CENWS-OD-TS-NR

MEMORANDUM FOR RECORD March 30, 2017

SUBJECT: DETERMINATION REGARDING THE SUITABILITY OF PROPOSED DREDGED MATERIAL FROM THE PORT OF EVERETT MARINA, EVALUATED UNDER SECTION 404 OF THE CLEAN WATER ACT, FOR PLACEMENT AT THE DREDGED MATERIAL MANAGEMENT PROGRAM'S UNCONFINED OPEN-WATER DISPOSAL SITE IN PORT GARDNER.

1. Introduction. This memorandum reflects the consensus determination of the Dredged Material Management Program (DMMP) agencies (U.S. Army Corps of Engineers, Environmental Protection Agency and the Washington Departments of Ecology and Natural Resources) regarding the suitability of 160,250 cubic yards (cy) of dredged material from the Port of Everett Marina for placement at the Port Gardner disposal site. The Everett Marina is located in Everett, Washington, adjacent to the Snohomish River (see Figure 1). This suitability determination pertains to proposed dredging in the basin containing the central and south docks of the marina.

2. Background. The Port of Everett proposed maintenance dredging in the basin containing the central and south docks in 2010. Eight dredged material management units (DMMUs) were characterized and all were found suitable for open-water disposal with regard to the standard DMMP chemicals of concern and tributyltin (DMMP, 2011). However, only DMMU 1 was found suitable for open-water disposal under the DMMP dioxin guidelines (DMMP, 2010). This DMMU was dredged and placed at the Port Gardner disposal site between December 2011 and February 2012. The remaining DMMUs had a volume-weighted average for dioxin that exceeded the DMMP site management objective of 4 nanograms/kilogram (ng/kg) toxic equivalents (TEQ). The Port of Everett requested that a suitability determination for DMMUs 2 to 8 be held in abeyance until the project could be re-evaluated, possibly with additional sediment testing. Figure 2 shows the DMMUs from 2010.

   In support of a potential redesign of the dredging project, the Port of Everett had Analytical Resources Incorporated (ARI) analyze individual cores and z-samples that had been archived following the 2010 sampling event. This testing was completed in March 2012. However, some of the archives from 2010 had already been discarded, so the Port recollected the missing cores and z-samples and had them analyzed for dioxin by ARI in August 2012. Data for the recollected samples were submitted to the DMMP agencies in February 2013. Dioxin data for the individual cores and z-samples are provided in Figure 3. Initial attempts to redesign the project DMMUs based on the individual core data were unsuccessful. These attempts included use of Thiessen polygons and modified Thiessen polygons that accounted for shoaling patterns and physical features in the marina. The goal was to identify additional areas that might qualify for open-water disposal based on existing data and areas that might be found suitable with more intensive sampling and testing.

   Contemporaneously to the DMMP characterization of proposed dredged material from the marina, a cleanup plan was under development for the former Everett Shipyard (ESY), located in the northeast corner of the marina (Figures 2 and 3). In June 2012, the Port of Everett submitted a

sampling and analysis plan (SAP) addendum to the DMMP agencies and Ecology's Toxics Cleanup Program (TCP) for a design-level sediment investigation at the ESY site (Landau, 2012). Data collected under the SAP addendum were to be used primarily by TCP to finalize the boundaries of the cleanup. By 2012, the anticipated cleanup already encompassed a smaller area than depicted in Figures 2 and 3. The Port proposed DMMP dioxin testing of the area lying between the cleanup site boundary that existed during the 2010 DMMP characterization and the anticipated limits of cleanup in 2012. This area is shown in Figure 4. The DMMP agencies reviewed the SAP addendum with the understanding that any data gaps that existed following finalization of the cleanup boundaries would need to be addressed as part of any later DMMP characterization. In-water cleanup at ESY was completed in 2014-2015.

In March 2015, the Port of Everett proposed a solution for dredging the marina that involved sequencing the disposal of material from the marina with clean dredged material from the Snohomish River federal navigation project. Dredged material from the marina would be placed at the Port Gardner site, followed by placement of dredged material from the federal navigation channel. The DMMP agencies considered this idea, but eventually rejected it. The primary reason for rejection was that many of the dioxin concentrations found in the marina exceeded the bioaccumulation trigger (BT) of 10 ng/kg TEQ. Allowing this material to be taken to the Port Gardner site without bioaccumulation testing was deemed to be beyond the bounds of case-by-case decision-making allowed for by the 2010 dioxin guidelines.

In May 2015, the Port of Everett notified the DMMP agencies that they were prepared to conduct bioaccumulation testing. A series of meetings and conference calls between the Port, the Port's consultant Windward Environmental LLC (Windward) and the DMMP agencies followed, during which the bioaccumulation study design and testing protocols were discussed and refined. During development of the study design, the DMMP agencies identified the data gaps remaining following the 2012 ESY design-level investigation and cleanup boundary delineation. Additional sampling and testing to address these data gaps were included in the bioaccumulation SAP, which was developed for the Port by Windward and approved by the DMMP agencies in March 2016.

The remainder of this memo focuses primarily on the 2016 dioxin bioaccumulation testing, but also includes an evaluation of data collected under the 2012 SAP addendum and results from the 2016 data-gap testing.

3. <u>Project Summary</u>. Table 1 includes project summary and tracking information.

Table 1. Project Summary

Project ranking	Mixed
Dredging volume	160,250 cubic yards
Proposed dredging depth	DMMUs 1-8 and 10-12: -12 ft MLLW plus 2 ft overdepth DMMU 9: -11 ft MLLW plus 2 ft overdepth
1st draft sampling and analysis plan (SAP) received	December 18, 2015
DMMP comments provided on 1st draft SAP	January 1, 2016

2nd draft SAP received	February 2, 2016
DMMP comments provided on 2nd draft SAP	February 16, 2016
Final revisions to SAP received	March 7, 2016
SAP revisions approved	March 14, 2016
Sampling dates	May 10-18, 2016
1st draft data report received	November 18, 2016
DMMP comments provided on 1st draft report	December 7, 2016
2nd draft data report received	January 17, 2017
DMMP comments provided on 2nd draft report	February 8, 2017
3rd draft data report received	February 24, 2017
DMMP comments provided on 3rd draft report	March 16, 2017
4th draft data report received	March 17, 2017
DMMP comments provided on 4th draft report	March 21, 2017
5th draft data report received	March 24, 2017
DMMP comments provided on 5th draft report	March 26, 2017
final data report received	March 27, 2017
DMMO tracking number	POEMA-1-C-F-377
EIM study ID	POEMA16
USACE Permit Application Number	TBD
Recency Determination	May 2021

4. Development of the Bioaccumulation Study Design. The DMMP agencies collaborated with the Port of Everett and Windward from June to November 2015 to develop a study design for the assessment of dioxin bioaccumulation potential in marina sediment. This was the first DMMP project to undergo bioaccumulation testing for dioxin and therefore required extensive planning. The DMMP User Manual (DMMP, 2015a) did not include bioaccumulation testing guidelines specific to dioxin so the sampling approach and data evaluation procedures needed to be established.

   Standard Tier 3 DMMP bioaccumulation testing utilizes a modified EPA protocol (Lee et al. 1989), which includes co-testing of *Macoma nasuta* and *Nephtys caecoides* in the same test chambers. The modified EPA protocol - with static water renewal, sediment addition, and no supplemental feeding - was selected for use in this study.

   The length of exposure is a critical parameter in the design of a bioaccumulation test. The longer the exposure, the closer tissue concentrations approach a steady-state condition. However, longer exposures can also result in increased stress on test organisms, especially if supplemental feeding does not occur. The DMMP User Manual does not provide a recommended exposure time for dioxin. However, a 45-day exposure time is recommended for PCBs. In addition, the User Manual provides percentages of steady-state tissue concentrations for two dioxin congeners for 10-day and 28-day exposures. After 28 days of exposure, *Macoma nasuta* is listed as having reached 100% of

steady state for 2,3,7,8-TCDD and 2,3,7,8-TCDF. However, *Nereis virens* was found to be at only 22% and 62% of steady state respectively for these two congeners after 28 days of exposure. Given the chemical similarity of dioxins and PCBs, and the failure of *Nereis virens* to reach steady state at 28 days, a 45-day exposure period was selected for the Everett Marina study.

The User Manual includes Target Tissue Levels (TTLs) for ten chemicals or groups of chemicals. Where a TTL exists, the tissue concentrations resulting from exposure to test sediment are compared to the TTL to determine suitability for open-water disposal. For COCs where a TTL does not exist, test tissue results are compared to tissue concentrations resulting from exposure to a reference sediment. There is no TTL for dioxin so a comparison to reference was used for Everett Marina. The User Manual specifies use of a one-tailed t-test with an alpha level of 0.1 when comparing test to reference results.

One concern expressed by the Port of Everett during development of the study design was that differences between results from marina samples and a reference sample could be statistically significant without having any human health or ecological importance. The DMMP agencies acknowledged that best professional judgment might be needed to assess the importance of any statistical differences, including an evaluation of analytical variability, practical quantitation limits and other considerations.

Development of the study design included a reconfiguration of DMMU boundaries. Alternatives included a) using the original 2010 DMMUs along with additional DMMUs in the vicinity of ESY; b) reconfiguring DMMUs based on previously collected dioxin data; c) use of larger DMMUs where dioxin concentrations had been lowest and smaller DMMUs where dioxin concentrations had been highest.

Which sediment dioxin concentrations to test for bioaccumulation potential was also carefully considered. Alternatives included a) testing all DMMUs with dioxin concentrations greater than 4 ng/kg TEQ; b) testing only those DMMUs with dioxin concentrations greater than 10 ng/kg TEQ; c) testing a range of sediment concentrations, but not every sample; d) grouping DMMUs together for testing of management areas based on similarities in dioxin and/or total organic carbon (TOC);

Between August and November 2015, Windward submitted four drafts of the study design in an iterative process that included conference calls with and written responses from the DMMP agencies. The final study design was detailed in the SAP and included the following elements:

a. The Port removed certain near-shore areas from consideration for open-water disposal (Figure 5). This included a band along the north shore of the marina, an area just south of the ESY cleanup site, and the shoreline area in the southeast corner of the marina. These areas had all been shown to have elevated dioxin concentrations. Because dredging was not critical in these areas, they were removed from further consideration.
b. The area proposed to be dredged was divided into 12 DMMUs (Figure 6) based on dioxin concentrations from 2010/2012, the shoaling pattern, dredgeability, and the proximity to the ESY cleanup site.
c. The DMMUs were grouped into five preliminary management areas (M1, M2, M3, M4 and M5). M1 was configured such that its volume-weighted dioxin concentration was 2.91 ng/kg TEQ (using the 2010/2012 dioxin data for individual core samples). DMMUs in M1 were

approved for open-water disposal by the DMMP agencies without additional testing. M2, M3, M4 and M5 were configured with the goal of establishing a range of dioxin concentrations to test.

d. Sampling was targeted at shoaled areas, with sampling stations used in 2010/2012 to be reoccupied where possible.
e. Each DMMU in M2, M3, M4 and M5 was to be tested individually to determine the concentration of dioxin in the sediment. Adjustments to the groupings of DMMUs into final management areas for bioaccumulation testing were to be made based on the sediment results and dredgeability. In addition to testing composites of sediment from each management area, the DMMP agencies wanted the DMMU with the highest dioxin concentration to be tested individually for bioaccumulation. However, collection of a sufficient volume of sediment from each DMMU for possible bioaccumulation testing of any one single DMMU would have required an inordinate number of sediment cores to be taken. As a compromise, the agencies pre-selected for more intensive sampling the four DMMUs with the greatest probability of having the highest individual dioxin concentration based on data from 2010/2012.
f. DMMU 9 presented a problem with regard to antidegradation. Previous testing had found dioxin concentrations above 20 ng/kg TEQ in z-samples (-14 to -16 ft) from this DMMU. Alternatives included a) bioaccumulation testing of a z-composite from DMMU 9 to compare to results from the overlying material; b) dredging only to -13 ft (including overdepth), leaving a 1-ft vertical buffer of relatively clean material in place over the previously tested z-layer; c) dredging to -15 ft (with upland disposal of material between -13 and -15 ft) and placement of a 1-ft sand cover. The Port agreed to limit the dredge depth to -13 ft (including overdepth) in DMMU 9, leaving the -13 to -14 ft layer in place to serve as a buffer. The Port also agreed to test the -13 to -14 ft z-sample from DMMU 9 for dioxin to make sure the sediment exposed by dredging would meet the State's antidegradation standard. However, in the SAP, the z-sample for DMMU 9 was specified to be collected from -13 to -15 instead. This discrepancy was not identified prior to sampling.
g. Windward identified a preferred sampling area in Carr Inlet to use as a reference. Grab samples were to be collected from five different stations from this area and analyzed for dioxin, grain size and TOC. Sediment from a single station or a composite of sediment from two or more stations was to be used depending on how well they matched the management areas with regard to grain size and TOC. The DMMP agencies specified that the dioxin concentration in the selected individual or composited reference sample should be less than or equal to the disposal site management objective of 4 ng/kg TEQ.

The bioaccumulation study design is detailed in the SAP. The DMMUs, preliminary management areas and target sampling stations from the SAP are shown in Figure 6.

5. <u>Evaluation of Standard COC and TBT Data Collected Under the 2012 SAP Addendum</u>. Results from the analysis of standard COCs and TBT collected under the 2012 SAP Addendum are presented in Figure 7. These data were collected for TCP in support of finalization of the ESY cleanup boundaries. All but one of these stations (SC-64) were located outside of the area fully characterized by DMMP in 2010.

