manufacturers were encountered and inspected during this investigation and, of these facilities, two sites routinely painted boats. These facilities notably painted a large number of boats, 129 and 105, during the year.

It is expected that boats serviced coincide to the number of boats washed per year. That is, if a boat is hauled out, taken to storage or prepared for painting, the assumption is that the boat will also be washed as a part of this process.

Process Wastewater

During these inspections 29% (32) of the 109 facilities inspected routinely generate process wastewater. These waste streams are typically associated with pressure washing and hand washing activities for storage, maintenance, painting, or other servicing.

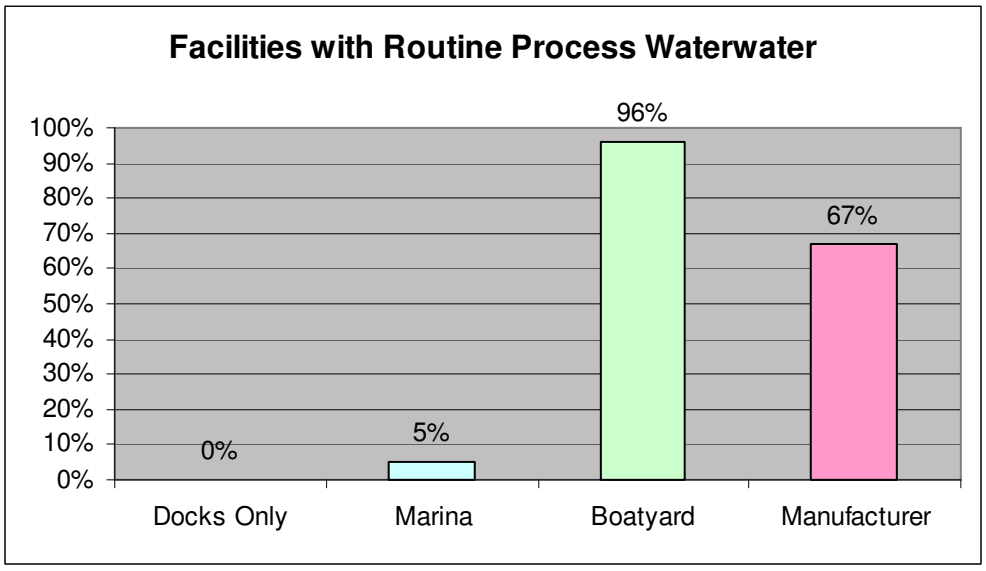

Figure 6. Percentages of Docks Only, Marinas, Boatyards, and Manufacturers facilities with routine process wastewater generation.

Process Wastewater - Pressure Wash and Hand Wash

During the period between August 2006 and June 2007, process wastewater samples were collected from pressure washing and hand washing activities. From simple visual inspection, the process wastewaters were often strongly colored and evidently mixed with residual boat paint. A total of 20 samples were collected and analyzed for aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc to characterize hand washing and pressure washing waste streams.

Table 5: Process Wastewater –Pressure Wash and Hand Wash (µg/L)

Metal	N[a]	Mean (µg/L) ± 1 SE	Surface Water Acute Std[b]
Copper	20	114,485 ± 67,227	4.8 µg/L
Iron	20	31,524 ± 17,283	--
Zinc	20	18,150 ± 9,628	90 µg/L
Aluminum	20	14,470 ± 7,417	--
Lead	19	817 ± 414	210 µg/L
Nickel	15	201 ± 124	74 µg/L
Chromium	15	109 ± 48	570 µg/L[c]
Arsenic	17	55.67 ± 15.81	69 µg/L
Cadmium	16	33.13 ± 17.95	40 µg/L
Mercury	2	1.04 ± 0.76	1.8 µg/L[d]

Mean metal concentration (µg/L) of water discharging from boat pressure washing and hand washing activities ± 1 standard error. (Appendix 2)
N[a] = number of samples analyzed that were above the detection minimums.
[b] At 100 mg/L hardness
[c] Freshwater
[d] As MeHg

A review of the sample results indicates that large amounts of copper, iron, zinc, and aluminum are common and a dominant component of process wastewater constituents at Boatyards. Mean copper, iron, zinc and aluminum concentrations are markedly elevated: Co = 114,485 µg/L, Fe = 31,524 µg/L, Zn = 18,150 µg/L, and Al = 14,469 µg/L. Lead, nickel, chromium, arsenic and cadmium concentrations are also elevated, but to a lesser extent. Two samples revealed the presence of mercury above detection minimums.

Elevated metal concentrations are attributed to the sloughing of residual paints from boat hulls during response to hand washing and pressure washing. In certain instances, boats are pressure washed to remove old hull paint. This is a common boat maintenance technique when preparing boats for painting.

Comparison Between Pressure Wash and Hand Wash Process Wastewater

A total of 20 samples were collected and analyzed for aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc to characterize process wastewater generated from

Boatyards. The 20 samples collected included both hand washing (rinse water) and pressure washing waste streams. Hand wash (rinse water) is a wastewater that is generated after the boat is removed from the water and the boat is then hand washed or lightly rinsed. Pressure washing waste streams result when facilities use a pressure washer to clean a boat, remove paint, and/or remove marine growth. Eleven (11) samples were collected from pressure washing activities and nine (9) samples were collected from rinsing activities.

Table 6: Boat Pressure Wash and Hand Wash Metal Results (µg/L) – Copper, Iron, Zinc and Aluminum

Metal	Hand Washing (µg/L)	Pressure Washing (µg/L)
Copper*	1,146	207,218
Iron	11,594	47,830
Zinc*	1,545	31,736
Aluminum*	3,539	23,413
Lead*	65	1,364
Nickel	32	349
Chromium	39	171
Arsenic	23	??
Cadmium	8	48
Mercury	0.28	1.8

Mean metal concentration (µg/L) of water discharging from boat pressure washing and hand washing activities. (Appendix 2)

* Indicates significant difference ($\alpha = .05$) between water discharging from boat pressure washing and hand washing activities.

Pressure Wash and Hand Wash Distributions

A Mann-Whitney U-test, a nonparametric version of the two sample unpaired t-test, was performed comparing the pressure washing and hand washing waste streams. For the pressure washing and hand washing waste streams, at a 95% confidence level the distributions for the following elements are <u>not</u> the same: copper, zinc, and aluminum. These results indicate that levels of copper, zinc, and aluminum are affected by the method of washing. According to the same test, the distribution for iron <u>is</u> the same (Appendix 4).

A Mann-Whitney U-test was performed comparing the pressure washing and hand washing waste streams. For the pressure washing and hand washing waste streams, at a 95% confidence

level the distribution for lead is not the same. Again, these results indicate that lead concentrations differ significantly in pressure wash waste streams compared to hand wash waste streams. According to the same test, the distributions for the following elements are the same: nickel, chromium, arsenic, and cadmium.

Mercury. Mercury was not analyzed using a Mann-Whitney U-test because only two samples were above detection minimums. Mercury may not be a typical metal constituent common to process wastewaters from Boatyards; however, two samples had very high amounts of mercury, 1.81 µg/L and 0.28 µg/L respectively.

