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State of Washington

# Quality Assurance Project Plan

# Copper, Zinc, and Lead in Five Marinas within Puget Sound

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# Quality Assurance Project Plan

# Copper, Zinc, and Lead in Five Marinas within Puget Sound

October 2016

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EAP: Environmental Assessment Program
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# 2.0 Abstract

Marinas have been shown to contribute elevated levels of metals – especially copper – to marine waters. The copper comes primarily from antifouling paints which are designed to discourage barnacles, mussels, and other organisms from attaching to boat hulls. In 2011 the Washington State Legislature passed SSB5436 to phase out copper in marine antifouling paints. This legislation states that new recreational vessels with copper containing bottom paint may not be sold in the state after January 1, 2018.

The bill calls for Washington State Department of Ecology (Ecology) to submit a report to the legislature by January 1, 2018 describing how antifouling paints affect marine organisms and water quality. Many boatyards have already implemented control measures to reduce the discharge of pollutants to receiving waters. However, we currently lack adequate data on current conditions (baseline data) of marine water quality in vessel moorage areas to assess future changes in water quality associated with phasing out copper in antifouling paint.

The goal of this project is to conduct a one-year monitoring project to provide baseline data on water quality and impacts to marine biota within vessel moorage areas (marinas). This study will establish baseline data for copper, zinc, and lead in five marinas of different configuration and size within Puget Sound. Both copper and zinc are common components in antifouling paint, while lead is associated with upland boatyard activities and is monitored under the *Boatyard General Permit*. Sample media will consist of water (dissolved and total recoverable concentrations), sediments (suspended and bottom), and transplanted mussel tissue. Sufficient samples will be taken within each marina to allow for future comparisons to this data set. The sampling will occur at the end of the boating season (September 2016), during the winter (January 2017) and at the start of boating season (March and June 2017).

# 3.0 Background

Marinas have been shown to contribute elevated levels of metals – especially copper – to marine waters (Schiff et al. 2004; Johnson, 2007; Neira et al., 2009; Biggs and D'Anna, 2012). The copper comes primarily from antifouling paints which are designed to discourage biofouling (barnacles, mussels, and other organisms) of boat hulls. Copper is also released through in-water hull cleaning which is currently banned, but still occurs on occasion. Copper is the most common pollutant found at toxic levels in marinas nationwide. Additional antifouling agents include zinc pyrithione or zinc omadine and numerous other biocides (Parks et al., 2010; Thomas and Brooks, 2010).

In 2011 the Washington State Legislature passed SSB5436 to phase out copper in marine antifouling paints[1] (Appendix A). This legislation states that new recreational vessels with copper-containing bottom paint may not be sold in the state after January 1, 2018. After January 1, 2020 copper-containing antifouling paints intended for use on recreational vessels may not be sold in the state. The bill also calls for Washington State Department of Ecology (Ecology) to submit a report to the legislature by January 1, 2018 describing how antifouling paints affect marine organisms and water quality.

Ecology is currently in the process of initiating an alternatives assessment for the use of copper-based antifouling bottom paints. As part of this alternatives assessment the ecotoxicological impact of antifouling paints on marine organisms will be assessed. Upland boatyards, which often discharge stormwater runoff to marinas, are required to monitor copper, zinc, and lead under Ecology's *General Boatyard Permit*. Boatyards have already implemented control measures to reduce the discharge of pollutants to receiving waters. However, we currently lack adequate data on current conditions (baseline data) of marine water quality in vessel moorage areas to assess future changes in water quality associated with phasing out copper in antifouling paints.

We will collect samples of water, sediment, particulates, and mussel tissue from five marine moorage areas of varying size and physical configuration in Puget Sound. Sampling will occur seasonally over one year to capture variability. The main objective of this project is to evaluate current conditions in metals concentrations (copper, zinc, and lead) in marine waters from vessel moorage areas (i.e. marinas). These data will be used to inform the 2018 report to the legislature on marine water quality impacts and assist in tracking changes in water quality as the legislation is implemented in the future.

## 3.1 Study area and surroundings

The study will be conducted in five marinas within Puget Sound (Figure 1). The selected marinas vary in size and configuration. Some have been sampled in the past (Crecelius et al., 1988; Johnson, 2007). Most of the selected study sites have upland boatyards with varying degrees of best management practices in place to minimize the contributions of contaminants in stormwater from the site. The boatyards conduct a range of activities related to boat

[1] http://lawfilesext.leg.wa.gov/biennium/2011-12/Htm/Bill%20Reports/Senate/5436-S%20SBR%20FBR%2011.htm

maintenance, including bottom painting and coating with antifouling paints. All of the boatyards are covered under Ecology's Boatyard General Permit (http://www.ecy.wa.gov/programs/wq/permits/boatyard/index.html), which requires monitoring of copper, lead, and zinc in wastewater and stormwater runoff. While boatyards are clearly a possible source of metals to the marinas, this project has been designed to focus on the current ambient concentrations of metals in the marine water of marina moorage areas.

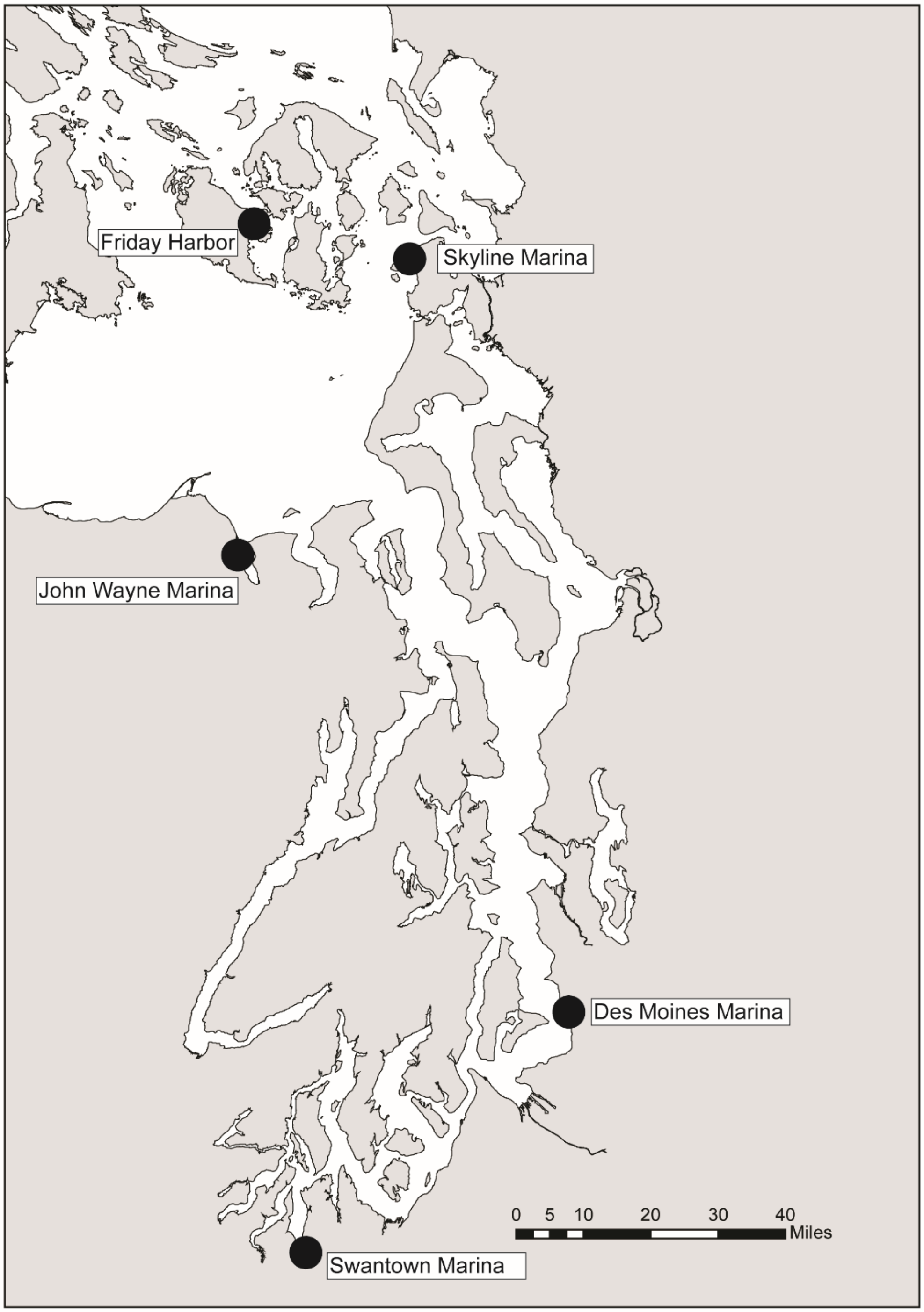


Figure 1. Map of study area marinas.

The study sites are summarized in Table 1. Study sites were selected based mainly on criteria from earlier studies (Crecelius et al., 1989; Johnson, 2007), where the marina:

- Has a single entrance and is enclosed.
- Has more than 500 boats.
- Has not had major construction in the last three years.
- Has no other known significant source of metals in the immediate vicinity.

In addition, Ecology included one marina that has an open configuration for comparison (Friday Harbor) and a smaller marina (John Wayne Marina) that has fewer than 500 boats and lacks a boatyard and the direct influence of stormwater runoff from discharge outfalls. Maps of each study marina can be found in Appendix B.

The variability in physical configurations among the marinas will also affect the flushing of the marinas during tidal cycles. This exchange of water will also impact factors like dissolved oxygen which can influence the fate of metals in aquatic environments.

Table 1. Study marinas.

| Marina | Location | Water Body | Latitude | Longitude | # of Moorage Slips | Age of Marina | Boatyard |
|---|---|---|---|---|---|---|---|
| Skyline Marine Center | Anacortes | Flounder Bay, North Puget Sound | 48.49235 | -122.679022 | ~ 400 | 1960s | Skyline Marina |
| John Wayne Marina | Sequim | Sequim Bay, Strait of Juan de Fuca | 48.0628 | -123.040284 | ~ 300 | 1985 | none |
| City of Des Moines Marina | Des Moines | Des Moines, Central Puget Sound | 47.39964 | -122.330031 | 840 | 1970 | CSR Marine South |
| Friday Harbor | San Juan Island | Friday Harbor, San Juan Channel | 48.53837 | -123.015409 | 500 | early 1970s | Albert Jensen & Sons, Inc. |
| Swantown Marina | Olympia | Budd Inlet, South Puget Sound | 47.055439 | -122.897028 | 656 | 1983 | Swantown Boatworks |

## 3.1.1 Logistical problems

Previous studies of copper concentrations in Puget Sound marinas during ebb and flood tides showed that samples collected near the entrance of the marina had higher concentrations during ebbing tides (Johnson, 2007). To sample the worst-case scenario, this study will collect all samples during the ebb tide of a neap tide[2] series where there is minimal tidal exchange. Furthermore, in order to reduce possible stormwater contributions into the marinas from the boatyards, all efforts will be made to sample during a period of no rainfall. A dry period[3] with a neap tide series may not occur, and in that case we will have to sample outside the neap tide series.

[2] A neap tide is a tidal series where there is the least difference between high and low water.
[3] Where a dry period is considered <0.1" of rainfall in the previous 24 hours.

Deploying sediment traps and transplanted mussels outside the marina may require the installation of a near-shore moorage buoy at low-tide. Permitting may be required for the samples sites outside the marinas.

## 3.1.2 History of study area

The selected study marinas have been in place since at least the late 1990s, and as far back as the early 1970s. The Port of Friday Harbor was created in 1950 and the marina was built in the early 1970s. The marina was used largely by fishing vessels in the early years but later transitioned to pleasure boats. Skyline Marina was built on the site of a former lumber mill that operated from 1924 to 1952 and was torn down in the 1960s. Construction of the Skyline marina began in the 1960s with a travel lift and the main marina was constructed in the 1970s. The marina has residential docks and moorings in small embayments off the main marina (Figure B-2) which were part of the original construction. The City of Des Moines Marina was finished in 1970 and in 1980 the 670-foot-long fishing pier was constructed outside the marina jetty (Figure B-4). Lastly, the John Wayne Marina was constructed in 1985 in Sequim Bay on land donated by the John Wayne family. It is the smallest of the marinas in this study and has no boatyard operations on the site. The marina is operated by the Port of Port Angeles. The Swantown Marina in Olympia has been operational since 1983 and is run by the Port of Olympia. The marina is open to Budd Inlet and sheltered by a breakwater dock. The Swantown boatworks opened in 1999.

All of the marinas have had some previous onsite sampling but the amount of metals data varies from one sediment sample (e.g., Port of Edmonds) to multiple sampling events of multiple media (e.g., Skyline Marina). Dredging has occurred over time in the marinas and the characterization of the sediments for disposal falls under the Dredged Material Management Program overseen by the US Army Corps of Engineers (http://www.nws.usace.army.mil/Missions/Civil-Works/Dredging/). Chemical characterization of dredged sediments is carried out prior to disposal and is discussed in later sections (*3.1.4 Results of Previous Studies*).

## 3.1.3 Parameters of interest

This study will focus on metals that are prominent in boat antifouling paints (copper and zinc) and have been shown to be present in stormwater discharges to marinas within Puget Sound (copper, zinc, and lead) (Johnson et al., 2006). All three metals are naturally occurring and are supplied through atmospheric deposition and weathering of rocks and minerals into freshwater inputs. At trace concentrations in seawater, copper and zinc are micronutrients for aquatic organisms (Schlesinger, 1997). Anthropogenic sources from urban environments include pesticides, wastewater effluent, stormwater runoff, atmospheric deposition from industry and antifouling paints. Metals are taken up by organisms through adsorption of dissolved metals and ingestion of metals in particulates and contaminated prey.

Copper has been the main biocide used in antifouling paints since tributyl-tin (TBT) was banned (Srinivasan and Swain, 2007). There are many different formulations and typically copper content varies from 20 to 76% (Schiff et al., 2004). There are also different matrix formulations of antifouling paint and therefore the release rates of copper from the paints will vary. Hard paints rely on contact leaching of copper from within the paint film. For example, epoxy-based paints form a honeycomb texture where cuprous oxide ($Cu_2O$) leaches through the channels. Ablating paints are designed to flake off or wash away, exposing fresh paint and a new surface from which the copper leaches. For example, self-polishing copolymer paints are partially soluble and water passes across the surface of the coating and wears the surface away.

There has been extensive review of the impacts of copper in the environment (EPA, 1985a, Valkirs et al., 1994). The toxicity of copper depends on its form ($Cu^{2+}$ is the free cupric ion), which is influenced by the pH and hardness of the water. Dissolved copper ions are highly reactive and can form strong complexes and precipitates with other compounds (EPA, 1985a). Once in the marine environment dissolved copper can be acutely toxic to organisms at concentrations as low as 9.5 µg $L^{-1}$ (Srinivasan and Swain, 2007) and can inhibit photosynthesis in the marine diatom *Thalassiosira pseudonana* at concentrations of 5 µg $L^{-1}$. Blue mussel embryo bioassays also showed acute toxicity at concentrations 5.8 µg $L^{-1}$ (EPA, 1985). Copper and other metals have been found to block ionic regulation in fish by binding to the gills (Niyoga and Wood, 2004).

Zinc has been used in antifouling paints as a co-biocide or booster biocide, usually present as zinc pyrithione (ZnPT) or zinc omadine. The purpose of the co-biocide is to enhance the toxicity of the primary biocide (generally copper) and/or to facilitate the leaching process. ZnPT has a half-life of ~ 96 days and photodegrades to 2-pyridine sulfonic acid (Thomas and Brooks, 2010). ZnPT has been shown to bind strongly to sediments suggesting a potential for accumulation in the sediments, especially if released in the form of paint particles (Turley et al., 2000). ZnPT is acutely toxic, but not bioaccumulative. Much like copper, the toxicity of zinc in water depends on the form it is in which is affected by pH, hardness and salinity. Zinc will also form complexes and bind readily to suspended material. Zinc is acutely toxic to hardshell clam larvae at concentrations of 50 µg $L^{-1}$ and oyster larvae at 75 µg $L^{-1}$ (EPA, 1980).

Lead (Pb) is not used in antifouling paints, but is found in marinas from activities taking place on upland boatyards which often discharge stormwater to the marina (Johnson et al., 2009). Indeed, lead is one of the metals that boatyards in Washington are required to monitor under Ecology's General Boatyard Permit. For this reason we have included it in our sampling program. Much like both copper and zinc, the toxicity of lead is dependent on its form. The acute toxicities of lead on marine bivalves have been observed to vary considerably, from 27,000 to 476 µg $L^{-1}$ (EPA, 1985b). Chronic effects on mysids and a macroalgae have been observed at concentrations of 37 and 20 µg $L^{-1}$, respectively.

### 3.1.4 Results of previous studies

The contamination of marina waters from the diffusion of copper in antifouling paints has been recognized since the late 1970s (Young et al., 1979). Cardwell et al. (1980a, b) found that water quality was highly variable and poor in a number of Puget Sound marinas and was related to the flushing rate and exchange of tidal waters. Marinas that were investigated included Skyline Marina in Anacortes and the City of Des Moines Marina. Additional studies have also documented the metals concentrations of receiving waters in the vicinity of marinas (Paulson et al., 1988; Crecelius, 1998; Johnson et al., 2009).