The DMMP agencies evaluated the adequacy of these data to characterize sediment that wasn't

included in the 2010 DMMP full characterization. Two issues were discovered. The first issue was that not all chemicals on DMMP's standard list of COCs were analyzed. For example, several metals and the pesticides were not analyzed for any depth stratum at any station. Other samples were not analyzed for PCBs, TBT or metals (other than mercury), while some depth strata at many of the stations were tested for mercury only. This is because the 2012 testing was focused on defining the cleanup boundaries, not on determining suitability for open-water disposal. To address this data gap, the DMMP agencies required that DMMUs 8 and 9 be analyzed for all DMMP standard COCs and TBT in 2016.

The second issue encountered was that a few of the chemicals that were tested for in 2012 exceeded DMMP guideline values or Sediment Management Standards (SMS). These occurrences were handled as follows:

a. Mercury exceeded the DMMP screening level (SL) and SMS sediment cleanup objective (SCO) at station SC-64 in DMMU 9. However, since the exceedance occurred in the -16 to -17 ft stratum and dredging is only planned to -13 ft MLLW in DMMU 9, the contaminated sediment will not be exposed by dredging. Mercury in the -14 to -16 ft stratum at SC-64 did not exceed the SL, so at least one foot of clean material will be left in place following dredging to isolate the -16 to -17 foot stratum with the elevated mercury.
b. The chemical 4-methylphenol exceeded the SL and SMS cleanup screening level (CSL) in the -11 to -12 ft stratum at station SC-60 in DMMU 9, with a concentration of 780 ug/kg. However, this concentration was below concentrations in other ESY samples that had passed bioassays (samples SG-32 and SG-33 had concentrations of 1,400 and 790 ug/kg respectively and had both passed bioassays). Therefore, the DMMP agencies did not require any special testing for 4-methylphenol. However, 4-methylphenol was still included on the list of standard COCs tested for in DMMUs 8 and 9.
c. Three other chemicals exceeded the CSL at one or more stations and in one or more sediment strata. These included 2,4-dimethylphenol in the -12 to -14 ft stratum at SC-56 (DMMU 8); 1,4-dichlorobenzene in the -12 to -14 ft stratum at station SC-60 (DMMU 9); and benzyl alcohol in the -12 to -14 ft stratum at station SC-56 (DMMU 8) and in the -11.4 to -14 ft stratum at station SC-62 (DMMU8). The DMMP agencies required focused testing for these chemicals. Subareas 8A and 9A (Figure 7) were identified for this focused testing; the stations within 8A and 9A that had exceedances in 2012 were to be reoccupied during the 2016 sampling event and the dredged material stratum analyzed for the chemicals with exceedances in 2012.

The data-gap testing identified in this section was included in the 2016 SAP. Figure 8 is the study design flow chart from the SAP.

6. Sampling. Sampling in the marina took place May 10-18, 2016 using a vibracore. Target and actual sampling locations are shown in Figure 9; sampling data are presented in Tables 2 and 3. There was only one deviation from the SAP during marina sampling. The target location of S8A-03 was blocked by a locked boathouse and could not be accessed (Windward, 2017). The sample was moved 9.3 m to the east, which was within the 10-m radius acceptance limit.

Two days were required to complete the sampling in Carr Inlet due to a technical problem. During the initial sampling on May 17, 2016, water depths in the preferred sampling area were deeper than

could be reached with the sampling equipment available. The sampling team moved to shallower water on the north side of Raft Island and at the head of Carr Inlet and collected five samples (Figure 10). The sampling team returned to Carr Inlet on May 23 with equipment capable of sampling in deeper water and collected three additional samples from the preferred sampling area.

7. Review of Sediment Data and Bioaccumulation Study Design Modifications. Sediment analysis proceeded as described in the SAP. Windward provided the preliminary results for dioxin, TOC and percent fines for the marina samples and Carr Inlet reference samples to the DMMP agencies in a memo dated June 15, 2016 (Attachment 1).

The preliminary bioaccumulation study design was modified to address the outcome of sediment testing. The first modification was in regard to the planned individual testing of the DMMU with the highest dioxin concentration. The highest dioxin concentration was found in DMMU 12 (14.4 ng/kg TEQ; Attachment 1). This DMMU was not among those that had been selected in advance by the DMMP agencies for potential individual bioaccumulation testing. As a consequence, an insufficient volume of sediment had been collected to test DMMU 12 individually. Therefore, the element of the study design calling for individual testing of the DMMU with the highest dioxin concentration was abandoned.

The second modification was to the composition of Management Area 1 (Figure 11). The sediment dioxin concentrations in DMMUs 5 and 6 (5.21 and 3.86 ng/kg TEQ respectively; Attachment 1) were found to be low enough to warrant their inclusion in Management Area 1 and exempted from bioaccumulation testing. Using the DMMU volumes from the SAP, historical testing results for DMMUs 1, 2 and 3, and the 2016 results for DMMUs 5 and 6, the volume-weighted concentration for Management Area 1 was calculated to be 3.4 ng/kg TEQ. If both the 2016 and 2010 data are used for DMMUs 5 and 6, the volume-weighted concentration is 4.1 ng/kg TEQ. The worst-case value of 4.1 ng/kg TEQ was considered similar enough to the site management objective of 4 ng/kg TEQ to permit the reconfigured Management Area 1 to be placed at the Port Gardner site without bioaccumulation testing using case-by-case decision-making.

The final modification to the preliminary bioaccumulation study design involved finalizing the grouping of the remaining DMMUs (i.e. DMMUs 4, 7, 8, 9, 10, 11 and 12) into management areas for bioaccumulation testing, per the procedure identified in the SAP. In the June 15, 2016 memo, Windward presented three options for compositing these DMMUs into management areas. The option selected by the agencies resulted in four management areas; three of which were identified for bioaccumulation testing. The final plan combined DMMUs based primarily on dioxin concentrations. As noted in the previous paragraph, DMMUs 1, 2, 3, 5 and 6 were combined to form M1, which did not require bioaccumulation testing. DMMUs 10 and 12 had the highest concentrations (13.0 and 14.4 ng/kg TEQ respectively; Attachment 1) and were grouped together as M4. DMMUs 7, 8 and 9 were the three DMMUs adjacent to the ESY cleanup site and were combined to form M3. These DMMUs all had preliminary dioxin concentrations ranging from 8.16 to 9.27 ng/kg TEQ. M2 was formed by combining DMMUs 4 and 11. These two DMMUs had similar dioxin concentration (7.79 and 7.69 ng/kg TEQ respectively). Although not contiguous, the DMMP agencies thought it best to combine these two DMMUs to achieve a range of dioxin concentrations for bioaccumulation testing.

The final management areas are shown in Figure 11. The volumes represented by the four management areas were as follows:

M1 = 69,133 cy
M2 = 35,220 cy
M3 = 29,205 cy
M4 = 26,692 cy

Selection of the reference sample compositing plan was based on the preliminary sediment testing results for total organic carbon and dioxin presented in Windward's June 15, 2016 memo. The mean TOC content for the three management areas being tested for bioaccumulation was 2.32, 2.14 and 2.10% for M2, M3 and M4 respectively. The only reference sample with TOC within this range was CI-6, with a TOC of 2.19%. However, CI-6 had a preliminary dioxin concentration of 5.21 ng/kg TEQ, which was above the DMMP site management objective of 4 ng/kg TEQ. Therefore, the reference sample with the next highest TOC was selected to combine with CI-6. This sample, CI-3, had a TOC of 1.75% and a dioxin concentration of 1.71 ng/kg TEQ. Combined, these two reference samples would have a TOC of 1.97% and a dioxin concentration of 3.46 ng/kg TEQ. The combined TOC was considered a good match for the management areas and the combined dioxin concentration an acceptable proxy for the site management objective. Therefore, the DMMP agencies determined that the reference sediment for the bioaccumulation test would be a combination of equal parts of CI-3 and CI-6.

The data validation process resulted in minor modifications to the preliminary data found in Attachment 1. The final validated results for sediment dioxin, TOC and grain size are presented in Table 4.

With regard to the non-dioxin testing, there were no detected exceedances of the DMMP SLs or BTs. Two pesticides – total chlordane and heptachlor – were reported as non-detects in DMMU 9 at concentrations greater than the SL values because of analytical interferences in the sample. Data from the 2010 DMMP characterization were reviewed to determine whether there was any reason to believe that these chemicals might be present in marina sediment at concentrations exceeding the SL. Total chlordane was reported as undetected in all 2010 samples at reporting limits that are below the 2016 SL. Heptachlor was also undetected in all samples, although chromatographic interference in two samples resulted in the reporting limit for those samples being raised to values that exceed the 2016 SL. However, those samples were from the 2010 DMMUs 1 and 2, which were the DMMUs located farthest away from DMMU 9. Based on the evidence from 2010, the DMMP agencies determined that there is little risk of total chlordane or heptachlor being present in DMMU 9 at concentrations above the 2016 SLs. In summary, there were no detected exceedances of the 2016 DMMP SLs and the non-detects reported above the SL were not of concern. Therefore, biological testing was not required. The non-dioxin results are shown in Tables 5 and 6.

8. Bioaccumulation Testing. Bioaccumulation testing was carried out by Northwestern Aquatic Sciences at its laboratory in Newport, Oregon. Two species – an adult marine clam (*Macoma nasuta*) and an adult polychaete (*Nephtys caecoides*) – were to be exposed to sediment from the three management areas and the Carr Inlet reference sediment for 45 days. The species were co-

tested, meaning they shared aquaria during the exposure. Five replicates were run for each management area, reference sediment and negative control. Static renewal with periodic water exchanges and sediment addition was employed. Overlying water in test chambers was renewed three times a week. An additional 175 ml of sediment was added to each test chamber every seven days. There was no supplemental feeding. The SAP (Windward, 2016) provides additional details regarding the protocol and test conditions.

Testing was terminated on Day 41 due to an increased rate of mortality for *Macoma nasuta*. The initial count was 12 clams in each aquarium, for a total of 60 clams per treatment and 300 clams for the entire experiment. On Day 35, the laboratory removed 17 dead clams from 12 aquaria. On Day 38 another 9 dead clams were removed from 8 aquaria. As can be seen in Figure 12, the mortality rate increased in the later stages of the test. The DMMP agencies were notified of the situation on Day 39 and a conference call was held to discuss the path forward. While all test, reference and control samples were affected, it was the control sediment that was experiencing the greatest mortality. The risk in continuing the test to Day 45 was the potential for having insufficient tissue to do the chemical testing at the end of exposure. Therefore, the DMMP agencies agreed that the test should be ended early. Mortality in test organisms is normal in an extended bioaccumulation test with no supplemental feeding. The fact that mortality was highest in the control sediment, which is a clean sand with relatively low organic carbon content, provides evidence that starvation, rather than dioxin, was likely the cause of the mortality seen.

While a small number of dead worms were removed from the test chambers during the first week of testing, the majority of the mortality experienced by *Nephtys caecoides* could only be determined at test termination due to the tendency of this species to remain buried throughout the test. Mortality rates for *Nephtys* were similar to those reported for *Macoma nasuta*, with the exception of the control sediment. While *Macoma* mortality was greater in the control sediment than in sediment from the reference and marina management areas, *Nephtys* mortality in the control was similar to that for the other samples. Mean survival for the two species can be found in Table 7.

At test termination there was sufficient tissue available for dioxin analysis in all test and reference treatments. Tissue samples were collected per the SAP and analyzed for dioxin and lipids. The tissue results can be found in Tables 8 and 9.

In addition to tissue analysis, the reference sediment (a composite of CI-3 and CI-6) was analyzed for TOC and dioxin to verify that it was in line with what had been predicted from the preliminary sediment results for the individual samples. The predicted TOC and dioxin concentrations were 1.97% and 3.46 ng/kg TEQ respectively, based on the preliminary data presented in Attachment 1. The measured concentrations of the composited reference were 1.81% and 4.20 ng/kg TEQ. While slightly higher than the site management objective of 4 ng/kg TEQ, the reference was still considered an adequate proxy given the analytical variability typically seen at these low concentrations.

9. <u>Bioaccumulation Test Results and Interpretation</u>. *Macoma* and *Nephtys* tissue concentrations (Tables 8 and 9; Figure 13) were low for both the reference sediment and all management area samples, with TEQs well below 1 ng/kg wet weight (ww) in all cases. For *Macoma nasuta*, tissue concentrations ranged from 0.101 to 0.115 ng/kg ww TEQ for the individual reference replicates and

0.119 to 0.264 ng/kg ww TEQ for the management area replicates. For *Nephtys caecoides*, tissue concentrations ranged from 0.103 to 0.116 ng/kg ww TEQ for the reference replicates and 0.159 to 0.241 ng/kg ww TEQ for the management area replicates. These concentrations were calculated with non-detects equal to one-half the detection limit.

As indicated previously, a TTL for the protection of human health and other higher trophic level species has not yet been established by the DMMP agencies for dioxin. In the absence of a TTL, the DMMP User Manual (DMMP, 2016) calls for comparison of test sediment tissue concentrations to reference sediment tissue concentrations using a one-tailed t-test with an alpha level of 0.10.

Windward Environmental used ProUCL to statistically compare the mean TEQ for the five replicate tissue samples from each management area to the mean TEQ for the five replicate tissue samples from the reference for each test species. Using a classical t-test with no data transformation, the TEQs for all management areas were found to be statistically greater than reference for both test species. The statistical results are provided in Table 10. Use of a variant of the t-test that did not assume equality of variance yielded results that were consistent with the classical t-test. Nonparametric tests were also run but did not change the outcome of the statistical comparisons.

USACE verified the statistical results using BioStat. Screen shots from the BioStat comparisons are provided in Attachment 2. BioStat uses the Shapiro-Wilk statistic to test for normality and Levene's test to assess equality of variance. The data were found to be normally distributed without data transformation. However, the test and reference variances were determined to be heteroscedastic for each comparison. Use of the classical t-test is based on an assumption of homoscedasticity (equality of variance). Because this assumption was not met, BioStat used an approximate t-test (Zar, 1984) to make statistical comparisons between test and reference TEQs. All comparisons between management areas and reference were found to be statistically significant for both species using the approximate t-test.