DISCUSSION

Standard Industrial Classification. The standard industrial classification (SIC) for ships and boat building and repairing are 3731 and 3732. The SIC Code for marinas is 4493. The standard industrial classification language respectively states the following and can be found at the following web site (http://www.osha.gov/pls/imis/sicsearch.html?p_sic=373&p_search=):

3731 Ship Building and Repairing
Establishments primarily engaged in building and repairing ships, barges, and lighters, whether self-propelled or towed by other craft. This industry also includes the conversion and alteration of ships and the manufacture of off-shore oil and gas well drilling and production platforms (whether or not self-propelled). Establishments primarily engaged in fabricating structural assemblies or components for ships, or subcontractors engaged in ship painting, joinery, carpentry work, and electrical wiring installation, are classified in other industries.

- Barges, building and repairing
- Cargo vessels, building and repairing
- Combat ships, building and repairing
- Crew boats, building and repairing
- Dredges, building and repairing
- Drilling and production platforms, floating, oil and gas
- Drydocks, floating
- Ferryboats, building and repairing
- Fireboats, building and repairing
- Fishing vessels, large: seiners and trawlers-building and repairing
- Hydrofoil vessels
- Landing ships, building and repairing
- Lighters, marine: building and repairing
- Lighthouse tenders, building and repairing
- Marine rigging
- Naval ships, building and repairing
- Offshore supply boats, building and repairing
- Passenger-cargo vessels, building and repairing
- Patrol boats, building and repairing
- Radar towers, floating

- Sailing vessels, commercial: building and repairing
- Scows, building and repairing
- Seiners, building and repairing
- Shipbuilding and repairing
- Submarine tenders, building and repairing
- Tankers (ships), building and repairing
- Tenders (ships), building and repairing
- Towboats, building and repairing
- Transport vessels, passenger and troop: building and repairing
- Trawlers, building and repairing
- Tugboats, building and repairing

3732 Boat Building and Repairing

Establishments primarily engaged in building and repairing boats. Establishments primarily engaged in manufacturing rubber and nonrigid plastics boats are classified in Major Group 30. Establishments primarily engaged in operating marinas and which perform incidental boat repair are classified in Transportation, Industry 4493; membership yacht clubs are classified in Services, Industry 7997; and those performing outboard motor repair are classified in Services, Industry 7699.

- Boat kits, not a model
- Boats, fiberglass: building and repairing
- Boats, rigid: plastics
- Boats: motorboats, sailboats, rowboats, and canoes-building and
- Canoes, building and repairing
- Dinghies, building and repairing
- Dories, building and repairing
- Fishing boats, small
- Houseboats, building and repairing
- Hydrofoil boats
- Kayaks, building and repairing
- Life boats, building and repairing
- Life rafts, except inflatable (rubber and plastics)
- Motorboats, inboard and outboard: building and repairing
- Pontoons, except aircraft and inflatable (rubber and plastics)
- Skiffs, building and repairing

4493 Marinas
Establishments primarily engaged in operating marinas. These establishments rent boat slips and store boats, and generally perform a range of other services including cleaning and incidental boat repair. They frequently sell food, fuel, and fishing supplies, and may sell boats. Establishments primarily engaged in building or repairing boats and ships are classified in Manufacturing, Industry Group 373. Establishments primarily engaged in the operation of charter or party fishing boats or rental of small recreational boats are classified in Services, Industry 7999.

- Boat yards, storage and incidental repair
- Marinas
- Marine basins, operation of
- Yacht basins, operation of

Coastal Area Management Act. The Coastal Area Management Act (CAMA) defines marinas as follows (NCCRC 1998):

> "Marinas are defined as any publicly or privately owned dock, basin or wet boat storage facility constructed to accommodate more than 10 boats and providing any of the following services: permanent or transient docking spaces, dry storage, fueling facilities, haulout facilities and repair service. Excluded from this definition are boat ramp facilities allowing access only, temporary docking and none of the preceding services."

For the purposes of this investigation, the number of slips is not used as a threshold for differentiating Docks Only, Marinas, Boatyards, and Manufacturers. However, the number of boat slips is a parameter that was investigated in this study (Table 3). Rather, a list of services and activities was developed to provide a detailed distinction between types of facilities. This distinction was necessary in order to investigate stormwater management concerns, boat repair, maintenance, painting activities and process wastewater issues for a diverse and complex service industry.

The results revealed notably fewer services and activities are offered by Manufacturers than by Marinas and Boatyards. This suggests that the Manufacturer category is a discrete industrial activity when compared to Marinas and Boatyards. The original dataset used to derive the subset of facilities investigated was a compilation of issued NPDES Stormwater permits from DWQ data sets and a list of facilities developed from the Boating Industry Services. These combined data sets should represent a comprehensive list of the Marinas and Boatyards that are operating in the 20 coastal counties. However, very few Manufacturers (6) were investigated as a part of this study. The low number is not surprising because there are fewer facilities that manufacture boats as compared to facilities that provide services common to Marinas and Boatyards. Because so few Manufacturers were identified during this study, additional investigation is merited.

This investigation was not designed to include inland repair shops, boat dealers, mobile repair and mobile pressure wash services. Process wastewater likely coincides with these services, and they merit further investigation and regulatory consideration.

NPDES Stormwater Permitting

Of the 109 sites inspected, 19% of the sites were Docks Only, 51% were Marinas, 24% were Boatyards and 6% Manufacturers. A total of 51 sites in the 20 coastal counties are currently covered by a NPDES Stormwater permit (NCG190000). While Docks Only facilities are likely

not the highest stormwater permitting priority, Boatyards, Marinas, and Manufacturers clearly merit attention and efforts to ensure their proper coverage under a NPDES Stormwater permit (NCG190000). The services and activities provided by these facilities have the potential to produce stormwater runoff with significant pollutant loads to coastal waters.

Process Wastewater

The average amount of copper from pressure washing activities was observed to be 207,218 µg/L. From field observations and discussions with Boatyard operators, it is estimated that 40 to 80 gallons of water are used during a boat washing effort.

A Boatyard facility services an average of 200 boats per year (Table 4). Serviced boats refer to the number of boats that are hauled out and respectively washed. Boatyards typically generate process wastewater. Ninety-two percent (92%) of the Boatyard facilities investigated have routine pressure wash process wastewater. Using these figures and the estimated number of Boatyards located in the 20 coastal counties and those Boatyards adjacent to SA waters (surface waters that are used for shellfishing for market purposes), the annual total of metals from Boatyard pressure washing activities may be approximated (Table 7).