Previous studies for each individual marina in this study are summarized below. The level of sampling and investigation varies among marinas. The complete data set of results from each marina with references can be found in Appendix C.

## Friday Harbor

Samples collected at Friday Harbor have consisted of sediment and mussel tissue. The sample locations are from both within and outside Friday Harbor (Table 2). Previous samples have been taken over three different studies between 1991 and 1997 (DNR, 1991; Serdar et al., 2001; Dutch et al., 2009) and statistical comparisons of the data from similar time periods is not possible. However, for all three metals of interest the mean sediment concentration within the marina appears greater than outside the marina. Furthermore, detectable concentrations of metals were present in mussel tissues collected outside the marina at nearby Friday Harbor Labs (Lanksbury et al., 2014). No water samples have been taken from within Friday Harbor.

Table 2. Summary of previous results from within and outside Friday Harbor, San Juan Island.

| | Copper | | | | Lead | | | | Zinc | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** |
| **Sediment (ppm)** | | | | | | | | | | | | |
| outside | 2 | 13.9 | 14.2 | 14.1 | 2 | 4.4 | 7.1 | 5.8 | 2 | 50.8 | 54.1 | 52.5 |
| inside | 5 | 15.9 | 78.2 | 36.2 | 5 | 8.8 | 32.2 | 17.4 | 5 | 57.0 | 129.0 | 97.9 |
| **Mussel Tissue (ppm)** | | | | | | | | | | | | |
| outside | 1 | 0.7 | 0.7 | 0.7 | 1 | 0.03 | 0.03 | 0.03 | 1 | 11.6 | 11.6 | 11.6 |

## Skyline Marina

In the late 1970s Cardwell et al. (1980) completed a comprehensive study of the biological and water quality characteristics of Skyline Marina and the adjacent bay (Burrows Bay). They found that copper concentrations in sediments were significantly higher outside the marina compared to inside the marina, however zinc and lead were not significantly different. Transplanted oysters were also deployed in a transect from within the marina to the bay. Oyster tissues from within the marina had significantly higher copper and zinc concentrations than the bay, whereas lead was not different. Lastly, Cardwell et al. (1980a) described the flushing of the Skyline marina as highly variable but among the slowest when compared to four other Puget Sound Marinas, including Edmonds and Des Moines. The authors estimated that over a 12-hour tidal period 8-40% of the marina's water is flushed.

More recent sampling (2006 – 2009) of Skyline Marina has consisted of some bottom sediments collected during dredge operations for the purpose of characterization prior to disposal (Table 3; Kendall et al., 2009). None of the sediment samples collected contained concentrations of metals that would prevent the disposal of sediments elsewhere in Puget Sound compared to the Sediment Management Standards (WAC 173-204). In addition, the metals concentrations in the more recent samples are lower than the 1978 samples (Table 3).

Water samples were collected by Johnson (2007) during his characterization of copper concentrations in Skyline and Cap Sante Marinas in Anacortes. As shown in Table 3 and described in the Johnson (2007) report, higher concentrations of copper were found within the marina than were found near the entrance to the marina. Copper concentrations from this study led to a 303(d) listing of the water body.

Table 3. Summary of previous results from within and outside the Skyline Marina, Anacortes.

| | Copper | | | | Lead | | | | Zinc | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** |
| **Sediment (ppm)** | | | | | | | | | | | | |
| **1978** | | | | | | | | | | | | |
| inside | 9 | 22.0 | 27.0 | 24.8 | 9 | 17.0 | 75.0 | 40.9 | 9 | 76.0 | 88.0 | 79.2 |
| outside | 8 | 30.0 | 52.0 | 43.1 | 8 | 22.0 | 244.0 | 87.0 | 8 | 65.0 | 103.0 | 80.6 |
| **2006-2009** | | | | | | | | | | | | |
| inside | 12 | 3.6 | 33.4 | 14.8 | 12 | 2.0 | 7.0 | 3.5 | 12 | 13.0 | 60.0 | 42.1 |
| **Tissue (1978) - ppm** | | | | | | | | | | | | |
| inside | 3 | 17.4 | 44.6 | 28.4 | 3 | 0.2 | 0.4 | 0.3 | 3 | 225.0 | 438.0 | 350.0 |
| outside | 3 | 8.1 | 10.5 | 9.0 | 3 | 0.1 | 0.2 | 0.2 | 3 | 200.0 | 1914.0 | 786.0 |
| **Water (2006-2009) - ppm** | | | | | | | | | | | | |
| inside | 7 | 4.7 | 7.2 | 6.1 | | | | | | | | |
| outside | 27 | 0.3 | 2.8 | 1.1 | | | | | | | | |

## John Wayne Marina

Very few investigations have been undertaken within or near John Wayne Marina. A single sediment sample was taken within the marina in 1983 as part of a survey of eight bays throughout Puget Sound (Strand et al., 1988). Sequim Bay was used as a reference bay and the concentration of lead found inside the marina was similar to that found outside the marina (Table 4). It should be noted that the accuracy of the sample location for the 1983 sample cannot be verified. Additional sediment sampling and tissue sampling of sand sole (*Psettichthys melanostictus*) have been completed by the EPA and contractors under the National Coastal Condition Assessment (EPA, 2012).

Table 4. Summary of previous results from within and outside John Wayne Marina, Sequim Bay.

| | Copper | | | | Lead | | | | Zinc | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** |
| **Sediment (ppm)** | | | | | | | | | | | | |
| inside | | | | | 1 | | | 4.1 | | | | |
| outside | 1 | | | 9.59 | 1 | | | 5.97 | 1 | | | 36.0 |
| **Tissue† 2010 (ppm)** | | | | | | | | | | | | |
| outside (fillet) | 1 | | | 0.62 | 1 | | | 0.019 | 1 | | | 0.24 |
| outside (whole) | 1 | | | 1.9 | 1 | | | 0.019 | 1 | | | 20 |

† sand sole tissue (*Psettichthys melanostictus*)

## Des Moines Marina

The Des Moines Marina has had a small number of sediment samples collected within the marina during the 2007 dredging operations (Anchor Environmental, 2007). Compared with the samples taken outside the marina during 2006-2007 (Midway, 2010) it appears there are higher concentrations of all metals present within the marina bottom sediments (Table 5). However, no samples collected within the marina were in excess of the state sediment management standards (WAC 173-204). It also appears that copper and zinc concentrations outside the marina have remained fairly consistent from the early 1990s (Midway Sewer District, 2005) to 2006-2007, with the exception of the 1998 sampling by Ecology under the Puget Sound Ecosystem Monitoring Program (Dutch et al., 2009). Measurable concentrations of metals were also found in mussel tissue outside the marina. The mussel samples were collected from the nearby city park where Des Moines Creek empties into Puget Sound (Lanksbury et al., 2014).

Table 5. Summary of previous results from within and outside Des Moines Marina, Central Puget Sound.

| | Copper | | | | Lead | | | | Zinc | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Min | Max | Average | n | Min | Max | Average | n | Min | Max | Average |
| **Sediment (ppm)** | | | | | | | | | | | | |
| inside 2006-2007 | 4 | 12.4 | 48.8 | 23.1 | 4 | 4.0 | 108.0 | 32.3 | 4 | 39.0 | 109.0 | 59.3 |
| outside 1992-1995 | 13 | 4.6 | 26.0 | 7.8 | 13 | 6.0 | 34.0 | 13.8 | 13 | 22.0 | 69.0 | 36.5 |
| 1998 | 2 | 18.2 | 20.6 | 19.4 | 2 | 15.5 | 18.2 | 16.9 | 2 | 43.6 | 72.6 | 58.1 |
| 2006/2007 | 22 | 4.9 | 9.0 | 6.1 | 22 | 5.0 | 8.0 | 6.6 | 22 | 21.1 | 89.0 | 31.2 |
| **Mussel tissue (ppm)** | | | | | | | | | | | | |
| outside (2012/13) | 1 | 0.95 | 0.95 | 0.95 | 1 | 0.05 | 0.05 | 0.05 | 1 | 14.2 | 14.2 | 14.2 |

North of Des Moines Marina is the mouth of Des Moines Creek, which has had previous investigations. Copper concentrations in the water were measured above state water quality criteria for the protection of aquatic life (WAC 173-201A) in freshwater samples collected upstream of the mouth in 2010 (Coots and Friese, 2012). Copper concentrations were not measured above the water quality criteria near the mouth of the creek near Des Moines Marina (Table 6). King County also collected stream sediments from Des Moines Creek in 2008 and concentrations were well below the sediment management standards for freshwater sediments (Table 6).

Table 6. Summary of previous results from Des Moines Creek.

| | Copper | | | | Lead | | | | Zinc | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Min | Max | Average | n | Min | Max | Average | n | Min | Max | Average |
| **Sediment** | | | | | | | | | | | | |
| 2008 | 1 | 14.5 | 14.5 | 14.5 | 1 | 11.7 | 11.7 | 11.7 | 1 | 73.1 | 73.1 | 73.1 |
| **Water** | | | | | | | | | | | | |
| 2008 | 4 | 1.1 | 1.5 | 1.2 | | | | | 4 | 1.8 | 5.8 | 3.9 |
| 2009 | 8 | 2.5 | 8.4 | 5.1 | | | | | 8 | 8.6 | 28.2 | 16.0 |
| 2010 | 10 | 2.1 | 29.5 | 8.6 | | | | | 10 | 8.6 | 118.0 | 30.3 |

**Swantown Marina**

North of the Swantown Marina is the site of the former Cascade Pole operation which resulted in the contamination and remediation of hydrocarbons and phenols in the sediments (Ecology, 2004; SAIC, 2008). Sediments from this area were not above the state sediment management standards for copper, zinc and lead (WAC 173-204). The small number of sediment samples taken from inside the marina do not appear to show much change in metal concentrations between sampling events in the late-1990s (SAIC, 2007) and 2007-2011 (SAIC, 2008; Partridge et al., 2014). In addition, sediment samples taken outside the marina are within the range of concentrations observed inside the marina. Tissue sampling of sand sole (*Psettichthys melanostictus*) has been completed by the EPA and contractors under the National Coastal Condition Assessment (EPA, 2012).

Table 7. Summary of previous results from Swantown Marina.

| | Copper | | | | Lead | | | | Zinc | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** | **n** | **Min** | **Max** | **Average** |
| **Solid/Sediment (ppm)** | | | | | | | | | | | | |
| inside 1999-2000 | 5 | 41.0 | 103.0 | 76.5 | 4 | 31.3 | 51.3 | 37.4 | 4 | 101 | 147 | 121.5 |
| 2007-2011 | 4 | 27.7 | 86.9 | 66.7 | 4 | 17.4 | 26.1 | 23.9 | 4 | 52.1 | 117 | 93.7 |
| outside 1990 | 2 | 55.0 | 65.0 | 60.0 | 2 | 18.0 | 18.0 | 18.0 | 2 | 88.0 | 96.0 | 92.0 |
| **Tissue (ppm)** | | | | | | | | | | | | |
| inside 999-2000 | 1 | | | 2.6 | 1 | | | 0.18 | 1 | | | 16.9 |

### 3.1.5 Regulatory criteria or standards

The criteria for the protection of aquatic life in the State of Washington is regulated under Chapter 173-201A of the Washington Administrative Code (WAC 173-201A) (Table 7). As defined by the EPA (1994), the exposure periods assigned to the acute criteria are expressed as: (1) an instantaneous concentration not to be exceeded at any time or (2) a 1-hour average concentration not to be exceeded more than once every three years on the average. The exposure periods for the chronic criteria are either: (1) a 24-hour average not to be exceeded at any time or (2) a 4-day average concentration not to be exceeded more than once every three years on the average.

In addition to adhering to the State of Washington water quality criteria, we will calculate site-specific values for chronic and acute exposure based on the biotic ligand model (BLM) (Niyoga and Wood, 2004). The BLM is used to calculate site-specific criteria based on other water quality parameters that impact the bioavailability of metals to aquatic organisms. Specifically, the BLM in marine and estuarine waters relies on pH, temperature, dissolved organic carbon and salinity. The US Environmental Protection Agency has released a draft model for copper, which we will adapt for zinc and lead (EPA, 2016).

The marine sediment standards for cleanup and screening are based on the protection of the benthic community and are established under the Sediment Management Standards WAC 173-204 (Table 7). Cleanup standards are expressed as dry weight and not normalized to organic carbon content (Michelson, 1992). The standards are based on the protection of sediment-dwelling invertebrates.

Table 8. Washington State water and sediment criteria for the protection of aquatic life for copper, lead, and zinc.

| Parameter | Aquatic life ($ng\ L^{-1}$)† | | Marine sediment ($mg\ Kg^{-1}$ dry weight) ‖ | | Marine Sediment AET ($mg\ Kg^{-1}$ dry weight) |
|---|---|---|---|---|---|
| | Marine chronic | Marine acute | Sediment cleanup objective | Sediment screening level | Sediment quality standard |
| Copper | 3.0 | 4.8 | 390 | 390 | 390 |
| Zinc | 81 | 90 | 410 | 960 | 410 |
| Lead | 8.1 | 210 | 450 | 530 | 450 |

† WAC 173-201A.
‖ WAC 173-204; concentrations are dry weight normalized.
AET: apparent effect threshold.

Ecological tissue residue benchmarks will be used to assess the concentrations of metals in mussel tissues. There are no criteria or standards in Washington State to assess copper, lead or zinc concentrations in mussel tissue. Table 8 lists the relevant effects concentrations summarized from Johnston et al. (2007). Water quality-based benchmarks are calculated from existing criteria for the protection of marine aquatic life and published bioaccumulation and bioconcentration factors. The critical body residues benchmarks are based on published studies of tissue concentrations relative to the ecotoxicological benchmarks of no observable effects level (NOEL) and low observable effects level (LOEL). These benchmarks have been used in additional regional studies of contaminants in mussel tissues (e.g., Brandenberger et al., 2012).

Table 9. Benchmarks ($\mu g\ g^{-1}$ wet weight) of ecological effects for invertebrate tissues.

| Parameter | Water Quality based ($\mu g\ g^{-1}$) | | Critical Body Residues ($\mu g\ g^{-1}$ ) | |
|---|---|---|---|---|
| | TSV | $B_{CV}$ | NOEL | LOEL |
| Copper | 3.0 | 12.4 | 3.4 | 4.0 |
| Zinc | 20.0 | 1620.0 | - | - |
| Lead | 0.06 | 81.0 | 4.0 | 20.4 |

TSV: Tissue screening value based on water quality criteria and bioaccumulation factors.
$B_{CV}$: Bioaccumulation critical values based on current chronic seawater and bioconcentration factors for bivalves.
NOEL: No observable effects level is the highest tissue residue that did not cause an effect.
LOEL: Low observable effects level is the lowest tissue residue that caused an effect.

# 4.0 Project Description

The Bill SSB5436 calls for Washington State to phase out the use of copper in boat antifouling paints. It also calls for Ecology to submit a report to the legislature by January 1, 2018 describing the alternative antifouling paints and how antifouling paints affect marine organisms and water quality (Appendix A). We presently lack adequate data on current conditions (baseline data) of marine water quality in vessel moorage areas to assess future changes in water quality related to phasing out the use of copper-based antifouling paints. The data collected in this study will be used to inform the 2018 report to the legislature on marine water quality impacts and to assist in tracking changes in water quality as the legislation is implemented in the future.

## 4.1 Project goals

Section 6 of Bill SSB5436 (adopted 04/06/2011) says that Ecology shall "study how antifouling paints affect marine organisms and water quality". To address this new section of the Bill the specific goal of the current project is to conduct a one-year monitoring study to provide baseline data on water quality and impacts to marine biota from antifouling paints in vessel moorage areas (marinas).

## 4.2 Project objectives

The objectives of this project relate to the characterization of copper, zinc, and lead concentrations in five (5) marinas within Puget Sound. The specific objectives include:

- Sampling water within and outside the marina at quarterly intervals.
- Assessing suspended sediment concentrations from sediment traps within and outside the marinas during the fall/winter, winter/spring, and spring periods.
- Assessing bottom sediment concentrations within and outside the marinas for potential impacts to benthic invertebrates.
- Assessing the accumulation of copper, zinc, and lead in transplanted, caged mussels during the spring for a 3-month period.

## 4.3 Information needed and sources

Prior sampling data will be used for comparison (e.g., Crecelius et al., 1988; Johnson, 2007). The mussel tissue data will be compared with the data from the larger Washington State Department of Fisheries and Wildlife Mussel Watch survey within Puget Sound (Lanksbury et al., 2014).

## 4.4 Target population

The target population is total recoverable and dissolved metals in marine water and total metals in marine sediments and mussel tissues.