As noted previously, the agencies had agreed prior to testing that a statistically significant difference between management area and reference results would be a necessary but insufficient condition for finding dredged material unsuitable for open-water disposal. Several additional aspects of the data set were considered in evaluating the significance of the statistical difference, including a) data variability; b) the role of non-detects; and c) comparison to practical quantitation limits (PQLs) and d) comparison to dioxin concentrations measured in field-collected polychaetes from unimpacted areas near the Port Gardiner disposal site.

a) With regard to data variability, the variance of the reference replicate TEQs was very low for both test species, primarily due to the large number of non-detects and the similarity of detection limits among replicates. The consequence of low variability in the reference replicates is that even small differences between means of management area and reference results are found to be statistically significant in a t-test or approximate t-test. For example, the difference between the mean *Macoma* tissue concentration for M2 and the reference sample was only 0.033 ng/kg ww TEQ. Yet because there was very little variability among the reference replicates, the difference was found to be statistically significant. The largest difference between a mean management area tissue concentration and a mean reference tissue concentration occurred for *Nephtys* for M4. In this case, the difference between means was

0.110 ng/kg ww TEQ. So even in the most extreme case, the difference between the test and reference results was only on the order of a tenth of a part per trillion.

It should be noted that low variability in the reference replicates, in and of itself, is not a sufficient reason to set aside a statistically significant difference between test and reference results. In conducting a bioaccumulation test, it may be expected that low or undetected tissue concentrations would result from exposure to a reference sediment. In the DMMP bioassays, the potential for low variability in the reference to drive the statistical results was acknowledged by requiring a minimum difference between the mean of the test sediment replicates and the mean of the control sediment replicates before a failure can occur. There is no such mechanism in bioaccumulation testing. Therefore, the role of non-detects was evaluated and a comparison to PQLs was made.

b) In addition to the contribution of non-detects to low variability in the reference samples, non-detects played a significant role in the summation of TEQs and the subsequent comparison of management area results to the reference. Figures 14 and 15 show this graphically. Only three congeners (1,2,3,4,6,7,8-HpCDD; 1,2,3,6,7,8-HxCDD and 2,3,7,8-TCDF) had more detects than non-detects in the management area samples for both *Macoma* and *Nephtys*. Some 69% of the individual congener results for *Macoma* for the marina samples were non-detects, while 61% of the *Nephtys* results were non-detects. With non-detects set equal to one-half the detection limit, the contribution of non-detects to the TEQ for the test samples ranged from 46.6 to 68.9% for *Macoma* and 39.1 to 50.0% for *Nephtys*. The magnitude of the effect of non-detects on the TEQ can be illustrated in another way by eliminating non-detects from the TEQ summations completely. If only detected values are used in the summation of TEQs (i.e. non-detects = 0), the tissue concentrations for the management area samples range from 0.018 to 0.188 (mean = 0.070) ng/kg ww TEQ for *Macoma* and 0.062 to 0.187 (mean = 0.114) ng/kg ww TEQ for *Nephtys.* For comparison, with non-detects set to ½ DL, the tissue concentrations range from 0.119 to 0.264 (mean = 0.165) ng/kg ww TEQ for *Macoma* and 0.159 to 0.241 (mean = 0.199) ng/kg ww TEQ for *Nephtys*. Alternative methods for addressing non-detects, such as Kaplan-Meier, were considered but the large number of non-detects (> 50%) precluded the use of such methods.

c) Practical quantitation limits (PQLs) can be an important consideration when concentrations are low. The PQL is the lowest concentration of an analyte that can be reliably measured within specified limits of precision and accuracy under routine laboratory operating conditions. Concentrations above the PQL can be measured with a high degree of confidence, while concentrations below the PQL are typically considered to be estimates. The PQL for each dioxin congener for this project was established as the lowest method calibration standard used by Axys to calibrate its instruments (Table 11). As can be seen in Figures 14 and 15, the majority of the detected congeners in both species were below the PQL. The only exceptions were 1,2,3,4,6,7,8-HpCDD and 2,3,7,8-TCDF. All management area tissue concentrations were above the PQL for 1,2,3,4,6,7,8-HpCDD in both test species. For 2,3,7,8-TCDF, two M3 replicates were above the PQL for *Macoma*, while four M2 replicates and all five M3 replicates were above the PQL for *Nephtys*. On average, congeners detected below the PQL accounted for more than 75% of the TEQ. A broader evaluation of the significance of PQLs can be achieved by comparing tissue TEQs to the sum of TEF-weighted PQLs. The sum of TEF-

weighted PQLs was 2.28 ng/kg (Table 11). As noted previously, *Macoma* tissue concentrations ranged from 0.119 to 0.264 ng/kg ww TEQ and *Nephtys* tissue concentrations ranged from 0.159 to 0.241 ng/kg ww TEQ for the management area replicates (with non-detects set to ½ DL). Hence, the management area tissue concentrations were approximately an order of magnitude below the sum of the TEF-weighted PQLs.

d) In addition to the technical aspects of the data set, the DMMP agencies evaluated the environmental significance of the bioaccumulation results by comparing them to monitoring data from the vicinity of the Port Gardner disposal site. In 2006, as part of a special dioxin study, specimens from the polychaete genera *Nephtys* and *Travisia* were collected from nine off-site stations (perimeter, transect and benchmark stations). Of these stations, the perimeter stations are closest to the disposal site, being located approximately 0.125 nautical miles (760 ft) outside the site boundary. Given their limited mobility and the distance of the collection stations from the site, *Nephtys* and *Travisia* collected from the off-site stations can be considered unimpacted by dredged material disposal and representative of background conditions in Port Gardner.

With non-detects set to ½ DL, the *Nephtys* tissue samples from the Port Gardner perimeter, transect and benchmark stations ranged from 0.093 to 0.164 (mean = 0.129) ng/kg ww TEQ (Figure 16). For *Travisia*, the Port Gardner tissue concentrations ranged from 0.351 to 0.597 (mean = 0.418) ng/kg ww TEQ. In comparison, the dioxin concentrations in tissue from *Macoma* exposed to sediment from the three management areas ranged from 0.119 to 0.264 (mean = 0.165) ng/kg ww TEQ. For *Nephtys*, the management area replicates ranged from 0.159 to 0.241 (mean = 0.199) ng/kg ww TEQ. As can be seen from this comparison, the Everett Marina *Macoma* and *Nephtys* samples had slightly higher mean concentrations than the Port Gardner *Nephtys* samples, although the individual replicate concentrations for both test species overlapped those for Port Gardner *Nephtys*. The Everett Marina results for both *Macoma* and *Nephtys* fell below those of the *Travisia* samples from the Port Gardner study.

The bioaccumulation testing data can be summarized as follows. Dredged material samples from Everett Marina resulted in tissue concentrations that were statistically greater than reference, despite the accumulated concentrations themselves being very low. Statistical comparisons were driven by the low measured variance among reference replicates, resulting in even small differences between test and reference being found statistically significant. In addition to bioaccumulated concentrations being very low, the TEQs were driven to a large extent by non-detects. Even when detected, most detected concentrations were below the PQL, which increases the uncertainty about the results. Finally, the test results were within the range of tissue concentrations found in the vicinity of the Port Gardner disposal site (but not impacted by the site) during testing in 2006.

10. Sediment Exposed by Dredging. The sediment to be exposed by dredging must either meet the State of Washington Sediment Quality Standards (SQS) or the State's antidegradation standard (Ecology, 2013) as described in DMMP guidance (DMMP, 2008).

In general, dioxin concentrations decrease with depth within the marina as evidenced by z-samples collected and analyzed in 2010 and 2012 (Figure 3). These z-samples were all taken from -14 to

-16 ft MLLW, with the exception of MBR-12, which was taken from -14 to -15 ft MLLW, and MBR-21, which was taken from -13 to -16 ft MLLW. The majority of the z-samples had lower concentrations than the overlying material. Exceptions were stations MBR-6 and MBR-10 (in 2016 DMMUs 2 and 3 respectively) and MBR-17, MBR-18 and MBR-19 (all in 2016 DMMU 9).

For M1, the mean dioxin concentration of the six z-samples collected there in 2010 (MBR-5, MBR-6, MBR-10, MBR-11, MBR-12 and MBR-15) was 3.74 ng/kg TEQ, which is below the site management objective of 4 ng/kg TEQ. In addition, the individual z-samples in M1 were all within or below the range of dioxin concentrations tested for bioaccumulation. The individual z-samples in M1 ranged from 0.13 to 9.93 ng/kg TEQ, while the range of sediment concentrations tested for bioaccumulation ranged from 7.74 to 13.7 ng/kg TEQ. The bioaccumulation testing results provided evidence that the dioxin concentrations found in the z-samples in M1 are not high enough to result in significant bioaccumulation and that the sediment represented by the z-samples would itself be suitable for open-water disposal.

For DMMU 9, the proposed dredge depth was changed from -14 ft MLLW (including 2 ft of overdepth) to -13 ft MLLW (including 2 ft of overdepth) in order to leave a 1-ft vertical buffer over the sediment layer (-14 to -16 ft MLLW) that had elevated dioxin concentrations (ranging from 20.03 to 23.12 ng/kg TEQ at stations MBR-17, MBR-18 and MBR-19) in 2010/2012. As indicated previously, it had been intended that the z-samples in DMMU 9 be taken from -13 to -14 ft MLLW to verify that the dioxin concentration was low enough for this layer to serve as a 1-ft vertical buffer. However, the z-samples in DMMU 9 were collected from -13 to -15 ft MLLW instead as an oversight in the SAP. The composite of z-samples collected from -13 to -15 ft MLLW in DMMU 9 had a dioxin concentration of 10.9 ng/kg TEQ, which was well below the concentrations found in the -14 to -16 ft MLLW z-samples collected in 2010/2012, despite there being a 1-ft overlap in sampling depths. Given this evidence, it is reasonable to believe that the 1-ft vertical buffer the Port plans to leave in DMMU 9 will be sufficient to isolate sediment with higher dioxin concentrations below. Further, while the 2016 z-sample composite had a dioxin concentration somewhat higher than the composite from DMMU 9 itself (10.9 ng/kg TEQ in the z-sample composite compared to 8.67 ng/kg TEQ in the DMMU 9 composite), the concentration found in the z-sample composite is within the range of sediment concentrations tested for bioaccumulation. Therefore, the newly exposed sediment should not result in significant bioaccumulation and would itself be suitable for open-water disposal.

As part of the data-gap testing, the z-samples from subareas 8A and 9A were analyzed for those chemicals that had SMS or DMMP guideline exceedances in the overlying material during the ESY predesign study. The concentrations of COCs tested in the z-samples were all below the DMMP SLs.

Based on the totality of data collected in 2010, 2012 and 2016, and the vertical buffer planned for DMMU 9, the DMMP agencies determined that the sediment to be exposed by dredging will meet the State's antidegradation standard.

11. Suitability Determination. There were no SL exceedances for the standard list of DMMP COCs in the DMMUs tested in 2010, nor were there any exceedances in the DMMUs tested for these COCs in 2016 (the standard COCs do not include dioxin). Therefore all dredged material is suitable for open-water disposal with regard to the standard COCs.

With regard to dioxin, the DMMP agencies evaluated data from the bioaccumulation test and found the following:

- Tissue concentrations of dioxin in *Macoma nasuta* and *Nephtys caecoides* following a 41-day exposure to sediment from the three marina management areas were low, well under 1 ng/kg ww TEQ.
- While low, the differences between dioxin tissue concentrations for the management areas and tissue concentrations for the reference were statistically significant.
- The statistical results were largely driven by low variability in the reference replicates. The actual difference between mean management area TEQs and mean reference TEQs was less than or equal to 0.110 ng/kg ww.
- The TEQs for all samples were heavily influenced by non-detects. With non-detects set equal to zero in the TEQ summation, the mean tissue concentration for all management area *Macoma* replicates fell from 0.165 to only 0.070 ng/kg ww TEQ. The mean tissue concentration for all management area *Nephtys* replicates fell from 0.199 to 0.114 ng/kg ww TEQ.
- For those congeners that *were* detected, the majority of them were detected below the PQL and are considered estimates.
- The marina tissue concentrations were within the range found in polychaetes collected from off-site stations in Port Gardner and therefore resemble conditions adjacent to the disposal site.

The DMMP dioxin guidelines allow for case-by-case determinations to be made based on consideration of the individual aspects of a dredging project. After careful evaluation, the DMMP agencies find that the weight of evidence supports a determination that placement of the marina material at the Port Gardner site will not result in adverse effects.

In summary, based on the results of the previously described testing, the DMMP agencies concluded that all 160,250 cubic yards proposed for dredging from Everett Marina are suitable for open-water disposal at the Port Gardner non-dispersive site.

With regard to the recency period applicable to this project, the DMMP agencies determined that five years is appropriate. The project was ranked 'low-moderate' for the original characterization in 2010. Given the elevated concentrations of dioxin found in 2010/2012, the project was treated as a high-ranked project for the purposes of deriving the number of required field samples for the 2016 bioaccumulation testing. The data for a high-ranked project are generally considered valid for a period of three years following sampling due to the on-going sources of contamination typically found in a high-ranked area. But because the likely source of dioxin in the marina was removed by the ESY cleanup, it is unlikely that dioxin levels in marina sediment will change in the near-term. Additionally, sediments passed bioaccumulation testing and no bioassays were triggered, so a rank of 'high' for the marina sediments is not warranted. Therefore, the DMMP agencies selected an intermediate ranking of 'moderate' to determine the recency period. The recency period associated with a moderate-ranked project is five years.

This suitability determination does not constitute final agency approval of the project. During the public comment period that follows a public notice, the resource agencies will provide input on the

overall project. A final decision will be made after full consideration of agency input, and after an alternatives analysis is done under section 404(b)(1) of the Clean Water Act.