Table 7: Annual Amounts of Metals From Boatyard Pressure Washing

Metal	Annual kg (lbs) in 20 Coastal Counties	Annual kg (lbs) adjacent to SA Waters
• Copper	335-670 kg (739-1478 lbs)	127-254 kg (281-562 lbs)
• Iron	98-199 kg (215-439 lbs)	37-74 kg (82-164 lbs)
• Zinc	59-119 kg (131-262 lbs)	23-45 kg (50-100 lbs)
• Aluminum	44-88 kg (97-194 lbs)	17-34 kg (37-74 lbs)
• Lead	2-4 kg (5-9 lbs)	1-2 kg (2-3 lbs)

The actual amount of metals generated from Marinas, Boatyards, and Manufacturers is unknown. However, as described above, the amounts of metals from these activities are clearly substantial. For example, the average amount of copper, zinc, and lead from pressure washing activities was observed to be 207,218 µg/L, 31,736 µg/L, and 1,363 µg/L, respectively (Table 6). The surface water standards in Title 15A NCAC 02B .0200 reflect the following ambient aquatic life

standards designed to protect from chronic (long-term) exposure to toxicants (NCEMC. 2007a; NCEMC. 2007b):

Table 8: Ambient Water Quality Aquatic Life Chronic Standards for Metals

Metal	Freshwater Aquatic Life Standard	Saltwater Aquatic Life Standard
Copper**	7 µg/L	3 µg/L *~5 µg/L at 100 mg/L hardness****
Iron**	1.0 mg/L	*
Zinc**	50 µg/L	86 µg/L *90 µg/L dissolved at 100 mg/L hardness****
Lead	25 µg/L	25 µg/L *210 µg/L dissolved at 100 mg/L hardness****

* no standard listed

** Action Level Standards (15A NCAC 2b .0211)

*** Copper, Zinc, and Lead are values are hardness dependent

The large quantities of metals, coupled with the fact that the majority of these facilities are adjacent to coastal surface waters, makes the environmental effects of these process wastewater streams a significant concern.

Wash waters exhibit markedly high concentrations of metals largely because residual paint is removed from the boat during the washing activities. Boats with paint known as "bottom paint" designed to prevent marine life growth on boat hulls have the highest concentrations of metals (as compared to boats without bottom paint). Regardless, all the process wastewaters contain metals, although the concentrations vary.

Wastewater generated from Marinas, Boatyards, and Manufacturers should be addressed, to prevent process wastewater and residuals from previous washes from commingling with storm event water.

This may be accomplished through the following:

1) Elimination of the waste stream
2) The use of other medias (sanding, sand blasting–provided the dry product is captured)
3) Recycle systems
4) Industrial pretreatment and connection to a POTW
5) Development of a non-discharge waste system for hand washing operations
6) Development of new service industry designed to collect, treat, perhaps recycle residual metals, and/or to use these process waters in other industrial production processes.

Compliance Initiatives:

The investigators believe this study shows that compliance initiatives are merited in order to significantly improve compliance with respect to both NPDES permit coverage and elimination of unauthorized process wastewater discharges.

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Investigation Prepared By:

-Danny Smith and Daryl Norris – Wetlands & Stormwater Branch, NCDWQ
-Washington and Wilmington Regional Offices
-Stormwater Permitting Unit
-NPS Assistance & Compliance Unit

Appendix 1

Marina/Boatyard Inspection Form

Company Name: _____
Mailing Address: _____ State: __ Zip Code: _____
Phone: ___-___-____ Fax: ___-___-____ Email: _____
Contact Name _____ Position: _____
Website: _____ Boating Guide Ref. #: _____
Physical Address: _____ State: __ Zip Code: _____
County: _____ Region: _____ Group: _____
Permits if any: _____, _____, _____

Date of Inspection: _____ Inspected by: _____
Weather Conditions: _____

Site:

Latitude: _____ Longitude: _____
Waterfront or direct access to navigable waters? ☐ Yes ☐ No Average Depth: __ ft
Water body: _____ Classification: _____ DWQ Index #: _____
River Basin: _____

Permeability:	Paved	Gravel	Grass	Covered	Bare earth	Other
Parking Lots	☐	☐	☐	☐	☐	_____
Hand Wash Area	☐	☐	☐	☐	☐	_____
Pressure Wash Area	☐	☐	☐	☐	☐	_____
Maintenance Area	☐	☐	☐	☐	☐	_____
Storage Area	☐	☐	☐	☐	☐	_____
Boat Ramp	☐	☐	☐	☐	☐	_____

(Circle where samples are taken)

# of Permanent Slips: ____<40ft ____≥40ft Transient Slips: ____ Liveaboards: ____
# of Dry Storage Slips: Indoor____ Covered____ No Cover____
Boats Present in Water: Sail: ____ Motor: ____ Commercial: ____
Description/Comments _____

_____

Other site observations: _____

_____

_____

NC Clean Marina: ☐ Yes ☐ No ☐ N/A
How often is the marina dredged? _____ By Who? _____
Where and how is the spoil deposited? _____

Motor	Sail	Commercial

Stormwater:

Is there a Stormwater Management Plan: ☐ Yes ☐ No ☐ N/A

Stormwater from maintenance/storage/processing areas observed to be discharging into waters at the time of the site visit: ☐ Yes ☐ No ☐ N/A

Maintenance/storage/processing areas routinely discharge stormwater into waters during precipitation events: ☐ Yes ☐ No ☐ N/A

Receiving Stream:_____DWQ Index #_____

Is there a permit for stormwater discharges: ☐ Yes ☐ No ☐ N/A

Stormwater collection/treatment system for maintenance/storage/processing areas:

- ☐ Retention Basins
- ☐ Constructed Wetlands
- ☐ Infiltration Practices
- ☐ Bio-retention Practices
- ☐ None
- ☐ Sand filters
- ☐ Grassed Swales
- ☐ Vegetated filter strips
- ☐ Other_____

Services/Activities**:**

	Onsite	Offsite	Not Offered		Onsite	Offsite	Not Offered
Transient slips	☐	☐	☐	Stormwater Treatment	☐	☐	☐
Permanent slips	☐	☐	☐	Haul Out	☐	☐	☐
Dry Boat Storage	☐	☐	☐	Lodging	☐	☐	☐
Live Aboard	☐	☐	☐	Restrooms	☐	☐	☐
Fuel	☐	☐	☐	Restaurant	☐	☐	☐
Electricity	☐	☐	☐	Retail Store	☐	☐	☐
Engine Repair	☐	☐	☐	Boat Sales	☐	☐	☐
Sanding	☐	☐	☐	Pump Out	☐	☐	☐
Sand Blasting	☐	☐	☐	Dump Station	☐	☐	☐
Painting	☐	☐	☐	Trash Collection	☐	☐	☐
Hand Wash	☐	☐	☐	Recycling	☐	☐	☐
Pressure Washing	☐	☐	☐	Boat Ramp	☐	☐	☐
Washwater Treatment	☐	☐	☐	Fish Cleaning Area	☐	☐	☐
Sewer Waste Treatment	☐	☐	☐	Charter	☐	☐	☐

Fuel:

Gasoline: ☐ Land ☐ Dock Tanks (#, gal., above/below ground): _____

Diesel: ☐ Land ☐ Dock Tanks (#, gal., above/below ground): _____

_____: ☐ Land ☐ Dock Tanks (#, gal., above/below ground): _____

Has spill prevention plan: ☐ Yes ☐ No Has spill response plan: ☐ Yes ☐ No

Spill containment equipment: _____

Containment around fuel tanks: ☐ Yes ☐ No ☐ N/A

If no:_____

Containment Valve Closed: ☐ Yes ☐ No ☐ N/A Visible Sheen: ☐ Yes ☐ No ☐ N/A

Removed all fueling clips: ☐ Yes ☐ No ☐ N/A

System in working order: ☐ Yes ☐ No ☐ N/A

If no:_____

Regular inspection program: ☐ Yes ☐ No ☐ N/A

Emergency Shutoffs: ☐ Yes ☐ No ☐ N/A

Observations/comments:_____

Maintenance/Sanding/Blasting/Painting:

All Maintenance performed indoors: ☐ Yes ☐ No ☐ N/A
Has Employee BMP Training Program: ☐ Yes ☐ No ☐ N/A
Allows or performs in-water maintenance: ☐ Yes ☐ No ☐ N/A
If yes, does debris fall into the water: ☐ Yes ☐ No ☐ N/A
Has designated area for boat repair and maintenance: ☐ Yes ☐ No ☐ N/A
Areas regularly cleared of trash and debris: ☐ Yes ☐ No ☐ N/A
Uses tarps under boats during service on land: ☐ Yes ☐ No ☐ N/A
How is debris caught on tarps disposed:
Abrasive blasting is done in enclosures: ☐ Yes ☐ No ☐ N/A
Uses vacuum sanders: ☐ Yes ☐ No ☐ N/A
Subcontractors sign maintenance compliance policy: ☐ Yes ☐ No ☐ N/A
Boats serviced per year: per month: Busiest month(s):
Boats painted per year: Mechanical repairs per year:
Observations/comments: _____

_____

Hand Washing/Pressure Washing:

Processed wastewater observed to be discharging into waters at the time of the site visit: ☐ Yes ☐ No ☐ N/A
Facility conducts activities that routinely discharge processed wastewater into waters: ☐ Yes ☐ No ☐ N/A
Has designated boat hand wash/rinsing area: ☐ Yes ☐ No ☐ N/A
Rinsing allowed on or near boat ramp: ☐ Yes ☐ No ☐ N/A
Hand wash collection/treatment system:

☐ Pump and Haul ☐ Municipal Sewer
☐ Septic tank ☐ Oil separator
☐ None ☐ Other_____

Cover or stormwater bypass on treatment systems: ☐ Yes ☐ No ☐ N/A
Has designated pressure-washing area: ☐ Yes ☐ No ☐ N/A
Pressure wash water is collected and treated: ☐ Yes ☐ No ☐ N/A
Pressure wash water is discharged: ☐ no discharge ☐ to sewer ☐ to water ☐ other
Is there a permit for a wastewater discharge: ☐ Yes ☐ No ☐ N/A
Pressure wash collection/treatment system:

☐ Pump and Haul
☐ Septic tank
☐ None
☐ Municipal Sewer
☐ Oil Separator
☐ Other_____

Cover or stormwater bypass on treatment systems:
☐ Yes ☐ No ☐ N/A
Observations/comments:_____

Recycling/Wastes/Sewage

Keeps shoreline clear of trash and debris: ☐ Yes ☐ No ☐ N/A
Offers used oil recycling/collection: ☐ Yes ☐ No ☐ N/A
Oil and other materials covered and stored properly: ☐ Yes ☐ No ☐ N/A
If no:_____
Proper disposal of hazardous material: ☐ Yes ☐ No ☐ N/A
If no:_____
Clean, functioning restrooms: ☐ Yes ☐ No ☐ N/A
Prohibits discharge of sewage in the marina basin. ☐ Yes ☐ No ☐ N/A
Boaters informed of no-discharge policy: ☐ Yes ☐ No ☐ N/A
Sewage system available: ☐ None ☐ Septic tank ☐ Municipal Sewer ☐ other
Septic system regularly maintained: ☐ Yes ☐ No ☐ N/A
Pump out regularly maintained and inspected: ☐ Yes ☐ No ☐ N/A
Posted pump out directions: ☐ Yes ☐ No ☐ N/A
Collection/treatment system for bilge water: ☐ Yes ☐ No ☐ N/A
If yes:_____
Has designated fish-cleaning area: ☐ Yes ☐ No ☐ N/A
Posted rules for fish cleaning and disposal: ☐ Yes ☐ No ☐ N/A

Photo # : **Description:**

Definitions:

- **Hand Wash**- Hand washing or lightly rinsing boats after coming out of the water
- **Pressure Washing**- Machine pump washing or any intense washing that could result in debris such as paint or fiberglass coming off the boat.
- **Retention Basins**- where stormwater runoff is temporarily stored to allow sediments to settle out
- **Constructed Wetlands**- man made shallow pools planted with native wetland vegetation
- **Infiltration Practices**- basins, trenches, downspouts, or porous pavement temporarily hold stormwater and discharge it through filtration into the surrounding soils.
- **Bio-retention Practices**- depressions in the land underlain with an engineered soil mixture to help filter runoff into underlying natural soils or a subsurface drain system.
- **Sand Filters**- underground facilities that capture, pretreat and filter stormwater runoff as it comes off a surface or through a point source.
- **Grassed Swales**- vegetated channels lined with erosion-resistant and flood tolerant grasses underlain by soil that facilitates runoff filtration and exfiltration into the underlying natural soils.
- **Vegetated Filter Strips**- a vegetated strip of land that is positioned to capture and filter sheet runoff.
- **Dry Boat Storage**- Storage stacks for boats out of the water.
- **Storage Area**- Area where boats or materials are stored. (trailer not connected to a vehicle)
- **Processing Area**- Any area where boats are transported, hauled out, temporarily stored, etc.
- **Pump Out**- service to pump sewage from boats holding tanks to some form of sewage treatment
- **Dump Station**- Area for boaters to empty portable toilets
- **Pump and Haul**- Waste is collected, stored, and transported to another location for treatment
- **Oil Separator**- Treatment that removes oil and hydrocarbons from water.

Appendix 2
Process Wastewater Results:
Process Wastewater –Pressure Wash and Hand Wash (µg/L)

	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	Variance	Median
Copper	114485.65	300647.27	67226.77	20	13.00	1200000.00	90388783707.92	9700.00
Iron	31524.00	77290.72	17282.73	20	300.00	350000.00	5973854835.79	7350.00
Zinc	18150.30	43055.51	9627.51	20	26.00	180000.00	1853777119.69	2250.00
Aluminum	14469.50	33168.75	7416.76	20	210.00	150000.00	1100165931.32	3350.00
Lead	816.84	1804.92	414.08	19	14.00	7700.00	3257718.47	89.00
Nickel	200.87	480.51	124.07	15	11.00	1900.00	230888.84	47.00
Chromium	109.20	186.68	48.20	15	10.00	730.00	34849.74	36.00
Arsenic	55.67	65.18	15.81	17	8.90	240.00	4248.80	30.00
Cadmium	33.13	71.80	17.95	16	1.40	280.00	5155.22	7.65
Mercury	1.04	1.07	.76	2	.28	1.80	1.16	1.04

Boat Pressure Wash and Hand Wash Metal Results (µg/L) – Copper, Iron, Zinc and Aluminum