## 4.5 Study boundaries

The distribution of the study sites can be seen in Figure 1. The study area encompasses the following Water Resource Inventory Areas (WRIA) and Hydrologic Unit Codes (HUC):

- San Juan Island: WRIA = San Juan (2); HUC8 = 17110003
- Anacortes: WRIA = Lower Skagit/Samish (3); HUC8 = 17110002
- Des Moines: WRIA = Duwamish/Green (9); HUC8 = 17110019
- Sequim: WRIA = Quilcene/Snow (17); HUC8 = 17110020
- Olympia: WRIA = Deschutes (13); HUC8 = 17110016

## 4.6 Tasks required

The tasks of the study depend on a field component and production of a final report. Specific tasks include:

- Liaise with Ecology Water Quality Boatyard Inspectors overseeing the study sites to assist with field planning.
- Construction of sediment traps and assembling field equipment.
- September 2016 sampling event: deploy sediment traps and collect water samples.
- January 2017 sampling event: retrieve and re-deploy sediment traps and conduct water sampling.
- Coordinate with WDFW Toxics in Biota program to plan deployment of caged mussels in March 2017.
- April 2017 sampling event: retrieve and re-deploy sediment traps and conduct water sampling.
- Retrieve mussel deployments May or June 2017.
- June 2017 sampling event: collect bottom sediment samples, retrieve sediment traps, and collect water samples.
- Analyze all samples and validate all data through Manchester Environmental Lab's quality control (QC) process.
- Data analysis and preparation of a final report in the summer of 2017.

## 4.7 Practical constraints

The sampling period is currently planned for a neap tide. However, if there is precipitation forecasted for this period (>0.1" in the 24 hours prior to sampling), the sampling will be re-scheduled for drier weather to reduce the influence of stormwater from upland sites.

## 4.8 Systematic planning process

This Quality Assurance Project Plan (QAPP) represents the systematic planning process.

# 5.0 Organization and Schedule

## 5.1 Key individuals and their responsibilities

Table 10. Organization of project staff and responsibilities.

| Staff<br>(all are EAP except client) | Title | Responsibilities |
|---|---|---|
| Blake Nelson<br>HWTR-RTT<br>Phone: 360-407-6940 | EAP Client | Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. |
| William Hobbs<br>TSU-SCS<br>Phone: 360-407-7512 | Project Manager | Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data. Writes the draft report and final report. |
| Melissa McCall<br>TSU-SCS<br>Phone: 360-407-7384 | Field Lead and Project Officer | Helps collect samples and records field information. Enters data into EIM. Assists with QAPP and report writing. |
| Siana Wong<br>TSU-SCS<br>Phone: 360-407-6432 | Field Assistant | Helps collect samples and records field information. Conducts QA on EIM data. |
| Debby Sargeant<br>TSU-SCS<br>Phone: 360-407-6771 | Unit Supervisor for the Project Manager | Provides internal review of the QAPP, approves the budget, and approves the final QAPP. |
| Jessica Archer<br>SCS<br>Phone: 360-407-6698 | Section Manager for the Project Manager | Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP. |
| Dale Norton<br>WOS<br>Phone: 360-407-6596 | Section Manager for the Study Area | Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP. |
| Jennifer Lanksbury<br>WDFW Toxics in Biota<br>Phone: 360-902-2820 | Project Scientific Advisor | Reviews the QAPP and assures necessary protocols are in place for mussel deployment. Assists with mussel deployment. |
| Joel Bird<br>Manchester Environmental Laboratory<br>Phone: 360-871-8801 | Director | Reviews and approves the final QAPP. |
| William R. Kammin<br>Phone: 360-407-6964 | Ecology Quality Assurance Officer | Reviews and approves the draft QAPP and the final QAPP. |

HWTR: Hazardous Waste and Toxics Reduction Program
RTT: Reducing Toxic Threats
TSU: Toxic Studies Unit
SCS: Statewide Coordination Section
WOS: Western Operations Section
EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

## 5.2 Special training and certifications

The project field lead will assist WDFW in processing mussels and measuring growth and mussel condition before and after the deployment. Training in the measurement and processing of mussels will be provided by WDFW.

## 5.3 Organization chart

See Table 9 for the description of the organization chart.

## 5.4 Project schedule

The schedule for the project is described in Table 10.

Table 11. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

| **Field and laboratory work** | **Due date** | **Lead staff** |
|---|---|---|
| Field work begins | September 2016 | Melissa McCall |
| Field work completed | June 2017 | Melissa McCall |
| Laboratory analyses completed | July 2017 | |
| **Environmental Information System (EIM) database** | | |
| EIM Study ID | ID number WHOB004 | |
| Product | Due date | Lead staff |
| EIM data loaded | August 2017 | Melissa McCall |
| EIM data entry review | September 2017 | Siana Wong |
| EIM complete | September 2017 | Melissa McCall |
| **Final report** | | |
| Author lead / Support staff | William Hobbs / Melissa McCall and Siana Wong | |
| Schedule | | |
| Draft due to supervisor | August 2017 | |
| Draft due to client/peer reviewer | September 2017 | |
| Draft due to external reviewer(s) | October 2017 | |
| Final (all reviews done) due to publications coordinator | November 2017 | |
| Final report due on web | December 2017 | |

## 5.5 Limitations on schedule

The analytical schedule for this project must be complete by June 30, 2017 as per the constraints of the grant funding through the National Estuary Program.

## 5.6 Budget and funding

The field and laboratory budget for the project is detailed in Table 11. The total project budget with personnel time is $159,000.

Table 12. Project budget detail of field and lab costs.

| **Water** | **Samples** | **QA** | **Cost** | **Subtotal** | **In-house** | **Contract** |
|---|---|---|---|---|---|---|
| salinity | 128 | 12 | $25 | $3,500 | $3,500 | $0 |
| total suspended solids | 128 | 12 | $15 | $2,100 | $2,100 | $0 |
| dissolved organic carbon | 128 | 12 | $35 | $4,900 | $4,900 | $0 |
| dissolved metals | 128 | 24 | $200 | $30,400 | $30,400 | $0 |
| total recoverable metals | 128 | 24 | $200 | $30,400 | $30,400 | $0 |
| | | | Total | $71,300 | $71,300 | $0 |
| **Sediments** | **Samples** | **QA** | **Cost** | **Subtotal** | **In-house** | **Contract** |
| TOC:TN | 20 | 5 | $45 | $1,125 | $1,125 | $0 |
| grain size | 15 | 5 | $100 | $2,000 | $0 | $2,000 |
| metals | 20 | 5 | $200 | $5,000 | $5,000 | $0 |
| | | | Total | $8,125 | $6,125 | $2,000 |
| **Particulates (SPM)** | **Samples** | **QA** | **Cost** | **Subtotal** | **In-house** | **Contract** |
| TOC:TN | 45 | 6 | $45 | $2,295 | $2,295 | $0 |
| metals | 45 | 6 | $200 | $10,200 | $10,200 | $0 |
| | | | Total | $12,495 | $12,495 | $0 |
| **Caged Mussel Composites** | **Samples** | **QA** | **Cost** | **Subtotal** | **In-house** | **Contract** |
| metals | 30 | 8 | $200 | $7,600 | $7,600 | $0 |
| | | | Total | $7,600 | $7,600 | $0 |
| | | | | | | |
| | | | Lab Total | $99,520 | | |
| | | | Supplies (sediment traps, tubing, mussel cages) | $4,659 | | |
| | | | Total | $104,179 | | |

TOC:TN = total organic carbon: total nitrogen

# 6.0 Quality Objectives

## 6.1 Decision quality objectives (DQOs)

All sampling will be carried out according to established standardized operating procedures (SOPs) and we do not foresee needing any DQOs.

## 6.2 Measurement quality objectives (MQOs)

The MQOs for the analytical data in this study are detailed in Table 12. The MQOs for the field parameters (pH, dissolved oxygen, temperature, and conductivity) are in Table 13.

### 6.2.1 Targets for precision, bias, and sensitivity

**6.2.1.1 Precision**

Precision is a measure of the variability in the results of replicate measurements due to random error. Precision for two replicate samples is measured as the relative percent difference (RPD) between the two results. If there are more than two replicate samples, then precision is measured as the relative standard deviation (RSD).

Measurement quality objectives for the precision of laboratory duplicate samples and matrix spike duplicate samples are shown in Table 12.

**6.2.1.2 Bias**

Bias is the difference between the population mean and the true value. For this project, bias is measured as acceptable % recovery. Acceptance limits for laboratory verification standards, matrix spikes, and surrogate standards are shown in Table 12.

**6.2.1.3 Sensitivity**

Sensitivity is a measure of the capability of a method to detect a substance above the background noise of the analytical system. The laboratory reporting limits (RLs) for the project are described in Section 9.2.

Table 13. Measurement quality objectives.

| Parameter | Verification Standards (LCS,CRM, CCV) | Duplicate Samples | Matrix Spikes | Matrix Spike-Duplicates | Surrogate Standards | Lowest Concentrations of Interest |
|---|---|---|---|---|---|---|
| | % Recovery Limits | Relative Percent Difference (RPD) | % Recovery Limits | Relative Percent Difference (RPD) | % Recovery Limits | Units of Concentration |
| **Water Samples** | | | | | | |
| Total suspended solids | 80-120% | ± 20% | NA | NA | NA | 1 mg $L^{-1}$ |
| Salinity | 80-120% | ± 20% | NA | NA | NA | 0.1 g $Kg^{-1}$ |
| Dissolved organic carbon | 80-120% | ± 20% | 75-125% | ± 20% | NA | 1 mg $L^{-1}$ |
| Dissolved/total copper | 75-125% | ± 20% | 70-130% | ± 20% | NA | 0.05 µg $L^{-1}$ |
| Dissolved/total zinc | 75-125% | ± 20% | 70-130% | ± 20% | NA | 0.08 µg $L^{-1}$ |
| Dissolved/total lead | 75-125% | ± 20% | 70-130% | ± 20% | NA | 0.01 µg $L^{-1}$ |
| **Sediments** | | | | | | |
| Metals | 85 – 115% | ≤20% | 75 – 125% | ≤20% | NA | 1 µg $g^{-1}$ DW; 5 µg $g^{-1}$ Zn DW |
| TOC:TN | 80 – 120% | ≤20% | NA | NA | NA | 1% |
| **Suspended Particulate Matter (sediment trap)** | | | | | | |
| Metals | 85 – 115% | ≤20% | 75 – 125 | ≤20% | NA | 1 µg $g^{-1}$ DW; 5 µg $g^{-1}$ Zn DW |
| TOC:TN | 80 – 120% | ≤20% | NA | NA | NA | 1% |
| **Mussel Tissue** | | | | | | |
| Metals | 85-115% | ± 20% | 75-125% | ± 20% | 80-120% | 0.25 µg $g^{-1}$ DW; 5 µg $g^{-1}$ Zn DW |

LCS: laboratory control sample
CRM: certified reference materials
CCV: continuing calibration verification standards
RPD: relative percent difference
DW: dry weight

Table 14. Measurement quality objectives for Hydrolab calibration checks.

| Parameter | Units | Accept | Qualify | Reject |
|---|---|---|---|---|
| pH | std. units | < or = ± 0.2 | > ± 0.2 and < or = ± 0.8 | > ± 0.8 |
| Conductivity* | uS/cm | < or = ± 5 | > ± 5 and < or = ± 15 | > ± 15 |
| Temperature | ° C | < or = ± 0.2 | > ± 0.2 and < or = ± 0.8 | > ± 0.8 |
| Dissolved Oxygen | % saturation | < or = ± 5% | > ± 5% and < or = ± 15% | > ± 15% |
| Dissolved Oxygen | mg/L | < or = ± 0.3 | > ± 0.3 and < or = ± 0.8 | > ± 0.8 |

* Criteria expressed as a percentage of readings; for example, buffer = 100.2 uS/cm and Hydrolab = 98.7 uS/cm; (100.2-98.7)/100.2 = 1.49% variation, which would fall into the acceptable data criteria of less than 5%.

### 6.2.2 Targets for comparability, representativeness, and completeness

#### 6.2.2.1 Comparability

Section 8.1 lists the SOPs to be followed for field sampling.

#### 6.2.2.2 Representativeness

Representativeness is a measure of whether the sample media reflects the current environmental conditions.  We will ensure proper representatives by adhering to the approved SOPs and sampling protocols.  Samples will be preserved and stored to ensure that lab holding conditions and times are met.

#### 6.2.2.3 Completeness

The data for this project will be considered complete if 95% of the planned samples were collected and analyzed acceptably.

# 7.0 Sampling Process Design (Experimental Design)

## 7.1 Study design

This study was designed to provide baseline data on copper, zinc, and lead in marinas throughout Puget Sound prior to the ban on copper in antifouling paints going into effect on January 1, 2018. We have selected five marinas of varying configurations in different geographic locations to assess the suite of metals. Metals will be analyzed in water, suspended sediment, bottom sediments, and tissues of transplanted, caged mussels. At each marina a background site outside the marina will also be assessed.

### 7.1.1 Field measurements

During sampling, a calibrated Hydrolab will be used to profile the sample location for temperature, dissolved oxygen, conductivity, and pH.

### 7.1.2 Sampling location and frequency

The marinas are located from the San Juan Islands in north Puget Sound to Swantown Marina in south Puget Sound (Figure 1). The proposed sampling plan and schedule is described in Table 14. Sample locations within the marinas will be determined subjectively based on communications with the marina operators and the initial site visit. Sample locations outside the marina will be near-shore in approximately 40 feet of water and away from any stormwater or wastewater discharges. The sample sites outside the marinas will be at least 300 feet from the marina entrance. Maps of each marina are included in Appendix B. Boating season usually begins in March/April and goes through September/October. Our proposed sampling program will capture the end of the 2016 boating season, the winter period, the early 2017 boating season, and an additional 2017 boating season sample.

Water samples will be collected quarterly from three sites within the marina and one outside the marina. Sediment traps will be deployed to gather three samples over the course of the nine-month project timeline representing fall/winter, winter/spring, and spring. Two sediment traps will be deployed within the marina and one outside the marina. Bottom sediments will be collected at the end of the sampling program representing accumulation over the period of sampling. Three bottom sediment samples will be collected within each marina and one outside the marina. The transplanted, caged mussels will be deployed once in the spring for approximately a 3-month deployment. Three cages will be deployed within the marina and three outside the marina. Where possible the sites of sample collection inside and outside the marina will be consistent.

Table 15. Proposed sampling schedule and number of samples collected, excluding QC samples.

| Month/ Year | Water | Sediment trap | | Bottom sediments | Caged mussels | |
|---|---|---|---|---|---|---|
| | | Deploy | Retrieve | | Deploy | Retrieve |
| 09/16 | **20** | | | | | |
| 10/16 | | | | | | |
| 11/16 | | | | | | |
| 12/16 | | | | | | |
| 1/17 | **20** | | **15** | | | |
| 2/17 | | | | | | |
| 3/17 | **20** | | **15** | | | |
| 4/17 | | | | | | |
| 5/17 | | | | | | **30** |
| 6/17 | **20** | | **15** | **20** | | |

### 7.1.3 Parameters to be determined

The focus of the study is on a suite of metals associated with boat antifouling paint and boatyards: copper, zinc, and lead. Ancillary parameters in water include: dissolved organic carbon, total suspended solids, salinity, pH, dissolved oxygen and temperature. Ancillary parameters in sediments include: total organic carbon and total nitrogen and grain size.

## 7.2 Maps or diagram

Sample sites are shown in Figure 1 and maps of each marina are in Appendix B.

## 7.3 Assumptions underlying design

The main assumption of this study is that metals concentrations will be detectable within the marinas. Based on previous results and studies we anticipate this assumption will be correct. We are also assuming that sampling during the late-spring will be good timing to assess the early boating season. Due to time constraints of the project we will not be sampling throughout the summer.

The number of samples inside each marina will be consistent among the marinas. We are assuming that three sites within each marina will be sufficient to adequately represent environmental conditions despite the variability in marina configuration.

## 7.4 Relation to objectives and site characteristics

The study was designed to fulfill the stated objectives of the project and the selected sites will allow us to address the project objectives.

## 7.5 Characteristics of existing data

There is limited data available for copper, zinc, and lead in marinas and this has been reviewed in section *3.1.4 Previous Results*. This study will provide the necessary baseline data from which to assess whether the ban on copper in antifouling paint for boats has had an impact with future sampling.

# 8.0 Sampling Procedures

## 8.1 Field measurement and field sampling SOPs

A number of established SOPs will be followed during sampling, including:

- EAP015 – *Manually Obtaining Surface Water Samples, Version 1.2* (Joy, 2013).
- EAP029 – *Collection and Field Processing of Metals Samples, Version 1.5* (Ward, 2015).
- EAP033 – *Hydrolab® DataSonde® and MiniSonde® Multiprobes, Version 1.0* (Swanson, 2007).
- EAP040 – *Standard Operating Procedure for Obtaining Freshwater Sediment Samples* (Blakley, 2008)
- EAP070 – *Minimizing the Spread of Invasive Species* (Parsons et al., 2012).
- EAP090 – *Decontaminating Field Equipment for Sampling Toxics in the Environment* (Friese, 2014).

### Water samples

Water samples for dissolved and total recoverable metals will be collected from an aluminum hull boat with no antifouling paint using a peristaltic pump. Collection and handling will follow EPA Method 1669 *Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels* (EPA, 1996). Filtering will be conducted on-site using a Nalgene filter unit with an acid-washed 0.45 µm filter. Samples will be collected in Teflon bottles. The first few milliliters of filtrate will be discarded. The metals samples will be acidified immediately following collection.