12. Pre-Dredge Meeting. A pre-dredge meeting with DNR, Ecology, EPA and the Corps of Engineers is required at least 7 days prior to dredging. A dredging and disposal quality control plan must be submitted to the Regulatory Branch of the Seattle District Corps of Engineers at least 7 days prior to the pre-dredge meeting. A DNR site use authorization must also be acquired. Disposal at the Port Gardner site must be by bottom-dump barge.

    While all material from the marina is suitable for placement at the Port Gardner open-water disposal site, the Port of Everett has agreed to sequence the dredging and disposal of the four management areas (Figure 10), with the order determined by sediment dioxin concentration. This means that M4 will be dredged and disposed first, followed by M3, M2 and M1 in that order. Further, since M1 includes both the DMMUs located farthest away from the ESY site as well as DMMUs in closer proximity to the site, the Port has agreed to dredge and dispose of DMMUs 5 and 6 before dredging and disposing of DMMU 1, 2 and 3. Sequencing the disposal will result in the dioxin concentration of the post-dredge surface sediment at the disposal site most closely resembling that of the management area with the lowest dioxin concentration. The sequencing of dredged material disposal must be included in the quality control plan as a best management practice.

    The DMMP agencies implemented a debris screening requirement following the 2015 Sediment Management Annual Review Meeting in order to prevent the disposal of solid waste and large debris at the open-water disposal sites (DMMP, 2015b). There is a high probability of debris being encountered when dredging a marina. Therefore, the DMMP agencies are requiring debris screening using a 1-ft x 1-ft grid for this project. Debris management, including use of a 1-ft x 1-ft grid, must be included in the quality control plan.

13. References.

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Windward, 2016. *Everett Marina – Bioaccumulation Sampling and Analysis Plan, Final*. Prepared by Windward Environmental for the Port of Everett. March 7, 2016.

Windward, 2017. *Port of Everett: Marina Sediment Characterization and Bioaccumulation Testing Data Report, Final*. Prepared by Windward Environmental for the Port of Everett. March 27, 2017.

14. Agency Signatures.

Concur:

The signed copy is on file in the Dredged Material Managment Office.

_____	_____
Date	David Fox - Seattle District Corps of Engineers
_____	_____
Date	Erika Hoffman - Environmental Protection Agency
_____	_____
Date	Laura Inouye, Ph.D. - Washington Department of Ecology
_____	_____
Date	Celia Barton - Washington Department of Natural Resources

Copies furnished:

DMMP signatories
Frank Nichols – Seattle District Regulatory
Susie McGroddy – Windward Environmental
Kathy Godtfredsen – Windward Environmental
Graham Anderson – Port of Everett
Erik Gerking – Port of Everett

Figure 1. Port of Everett Marina location

Prepared by craigh, 3/4/2016; W:\Projects\Port of Everett\Data\GIS\Maps_and_Analyses\Marina Dredge Support\SAP\Map 1 6265 PoE vicinity.mxd

N

0 500 1,000 1,500 Feet

2010 DMMU boundaries (with dioxin results in ng/kg TEQ)

Everett Shipyard cleanup site (2010 boundary)

Figure 2

DMMU Layout from 2010

N

0 250 500 750 Feet

2010 sampling stations

2012 sampling stations

2010 DMMU boundaries

Everett Shipyard cleanup site (2010 boundary)

Figure 3
Dioxin data from 2010-12 for 2010 DMMUs 2 to 8

2010 DMMU boundaries

2012 SAP Addendum boundaries for DMMP evaluation

Everett Shipyard cleanup site (2010 boundary)

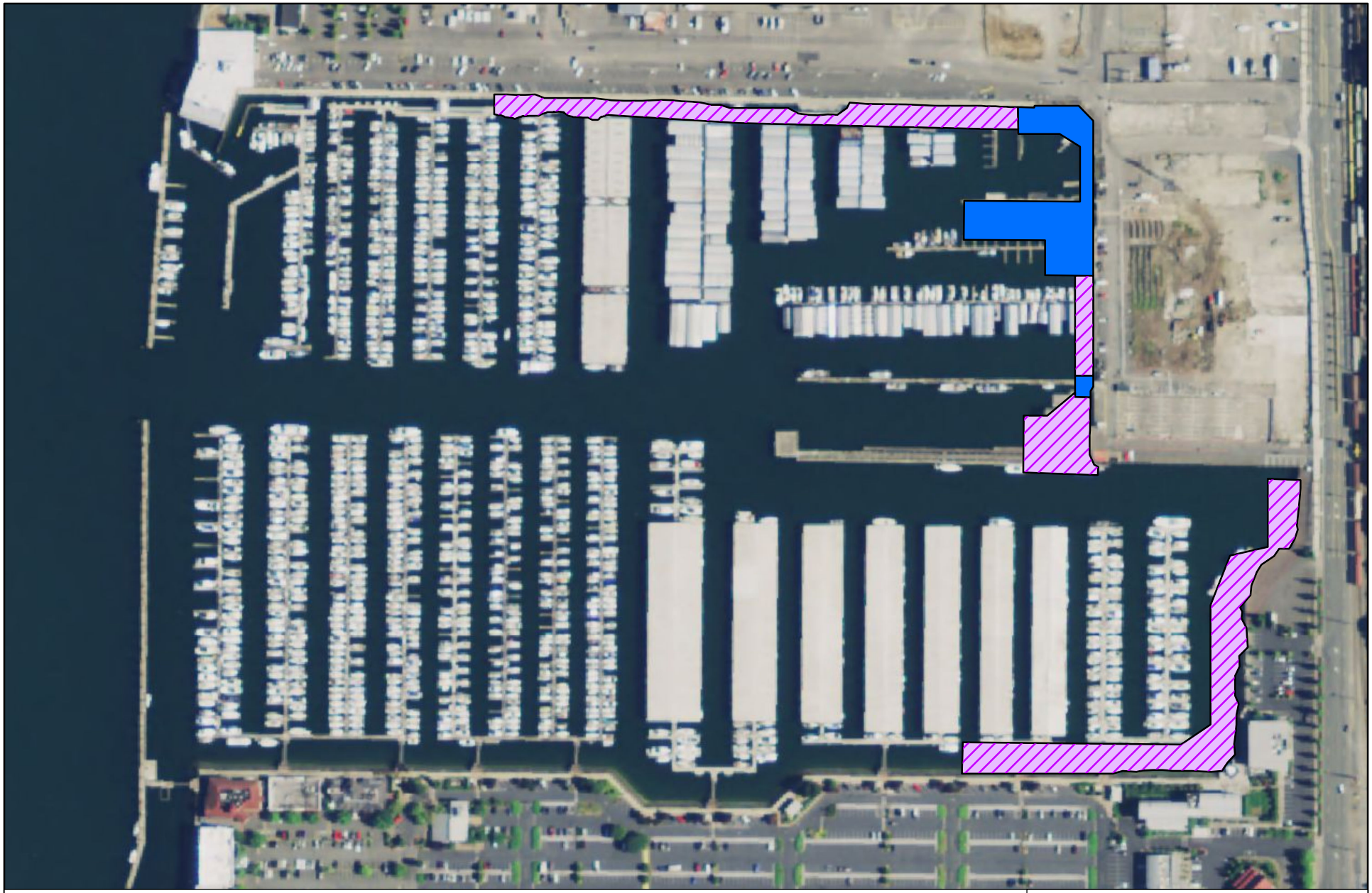
Everett Shipyard anticipated cleanup (2012 boundary)

Figure 4

2012 SAP Addendum area for DMMP evaluation

N

0 100 200 300 Feet



N

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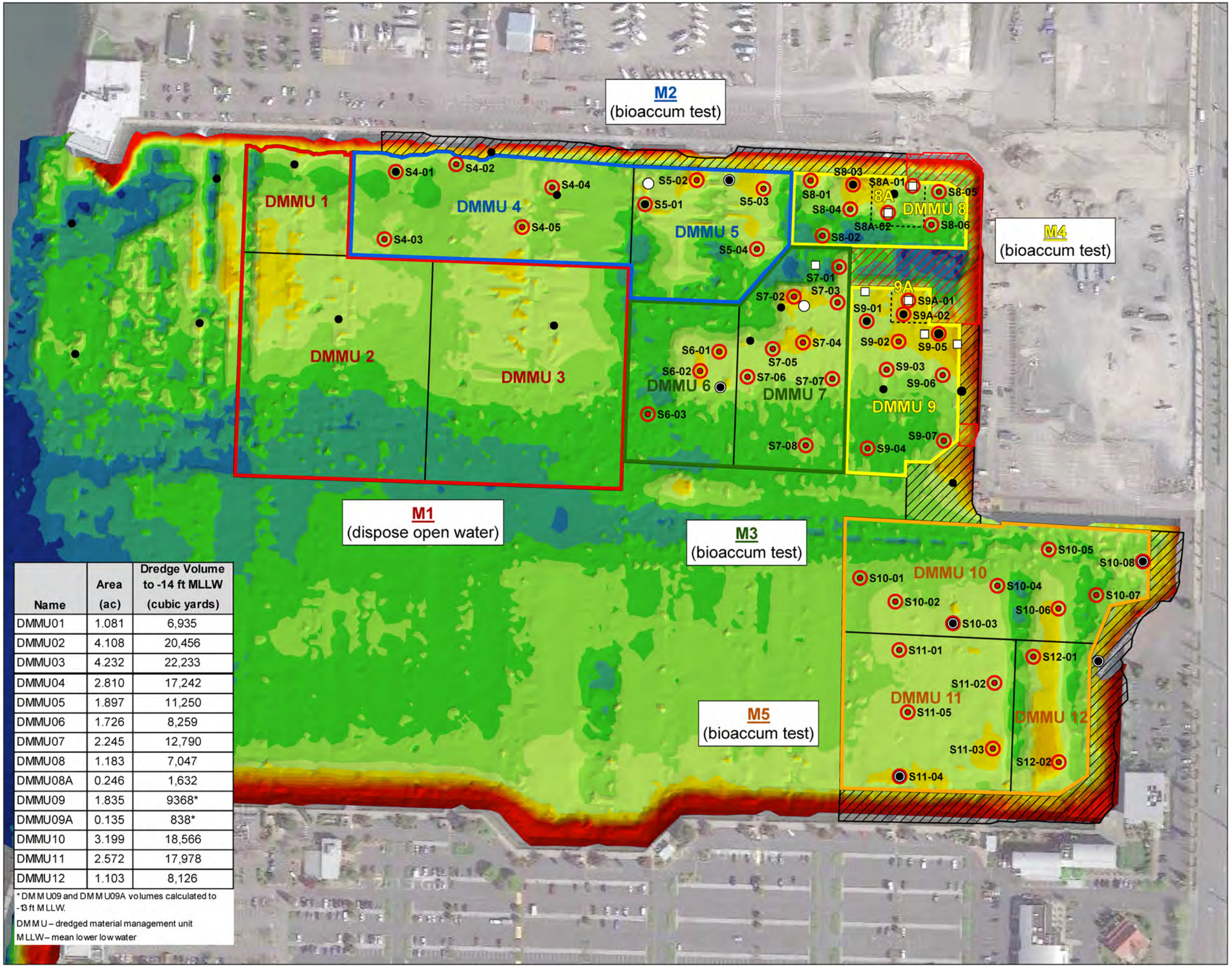
Everett Shipyard final cleanup boundary (2014)

Areas removed by POE from consideration for dredging

Figure 5
Areas Removed from Consideration for Dredging



Name	Area (ac)	Dredge Volume to -14 ft MLLW (cubic yards)
DMMU01	1.081	6,935
DMMU02	4.108	20,456
DMMU03	4.232	22,233
DMMU04	2.810	17,242
DMMU05	1.897	11,250
DMMU06	1.726	8,259
DMMU07	2.245	12,790
DMMU08	1.183	7,047
DMMU08A	0.246	1,632
DMMU09	1.835	9368*
DMMU09A	0.135	838*
DMMU10	3.199	18,566
DMMU11	2.572	17,978
DMMU12	1.103	8,126

* DMMU09 and DMMU09A volumes calculated to -13 ft MLLW.