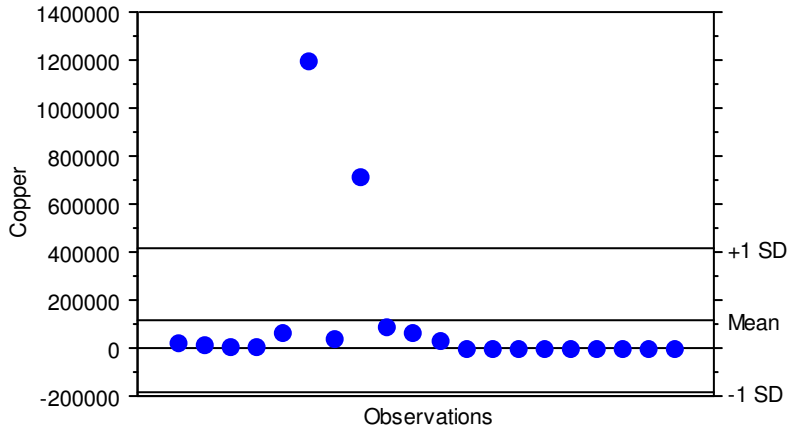
	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	Variance	Median
Cu-Pressure	207218.2	388223.3	117053.7	11	9400.0	1200000.0	150717323636.4	44000.0
Cu-Hand Wash	1145.9	999.6	333.2	9	13.0	2700.0	999252.1	690.0
Fe-Pressure	47830.0	101470.6	30594.5	11	530.0	350000.0	10296282300.0	17000.0
Fe-Hand Wash	11594.4	22475.0	7491.7	9	300.0	71000.0	505124027.8	5000.0
Zn-Pressure	31736.4	55402.3	16704.4	11	1600.0	180000.0	3069412545.5	6800.0
Zn-Hand Wash	1545.1	1399.0	466.3	9	26.0	5000.0	1957095.1	1200.0
Al-Pressure	23412.7	43313.9	13059.6	11	640.0	150000.0	1876096581.8	8600.0
Al-Hand Wash	3538.9	4835.9	1612.0	9	210.0	16000.0	23386011.1	2100.0

Descriptive Statistics: Boat Pressure Wash and Hand Wash Metal Results (µg/L) – Lead, Nickel, Chromium, Arsenic, Cadmium, and Mercury.

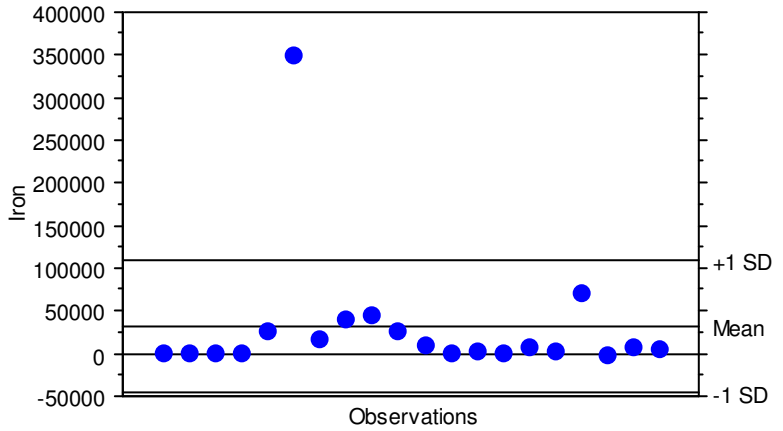
	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	Variance	Median
Pb-Pressure	1363.73	2254.04	679.62	11	19.00	7700.00	5080693.42	590.00
Pb-Hand Wash	64.88	51.33	18.15	8	14.00	140.00	2634.98	39.00
Ni-Pressure	348.63	638.69	225.81	8	13.00	1900.00	407922.27	118.50
Ni-Hand Wash	32.00	21.28	8.04	7	11.00	63.00	452.67	20.00
Cr-Pressure	170.75	244.49	86.44	8	10.00	730.00	59776.79	71.00
Cr-Hand Wash	38.86	27.43	10.37	7	13.00	93.00	752.48	27.00
As-Hand Wash	22.93	9.37	3.54	7	9.50	36.00	87.87	25.00
Cd-Pressure	48.41	88.81	28.08	10	1.40	280.00	7887.11	8.75
Cd-Hand Wash	7.65	4.78	1.95	6	2.50	16.00	22.82	6.40
Hg-Pressure	1.80	•	•	1	1.80	1.80	•	1.80
Hg-Hand Wash	.28	•	•	1	.28	.28	•	.28

Appendix 3
Process Wastewater Results:
Univariate Scattergrams for both Pressure Wash and Hand Wash Waters

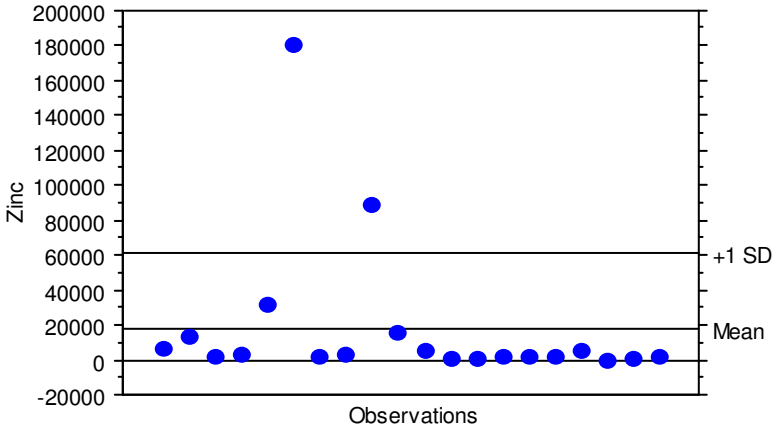
Univariate Scattergram: Copper (µg/L)



Univariate Scattergram: Iron (µg/L)

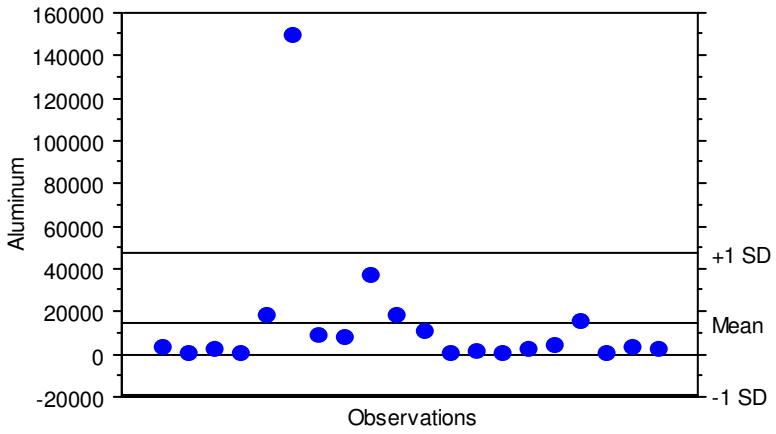


Univariate Scattergram: Zinc (µg/L)