All tubing, filters, and bottles will be acid-washed prior to the field. The tubing will be cleaned between sites by pumping one liter of deionized water acidified with high-purity nitric acid, followed by deionized water. Non-talc gloves will be worn by sampling personnel. An equipment blank of laboratory grade deionized water will be collected during each sampling event prior to collection of the first samples.

Samples will also be collected for dissolved organic carbon, salinity and total suspended solids.

### Suspended sediments (sediment traps)

Two sediment traps will be deployed within the marinas following discussion with marina personnel about locations. The traps are designed for shallow waters and will remain submerged for approximately 3 to 4 months.

The sediment trap is suspended approximately one meter (3 feet) above the bottom sediment with an anchor, snag line, and hardball float (Figure 2). This method is described in detail in Norton (1996). The hardball float sits approximately 6 feet below the water surface so that it can stay taut with fluctuating water levels and so it's not disturbed by vessel traffic or floating debris. The trap is then retrieved by dragging a hook to grab the snag line underwater. Alternatively, the trap will be secured to a piling or dock with cable for ease of retrieval.

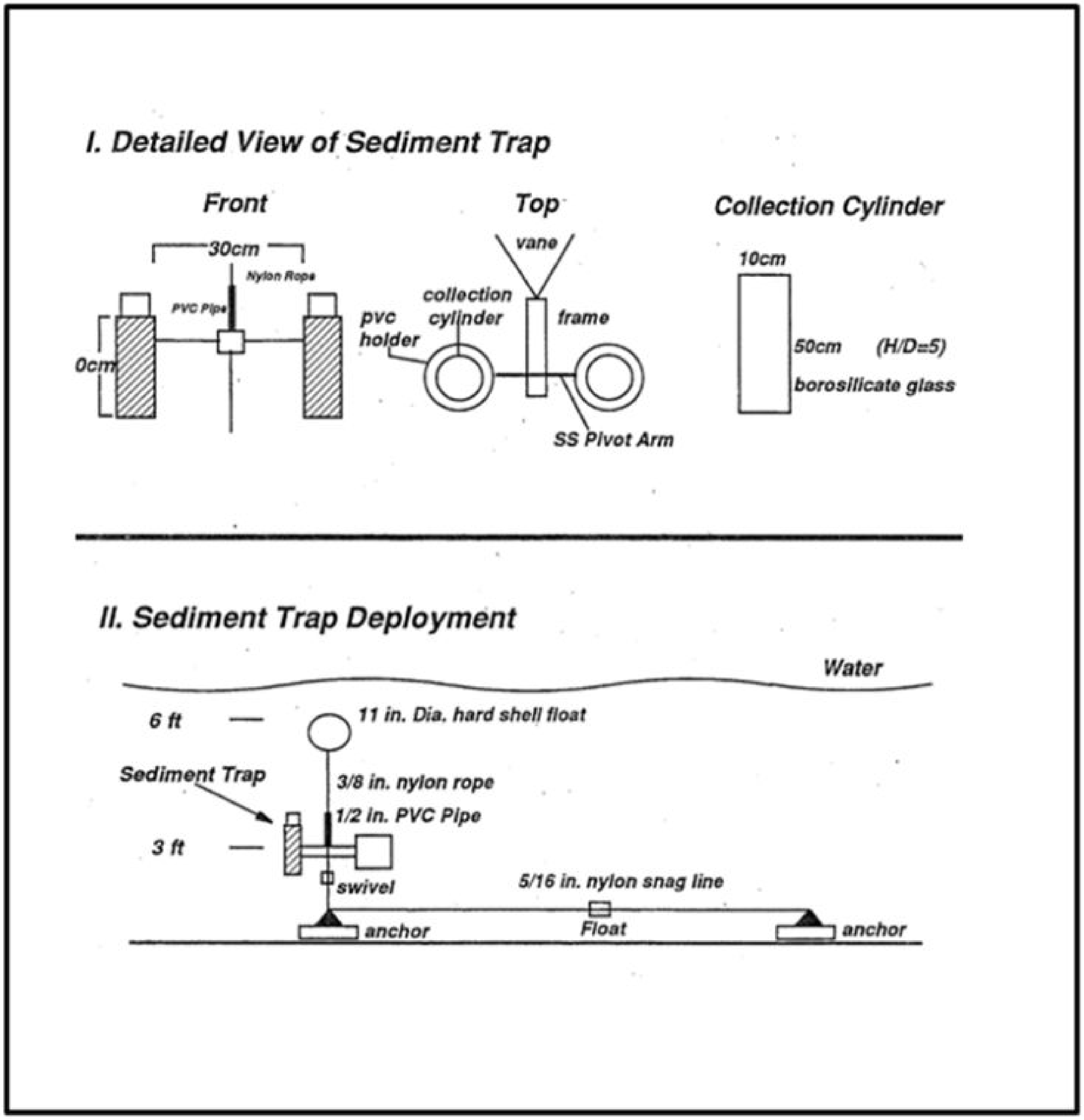


Figure 2. Schematic of sediment trap design and deployment configuration (Norton, 1996).

Each sediment trap holds two glass collection cylinders each with a collection area of 78.5 $cm^2$ and a height-to-width ratio of 5. Before deployment, cylinders will be cleaned with Liquinox soap and hot water, followed by 10% nitric acid, and then rinsed with deionized water. At deployment, the cylinders are partially filled with high salinity water (4% sodium chloride – NaCl), which contains 2% sodium azide ($Na_3N$) as a preservative to reduce microbial degradation of the samples.

Sediment traps will be emptied and re-deployed with cleaned cylinders during the sampling events. Once the trap has been pulled onboard the boat, sediments will be allowed to settle and the overlying water decanted off. Sediments will then be poured into ½ gallon acid-cleaned glass jars and placed in an iced cooler for transport to the Ecology laboratory in Lacey, Washington. Sediment samples will then be transferred to 16 oz. acid-cleaned jars and centrifuged to remove additional excess water before shipment to MEL for analysis.

## Bottom sediments

Surface sediments will be collected from three locations within each marina near the position of the sediment traps. Three individual grab samples of the surface sediments (upper 2 cm) will be collected and composited using a standard Ponar dredge sampler with the assistance of a winch. Sediments will be mixed in a Teflon container and placed in acid-washed glass jars for metals and plastic containers for grain size analysis. The Ponar will be rinsed with site water between samples and the Teflon container will be cleaned with deionized water and acid-rinsed between marinas.

## Transplanted, caged mussels

Ecology will collaborate with WDFW to plan, deploy, retrieve and process mussels as a biological indicator for the accumulation of metals in tissues. WDFW runs a biennial nearshore toxic contaminant monitoring program that uses transplanted mussels as the indicator species (Lanksbury et al., 2010, 2014). WDFW has the equipment and expertise to assist Ecology in deploying three mussel monitoring units (i.e., mussel cages) within each marina and three outside the marina (pers. comm., Jennifer Lanksbury and James West). WDFW's next round of mussel monitoring will occur in the winter of 2017-18; they are not scheduled to deploy mussel cages during the spring of 2017, so this project will not be concurrent with WDFW's regular mussel sampling in Puget Sound.

Recently, WDFW contracted with the Regional Stormwater Monitoring Program (RSMP) to deploy a large number of cages for its Status and Trends in Receiving Waters program. A detailed QAPP was compiled to describe the methods and approaches used for the mussel monitoring component of the RSMP (Lanksbury and Lubliner, 2015). A modified version of this mussel monitoring approach will be followed for the proposed project. There will be two deployments of mussels, each for a period of approximately 3 months.

Mussels used for this study will be of the species *Mytilus trossulus* (bay or foolish mussel), which is indigenous to intertidal habitats in the Puget Sound. As recommended in the *Standard Guide for Conducting In-situ Field Bioassays with Caged Bivalves* (ASTM E2122-02, 2007), mussels for this study will come from an aquaculture facility. The source will be Penn Cove Shellfish, Inc. in Penn Cove, Whidbey Island, Washington. The advantage of using mussels from this facility is that all individuals will be of similar ages from the same population, will have a similar genetic and environmental history and are expected to be relatively uncontaminated (Lanksbury et al., 2014).

Mussels used for bioaccumulation studies are commonly deployed outside periods of spawning, due to a loss of mussel weight (Lanksbury et al., 2014). *M. trossulus* typically spawns in the early spring. Because the time period we are interested in (spring) will likely overlap with spawning, we measure mussel condition and growth to control for possible changes in mussel weight that would affect the accumulation of metals. Mussels will be bagged and measured at the Penn Cove Shellfish Inc. facility and held to reacclimatize prior to deployment. Ecology will collect the mussels from Penn Cove, transport them on ice and deploy them the same day. Four bags of mussels, each containing 16 individuals, will be placed in each study cage and six cages will be placed at each study site (Figure 3), for a total of 384 mussels per marina. The cages will be suspended near the sediment traps, from a dock if possible.

Figure 3. Typical mussel cage ready for deployment (Lanksbury et al., 2014).

After retrieval of the mussels, individuals will be measured, assessed for mortality and condition, and approximately 30 living individuals will be harvested and their soft tissues composited for chemical analysis. Ecology staff will be advised by WDFW on the processing of the mussels. An archive sample of the mussel tissues will be held for future analysis should additional parameters used in future antifouling paints become of interest.

## 8.2 Containers, preservation methods, holding times

Table 16. Sample containers, preservation, and holding times.

| Parameter | Matrix | Container | Preservation | Holding Time |
|---|---|---|---|---|
| TSS | Seawater | 1 L poly bottle | Cool to 4°C | 7 days |
| Salinity | | 500 mL poly bottle | Cool to 4°C | 28 days |
| DOC | | 125 mL poly bottle | Field filter for dissolved; 1:1 HCl to pH<2; Cool to 4°C | 28 days |
| Diss. and tot rec. metals | | 250 mL or 500 mL Teflon bottle | Field filter for dissolved; 1:1 $HNO_3$ to pH<2; Cool to 4°C | 6 months after preservation |
| TOC:TN | Suspended particulate matter and bottom sediments | Certified 2-oz amber glass w/ Teflon lid liner | Cool to 6°C | 14 days or 6 months frozen |
| Metals | | Certified 4-oz amber glass w/ Teflon lid liner | Transport at 6°C; can store frozen at -18°C | 6 months or 2 years frozen |
| Metals | Mussel tissue | Certified 4-oz amber glass w/ Teflon lid liner | Transport at 6°C; can store frozen at -18°C | 6 months or 2 years frozen |

TSS: total suspended solids
DOC: dissolved organic carbon
TOC: total organic carbon
TN: total nitrogen

## 8.3 Invasive species evaluation

Field personnel for this project are required to be familiar with and follow the procedures described in SOP EAP070 (Parsons et al., 2012), *Minimizing the Spread of Invasive Species*. Our study areas are not considered to be of high concern. Ecology will work with WDFW to acquire a Shellfish Transfer Permit to allow for the deployment of shellfish from an aquaculture facility.

## 8.4 Equipment decontamination

Decontamination will follow Ecology's SOP EAP090, *Decontamination of Sampling Equipment for Use in Collecting Toxic Chemical Samples* (Friese, 2014). We will transport the necessary dilute acids for decontamination in the field between marinas.

## 8.5 Sample ID

Laboratory sample IDs will be assigned by MEL.

## 8.6 Chain-of-custody, if required

Chain of custody will be maintained for all samples throughout the project.

## 8.7 Field log requirements

Field data will be recorded in a bound, waterproof notebook on Rite in the Rain paper. Corrections will be made with single line strikethroughs, initials, and date.

The following information will be recorded in the project field log:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results
- Identity of QC samples collected
- Unusual circumstances that might affect interpretation of results

A separate field sheet will be filled out for the mussel sampling which is used by WDFW during Mussel Watch deployments (Appendix D).

## 8.8 Other activities

There are a number of activities and meetings that need to occur prior to the field work, including:

- Liaison with the Ecology inspectors and marina operators to approve the sampling schedule and locations.
- Construction of the sediment traps.
- Verifying and acquiring the necessary permits for retrieval of bottom sediments if the locations are sited over aquatic areas managed by the Department of Natural Resources.
- Training and discussion of protocols for the mussel deployments.
- Liaison with Penn Cove Shellfish Inc. to set up the necessary conditioning and acquisition of mussels.
- Establishing the duties and tasks for WDFW within the project.

# 9.0 Measurement Methods

## 9.1 Field procedures table/field analysis table

Field data will be measured using a MiniSonde multi-meter following guidance in SOP EAP033 – Hydrolab® DataSonde® and MiniSonde® Multiprobes, Version 1.0 (Swanson, 2007).

Field parameters for the project include:

- Temperature
- pH
- Conductivity
- Dissolved Oxygen

## 9.2 Lab procedures table

Table 17. Measurement methods (laboratory).

| Analyte | Sample Matrix | Samples | Expected Range of Results | Reporting Limit | Sample Prep Method | Analytical (Instrumental) Method |
|---|---|---|---|---|---|---|
| **Water Samples** | | | | | | |
| Total Suspended Solids (mg $L^{-1}$) | Seawater | 92 | 1 - 50 | 1 | NA | SM 2540 D-97 |
| Salinity (g $Kg^{-1}$) | Seawater | 92 | 30-35 | 0.1 | NA | SM 2510 |
| Dissolved organic carbon (mg $L^{-1}$) | Seawater | 92 | <1 - 20 mg $L^{-1}$ | 1 mg $L^{-1}$ | N/A | SM 5310B |
| Dissolved / tot rec copper (µg $L^{-1}$) | Seawater | 96 | <0.05-8.0 | 0.05 | EPA 1640 | EPA 200.8 |
| Dissolved / tot rec lead (µg $L^{-1}$) | Seawater | 96 | <0.01-0.3 | 0.01 | EPA 1640 | EPA 200.8 |
| Dissolved / tot rec zinc (µg $L^{-1}$) | Seawater | 96 | <0.08-5.0 | 0.08 | EPA 1640 | EPA 200.8 |
| **Suspended and Bottom Sediments** | | | | | | |
| TOC:TN (%) | Sediments | 76 | 1-10% | 0.1 | EPA 440 | EPA 440 |
| copper (µg $g^{-1}$) | Sediments | 76 | 5 – 100 | 0.1 | EPA 3050B | EPA 6020A |
| lead (µg $g^{-1}$) | Sediments | 76 | 5 - 60 | 0.1 | EPA 3050B | EPA 6020A |
| zinc (µg $g^{-1}$) | Sediments | 76 | 5 – 300 | 5.0 | EPA 3050B | EPA 6020A |
| Grain size | Bottom sediments | 20 | 1-15% | 0.1% | NA | PSEP TOC |
| **Mussel Tissues** | | | | | | |
| copper (µg $g^{-1}$) | Tissue | 37 | MDL to 10 | 0.25 | EPA 3051 | EPA 6020A |
| lead (µg $g^{-1}$) | Tissue | 37 | MDL to 2 | 0.25 | EPA 3051 | EPA 6020A |
| zinc (µg $g^{-1}$) | Tissue | 37 | MDL to 125 | 12.5 | EPA 3051 | EPA 6020A |

Tot rec: total recoverable metals
TOC: total organic carbon
TN: total nitrogen
MDL: method detection limit
EPA: US Environmental Protection Agency
SM: Standard Method
PSEP: Puget Sound Estuary Program

## 9.3 Sample preparation method(s)

See Table 16.

## 9.4 Special method requirements

The pre-concentration of seawater samples will take place in accordance with EPA 1640: *Determination of Trace Elements in Water by Preconcentration and Inductively Coupled Plasma-Mass Spectrometry*.

## 9.5 Lab(s) accredited for method(s)

All analyses with the exception of grain size will be carried out at Manchester Environmental Laboratory.  Grain size will be analyzed by the accredited lab, Materials Testing and Consulting, Inc., Tukwila, WA.

# 10.0 Quality Control Procedures

## 10.1 Table of field and lab quality control (QC) required

Table 18. QC samples, types, and frequency.

| Parameter | Field | | Laboratory | | | |
|---|---|---|---|---|---|---|
| | Replicates | Equipment blank | Check Standards | Method Blanks | Matrix Spikes | Duplicate |
| **Water Samples** | | | | | | |
| TSS | 1/batch | - | 1/batch | 1/batch | - | 1/batch |
| salinity | 1/batch | - | 1/batch | 1/batch | - | 1/batch |
| DOC | 1/batch | - | 1/batch | 1/batch | - | 1/batch |
| metals | 5/batch | 1/batch | 1/batch | 1/batch | 1/batch | 1/batch |
| **Suspended Sediments** | | | | | | |
| TOC:TN | 2/batch | - | 1/batch | 1/batch | 1/batch | 1/batch |
| Metals | 2/batch | | 1/batch | 1/batch | 1/batch | 1/batch |
| **Bottom Sediments** | | | | | | |
| TOC:TN | 1/batch | - | 1/batch | 1/batch | 1/batch | 1/batch |
| Metals | 1/batch | - | 1/batch | 1/batch | 1/batch | 1/batch |
| Grain size | 1/batch | - | - | 1/batch | - | 1/batch |
| **Mussel Tissue** | | | | | | |
| metals | 2/batch | 5/batch[a] | 1/batch | 1/batch | 1/batch | 1/batch |

[a] equipment blank for mussel tissue refers to the analysis of 5 composite samples as a background from Penn Cove prior to deployment of cages.

batch: one sampling event and laboratory run.