DMMU – dredged material management unit

MLLW – mean lower low water

Proposed core location

Existing core collected for analysis of dioxins and furans

Existing alternate A-sample

Existing pre-design core location

M1 (dispose open water)

M2 (bioaccum test)

M3 (bioaccum test)

M4 (bioaccum test)

M5 (bioaccum test)

DMMU boundary

DMMU subarea

ESY sediment dredge area

No dredging proposed

Bathymetry (ft MLLW)

- > -4
- > -5 and ≤ -4
- > -6 and ≤ -5
- > -7 and ≤ -6
- > -8 and ≤ -7
- > -9 and ≤ -8
- > -10 and ≤ -9
- > -11 and ≤ -10
- > -12 and ≤ -11
- > -13 and ≤ -12
- > -14 and ≤ -13
- ≤ -14

N

0 40 80 Yards

0 40 80 Meters

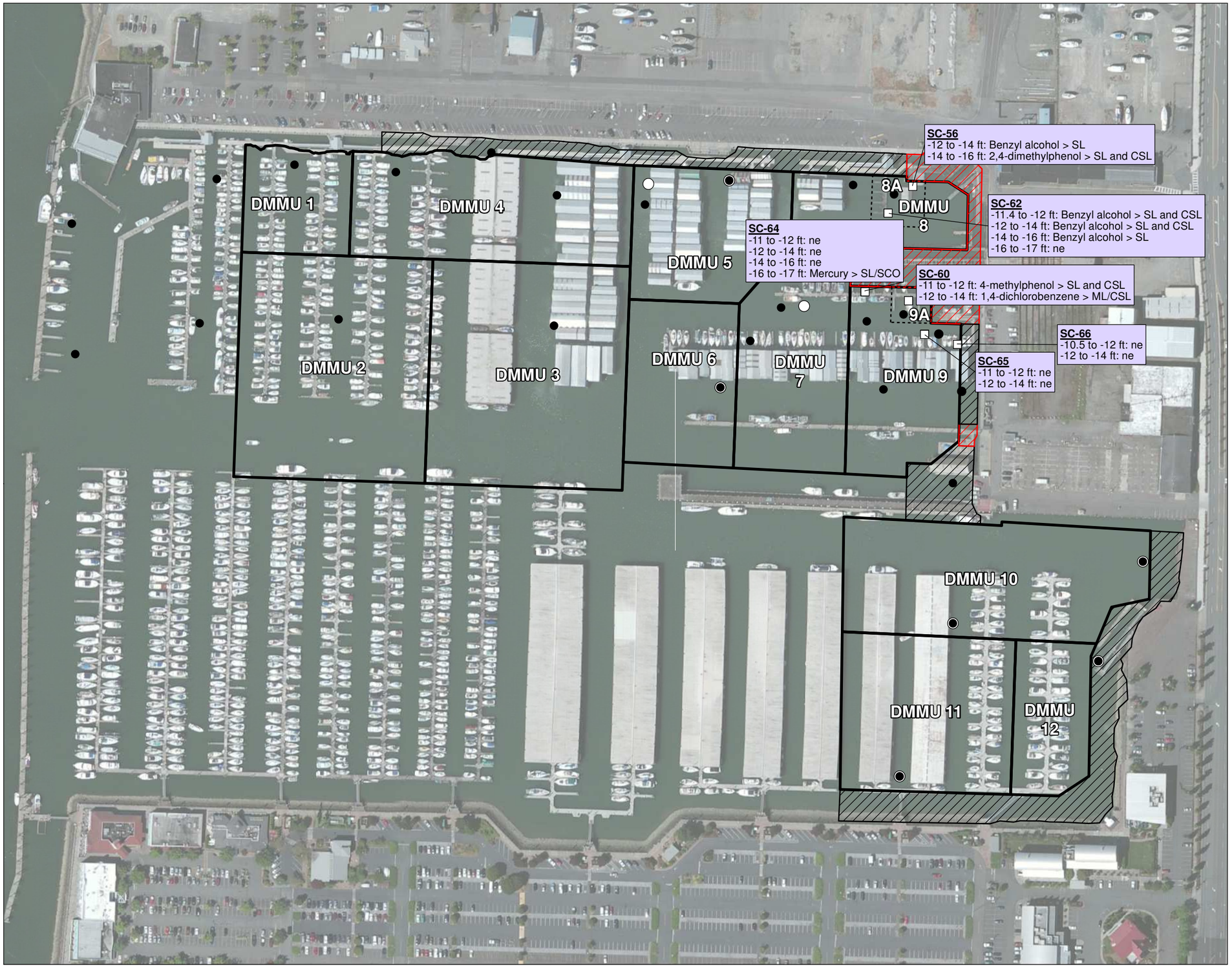
Scale is the same for each map frame

Figure 6

2016 DMMUs, target sampling stations and preliminary management areas.

Wind Ward environmental LLC

Prepared by craigh, 3/4/2016; W:\Projects\Port of Everett\Data\GIS\Maps, and_Analyses\Marina Dredge Support\SAP\Map 4 6205 Marina bathymetry w core locations.mxd



SC-65
-11 to -12 ft: ne
-12 to -14 ft: ne
ESY pre-design study

ne: no exceedances

- ● 2012 DMMP core location
- ○ 2012 Alternate A-sample location
- □ 2012 ESY pre-design core location
- DMMU boundary
- DMMU subarea
- ESY sediment dredge area
- No dredging proposed

Note: Sediment intervals in the ESY pre-design cores that were only analyzed for one analyte are not shown.

N

0 40 80 Yards

0 40 80 Meters

Scale is the same for each map frame

Figure 7

DMMP/SMS exceedances for non-dioxin COCs analyzed for the 2012 ESY predesign study

Windward environmental LLC

Prepared by craigh, 11/14/2016; W:\Projects\Port of Everett\Data\GIS\Maps_and_Analyses\Marina Dredge Support\Data Report\Map 2 6263 Marina data.mxd

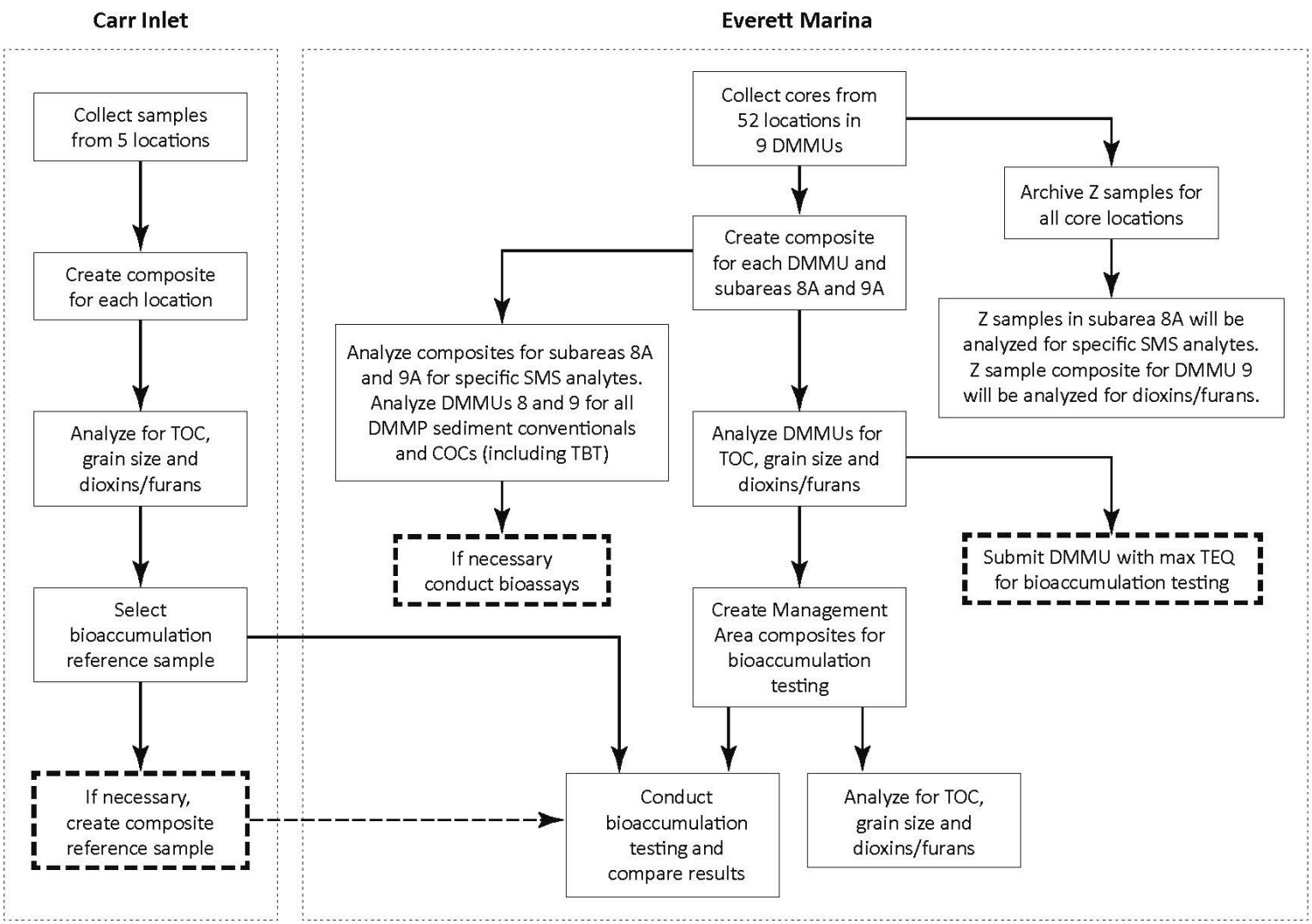
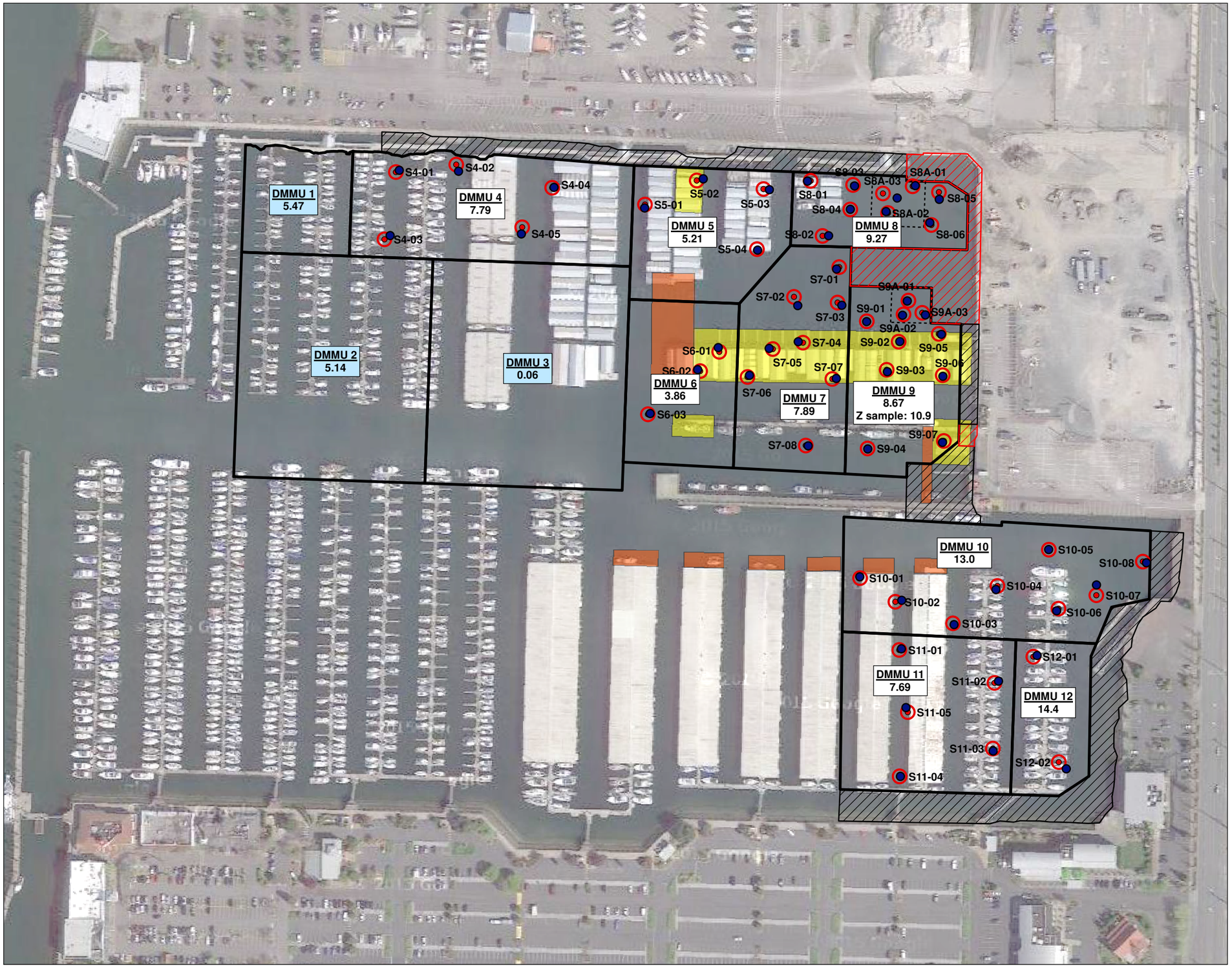


Figure 8. Study design flow chart



DMMU 1 5.47 — 2012 TEQ (ng/kg dw)

DMMU 4 7.79 — 2016 TEQ ng/kg dw

- Actual core location
- Proposed core location
- DMMU boundary
- DMMU subarea
- ESY sediment dredge area
- No dredging proposed
- Berth to be added
- Berth to be removed

N

0 40 80 Yards

0 40 80 Meters

Scale is the same for each map frame

Figure 9

Target and actual 2016 core locations and 2012/2016 dioxin/furan TEQs for the 2016 DMMUs

Windward environmental LLC

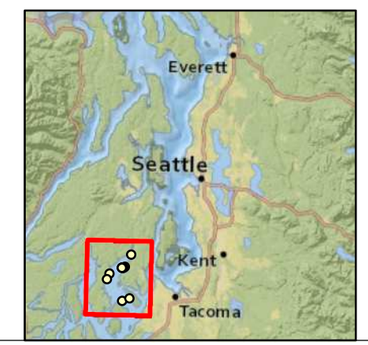
Prepared by craigh, 11/14/2016; W:\Projects\Port of Everett\Data\GIS\Maps_and_Analyses\Marina Dredge Support\Data Report\Map 4 6387 Proposed vs actual sampling locations.mxd

CI-16-1 / 1.75 J — Sample location ID / Dioxin/furan TEQ (ng/kg dw)