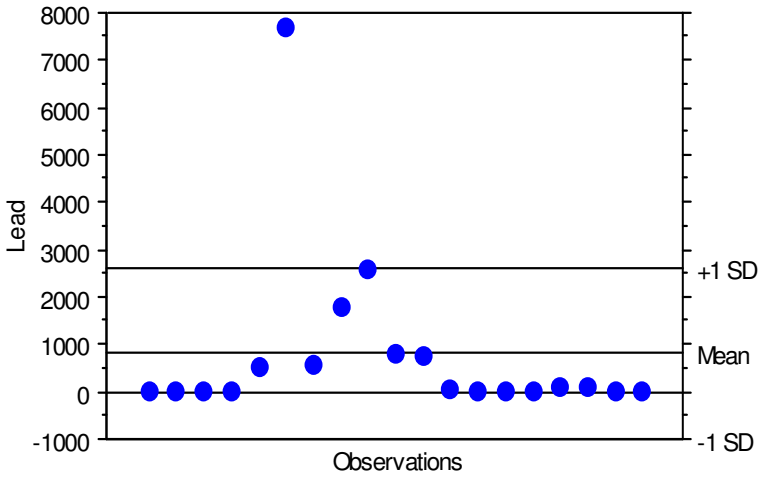


Appendix 3 Continued
Process Wastewater Results:
Univariate Scattergrams for both Pressure Wash and Hand Wash Waters

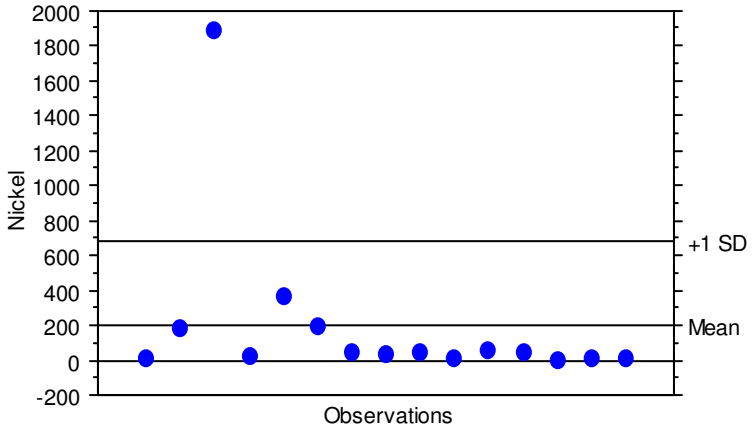
Univariate Scattergram: Aluminum (µg/L)



Univariate Scattergram: Lead (µg/L)

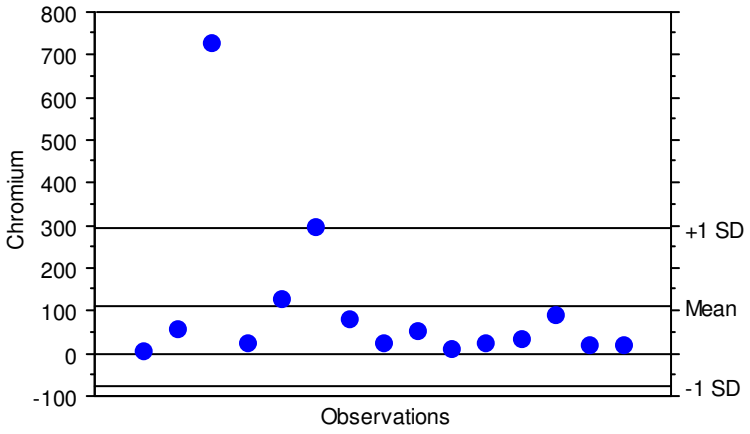


Univariate Scattergram: Nickel (µg/L)

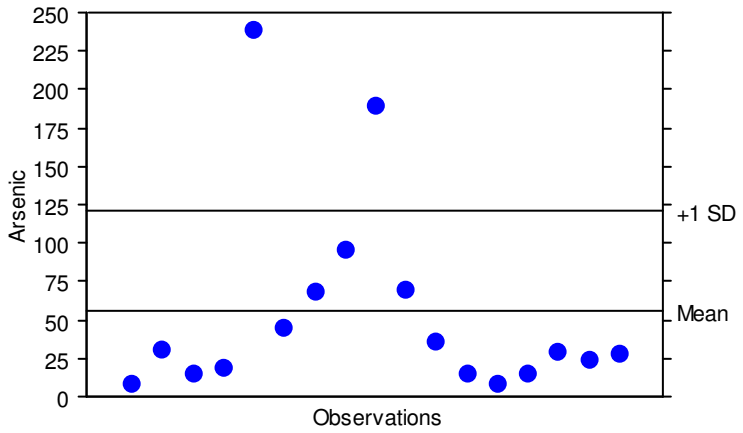


Appendix 3 Continued
Process Wastewater Results:
Univariate Scattergrams for both Pressure Wash and Hand Wash Waters

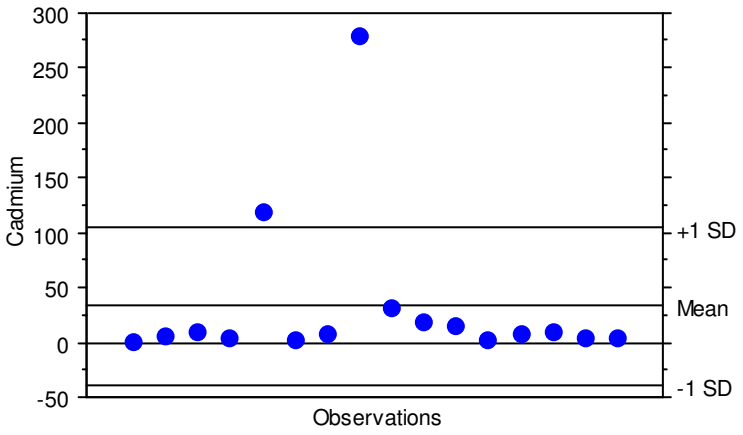
Univariate Scattergram: Chromium (µg/L)



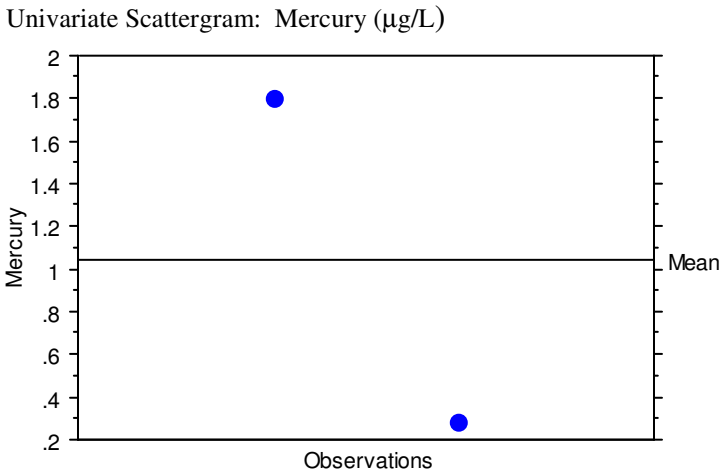
Univariate Scattergram: Arsenic (µg/L)



Univariate Scattergram: Cadmium (µg/L)