## 10.2 Corrective action processes

The laboratory analysts will document whether project data meets method QC criteria. Any departures from normal analytical methods will be documented by the laboratory and described in the data package from the laboratories and also in the final report for the project. If any samples do not meet QC criteria, the project manager will determine whether data should be re-analyzed, rejected, or used with appropriate qualification.

Field instruments will be checked and calibrated before the field work begins. The post-field check of the instrument should be within the MQOs defined in Table 13. The appropriate qualification or rejection threshold is detailed in the MQOs.

# 11.0 Data Management Procedures

## 11.1 Data recording/reporting requirements

Field data will be recorded in a bound, waterproof notebook on Rite in the Rain paper. Corrections will be made with single line strikethroughs, initials, and date. Data will be transferred to Microsoft Excel for creating data tables.

Statistical analysis will be completed in R and will consist of comparisons among the marinas using an analysis of variance (ANOVA) with a Levene's test for equality of variance. Non-parametric methods, such as the Kruskal-Wallis test or one-way ANOVA on ranks, may also be used to analyze non-normally distributed data rather than transforming the data. Comparisons between the within-marina samples to the outside-marina sample will be made visually and by calculating the 95% confidence interval for the within-marina samples. The minimum sample size of three for the samples collected within the marinas will allow for future samples of similar numbers from each marina to be compared statistically to the baseline collected in this study.

## 11.2 Laboratory data package requirements

The laboratory data package will be generated by MEL. MEL will provide a project data package that will include: a narrative discussing any problems encountered in the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. Quality control results will be evaluated by MEL (discussed below in *Section 13.0 Data Verification*).

The following data qualifiers will be used:

- "J" – The analyte was positively identified. The associated numerical result is an estimate.
- "UJ" – The analyte was not detected at or above the estimated reporting limit.
- "U" – The analyte was not detected above the reporting limit.
- "NJ" – The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.

The qualifiers will be used in accordance with the method reporting limits such that:

- For non-detect values, the estimated detection limit (EDL) is recorded in the "Result Reported Value" column and a "UJ" in the "Result Data Qualifier" column.
- Detected values that are below the quantitation limits (QL) are reported and qualified as estimates ("J").

## 11.3 Electronic transfer requirements

All laboratory data will be accessed and downloaded from MEL's Laboratory Information Management System (LIMS) into Excel spreadsheets. MEL will provide an electronic data deliverable (EDD).

## 11.4 Acceptance criteria for existing data

All existing data are stored in EIM and as such are acceptable for use as described under the data quality descriptions in EIM.

## 11.5 EIM/STORET data upload procedures

All completed project data will be entered into Ecology's Environmental Information (EIM). Data entered into EIM follow a formal data review process where data are reviewed by the project manager, the person entering the data, and an independent reviewer.

EIM can be accessed on Ecology's Internet homepage at www.ecy.wa.gov. The project will be searchable under Study ID WHOB004.

# 12.0 Audits and Reports

## 12.1 Number, frequency, type, and schedule of audits

No defined audit exists for the field work in this project. WDFW will be overseeing the organization and deployment of the mussel samples.

The Ecology Environmental Laboratory Accreditation Program evaluates a laboratory's quality system, staff, facilities and equipment, test methods, records, and reports. It also establishes that the laboratory is capable of providing accurate, defensible data. All assessments are available from Ecology upon request, including MEL's internal performance and audits.

## 12.2 Responsible personnel

The project manager will be responsible for all reporting.

## 12.3 Frequency and distribution of report

One final report will be written at the end of the project summarizing the results. Presentation of the findings from this study will also be given to the Hazardous Waste and Toxics Reduction group who are the lead in compiling the 2018 report for the legislature. These data will provide the baseline for the assessment of effects from the reduction of metals from antifouling paints.

## 12.4 Responsibility for reports

The report will be co-authored by William Hobbs and Melissa McCall.

# 13.0 Data Verification

## 13.1 Field data verification, requirements, and responsibilities

The field assistant will review field notes once they are entered into Excel spreadsheets. Oversight will be provided by the project manager.

## 13.2 Lab data verification

As previously described, MEL will oversee the review and verification of all laboratory data packages. All data generated by the contract lab must be included in the final data package, including but not limited to: a text narrative; analytical result reports; analytical sequence (run) logs, environmental samples, batch QC samples, and preparation benchsheets. All of the necessary QA/QC documentation must be provided, including results from matrix spikes, replicates, and blanks.

## 13.3 Validation requirements, if necessary

It is expected that external data validation will not be necessary for this project.

# 14.0 Data Quality (Usability) Assessment

## 14.1 Process for determining whether project objectives have been met

The project manager will determine if the project data are useable by assessing whether the data have met the MQOs outlined in Tables 12 and 13. Based on this assessment, the data will either be accepted, accepted with appropriate qualifications, or rejected and re-analysis considered.

## 14.2 Data analysis and presentation methods

No specific numerical analyses are necessary for this project.

## 14.3 Treatment of non-detects

There is no specific approach necessary for the treatment of non-detects. MEL will report whether or not the analyte was not detected at or above the estimated reporting limit. It is not anticipated that non-detects will be an issue for the parameters being measured.

## 14.4 Sampling design evaluation

The number of samples within each marina for water, sediment and mussels is the minimum required to evaluate the variability within and among marinas. We will be able to test for significant difference among the marinas using a 3-sample one-way ANOVA. More replication would increase the power of this comparison. We should also be able to test for significance among samples from the same marina over time when future studies are conducted.

## 14.5 Documentation of assessment

The final report will present the findings, interpretations, and recommendations from this study.

# 15.0 References

**Personal Communications**

Jennifer Lanksbury, WDFW Mussel Watch, 8/8/16
James West, WDFW, 8/8/16

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# 16.0 Figures

The figures in this QAPP are inserted after they are first mentioned in the text.

# 17.0 Tables

The tables in this QAPP are inserted after they are first mentioned in the text.

# 18.0 Appendices

# Appendix A. Amendment to Bill SSB 5436

**5436-S AMH ENVI H2267.3**

SSB 5436 - H COMM AMD
By Committee on Environment

**ADOPTED 04/06/2011**

Strike everything after the enacting clause and insert the following:

"NEW SECTION. **Sec. 1.** The legislature intends to phase out the use of copper-based antifouling paints used on recreational water vessels.

NEW SECTION. **Sec. 2.** The definitions in this section apply throughout this chapter unless the context clearly requires otherwise.

(1) "Department" means the department of ecology.

(2) "Director" means the director of the department of ecology.

(3)(a) "Recreational water vessel" means any vessel that is no more than sixty-five feet in length and is: (i) Manufactured or used primarily for pleasure; or (ii) leased, rented, or chartered by a person for the pleasure of that person.

(b) "Recreational water vessel" does not include a vessel that is subject to United States coast guard inspection and that: (i) Is engaged in commercial use; or (ii) carries paying passengers.

NEW SECTION. **Sec. 3.** (1) Beginning January 1, 2018, no manufacturer, wholesaler, retailer, or distributor may sell or offer for sale in this state any new recreational water vessel manufactured on or after January 1, 2018, with antifouling paint containing copper.

(2) Beginning January 1, 2020, no antifouling paint that is intended for use on a recreational water vessel and that contains more than 0.5 percent copper may be offered for sale in this state.

(3) Beginning January 1, 2020, no antifouling paint containing more than 0.5 percent copper may be applied to a recreational water vessel in this state.

NEW SECTION. **Sec. 4.** The department, in consultation and cooperation with other state natural resources agencies, must increase educational efforts regarding recreational water vessel hull cleaning to reduce the spread of invasive species. This effort must include a review of best practices that consider the type of antifouling paint used and recommendations regarding appropriate hull cleaning that includes in-water methods.

NEW SECTION. **Sec. 5.** (1) The department shall enforce the requirements of this chapter.

(2)(a) A person or entity that violates this chapter is subject to a civil penalty. The department may assess and collect a civil penalty of up to ten thousand dollars per day per violation.

(b) All penalties collected by the department under this chapter must be deposited in the state toxics control account created in RCW 70.105D.070.

NEW SECTION. **Sec. 6.** (1) On or after January 1, 2016, the director may establish and maintain a statewide advisory committee to assist the department in implementing the requirements of this chapter.

(2)(a) By January 1, 2017, the department shall survey the manufacturers of antifouling paints sold or offered for sale in this state to determine the types of antifouling paints that are available in this state. The department shall also study how antifouling paints affect marine organisms and water quality. The department shall report its findings to the legislature, consistent with RCW 43.01.036, by December 31, 2017.

(b) If the statewide advisory committee authorized under subsection (1) of this section is established by the director, the department may consult with the statewide advisory committee to prepare the report required under (a) of this subsection.

NEW SECTION. **Sec. 7.** The department may adopt rules as necessary to implement this chapter.

NEW SECTION. **Sec. 8.** Sections 2 through 7 of this act constitute a new chapter in Title 70 RCW.

<u>NEW SECTION.</u> **Sec. 9.** If any provision of this act or its application to any person or circumstance is held invalid, the remainder of the act or the application of the provision to other persons or circumstances is not affected."

Correct the title.

<u>EFFECT:</u> Modifies the intent section;

Modifies the definition of "recreational water vessel;"

Changes the date of the prohibition concerning selling a new recreational water vessel with antifouling paint containing copper (from January 2, 2017, to January 1, 2018) and specifies that the prohibition applies to recreational water vessels manufactured on or after January 1, 2018;

Modifies the prohibition on the sale of antifouling paint containing more than 0.5 percent copper by specifying that the prohibition applies to paint intended for use on a recreational water vessel;

Prohibits the application of antifouling paint containing more than 0.5 percent copper on a recreational water vessel beginning January 1, 2020;

Specifies that the department of ecology (DOE) is responsible for enforcing the requirements of the chapter, including collecting civil penalties;

Requires civil penalties collected by the DOE to be deposited in the state toxics control account;

Permits the DOE to establish a statewide advisory committee to assist the DOE in implementing the requirements of the bill and assist with the DOE's report to the legislature;

Modifies the requirements of the DOE's report to the legislature by requiring the DOE to study how antifouling paints affect marine organisms and water quality (in addition to the requirement to survey the manufacturers of antifouling paint);

Permits the DOE to adopt rules necessary to implement the requirements of the bill; and

Adds a severability clause.