2016 Sampling location

2016 Attempted sampling location

Preferred sampling area



N

0 1 2 Miles

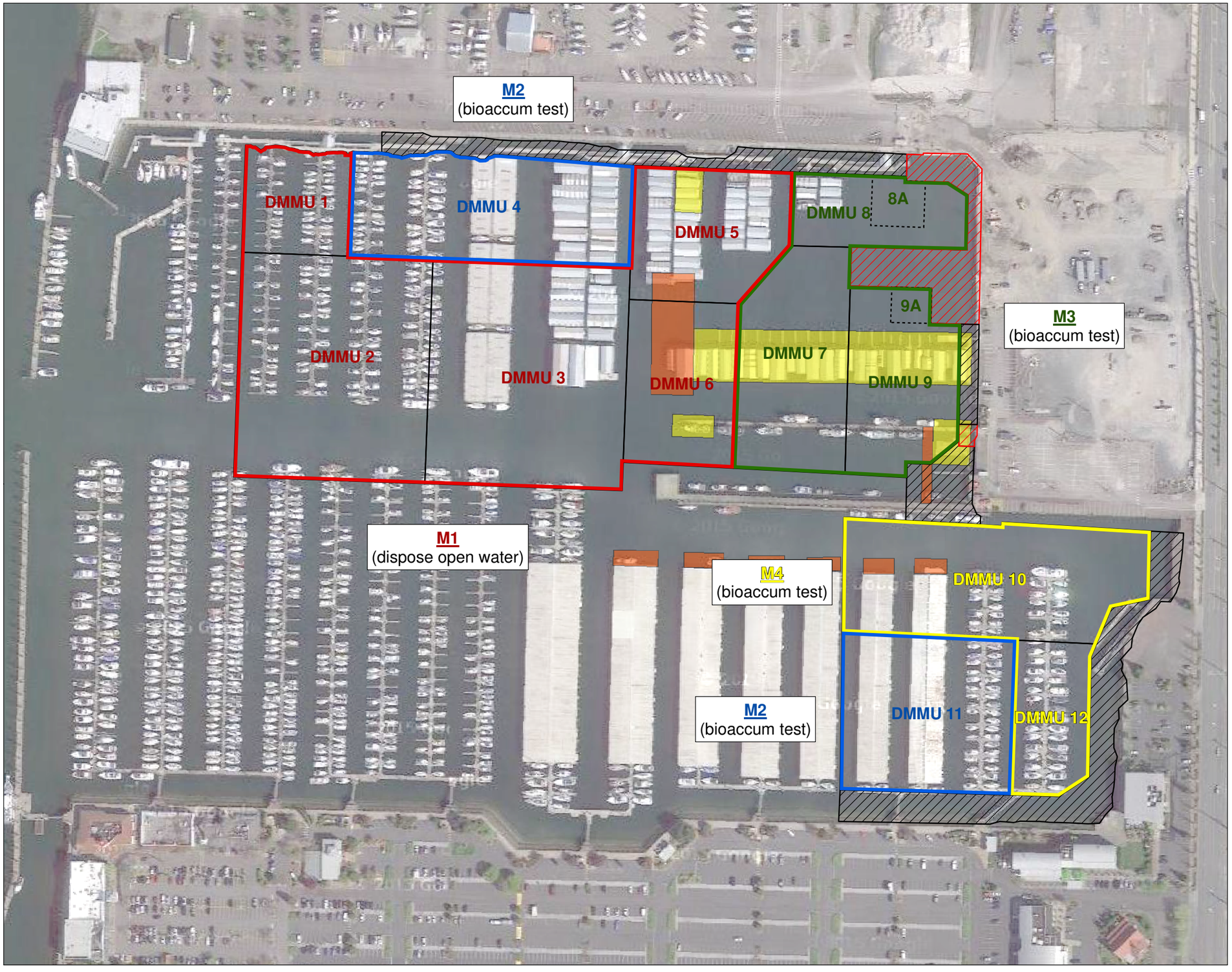
0 2 4 Kilometers

Figure 10

Carr Inlet reference sampling stations and final dioxin/furan TEQs

Windward environmental LLC

Prepared by craigh, 2/8/2017. W:\Projects\Port of Everett\Data\GIS\Maps_and_Analyses\Marina Dredge Support\Data Report\Map 6 6388 Carr Inlet actual locations.mxd



M1 (dispose open water)
M2 (bioaccum test)
M3 (bioaccum test)
M4 (bioaccum test)
DMMU boundary
DMMU subarea
ESY sediment dredge area
No dredging proposed
Berth to be added
Berth to be removed

N

0 40 80 Yards

0 40 80 Meters

Scale is the same for each map frame

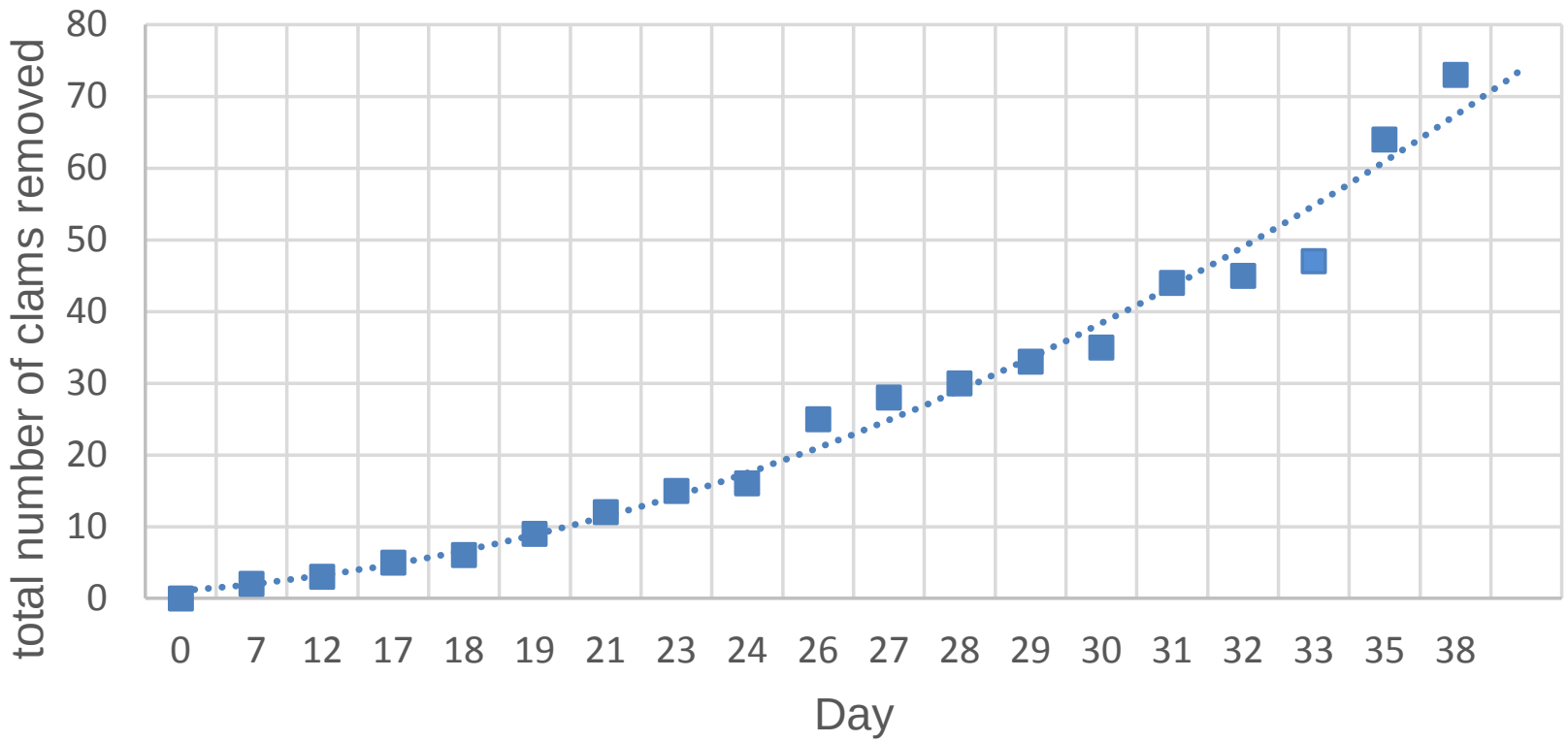
Figure 11

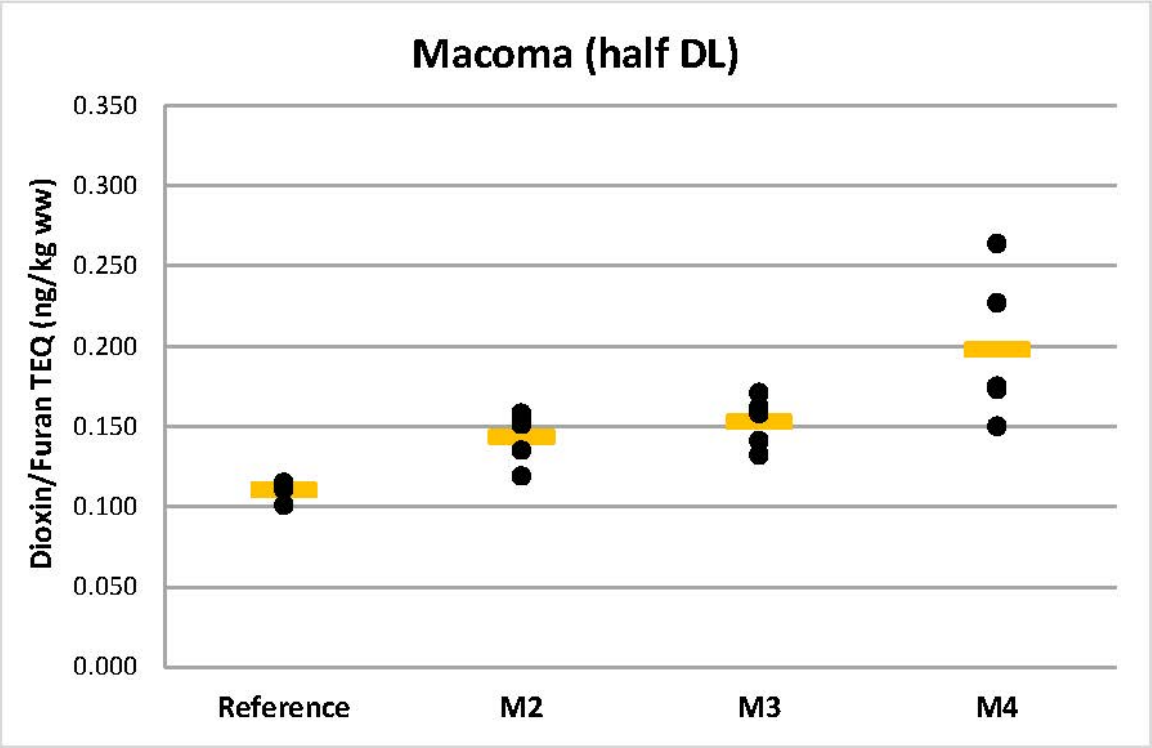
Revised management area configuration following 2016 sediment testing

Windward environmental LLC

Prepared by craigh, 1/12/2017; W:\Projects\Port of Everett\Data\GIS\Maps_and_Analyses\Marina Dredge Support\Data Report\Map 6 6201 DMMU config.mxd

Figure 12. *Macoma nasuta* mortality trend line





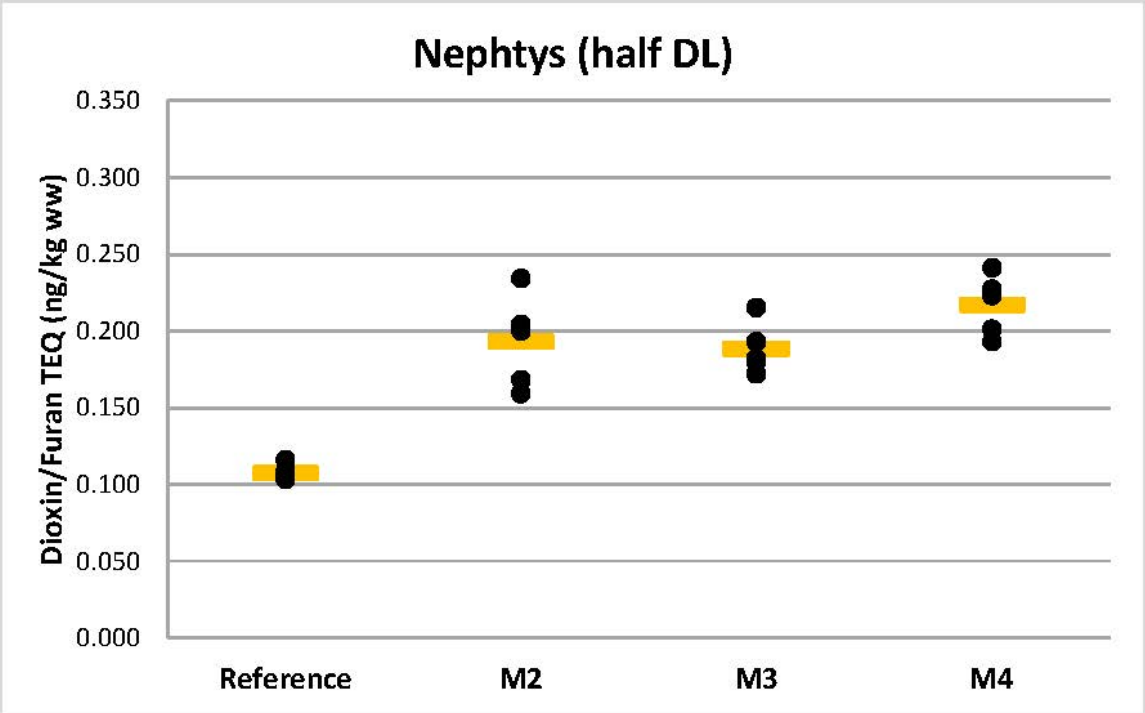


Figure 13. Mean dioxin TEQ values for *Macoma nasuta and Nephtys caecoides* exposed to Carr Inlet reference sediment and marina management area sediments (from Windward, 2017)