Appendix 3 Continued
Process Wastewater Results:
Univariate Scattergrams for both Pressure Wash and Hand Wash Waters



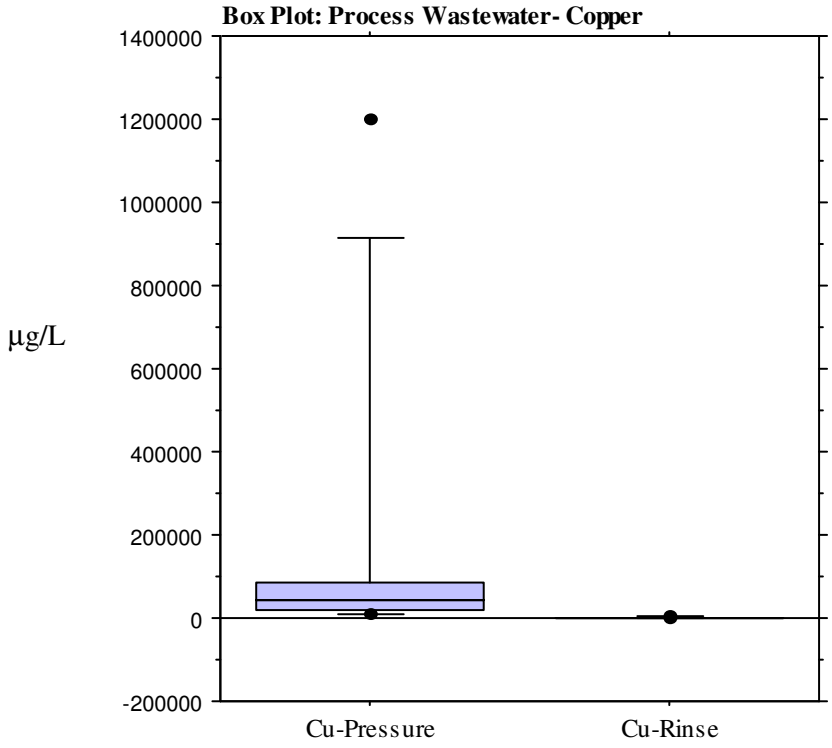
Appendix 4
Process Wastewater Results:
Mann-Whitney U test and Box Plots for Pressure Wash and Hand Wash

Mann-Whitney U for Copper
Grouping Variable: Wastewater

U	0.000
U Prime	99.000
Z-Value	-3.761
P-Value	.0002
Tied Z-Value	-3.761
Tied P-Value	.0002
# Ties	0

Mann-Whitney Rank Info for Copper
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Cu-Hand Wash	9	45.000	5.000
Cu-Pressure	11	165.000	15.000



This figure depicts a box plot in µg/L for copper analyzed from comparing Boatyard pressure wash and hand wash waters.

Appendix 4- continued
Process Wastewater Results:
Mann-Whitney U test and Box Plots for Pressure Wash and Hand Wash

Mann-Whitney U for Iron
Grouping Variable: Wastewater

U	32.000
U Prime	67.000
Z-Value	-1.330
P-Value	.1837
Tied Z-Value	-1.330
Tied P-Value	.1835
# Ties	1

Mann-Whitney U for Zinc
Grouping Variable: Wastewater

U	5.500
U Prime	93.500
Z-Value	-3.343
P-Value	.0008
Tied Z-Value	-3.347
Tied P-Value	.0008
# Ties	3

Mann-Whitney Rank Info for Iron
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Fe-Hand Wash	9	77.000	8.556
Fe-Pressure	11	133.000	12.091

Mann-Whitney Rank Info for Zinc
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Zn-Hand Wash	9	50.500	5.611
Zn-Pressure	11	159.500	14.500

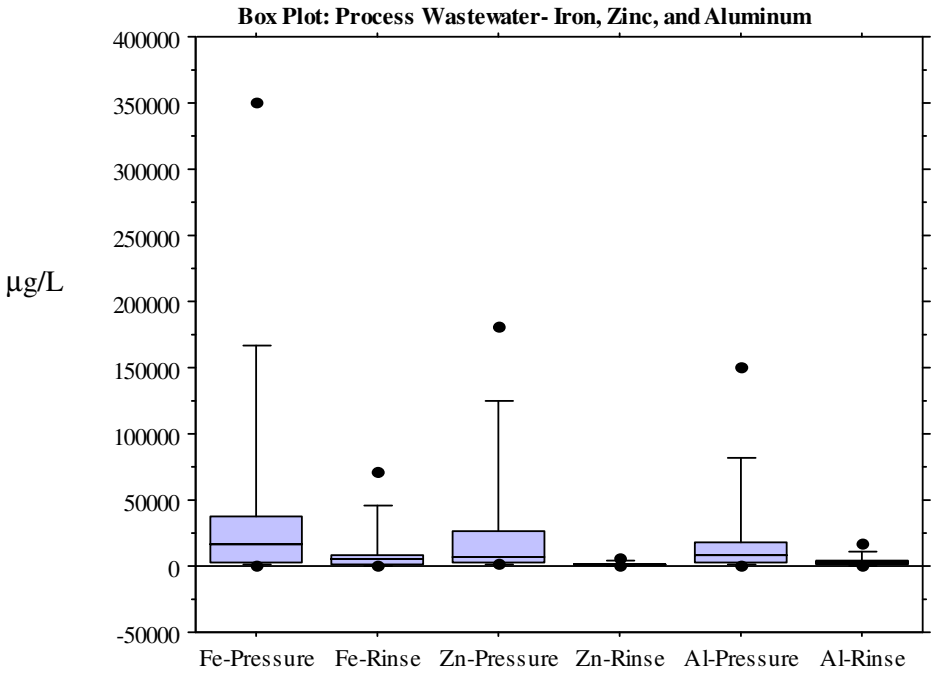
Mann-Whitney U for Aluminum
Grouping Variable: Wastewater

U	23.500
U Prime	75.500
Z-Value	-1.975
P-Value	.0482
Tied Z-Value	-1.977
Tied P-Value	.0481
# Ties	2

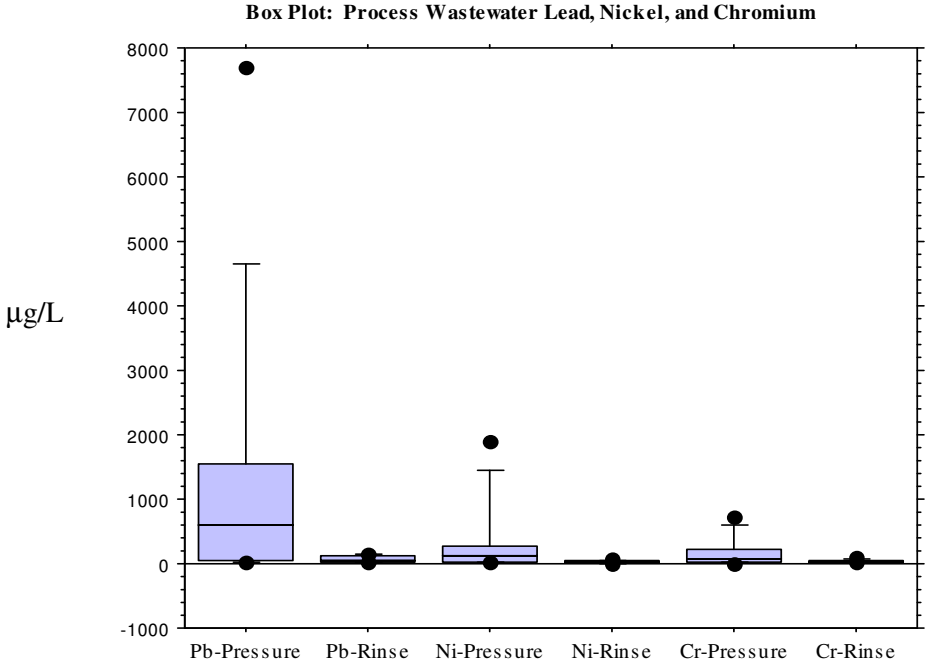
Mann-Whitney Rank Info for Aluminum
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Al-Hand Wash	9	68.500	7.611
Al-Pressure	11	141.500	12.864