--- **END** ---

# Appendix B. Marina maps

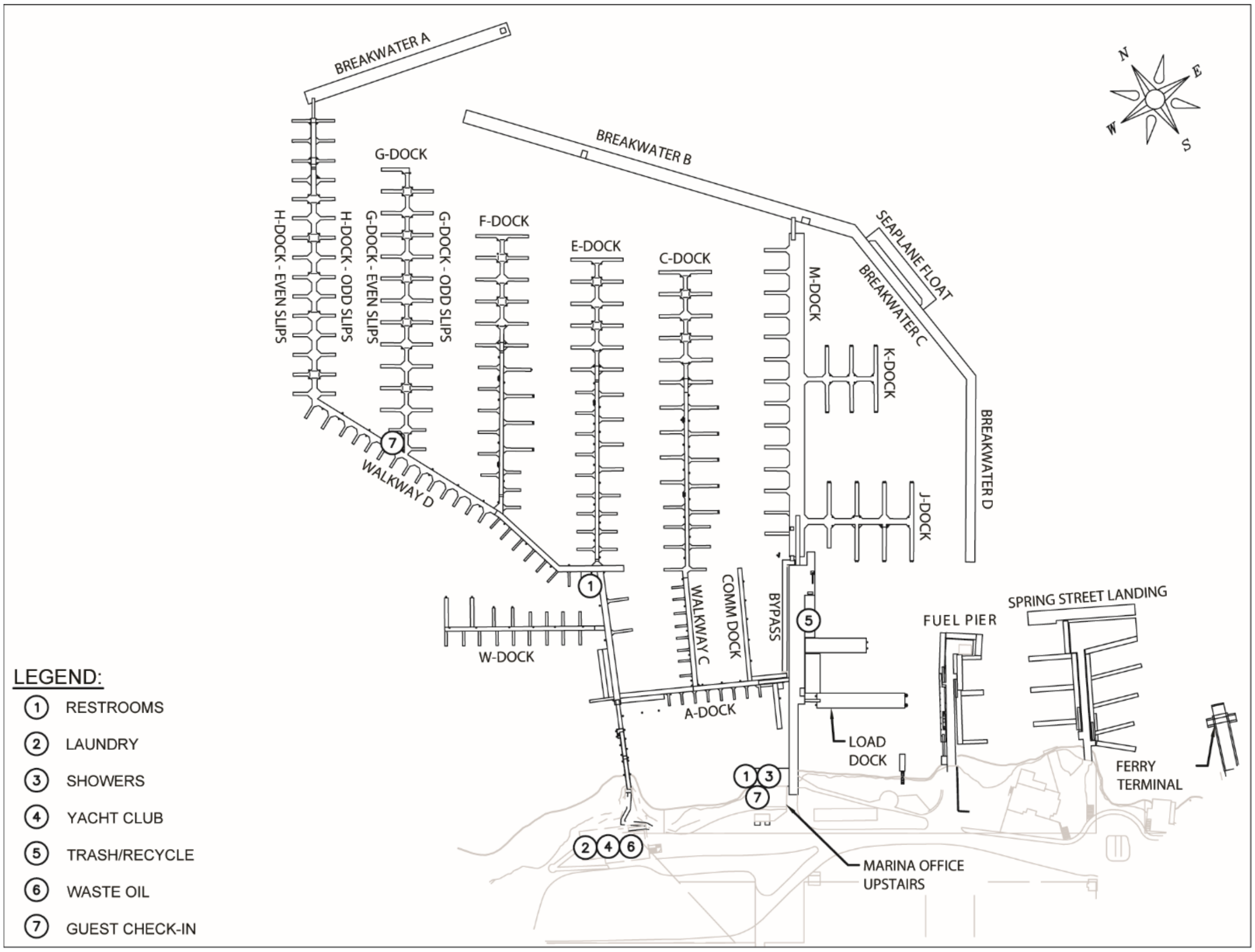


**Figure B-1. Friday Harbor.**

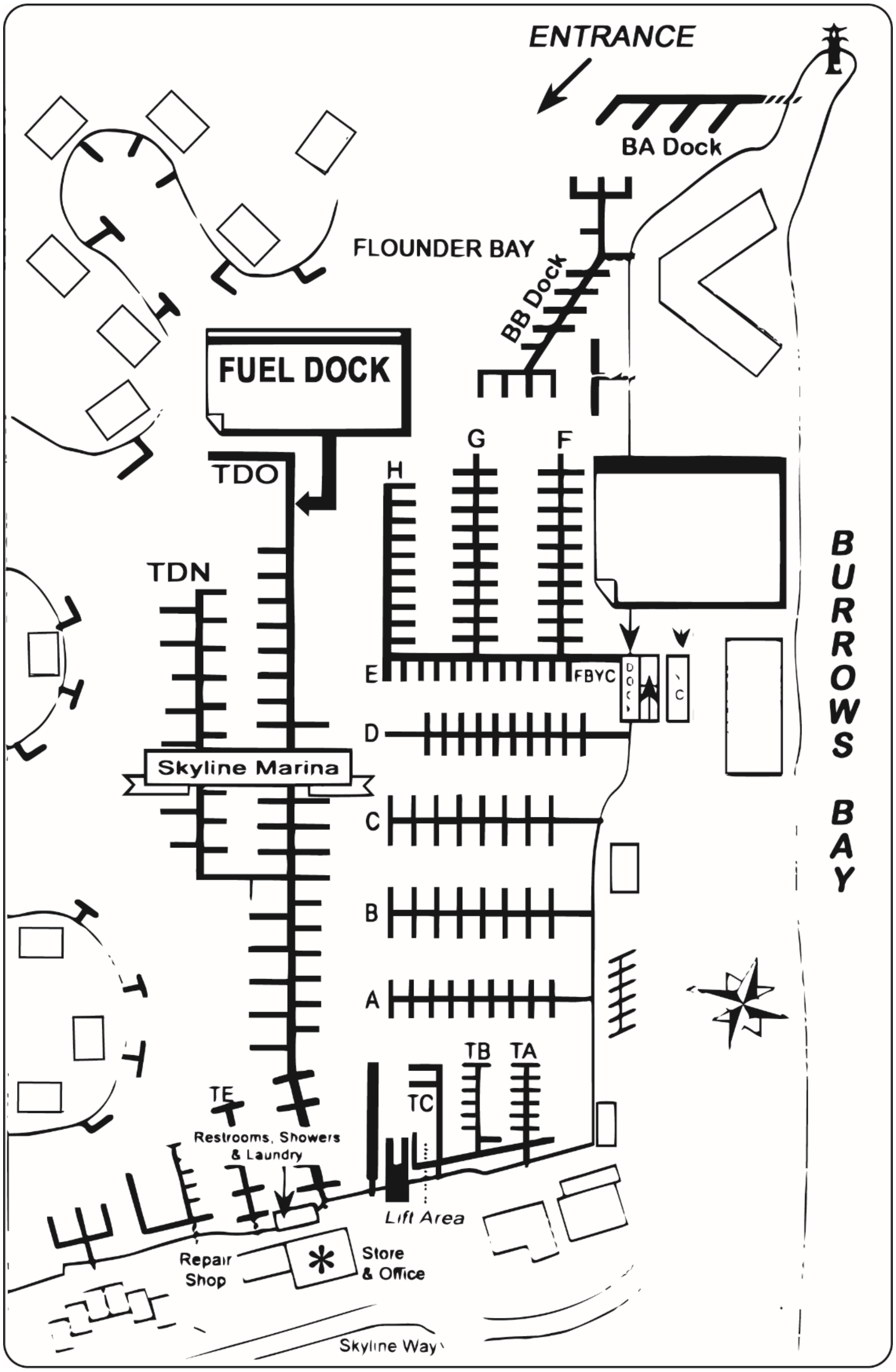


**Figure B-2. Skyline Marina.**

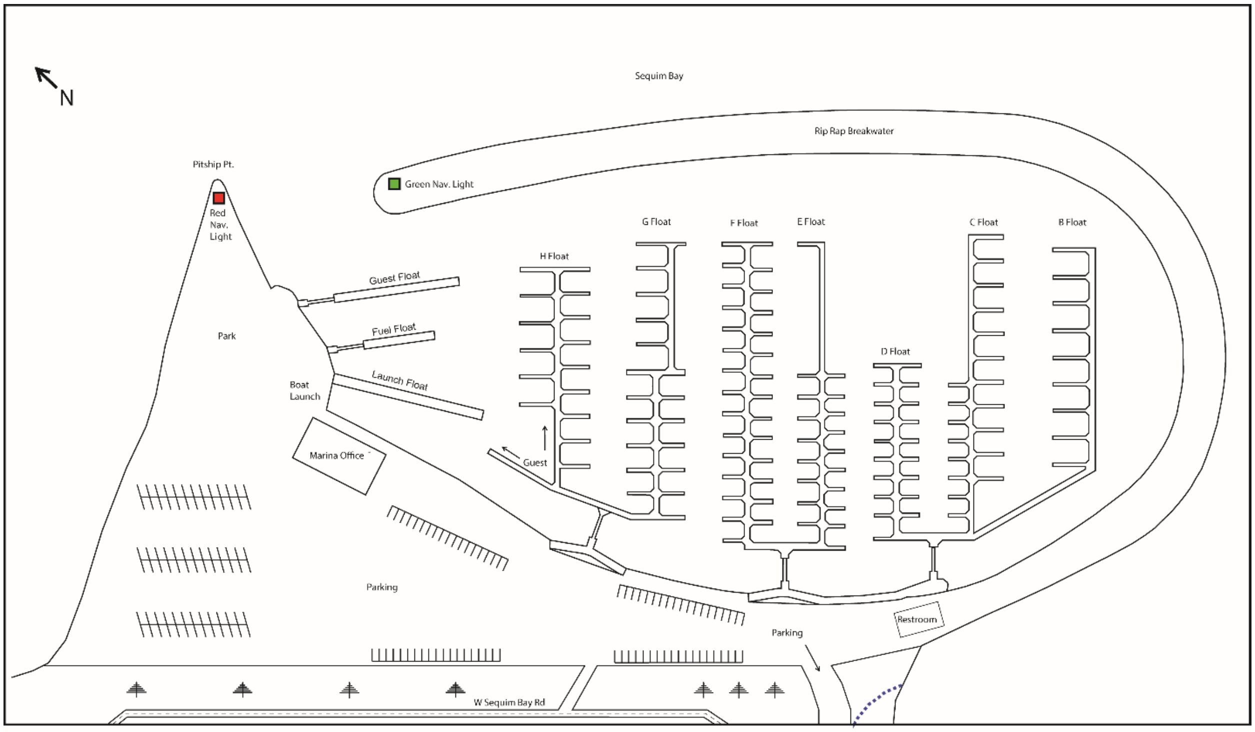


**Figure B-3. John Wayne Marina.**

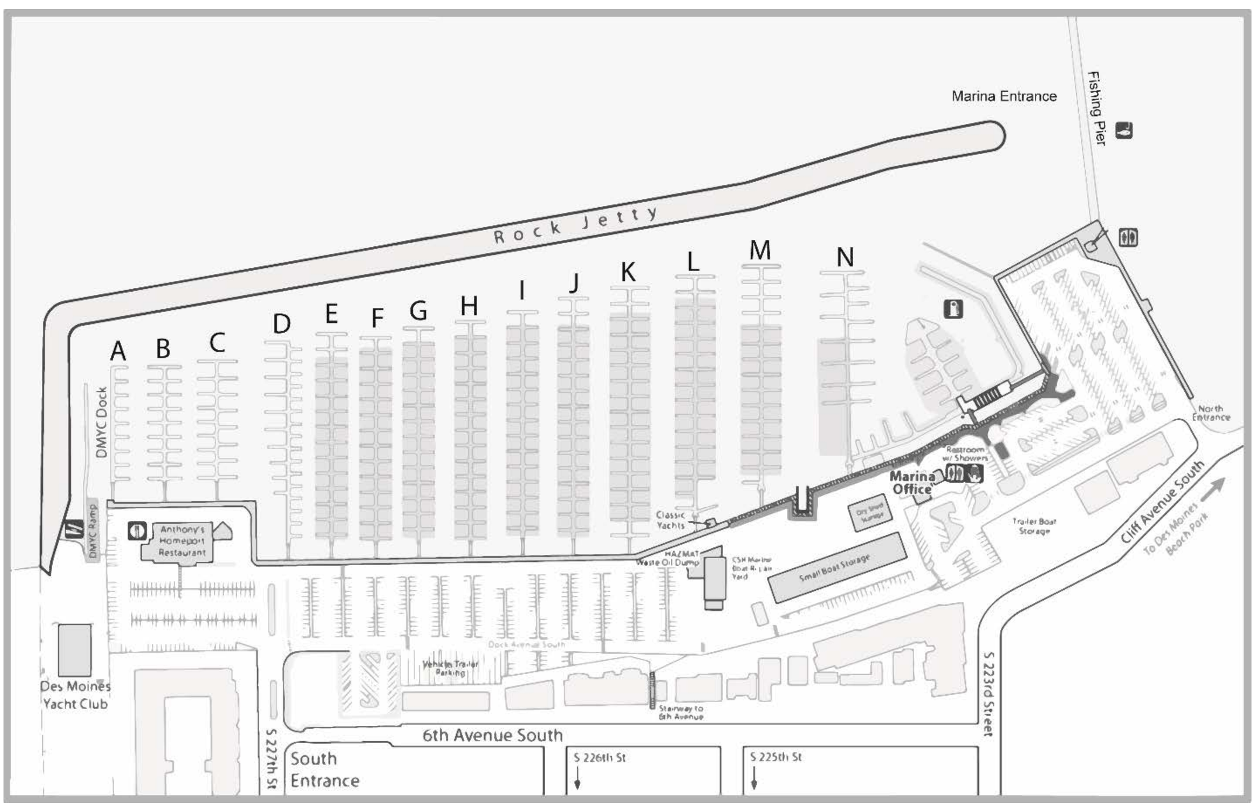


**Figure B-4. Des Moines Marina.**


**Figure B-5. Swantown Marina.**

# Appendix C. Previous data for study marinas

### Table C-1. Previous results from Friday Harbor, San Juan Island.

| Study ID | Location Name | Field Collection Date | Sample ID | Sample Matrix | Result Parameter | Result Value | Units | Inside or Outside Harbor | Reference |
|---|---|---|---|---|---|---|---|---|---|
| DNRREC91 | DNREC91FRIH01XX | 2/12/1991 | FRIHAR91S001 | Sediment | Copper | 16.1 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH01XX | 2/12/1991 | FRIHAR91S001 | Sediment | Copper | 15.9 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH01XX | 2/12/1991 | FRIHAR91S001 | Sediment | Lead | 9 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH01XX | 2/12/1991 | FRIHAR91S001 | Sediment | Lead | 8.8 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH01XX | 2/12/1991 | FRIHAR91S001 | Sediment | Zinc | 62.4 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH01XX | 2/12/1991 | FRIHAR91S001 | Sediment | Zinc | 57 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH02XX | 2/12/1991 | FRIHAR91S002 | Sediment | Copper | 32.6 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH02XX | 2/12/1991 | FRIHAR91S002 | Sediment | Lead | 23 | ppm | inside | DNR, 1991 |
| DNRREC91 | DNREC91FRIH02XX | 2/12/1991 | FRIHAR91S002 | Sediment | Zinc | 129 | ppm | inside | DNR, 1991 |
| DSER0014 | FR7 | 5/28/1997 | 97228242 | Sediment | Copper | 78.2 | ppm | inside | Serdar et al., 2001 |
| DSER0014 | FR7 | 5/28/1997 | 97228242 | Sediment | Lead | 32.2 | ppm | inside | Serdar et al., 2001 |
| DSER0014 | FR7 | 5/28/1997 | 97228242 | Sediment | Zinc | 114 | ppm | inside | Serdar et al., 2001 |
| DSER0014 | FR8 | 5/28/1997 | 97228243 | Sediment | Copper | 38.3 | ppm | inside | Serdar et al., 2001 |
| DSER0014 | FR8 | 5/28/1997 | 97228243 | Sediment | Lead | 14 | ppm | inside | Serdar et al., 2001 |
| DSER0014 | FR8 | 5/28/1997 | 97228243 | Sediment | Zinc | 127 | ppm | inside | Serdar et al., 2001 |
| PSAMP_HP | PSAMP_HP-206R | 4/1/1991 | PSAMP_HP-206R | Sediment | Copper | 14.2 | ppm | outside | Dutch et al., 2009 |
| PSAMP_HP | PSAMP_HP-206R | 4/13/1994 | PSAMP_HP-206R | Sediment | Copper | 13.9 | ppm | outside | Dutch et al., 2009 |
| PSAMP_HP | PSAMP_HP-206R | 4/1/1991 | PSAMP_HP-206R | Sediment | Lead | 7.1 | ppm | outside | Dutch et al., 2009 |
| PSAMP_HP | PSAMP_HP-206R | 4/13/1994 | PSAMP_HP-206R | Sediment | Lead | 4.4 | ppm | outside | Dutch et al., 2009 |
| PSAMP_HP | PSAMP_HP-206R | 4/1/1991 | PSAMP_HP-206R | Sediment | Zinc | 54.1 | ppm | outside | Dutch et al., 2009 |
| PSAMP_HP | PSAMP_HP-206R | 4/13/1994 | PSAMP_HP-206R | Sediment | Zinc | 50.8 | ppm | outside | Dutch et al., 2009 |
| WDFW 11-1916 | SJI_SJFH | 11/13/2012 | 13SJI_SJFH-MTW01 | Tissue | Copper | 0.699 | ug/g | outside | Lanksbury et al., 2014 |
| WDFW 11-1916 | SJI_SJFH | 11/13/2012 | 13SJI_SJFH-MTW01 | Tissue | Lead | 0.034 | ug/g | outside | Lanksbury et al., 2014 |
| WDFW 11-1916 | SJI_SJFH | 11/13/2012 | 13SJI_SJFH-MTW01 | Tissue | Zinc | 11.6 | ug/g | outside | Lanksbury et al., 2014 |

UOM: units of measure

## Table C-2. Previous results from Skyline Marina, Anacortes.

| Study Name | Location ID | Study Specific Location ID | Field Collection End Date | Sample Matrix | Result Parameter Name | Result Value | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S1 | DMMP-SKYLM-AF-0274-S1 | 4/13/2009 | Sediment | Zinc | 47 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S1 | DMMP-SKYLM-AF-0274-S1 | 4/13/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S1 | DMMP-SKYLM-AF-0274-S1 | 4/13/2009 | Sediment | Copper | 15.1 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C9 | DMMP-SKYLM-AF-0274-C9 | 4/13/2009 | Sediment | Lead | 7 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C9 | DMMP-SKYLM-AF-0274-C9 | 4/13/2009 | Sediment | Copper | 33.4 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C9 | DMMP-SKYLM-AF-0274-C9 | 4/13/2009 | Sediment | Zinc | 54 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S2 | DMMP-SKYLM-AF-0274-S2 | 4/14/2009 | Sediment | Copper | 12.2 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S2 | DMMP-SKYLM-AF-0274-S2 | 4/14/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S2 | DMMP-SKYLM-AF-0274-S2 | 4/14/2009 | Sediment | Zinc | 42 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S4 | DMMP-SKYLM-AF-0274-S4 | 4/14/2009 | Sediment | Copper | 12.1 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S4 | DMMP-SKYLM-AF-0274-S4 | 4/14/2009 | Sediment | Zinc | 32 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S4 | DMMP-SKYLM-AF-0274-S4 | 4/14/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C7 | DMMP-SKYLM-AF-0274-C7 | 4/14/2009 | Sediment | Zinc | 37 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C7 | DMMP-SKYLM-AF-0274-C7 | 4/14/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C7 | DMMP-SKYLM-AF-0274-C7 | 4/14/2009 | Sediment | Copper | 12.7 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C3 | DMMP-SKYLM-AF-0274-C3 | 4/14/2009 | Sediment | Zinc | 60 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C3 | DMMP-SKYLM-AF-0274-C3 | 4/14/2009 | Sediment | Lead | 5 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C3 | DMMP-SKYLM-AF-0274-C3 | 4/14/2009 | Sediment | Copper | 19 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C6 | DMMP-SKYLM-AF-0274-C6 | 4/14/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C6 | DMMP-SKYLM-AF-0274-C6 | 4/14/2009 | Sediment | Copper | 17.7 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C6 | DMMP-SKYLM-AF-0274-C6 | 4/14/2009 | Sediment | Zinc | 46 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C2 | DMMP-SKYLM-AF-0274-C2 | 4/14/2009 | Sediment | Zinc | 13 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C2 | DMMP-SKYLM-AF-0274-C2 | 4/14/2009 | Sediment | Copper | 3.6 | mg/Kg | inside | Kendall et al., 2009 |

| Study Name | Location ID | Study Specific Location ID | Field Collection End Date | Sample Matrix | Result Parameter Name | Result Value | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C2 | DMMP-SKYLM-AF-0274-C2 | 4/14/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C1 | DMMP-SKYLM-AF-0274-C1 | 4/14/2009 | Sediment | Lead | 4 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C1 | DMMP-SKYLM-AF-0274-C1 | 4/14/2009 | Sediment | Copper | 14 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C1 | DMMP-SKYLM-AF-0274-C1 | 4/14/2009 | Sediment | Zinc | 52 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S3 | DMMP-SKYLM-AF-0274-S3 | 4/15/2009 | Sediment | Lead | 2 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S3 | DMMP-SKYLM-AF-0274-S3 | 4/15/2009 | Sediment | Zinc | 43 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-S3 | DMMP-SKYLM-AF-0274-S3 | 4/15/2009 | Sediment | Copper | 13.8 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C4 | DMMP-SKYLM-AF-0274-C4 | 4/15/2009 | Sediment | Zinc | 43 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C4 | DMMP-SKYLM-AF-0274-C4 | 4/15/2009 | Sediment | Copper | 13.3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C4 | DMMP-SKYLM-AF-0274-C4 | 4/15/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C8 | DMMP-SKYLM-AF-0274-C8 | 4/15/2009 | Sediment | Zinc | 36 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C8 | DMMP-SKYLM-AF-0274-C8 | 4/15/2009 | Sediment | Lead | 3 | mg/Kg | inside | Kendall et al., 2009 |
| Skyline Marina Maintenance Dredging, Anacortes, DY10 | SKYLM0274-C8 | DMMP-SKYLM-AF-0274-C8 | 4/15/2009 | Sediment | Copper | 10.5 | mg/Kg | inside | Kendall et al., 2009 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/5/2007 | Water | Copper | 1.65 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/5/2007 | Water | Copper | 1.84 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-inner | Skyline-inner | 3/5/2007 | Water | Copper | 6.66 | ug/L | inside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/5/2007 | Water | Copper | 0.35 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/5/2007 | Water | Copper | 0.38 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-inner | Skyline-inner | 3/6/2007 | Water | Copper | 6.26 | ug/L | inside | Johnson, 2007 |
| Marina Copper Study | Skyline-inner | Skyline-inner | 3/6/2007 | Water | Copper | 6.65 | ug/L | inside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/6/2007 | Water | Copper | 1.46 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/6/2007 | Water | Copper | 1.59 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/6/2007 | Water | Copper | 1.54 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/6/2007 | Water | Copper | 0.46 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/6/2007 | Water | Copper | 0.47 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-inner | Skyline-inner | 3/7/2007 | Water | Copper | 4.71 | ug/L | inside | Johnson, 2007 |