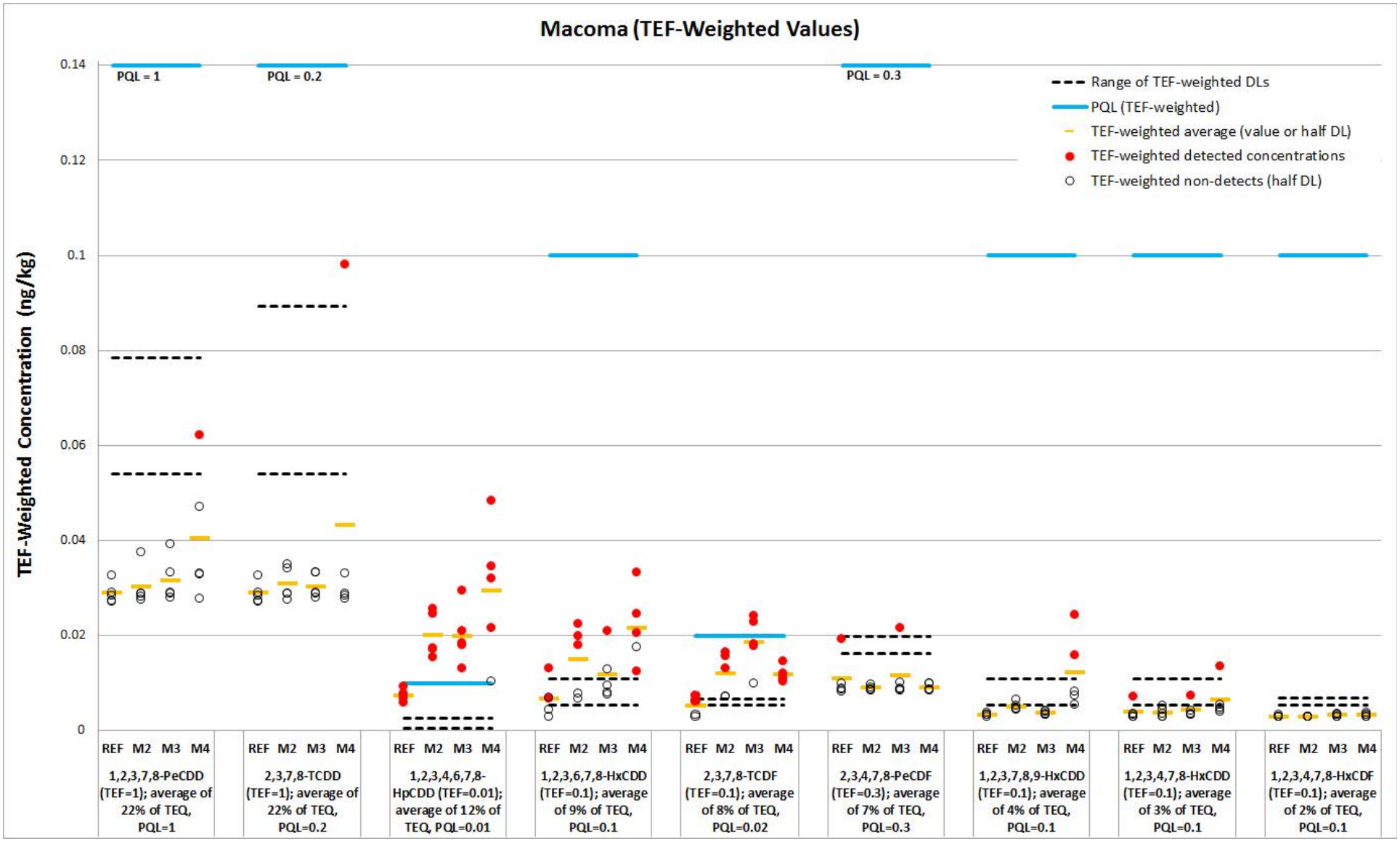


Figure 14. TEF-weighted dioxin and furan congener results, DLs, and PQL values for *Macoma nasuta* (from Windward, 2017)

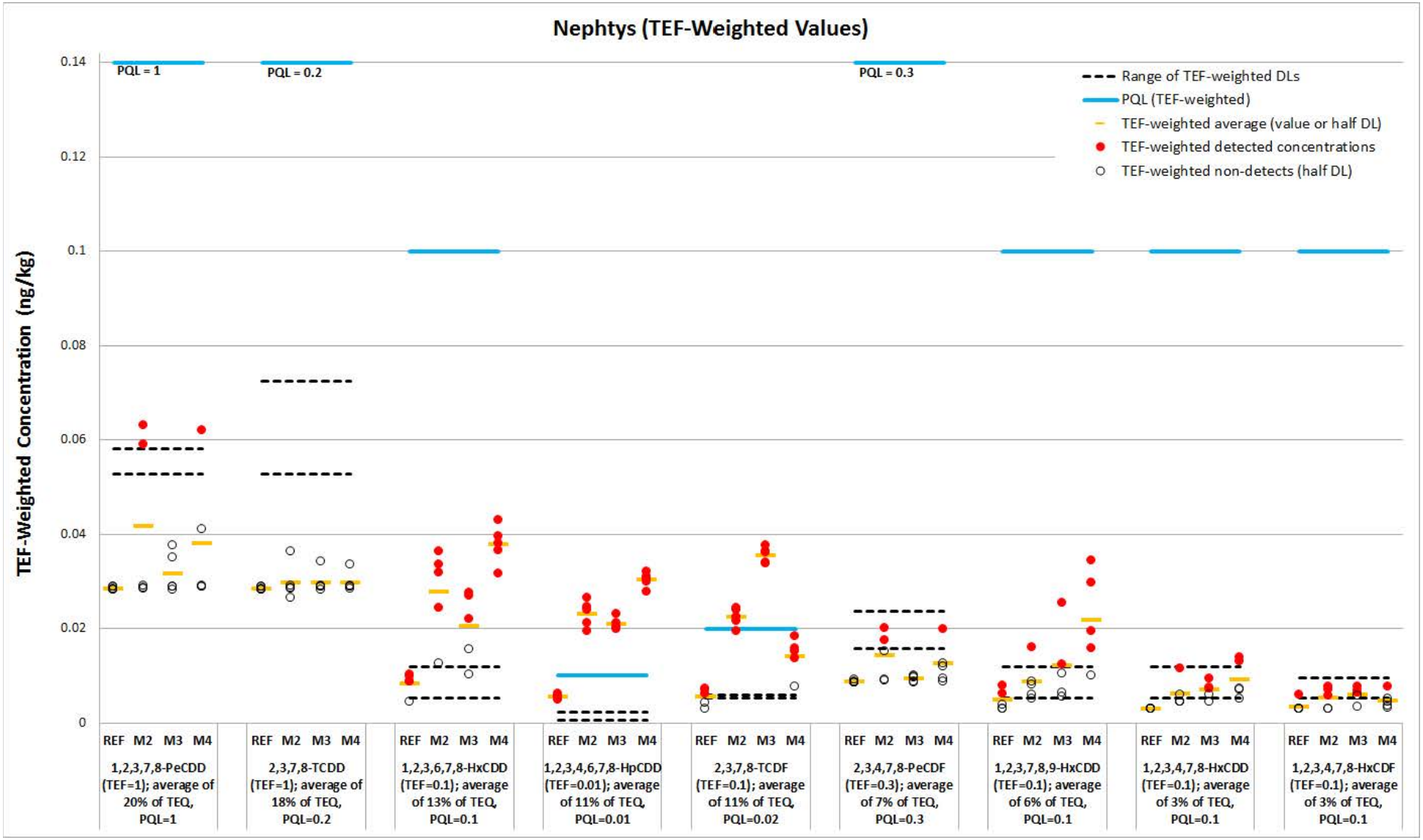


Figure 15. TEF-weighted dioxin and furan congener results, DLs, and PQL values for *Nephtys caecoides* (from Windward, 2017)

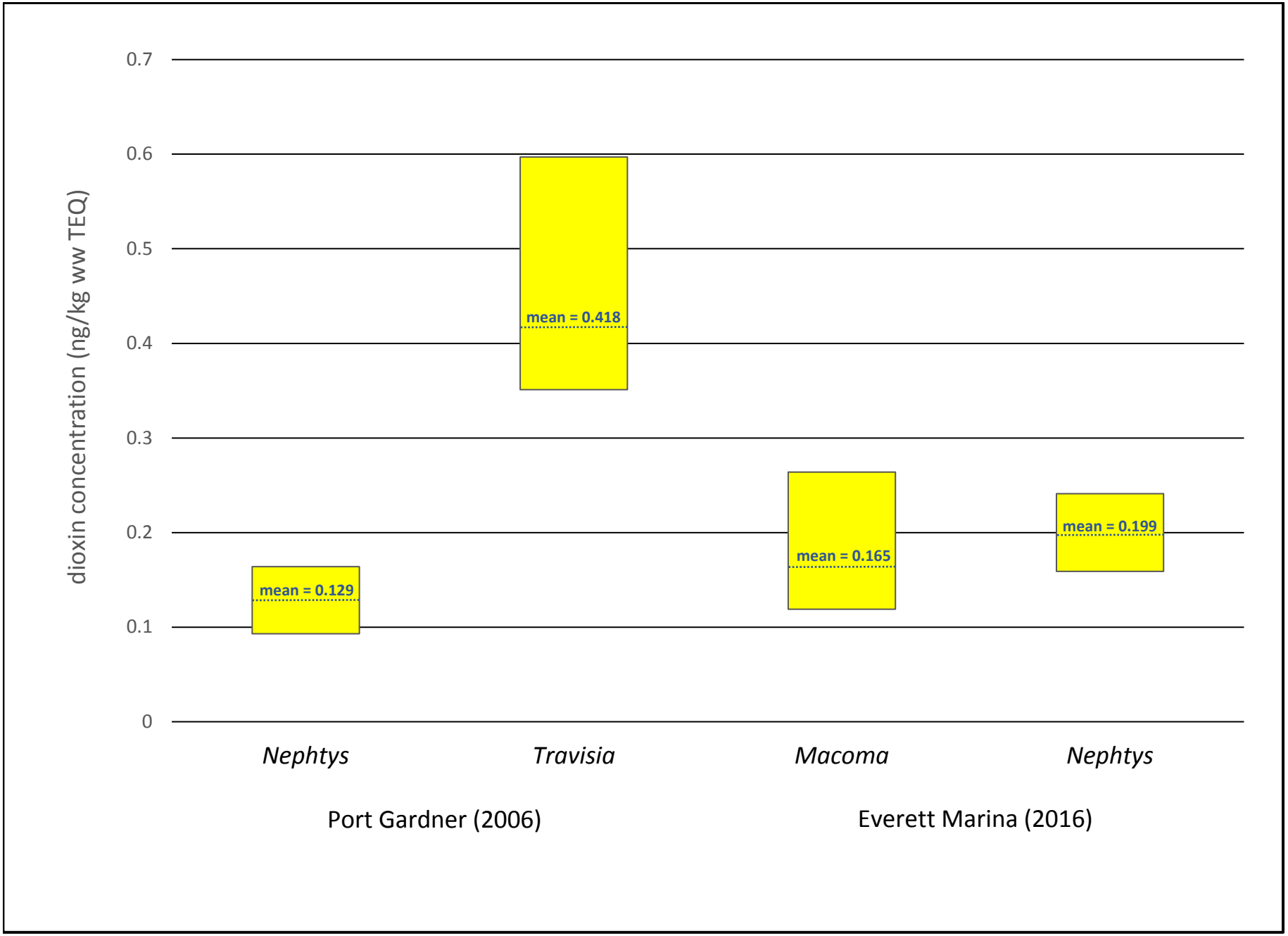


Figure 16. Comparison of to 2006 Port Gardner Monitoring Results

Table 2. Marina sediment sampling coordinates, mudline elevation, penetration depth, and recoveries (from Windward, 2017)

Location ID	Target Coordinates		Actual Coordinates		Distance from Target	Mudline Elevation	Penetration Depth	Core Recovery Depth	Recovery
	Easting[a]	Northing[a]	Easting[a]	Northing[a]	meters	(ft MLLW)	(ft)	(ft)	(%)
DMMU 4									
S4-01	1300768	367463	1300775	367467	2.4	- 9.7	8.0	7.4	92.5
S4-02	1300891	367478	1300896	367465	4.3	- 10.0	7.9	7.0	88.6
S4-03	1300745	367326	1300756	367334	4.2	- 10.0	8.0	7.8	97.5
S4-04	1301087	367431	1301091	367432	1.3	- 9.9	6.7	5.8	86.6
S4-05	1301026	367351	1301024	367337	4.3	- 11.1	7.0	5.8	82.9
DMMU 5									
S5-01	1301277	367397	1301276	367390	2.2	- 10.9	8.0	6.1	76.3
S5-02	1301382	367446	1301396	367450	4.4	- 10.7	8.0	7.9	98.8
S5-03	1301519	367429	1301531	367427	3.7	-12.3	8.0	7.0	87.5
S5-04	1301506	367306	1301507	367304	0.7	-10.8	8.0	6.6	82.5
DMMU 6									
S6-01	1301429	367097	1301427	367106	2.8	-9.2	8.4	7.6	90.5
S6-02	1301390	367057	1301385	367061	2.0	-9.3	8.0	7.9	98.8
S6-03	1301283	366969	1301288	366971	1.6	-12.3	7.1	5.8	81.7
DMMU 7									
S7-01	1301673	367269	1301668	367265	2.0	-10.3	8.0	7.1	88.8
S7-02	1301581	367209	1301589	367191	6.0	-9.2	8.0	7.0	87.5
S7-03	1301670	367197	1301679	367192	3.1	-9.2	8.0	7.3	91.3
S7-04	1301600	367115	1301590	367117	3.1	-9.5	8.0	7.4	92.5
S7-05	1301538	367102	1301531	367104	2.2	-9.0	8.0	7.9	98.8
S7-06	1301486	367045	1301490	367049	1.7	-9.2	8.0	7.9	98.8
S7-07	1301660	367042	1301668	367042	2.4	-11.0	6.8	5.1	75.0
S7-08	1301605	366906	1301610	366905	1.6	-11.1	5.9	5.0	84.7