Appendix 4- continued
Process Wastewater Results:
Mann-Whitney U test and Box Plots for Pressure Wash and Hand Wash



Depicts a box plot in µg/L for iron, zinc, and aluminum analyzed from comparing Boatyard pressure wash and hand wash waters.



Depicts a box plot in µg/L for lead, nickel, and chromium analyzed from comparing Boatyard pressure wash and hand wash water.

Appendix 4- continued
Process Wastewater Results:
Mann-Whitney U test and Box Plots for Pressure Wash and Hand Wash

Mann-Whitney U for Lead
Grouping Variable: Wastewater

U	19.000
U Prime	69.000
Z-Value	-2.064
P-Value	.0390
Tied Z-Value	-2.065
Tied P-Value	.0389
# Ties	1

One case was omitted due to missing values.

Mann-Whitney U for Nickel
Grouping Variable: Wastewater

U	14.500
U Prime	41.500
Z-Value	-1.562
P-Value	.1182
Tied Z-Value	-1.564
Tied P-Value	.1179
# Ties	1

5 cases were omitted due to missing values.

Mann-Whitney Rank Info for Lead
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Pb-Hand Wash	8	55.000	6.875
Pb-Pressure	11	135.000	12.273

One case was omitted due to missing values.

Mann-Whitney Rank Info for Nickel
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Ni-Hand Wash	7	42.500	6.071
Ni-Pressure	8	77.500	9.688

5 cases were omitted due to missing values.

Mann-Whitney U for Chromium
Grouping Variable: Wastewater

U	16.000
U Prime	40.000
Z-Value	-1.389
P-Value	.1649
Tied Z-Value	-1.394
Tied P-Value	.1634
# Ties	1

5 cases were omitted due to missing values.

Mann-Whitney U for Arsenic
Grouping Variable: Wastewater

U	18.000
U Prime	52.000
Z-Value	-1.659
P-Value	.0971
Tied Z-Value	-1.660
Tied P-Value	.0969
# Ties	1

3 cases were omitted due to missing values.

Mann-Whitney Rank Info for Chromium
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Cr-Hand Wash	7	44.000	6.286
Cr-Pressure	8	76.000	9.500

5 cases were omitted due to missing values.

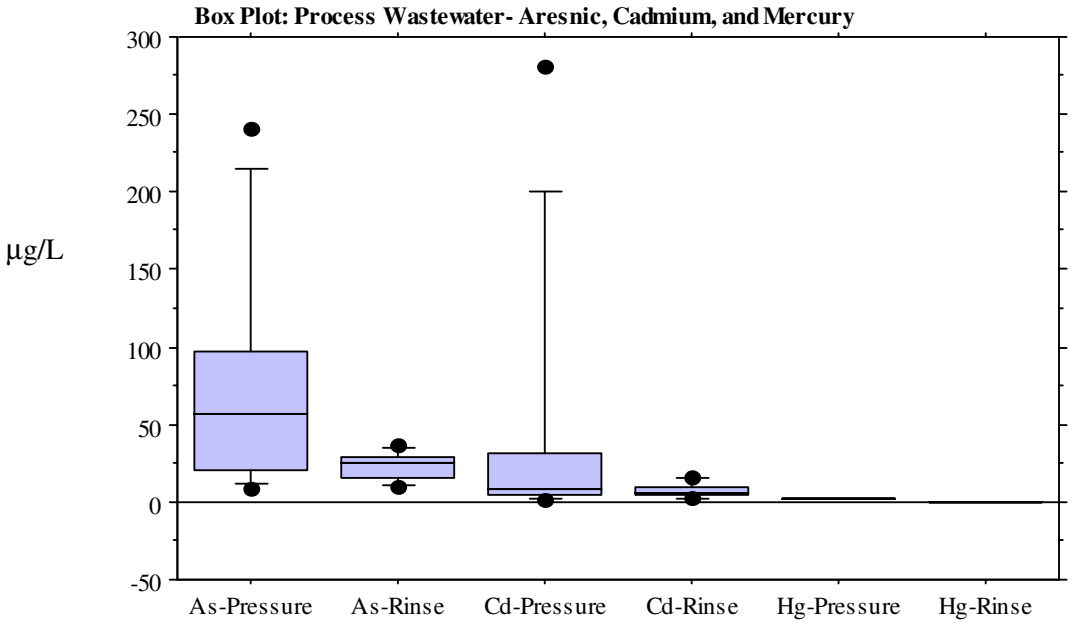
Mann-Whitney Rank Info for Arsenic
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
As-Hand Wash	7	46.000	6.571
As-Pressure	10	107.000	10.700

3 cases were omitted due to missing values.

* Lead (1), Nickel (5), Chromium (5), Arsenic (3). It is important to understand that while 20 samples were collected, the missing values represents samples that were below detection. It is unknown if these below-detection values are zero or some other value just below the detection thresholds. The below-detection sample results were omitted from the Mann-Whitney U test analysis.

Appendix 4- continued
Process Wastewater Results:
Mann-Whitney U test and Box Plots for Pressure Wash and Hand Wash



Depicts the a box plot in µg/L for arsenic, cadmium, and mercury analyzed from comparing Boatyard pressure wash and hand wash water activities to each other.

Mann-Whitney U for Cadmium
Grouping Variable: Wastewater

U	23.000
U Prime	37.000
Z-Value	-.759
P-Value	.4477
Tied Z-Value	-.760
Tied P-Value	.4474
# Ties	1

4 cases were omitted due to missing values.

Mann-Whitney Rank Info for Cadmium
Grouping Variable: Wastewater

	Count	Sum Ranks	Mean Rank
Cd-Hand Wash	6	44.000	7.333
Cd-Pressure	10	92.000	9.200

4 cases were omitted due to missing values.

Cadmium (4) and Mercury (18). It is important to understand that while 20 samples were collected, the missing values represents samples that were below detection. It is unknown if these below-detection values are zero or some other value just below the detection thresholds. The below-detection sample results were omitted from the Mann-Whitney U test analysis. Also, Mercury was not analyzed in this manner due to encountering only 2 samples above detection thresholds.