| Study Name | Location ID | Study Specific Location ID | Field Collection End Date | Sample Matrix | Result Parameter Name | Result Value | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/7/2007 | Water | Copper | 2.69 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/7/2007 | Water | Copper | 2.48 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/7/2007 | Water | Copper | 0.35 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 3/7/2007 | Water | Copper | 0.35 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/14/2006 | Water | Copper | 2.76 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/14/2006 | Water | Copper | 2.65 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-inner | Skyline-inner | 8/14/2006 | Water | Copper | 7.15 | ug/L | inside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/14/2006 | Water | Copper | 0.32 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/14/2006 | Water | Copper | 0.39 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 0.3 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 0.3 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 0.29 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 1.08 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 1.19 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-inner | Skyline-inner | 8/15/2006 | Water | Copper | 4.82 | ug/L | inside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 1.89 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 0.28 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/15/2006 | Water | Copper | 0.31 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-inner | Skyline-inner | 8/16/2006 | Water | Copper | 6.19 | ug/L | inside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/16/2006 | Water | Copper | 1.62 | ug/L | outside | Johnson, 2007 |
| Marina Copper Study | Skyline-outer | Skyline-outer | 8/16/2006 | Water | Copper | 0.38 | ug/L | outside | Johnson, 2007 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | Copper | 22 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | Copper | 25 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | Copper | 25 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | Copper | 52 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | Copper | 52 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | Copper | 44 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | Copper | 24 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | Copper | 25 | mg/Kg | inside | Cardwell et al., 1980 |

| Study Name | Location ID | Study Specific Location ID | Field Collection End Date | Sample Matrix | Result Parameter Name | Result Value | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | Copper | 25 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | zinc | 78 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | zinc | 79 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | zinc | 77 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | zinc | 77 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | zinc | 103 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | zinc | 92 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | zinc | 76 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | zinc | 82 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | zinc | 88 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | lead | 25 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | lead | 35 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | sediment | lead | 30 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | lead | 22 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | lead | 32 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | sediment | lead | 24 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | lead | 19 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | lead | 17 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 7/10/1978 | sediment | lead | 42 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 7/10/1978 | sediment | Copper | 30 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 7/10/1978 | sediment | Copper | 41 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | Copper | 27 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | Copper | 26 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | Copper | 24 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | Copper | 42 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | Copper | 41 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | Copper | 43 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 7/10/1978 | sediment | zinc | 66 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 7/10/1978 | sediment | zinc | 85 | mg/Kg | outside | Cardwell et al., 1980 |

| Study Name | Location ID | Study Specific Location ID | Field Collection End Date | Sample Matrix | Result Parameter Name | Result Value | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | zinc | 78 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | zinc | 77 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | zinc | 78 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | zinc | 65 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | zinc | 79 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | zinc | 78 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 7/10/1978 | sediment | lead | 28 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 7/10/1978 | sediment | lead | 24 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | lead | 62 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | lead | 63 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 10/24/1978 | sediment | lead | 75 | mg/Kg | inside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | lead | 223 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | lead | 244 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04105 | 10/24/1978 | sediment | lead | 99 | mg/Kg | outside | Cardwell et al., 1980 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | tissue | Copper | 17.4 | mg/Kg | inside | Cardwell et al., 1981 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | tissue | zinc | 225 | mg/Kg | inside | Cardwell et al., 1982 |
| Skyline Marina Characteristics | - | 04100 | 4/17/1978 | tissue | lead | 0.19 | mg/Kg | inside | Cardwell et al., 1983 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | tissue | Copper | 10.5 | mg/Kg | outside | Cardwell et al., 1984 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | tissue | zinc | 200 | mg/Kg | outside | Cardwell et al., 1985 |
| Skyline Marina Characteristics | - | 04105 | 4/17/1978 | tissue | lead | 0.09 | mg/Kg | outside | Cardwell et al., 1986 |
| Skyline Marina Characteristics | - | 04100 | 8/11/1978 | tissue | Copper | 23.3 | mg/Kg | inside | Cardwell et al., 1987 |
| Skyline Marina Characteristics | - | 04100 | 8/11/1978 | tissue | zinc | 387 | mg/Kg | inside | Cardwell et al., 1988 |
| Skyline Marina Characteristics | - | 04100 | 8/11/1978 | tissue | lead | 0.4 | mg/Kg | inside | Cardwell et al., 1989 |
| Skyline Marina Characteristics | - | 04108 | 8/11/1978 | tissue | Copper | 8.1 | mg/Kg | outside | Cardwell et al., 1990 |
| Skyline Marina Characteristics | - | 04108 | 8/11/1978 | tissue | zinc | 244 | mg/Kg | outside | Cardwell et al., 1991 |
| Skyline Marina Characteristics | - | 04108 | 8/11/1978 | tissue | lead | 0.2 | mg/Kg | outside | Cardwell et al., 1992 |
| Skyline Marina Characteristics | - | 04100 | 10/23/1978 | tissue | Copper | 44.6 | mg/Kg | inside | Cardwell et al., 1993 |
| Skyline Marina Characteristics | - | 04100 | 10/23/1978 | tissue | zinc | 438 | mg/Kg | inside | Cardwell et al., 1994 |
| Skyline Marina Characteristics | - | 04100 | 10/23/1978 | tissue | lead | 0.2 | mg/Kg | inside | Cardwell et al., 1995 |

| Study Name | Location ID | Study Specific Location ID | Field Collection End Date | Sample Matrix | Result Parameter Name | Result Value | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|---|
| Skyline Marina Characteristics | - | 04108 | 10/23/1978 | tissue | Copper | 8.3 | mg/Kg | outside | Cardwell et al., 1996 |
| Skyline Marina Characteristics | - | 04108 | 10/23/1978 | tissue | zinc | 1914 | mg/Kg | outside | Cardwell et al., 1997 |
| Skyline Marina Characteristics | - | 04108 | 10/23/1978 | tissue | lead | 0.17 | mg/Kg | outside | Cardwell et al., 1998 |

## Table C-3. Previous results from John Wayne Marina, Sequim Bay.

| Study ID | Location Name | Field Collection End Date | Sample ID | Sample Matrix | Result Parameter Name | Result Value | Result Value Units | Inside-Outside | References |
|---|---|---|---|---|---|---|---|---|---|
| EIGHTBAY | EIGHTBAY | 9/17/1983 | SQ12 | Solid/Sediment | Lead | 4.1 | ppm | inside | Strand et al., 1988 |
| NCCA | WA04-0023 | 9/18/2006 | 5184310 | Tissue (whole) | Lead | 0.019 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | 5184310 | Tissue | Zinc | 20 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | 5184310 | Tissue | Copper | 1.9 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | 5184311 | Tissue (fillet) | Copper | 0.62 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | 5184311 | Tissue | Zinc | 0.24 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | 5184311 | Tissue | Lead | 0.019 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | Lab ID 4322123 | Solid/Sediment | Copper | 9.59 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | Lab ID 4322123 | Solid/Sediment | Lead | 5.97 | ug/g | outside | EPA, 2012 |
| NCCA | WA04-0023 | 9/18/2006 | Lab ID 4322123 | Solid/Sediment | Zinc | 36 | ug/g | outside | EPA, 2012 |

## Table C-4. Previous results from City of Des Moines Marina, Central Puget Sound.

| Location ID | Location Name | Field Collection End Date | Sample Matrix | Result Parameter Name | Result | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|
| DNREC92DESM01XX | DNRREC92 | 1/20/1992 | sediment | Zinc | 27 | ppm | outside | WA DNR, 1992 |
| DNREC92DESM01XX | DNRREC92 | 1/20/1992 | sediment | Lead | 6 | ppm | outside | WA DNR, 1992 |
| DNREC92DESM01XX | DNRREC92 | 1/20/1992 | sediment | Copper | 5.3 | ppm | outside | WA DNR, 1992 |
| DNREC92DESM02XX | DNRREC92 | 1/21/1992 | sediment | Zinc | 22 | ppm | outside | WA DNR, 1992 |
| DNREC92DESM02XX | DNRREC92 | 1/21/1992 | sediment | Copper | 4.6 | ppm | outside | WA DNR, 1992 |
| DNREC92DESM02XX | DNRREC92 | 1/21/1992 | sediment | Lead | 8 | ppm | outside | WA DNR, 1992 |
| MIDWAY951-107 | MIDWAY95 | 4/3/1995 | sediment | Lead | 7.2 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-107 | MIDWAY95 | 4/3/1995 | sediment | Copper | 5.2 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-107 | MIDWAY95 | 4/3/1995 | sediment | Zinc | 30.5 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-103 | MIDWAY95 | 4/5/1995 | sediment | Copper | 4.8 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-103 | MIDWAY95 | 4/5/1995 | sediment | Zinc | 29.2 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-103 | MIDWAY95 | 4/5/1995 | sediment | Lead | 8.6 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-104 | MIDWAY95 | 4/5/1995 | sediment | Zinc | 29.6 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-104 | MIDWAY95 | 4/5/1995 | sediment | Lead | 9.4 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-104 | MIDWAY95 | 4/5/1995 | sediment | Copper | 5.3 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-109 | MIDWAY95 | 4/5/1995 | sediment | Lead | 9.2 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-109 | MIDWAY95 | 4/5/1995 | sediment | Zinc | 29.5 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-109 | MIDWAY95 | 4/5/1995 | sediment | Copper | 5.1 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-110 | MIDWAY95 | 4/5/1995 | sediment | Copper | 4.8 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-110 | MIDWAY95 | 4/5/1995 | sediment | Zinc | 29.6 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-110 | MIDWAY95 | 4/5/1995 | sediment | Lead | 8.7 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-106 | MIDWAY95 | 4/6/1995 | sediment | Copper | 5.6 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-106 | MIDWAY95 | 4/6/1995 | sediment | Lead | 7.5 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-106 | MIDWAY95 | 4/6/1995 | sediment | Zinc | 29.2 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-105 | MIDWAY95 | 4/6/1995 | sediment | Copper | 7.1 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-105 | MIDWAY95 | 4/6/1995 | sediment | Zinc | 35.8 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-105 | MIDWAY95 | 4/6/1995 | sediment | Lead | 8 | ppm | outside | Midway Sewer District, 2005 |

| Location ID | Location Name | Field Collection End Date | Sample Matrix | Result Parameter Name | Result | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|
| MIDWAY951-108 | MIDWAY95 | 4/6/1995 | sediment | Zinc | 28.6 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-108 | MIDWAY95 | 4/6/1995 | sediment | Copper | 5.2 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY951-108 | MIDWAY95 | 4/6/1995 | sediment | Lead | 7.4 | ppm | outside | Midway Sewer District, 2005 |
| MIDWAY06MSD-110 | MIDWAY06 | 6/28/2006 | sediment | Copper | 5.9 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-110 | MIDWAY06 | 6/28/2006 | sediment | Lead | 7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-110 | MIDWAY06 | 6/28/2006 | sediment | Zinc | 28.8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-104 | MIDWAY06 | 6/28/2006 | sediment | Zinc | 29.7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-104 | MIDWAY06 | 6/28/2006 | sediment | Lead | 8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-104 | MIDWAY06 | 6/28/2006 | sediment | Copper | 6.4 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-251 | MIDWAY06 | 6/28/2006 | sediment | Lead | 7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-251 | MIDWAY06 | 6/28/2006 | sediment | Copper | 5.7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-251 | MIDWAY06 | 6/28/2006 | sediment | Zinc | 23.4 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-103 | MIDWAY06 | 6/28/2006 | sediment | Lead | 7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-103 | MIDWAY06 | 6/28/2006 | sediment | Copper | 6.3 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-103 | MIDWAY06 | 6/28/2006 | sediment | Zinc | 28.8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-103 | MIDWAY06 | 6/28/2006 | sediment | Copper | 6.5 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-103 | MIDWAY06 | 6/28/2006 | sediment | Zinc | 29.6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-103 | MIDWAY06 | 6/28/2006 | sediment | Lead | 7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-252 | MIDWAY06 | 6/28/2006 | sediment | Lead | 5 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-252 | MIDWAY06 | 6/28/2006 | sediment | Copper | 4.9 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-252 | MIDWAY06 | 6/28/2006 | sediment | Zinc | 21.1 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-107 | MIDWAY06 | 6/29/2006 | sediment | Copper | 6.3 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-107 | MIDWAY06 | 6/29/2006 | sediment | Lead | 8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-107 | MIDWAY06 | 6/29/2006 | sediment | Zinc | 30.4 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-109 | MIDWAY06 | 6/29/2006 | sediment | Zinc | 34.5 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-109 | MIDWAY06 | 6/29/2006 | sediment | Copper | 6.8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-109 | MIDWAY06 | 6/29/2006 | sediment | Lead | 8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-106 | MIDWAY06 | 6/30/2006 | sediment | Zinc | 30.3 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-106 | MIDWAY06 | 6/30/2006 | sediment | Copper | 6.3 | ppm | outside | Midway Sewer District, 2010 |

| Location ID | Location Name | Field Collection End Date | Sample Matrix | Result Parameter Name | Result | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|
| MIDWAY06MSD-106 | MIDWAY06 | 6/30/2006 | sediment | Lead | 7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-108 | MIDWAY06 | 6/30/2006 | sediment | Lead | 5 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-108 | MIDWAY06 | 6/30/2006 | sediment | Zinc | 32 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-108 | MIDWAY06 | 6/30/2006 | sediment | Copper | 7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-200 | MIDWAY06 | 6/30/2006 | sediment | Lead | 8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-200 | MIDWAY06 | 6/30/2006 | sediment | Copper | 6.5 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-200 | MIDWAY06 | 6/30/2006 | sediment | Zinc | 30.4 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-105 | MIDWAY06 | 6/30/2006 | sediment | Lead | 8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-105 | MIDWAY06 | 6/30/2006 | sediment | Zinc | 33.3 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY06MSD-105 | MIDWAY06 | 6/30/2006 | sediment | Copper | 7.7 | ppm | outside | Midway Sewer District, 2010 |
| DMOINS931 | DMOINS93 | 9/28/1993 | sediment | Copper | 11 | ppm | outside | |
| DMOINS931 | DMOINS93 | 9/28/1993 | sediment | Zinc | 57 | ppm | outside | |
| DMOINS931 | DMOINS93 | 9/28/1993 | sediment | Lead | 33 | ppm | outside | |
| DMOINS931 | DMOINS93 | 9/28/1993 | sediment | Copper | 11 | ppm | outside | |
| DMOINS931 | DMOINS93 | 9/28/1993 | sediment | Lead | 32 | ppm | outside | |
| DMOINS931 | DMOINS93 | 9/28/1993 | sediment | Zinc | 58 | ppm | outside | |
| DMOINS933 | DMOINS93 | 9/29/1993 | sediment | Copper | 26 | ppm | outside | |
| DMOINS933 | DMOINS93 | 9/29/1993 | sediment | Lead | 34 | ppm | outside | |
| DMOINS933 | DMOINS93 | 9/29/1993 | sediment | Zinc | 69 | ppm | outside | |
| MIDWAY07MSD-105 | MIDWAY07 | 10/16/2007 | sediment | Lead | 5 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-105 | MIDWAY07 | 10/16/2007 | sediment | Zinc | 28 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-105 | MIDWAY07 | 10/16/2007 | sediment | Copper | 9 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-106 | MIDWAY07 | 10/16/2007 | sediment | Copper | 5.4 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-106 | MIDWAY07 | 10/16/2007 | sediment | Lead | 6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-106 | MIDWAY07 | 10/16/2007 | sediment | Zinc | 28 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-109 | MIDWAY07 | 10/16/2007 | sediment | Lead | 6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-109 | MIDWAY07 | 10/16/2007 | sediment | Copper | 5.8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-109 | MIDWAY07 | 10/16/2007 | sediment | Zinc | 29 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-202 | MIDWAY07 | 10/17/2007 | sediment | Copper | 6.9 | ppm | outside | Midway Sewer District, 2010 |

| Location ID | Location Name | Field Collection End Date | Sample Matrix | Result Parameter Name | Result | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|
| MIDWAY07MSD-202 | MIDWAY07 | 10/17/2007 | sediment | Lead | 5 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-202 | MIDWAY07 | 10/17/2007 | sediment | Zinc | 31 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-108 | MIDWAY07 | 10/17/2007 | sediment | Lead | 6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-108 | MIDWAY07 | 10/17/2007 | sediment | Copper | 5.7 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-108 | MIDWAY07 | 10/17/2007 | sediment | Zinc | 89 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-108 | MIDWAY07 | 10/17/2007 | sediment | Zinc | 26 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-108 | MIDWAY07 | 10/17/2007 | sediment | Lead | 8 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-108 | MIDWAY07 | 10/17/2007 | sediment | Copper | 5.4 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-107 | MIDWAY07 | 10/17/2007 | sediment | Lead | 6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-107 | MIDWAY07 | 10/17/2007 | sediment | Zinc | 25 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-107 | MIDWAY07 | 10/17/2007 | sediment | Copper | 5.1 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-201 | MIDWAY07 | 10/23/2007 | sediment | Lead | 6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-201 | MIDWAY07 | 10/23/2007 | sediment | Copper | 5.3 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-201 | MIDWAY07 | 10/23/2007 | sediment | Zinc | 26 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-203 | MIDWAY07 | 10/23/2007 | sediment | Zinc | 26 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-203 | MIDWAY07 | 10/23/2007 | sediment | Lead | 6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-203 | MIDWAY07 | 10/23/2007 | sediment | Copper | 5.1 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-204 | MIDWAY07 | 10/23/2007 | sediment | Zinc | 27 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-204 | MIDWAY07 | 10/23/2007 | sediment | Lead | 6 | ppm | outside | Midway Sewer District, 2010 |
| MIDWAY07MSD-204 | MIDWAY07 | 10/23/2007 | sediment | Copper | 5.1 | ppm | outside | Midway Sewer District, 2010 |
| DESMM0277-C2 | DMMP-DESMM-BF-0277-C2 | 9/11/2007 | sediment | Zinc | 109 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C2 | DMMP-DESMM-BF-0277-C2 | 9/11/2007 | sediment | Lead | 108 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C2 | DMMP-DESMM-BF-0277-C2 | 9/11/2007 | sediment | Copper | 48.8 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C1 | DMMP-DESMM-BF-0277-C1 | 9/11/2007 | sediment | Copper | 13.1 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C1 | DMMP-DESMM-BF-0277-C1 | 9/11/2007 | sediment | Zinc | 44 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C1 | DMMP-DESMM-BF-0277-C1 | 9/11/2007 | sediment | Zinc | 45 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C1 | DMMP-DESMM-BF-0277-C1 | 9/11/2007 | sediment | Copper | 12.4 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C1 | DMMP-DESMM-BF-0277-C1 | 9/11/2007 | sediment | Lead | 8 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-C1 | DMMP-DESMM-BF-0277-C1 | 9/11/2007 | sediment | Lead | 9 | mg/Kg | inside | Anchor Environmental, 2007 |

| Location ID | Location Name | Field Collection End Date | Sample Matrix | Result Parameter Name | Result | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|
| DESMM0277-S1 | DMMP-DESMM-BF-0277-S1 | 9/11/2007 | sediment | Lead | 4 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-S1 | DMMP-DESMM-BF-0277-S1 | 9/11/2007 | sediment | Copper | 18 | mg/Kg | inside | Anchor Environmental, 2007 |
| DESMM0277-S1 | DMMP-DESMM-BF-0277-S1 | 9/11/2007 | sediment | Zinc | 39 | mg/Kg | inside | Anchor Environmental, 2007 |
| PSAMP/NOAA-141 | EAST PASSAGE | 6/1/1998 | sediment | Zinc | 43.6 | mg/Kg | outside | Dutch et al., 2009 |
| PSAMP/NOAA-141 | EAST PASSAGE | 6/1/1998 | sediment | Copper | 18.2 | mg/Kg | outside | Dutch et al., 2009 |
| PSAMP/NOAA-141 | EAST PASSAGE | 6/1/1998 | sediment | Lead | 15.5 | mg/Kg | outside | Dutch et al., 2009 |
| PSAMP/NOAA-141 | EAST PASSAGE | 6/1/1998 | sediment | Lead | 18.2 | mg/Kg | outside | Dutch et al., 2009 |
| PSAMP/NOAA-141 | EAST PASSAGE | 6/1/1998 | sediment | Copper | 20.6 | mg/Kg | outside | Dutch et al., 2009 |
| PSAMP/NOAA-141 | EAST PASSAGE | 6/1/1998 | sediment | Zinc | 72.6 | mg/Kg | outside | Dutch et al., 2009 |
| CPS_DM | Des Moines Marina City Bch Pk | 1/9/2013 | Tissue | Copper | 0.953 | ug/g | outside | Lanksbury et al., 2014 |
| CPS_DM | Des Moines Marina City Bch Pk | 1/9/2013 | Tissue | Lead | 0.0456 | ug/g | outside | Lanksbury et al., 2014 |
| CPS_DM | Des Moines Marina City Bch Pk | 1/9/2013 | Tissue | Zinc | 14.2 | ug/g | outside | Lanksbury et al., 2014 |

## Table C-5. Previous results from City of Des Moines Marina, Central Puget Sound.

| Location ID | Location Name | Field Collection End Date | Sample Matrix | Result Parameter Name | Result | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|
| BUDD07 | BI-C10-0-10cm SBI, EB | 4/13/2007 | Solid/Sediment | Copper | 65.2 | mg/Kg | inside | SAIC, 2008 |
| BUDD07 | BI-C10-0-10cm SBI, EB | 4/13/2007 | Solid/Sediment | Zinc | 88.7 | mg/Kg | inside | SAIC, 2008 |
| BUDD07 | BI-C10-0-10cm SBI, EB | 4/13/2007 | Solid/Sediment | Lead | 26 | mg/Kg | inside | SAIC, 2008 |
| BUDD07 | BI-S9-0-10cm SBI, EB | 4/13/2007 | Solid/Sediment | Lead | 17.4 | mg/Kg | inside | SAIC, 2008 |
| BUDD07 | BI-S9-0-10cm SBI, EB | 4/13/2007 | Solid/Sediment | Zinc | 52.1 | mg/Kg | inside | SAIC, 2008 |
| BUDD07 | BI-S9-0-10cm SBI, EB | 4/13/2007 | Solid/Sediment | Copper | 27.7 | mg/Kg | inside | SAIC, 2008 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Zinc | 134 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Copper | 103 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Copper | 82.4 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Lead | 34.8 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Zinc | 104 | mg/Kg | inside | Dutch et al., 2009 |

| Location ID | Location Name | Field Collection End Date | Sample Matrix | Result Parameter Name | Result | Units | Inside-Outside | Reference |
|---|---|---|---|---|---|---|---|---|
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Copper | 77.3 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Copper | 78.7 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Zinc | 101 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Lead | 31.3 | mg/Kg | inside | Dutch et al., 2009 |
| PSAMPNOA | East Bay-UWNO242 | 6/8/1999 | Solid/Sediment | Lead | 32.1 | mg/Kg | inside | Dutch et al., 2009 |
| UWI2011 | East Bay-UWNO242 | 6/1/2011 | Solid/Sediment | Lead | 26.1 | mg/Kg | inside | Partridge et al., 2014 |
| UWI2011 | East Bay-UWNO242 | 6/1/2011 | Solid/Sediment | Zinc | 117 | mg/Kg | inside | Partridge et al., 2014 |
| UWI2011 | East Bay-UWNO242 | 6/1/2011 | Solid/Sediment | Copper | 86.9 | mg/Kg | inside | Partridge et al., 2014 |
| UWI2011 | East Bay-UWNO242 | 6/1/2011 | Solid/Sediment | Copper | 86.9 | mg/Kg | inside | Partridge et al., 2014 |
| UWI2011 | East Bay-UWNO242 | 6/1/2011 | Solid/Sediment | Lead | 26.1 | mg/Kg | inside | Partridge et al., 2014 |
| UWI2011 | East Bay-UWNO242 | 6/1/2011 | Solid/Sediment | Zinc | 117 | mg/Kg | inside | Partridge et al., 2014 |
| EMAP_1999-2002 | WA00-0033 | 7/21/2000 | Tissue | Zinc | 16.9 | ug/g | inside | EPA, 2012 |
| EMAP_1999-2002 | WA00-0033 | 7/21/2000 | Tissue | Copper | 2.6 | ug/g | inside | EPA, 2012 |
| EMAP_1999-2002 | WA00-0033 | 7/21/2000 | Tissue | Lead | 0.18 | ug/g | inside | EPA, 2012 |
| EMAP_1999-2002 | WA00-0033 | 7/21/2000 | Solid/Sediment | Zinc | 147 | ug/g | inside | EPA, 2012 |
| EMAP_1999-2002 | WA00-0033 | 7/21/2000 | Solid/Sediment | Copper | 40.975 | ug/g | inside | EPA, 2012 |
| EMAP_1999-2002 | WA00-0033 | 7/21/2000 | Solid/Sediment | Lead | 51.3 | ug/g | inside | EPA, 2012 |
| CASCADRI | CASCADRI | 12/6/1990 | Solid/Sediment | Zinc | 88 | ppm | outside | summarized in SAIC, 2007 |
| CASCADRI | CASCADRI | 12/6/1990 | Solid/Sediment | Copper | 55 | ppm | outside | summarized in SAIC, 2007 |
| CASCADRI | CASCADRI | 12/6/1990 | Solid/Sediment | Lead | 18 | ppm | outside | summarized in SAIC, 2007 |
| CASCADRI | CASCADRI | 12/6/1990 | Solid/Sediment | Zinc | 96 | ppm | outside | summarized in SAIC, 2007 |
| CASCADRI | CASCADRI | 12/6/1990 | Solid/Sediment | Lead | 18 | ppm | outside | summarized in SAIC, 2007 |
| CASCADRI | CASCADRI | 12/6/1990 | Solid/Sediment | Copper | 65 | ppm | outside | summarized in SAIC, 2007 |

# Appendix D. Field sheet for Mussel Watch

**Washington State 2015/16 RSMP**
**Mussel Monitoring Site Datasheet**

| DEPLOYMENT INFORMATION | | | | |
|---|---|---|---|---|
| Site ID: | Site Name: | | | |
| Bag numbers: | | | | |
| Deployer name(s): | | | | |
| Recorder name: | | | | |
| Deployment date: | Time cage anchored: | | | |
| Cage GPS location (decimal degrees) | Latitude: | Longitude: | Accuracy (± XX feet): | |
| GPS make/model or app name: (must be set to datum NAD83) | | | | |
| Anchors - type/number used: | | | | |

**WATER & WEATHER CONDITIONS (at cage)**

**Sea conditions:** Wave energy: ☐ Flat; ☐ Calm; ☐ Wind chop; ☐ Swells; ☐ Breaking waves
Beach exposure level: ☐ Exposed; ☐ Moderately exposed; ☐ Sheltered

**Time of most recent LOW tide:** | **Height of most recent LOW tide (feet):**

**Precipitation:** ☐ None; ☐ Steady rain; ☐ Showers; ☐ Snow; ☐ Hail

**HABITAT (within 200 foot radius of cage)**

**Substrate type** – select ONE category that describes the majority (at least 50%) of substrate around cage:

| Bedrock, hardpan ☐ | Cobble-gravel mix ☐ | Sand-gravel mix ☐ | Sand ☐ | Sand-mud mix ☐ | Mud, silt ☐ |
|---|---|---|---|---|---|

**Aquatic vegetation coverage** – percent substrate around cage covered by seagrasses and/or algae:

| None (<1%) ☐ | 1 - 20% ☐ | 20 - 40% ☐ | 40 - 60% ☐ | 60 - 80% ☐ | 80 - 100% ☐ |
|---|---|---|---|---|---|

**Type of aquatic vegetation present:** ☐ None; ☐ Eelgrass; ☐ Kelps; ☐ Fucus; ☐ Ulva; ☐ Other

Natural streams/rivers present: ☐ No; ☐ Yes; Natural spring/freshwater seep: ☐ No; ☐ Yes

Other habitat comments/observations:

**ANTHROPOGENIC STRUCTURES ALONG SHORELINE**
**visible from cage up to 400 m (1300 feet, ¼ mile) along either side of beach**

Adjacent upland use (check all that apply):
☐ Agricultural; ☐ Commercial; ☐ Industrial; ☐ Major road/highway; ☐ Park; ☐ Public access;
☐ Rural residential; ☐ Undeveloped; ☐ Urban residential; ☐ Other ______________

Erosion control structures (i.e. armoring of shoreline): ☐ None;
☐ Hard (bulkhead, riprap, etc.) - _______% shoreline armored; Materials used: ______________
☐ Soft (plantings, large woody debris, etc.) - _________% shoreline armored (↑ creosote in armoring?)

Abandoned or derelict structures (includes old pilings, docks, half-sunken boats, metal pieces, etc.)
☐ No; ☐ Yes, type/makeup:

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**Washington State 2015/16 RSMP**
**Mussel Monitoring Site Datasheet**

Current shoreline use (check all that apply): ☐ Boat ramp/launch; ☐ Boathouse/shed; ☐ Bridge; ☐ Breakwater; ☐ Dock/pier/wharf; ☐ Floating home; ☐ Marina; ☐ Mooring buoy; ☐ Outfall; ☐ Piling/dolphin; ☐ Raft/float; ☐ Road; ☐ Shipyard or terminal; ☐ Utilities; ☐ Other: ______________

Dock/pier/wharf material: ☐ Creosote ☐ Other treated wood; ☐ Concrete; ☐ Steel; ☐ Other:

Piling/dolphin material: ☐ Creosote ☐ Other treated wood; ☐ Concrete; ☐ Steel; ☐ Other:

Tires present: ☐ No; ☐ Yes - Estimated Number: Used for:

Outfall (pipe, culvert, point of flow onto beach): Size: ____________ (i.e. mouth diameter);
Type: Condition:

Outfall (pipe, culvert, point of flow onto beach): Size: ____________ (i.e. mouth diameter);
Type: Condition:

Outfall (pipe, culvert, point of flow onto beach): Size: ____________ (i.e. mouth diameter);
Type: Condition:

Other obvious sources of pollution (oil slicks, seeps, etc.):

Additional comments/observations (it's a good idea to note landmarks that will help you find the cage later!):

**TAKE PHOTOS of the deployed cage and surrounding substrate, including any interesting observations!**

| RETRIEVAL INFORMATION (TAKE PHOTO of the mussel cage BEFORE removal, to document condition of cage.) | | | | |
|---|---|---|---|---|
| Site ID: | Site Name: | | | |
| Bag numbers: | | | | |
| Retriever name(s): | | | | |
| Recorder name: | | | | |
| Retrieval date: | Time cage removed: | | | |
| Cage GPS location (decimal degrees) | Latitude: | Longitude: | Accuracy (± XX feet): | |
| GPS make/model or app name: (must be set to datum NAD83) | | | | |
| ANY NEW obvious sources of pollution (oil slicks, seeps, etc.)? | | | | |
| Additional comments/observations (including condition of CAGE on retrieval, major changes in habitat or structures around cage): | | | | |

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# Appendix E. Glossaries, acronyms, and abbreviations

## Glossary of general terms

**Clean Water Act:** A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

**Conductivity:** A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

**National Pollutant Discharge Elimination System (NPDES):** National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

**Sediment:** Soil and organic matter that is covered with water (for example, river or lake bottom).

**Turbidity:** A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

**Watershed:** A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

**303(d) list:** Section 303(d) of the federal Clean Water Act, requiring Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

## Acronyms and abbreviations

| | |
|---|---|
| Ecology | Washington State Department of Ecology |
| e.g. | For example |
| EIM | Environmental Information Management database |
| EPA | U.S. Environmental Protection Agency |
| et al. | And others |
| i.e. | In other words |
| MEL | Manchester Environmental Laboratory |
| MQO | Measurement quality objective |
| NPDES | (See Glossary above) |
| QA | Quality assurance |
| RPD | Relative percent difference |
| SOP | Standard operating procedures |
| WAC | Washington Administrative Code |

| | |
|---|---|
| WDFW | Washington Department of Fish and Wildlife |
| WRIA | Water Resource Inventory Area |

*Units of Measurement*

| | |
|---|---|
| dw | dry weight |
| g | gram, a unit of mass |
| kg | kilograms, a unit of mass equal to 1,000 grams |
| mg/Kg | milligrams per kilogram (parts per million) |
| mg/L | milligrams per liter (parts per million) |
| ng/L | nanograms per liter (parts per trillion) |
| ug/g | micrograms per gram (parts per million) |
| uS/cm | microsiemens per centimeter, a unit of conductivity |
| ww | wet weight |

## Quality assurance glossary

**Accreditation:** A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

**Accuracy:** The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

**Analyte:** An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

**Bias:** The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

**Blank:** A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

**Calibration:** The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

**Check standard:** A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

**Comparability:** The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

**Completeness:** The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

**Continuing Calibration Verification Standard (CCV):** A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

**Control chart:** A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

**Control limits:** Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

**Data Integrity:** A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

**Data Quality Indicators (DQI):** Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

**Data Quality Objectives (DQO):** Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
(USEPA, 2006)

**Data set:** A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

**Data validation:** An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004).

**Data verification:** Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

**Detection limit** (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

**Duplicate samples:** Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

**Field blank:** A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

**Initial Calibration Verification Standard (ICV):** A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

**Laboratory Control Sample (LCS):** A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

**Matrix spike:** A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

**Measurement Quality Objectives** (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

**Measurement result:** A value obtained by performing the procedure described in a method. (Ecology, 2004)

**Method:** A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

**Method blank:** A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

**Method Detection Limit (MDL):** This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

**Percent Relative Standard Deviation (%RSD):** A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

**Parameter:** A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

**Population:** The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

**Precision:** The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

**Quality Assurance (QA):** A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

**Quality Assurance Project Plan (QAPP):** A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

**Quality Control (QC):** The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

**Relative Percent Difference (RPD):** RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

**Replicate samples:** Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

**Representativeness:** The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

**Sample (field):** A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

**Sample (statistical):** A finite part or subset of a statistical population. (USEPA, 1997)

**Sensitivity:** In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

**Spiked blank:** A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

**Spiked sample:** A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

**Split sample:** A discrete sample that is further subdivided into portions, usually duplicates. (Kammin, 2010)

**Standard Operating Procedure (SOP):** A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

**Surrogate:** For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

**Systematic planning:** A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

## References for QA Glossary

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