Location ID	Target Coordinates		Actual Coordinates		Distance from Target	Mudline Elevation	Penetration Depth	Core Recovery Depth	Recovery
	Easting[a]	Northing[a]	Easting[a]	Northing[a]	meters	(ft MLLW)	(ft)	(ft)	(%)
DMMU 8									
S8-01	1301615	367445	1301609	367445	1.8	-9.1	8.0	7.9	98.8
S8-02	1301640	367333	1301652	367333	3.7	-13.0	6.3	5.7	90.5
S8-03	1301702	367437	1301705	367435	1.1	-8.2	9.5	8.9	93.7
S8-04	1301696	367387	1301696	367387	0.0	-10.9	8.0	7.8	97.5
S8-05	1301877	367423	1301878	367408	4.6	-11.7	6.5	5.0	76.9
S8-06	1301862	367355	1301859	367360	1.8	-12.0	6.0	5.0	83.3
S8A-01	1301824	367434	1301829	367436	1.6	-10.2	8.0	7.7	96.3
S8A-02	1301773	367380	1301769	367383	1.5	-10.0	8.0	7.6	95.0
S8A-03	1301763	367420	1301792	367410	9.3	-10.1	8.0	6.0	75.0
DMMU 9									
S9-01	1301730	367159	1301730	367159	0.0	-10.0	8.0	7.8	97.5
S9-02	1301795	367118	1301797	367118	0.6	-9.0	7.8	7.0	89.7
S9-03	1301771	367060	1301772	367056	1.3	-9.5	10.0	9.0	90.0
S9-04	1301732	366900	1301732	366899	0.3	-11.8	8.0	6.6	82.5
S9-05	1301877	367133	1301882	367133	1.5	-10.8	8.0	6.4	80.0
S9-06	1301885	367049	1301885	367047	0.6	-10.0	8.0	7.5	93.8
S9-07	1301887	366915	1301885	366912	1.1	-10.9	6.5	5.6	86.2
S9A-01	1301815	367201	1301813	367200	0.7	-10.2	8.0	6.7	83.8
S9A-02	1301805	367173	1301803	367172	0.7	-9.2	8.0	7.6	95.0
S9A-03	1301843	367177	1301850	367172	2.5	-8.9	6.4	6.1	95.3
DMMU 10									
S10-01	1301716	366635	1301715	366638	1.0	-10.8	8.0	7.7	96.3
S10-02	1301788	366587	1301801	366590	4.1	-10.2	7.6	6.2	81.6
S10-03	1301906	366543	1301908	366541	0.9	-9.8	9.0	8.8	97.8
S10-04	1301997	366619	1301994	366612	2.3	-10.4	6.7	5.6	83.6

Location ID	Target Coordinates		Actual Coordinates		Distance from Target	Mudline Elevation	Penetration Depth	Core Recovery Depth	Recovery
	Easting[a]	Northing[a]	Easting[a]	Northing[a]	meters	(ft MLLW)	(ft)	(ft)	(%)
S10-05	1302102	366693	1302102	366694	0.3	-11.1	8.0	7.0	87.5
S10-06	1302122	366573	1302118	366569	1.7	-9.5	8.0	7.8	97.5
S10-07	1302199	366600	1302199	366622	6.7	-11.9	8.0	7.9	98.8
S10-08	1302294	366669	1302301	366667	2.2	-9.2	8.0	7.2	90.0
DMMU 11									
S11-01	1301796	366489	1301801	366491	1.6	-10.3	7.9	7.5	94.9
S11-02	1301991	366422	1301999	366425	2.6	-9.7	7.4	6.8	91.9
S11-03	1301988	366288	1301988	366283	1.5	-9.4	8.0	7.3	91.3
S11-04	1301797	366231	1301799	366231	0.6	-9.4	8.0	7.2	90.0
S11-05	1301814	366362	1301810	366372	3.3	-10.2	8.0	6.3	78.8
DMMU 12									
S12-01	1302070	366475	1302078	366478	2.6	-9.5	8.0	7.1	88.8
S12-02	1302122	366260	1302137	366246	6.3	-11.2	9.0	8.5	94.4

[a] Washington North Zone, North American Datum of 1983 state plane coordinates – US survey feet.

DMMU – dredged material management unit

MLLW – mean lower low water

ID – identification

Table 3. Marina sediment core lengths and sample intervals for all composite samples (from Windward, 2017)

Location ID	Mudline Elevation (ft MLLW)	Core Length[a] (ft)	Core Interval (ft MLLW)	Dredged Material Sample Interval (ft MLLW)	Composite Sample ID	Z-sample Interval (ft MLLW)	Z-sample ID
DMMU 4							
S4-01	-9.7	7.4	-9.7 to -17.1	-9.7 to -14.0	S4-CS	-14 to -16	S4-01-Z
S4-02	-10.0	7.0	-10.0 to -17.0	-10.0 to -14.0	S4-CS	-14 to -16	S4-02-Z
S4-03	-10.0	7.8	-10.0 to -17.8	-10.0 to -14.0	S4-CS	-14 to -16	S4-03-Z
S4-04	-9.9	5.8	-9.9 to -15.7	-9.9 to -14.0	S4-CS	-14 to -15.7	S4-04-Z
S4-05	-11.1	5.8	-11.1 to -16.9	-11.1 to -14.0	S4-CS	-14 to -16	S4-05-Z
DMMU 5							
S5-01	-10.9	6.1	-10.9 to -17.0	-10.9 to -14.0	S5-CS	-14 to -16	S5-01-Z
S5-02	-10.7	7.9	-10.7 to -18.6	-10.7 to -14.0	S5-CS	-14 to -16	S5-02-Z
S5-03	-12.3	7.0	-12.3 to -19.3	-12.3 to -14.0	S5-CS	-14 to -16	S5-03-Z
S5-04	-10.8	6.6	-10.8 to -17.4	-10.8 to -14.0	S5-CS	-14 to -16	S5-04-Z
DMMU 6							
S6-01	-9.2	7.6	-9.2 to -16.8	-9.2 to -14.0	S6-CS	-14 to -16	S6-01-Z
S6-02	-9.3	7.9	-9.3 to -17.2	-9.3 to -14.0	S6-CS	-14 to -16	S6-02-Z
S6-03	-12.3	5.8	-12.3 to -18.1	-.12.3 to -14.0	S6-CS	-14 to -16	S6-03-Z
DMMU 7							
S7-01	-10.3	7.1	-10.3 to -17.4	-10.3 to -14.0	S7-CS	-14 to -16	S7-01-Z
S7-02	-9.2	7.0	-9.2 to -16.2	-9.2 to -14.0	S7-CS	-14 to -16	S7-02-Z
S7-03	-9.2	7.3	-9.2 to -16.5	-9.2 to -14.0	S7-CS	-14 to -16	S7-03-Z
S7-04	-9.5	7.4	-9.5 to -16.9	-9.5 to -14.0	S7-CS	-14 to -16	S7-04-Z
S7-05	-9.0	7.9	-9.0 to -16.9	-9.0 to -14.0	S7-CS	-14 to -16	S7-05-Z
S7-06	-9.2	7.9	-9.2 to -17.1	-9.2 to -14.0	S7-CS	-14 to -16	S7-06-Z

Location ID	Mudline Elevation (ft MLLW)	Core Length[a] (ft)	Core Interval (ft MLLW)	Dredged Material Sample Interval (ft MLLW)	Composite Sample ID	Z-sample Interval (ft MLLW)	Z-sample ID
S7-07	-11.0	5.1	-11.0 to -16.1	-11.0 to -14.0	S7-CS	-14 to -16	S7-07-Z
S7-08	-11.1	5.0	-11.1 to -16.1	-11.1 to -14.0	S7-CS	-14 to -16	S7-08-Z
DMMU 8							
S8-01	-9.1	7.9	-9.1 to -17.0	-9.1 to -14.0	S8-CS	-14 to -16	S8-01-Z
S8-02	-13.0	5.7	-13.0 to -18.7	-13.0 to -14.0	S8-CS	-14 to -16	S8-02-Z
S8-03	-8.2	8.9	-8.2 to -17.1	-8.2 to -14.0	S8-CS	-14 to -16	S8-03-Z
S8-04	-10.9	7.8	-10.9 to -18.7	-10.9 to -14.0	S8-CS	-14 to -16	S8-04-Z
S8-05	-11.7	5.0	-11.7 to -16.7	-11.7 to -14.0	S8-CS	-14 to -16	S8-05-Z
S8-06	-12.0	5.0	-12.0 to -17.0	-12.0 to -14.0	S8-CS	-14 to -16	S8-06-Z
S8A-01	-10.2	7.7	-10.2 to -17.9	-10.2 to -14.0	S8A-CS[b]	-14 to -16	S8A-CS-Z
S8A-02	-10.0	7.6	-10.0 to -17.6	-10.0 to -14.0	S8A-CS[b]	-14 to -16	S8A-CS-Z
S8A-03	-10.1	6.0	-10.1 to -16.1	-10.1 to -14.0	S8A-CS[b]	-14 to -16	S8A-CS-Z
DMMU 9							
S9-01	-10.0	7.8	-10.0 to -17.8	-10.0 to -13.0	S9-CS	-13 to -15	S9-CS-Z
S9-02	-9.0	7.0	-9.0 to -16.0	-9.0 to -13.0	S9-CS	-13 to -15	S9-CS-Z
S9-03	-9.5	9.0	-9.5 to -18.5	-9.5 to -13.0	S9-CS	-13 to -15	S9-CS-Z
S9-04	-11.8	6.6	-11.8 to -18.4	-11.8 to -13.0	S9-CS	-13 to -15	S9-CS-Z
S9-05	-10.8	6.4	-10.8 to -17.2	-10.8 to -13.0	S9-CS	-13 to -15	S9-CS-Z
S9-06	-10.0	7.5	-10.0 to-17.5	-10.0 to -13.0	S9-CS	-13 to -15	S9-CS-Z
S9-07	-10.9	5.6	-10.9 to -16.5	-10.9 to -13.0	S9-CS	-13 to -15	S9-CS-Z
S9A-01	-10.2	6.7	-10.2 to -16.9	-10.2 to -13.0	S9A-CS[c]	-13 to -15	S9A-CS-Z
S9A-02	-9.2	7.6	-9.2 to -16.8	-9.2 to -13.0	S9A-CS[c]	-13 to -15	S9A-CS-Z
S9A-03	-8.9	6.1	-8.9 to -15.0	-8.9 to -13.0	S9A-CS[c]	-13 to -15	S9A-CS-Z

DMMU 10							
S10-01	-10.8	7.7	-10.8 to -18.5	-10.8 to -14.0	S10-CS	-14 to -16	S10-01-Z
S10-02	-10.2	6.2	-10.2 to -16.4	-10.2 to -14.0	S10-CS	-14 to -16	S10-02-Z
S10-03	-9.8	8.8	-9.8 to -18.6	-9.8 to -14.0	S10-CS	-14 to -16	S10-03-Z
S10-04	-10.4	5.6	-10.4 to -16.0	-10.4 to -14.0	S10-CS	-14 to -16	S10-04-Z
S10-05	-11.1	7.0	-11.1 to -18.1	-11.1 to -14.0	S10-CS	-14 to -16	S10-05-Z
S10-06	-9.5	7.8	-9.5 to -17.3	-9.5 to -14.0	S10-CS	-14 to -16	S10-06-Z
S10-07	-11.9	7.9	-11.9 to -19.8	-11.9 to -14.0	S10-CS	-14 to -16	S10-07-Z
S10-08	-9.2	7.2	-9.2 to -16.4	-9.2 to -14.0	S10-CS	-14 to -16	S10-08-Z
DMMU 11							
S11-01	-10.3	7.5	-10.3 to -17.8	-10.3 to -14.0	S11-CS	-14 to -16	S11-01-Z
S11-02	-9.7	6.8	-9.7 to -16.5	-9.7 to -14.0	S11-CS	-14 to -16	S11-02-Z
S11-03	-9.4	7.3	-9.4 to -16.7	-9.4 to -14.0	S11-CS	-14 to -16	S11-03-Z
S11-04	-9.4	7.2	-9.4 to -16.6	-9.4 to -14.0	S11-CS	-14 to -16	S11-04-Z
S11-05	-10.2	6.3	-10.2 to -16.5	-10.2 to -14.0	S11-CS	-14 to -16	S11-05-Z
DMMU 12							
S12-01	-9.5	7.1	-9.5 to -16.6	-9.5 to -14.0	S12-CS	-14 to -16	S12-01-Z
S12-02	-11.2	8.5	-11.2 to -19.7	-11.2 to -14.0	S12-CS	-14 to -16	S12-02-Z

[a] Core length is actual core length with no recovery correction.

[b] S8A-CS was analyzed for ammonia, total sulfides, benzyl alcohol, and 2,4-dimethylphenol. In addition, a portion of the sample was included in the S8-CS composite that was analyzed for dioxins/furans.

[c] S9A-CS was analyzed for ammonia, total sulfides, and 1,4-dichlorobenzene. In addition, a portion of the sample was included in the S9-CS composite that was analyzed for dioxins/furans.

DMMU – dredged material management unit

MLLW – mean lower low water

ID – identification

Table 4. Final dioxin/furan TEQs, percent fines, and TOC in Carr Inlet and Marina samples (from Windward, 2017)

Sample Location	Composite Sample ID	Sample Date	Dioxin/Furan TEQ - Mammal (Half DL)	Percent Fines	TOC
			ng/kg dw	% dw	% dw
Marina samples mudline to -14 ft MLLW					
DMMU 4	S4-CS	5/10/2016	7.79 J	84.0	2.01
DMMU 5	S5-CS	5/12/2016	5.21 J	68.9	2.11
DMMU 6	S6-CS	5/12/2016	3.86 J	99.9	1.80
DMMU 7	S7-CS	5/11/2016	7.89[a] J	91.6	2.23
DMMU 8	S8-CS	5/13/2016	9.27 J	77.0	1.62
DMMU 9[b]	S9-CS	5/18/2016	8.67 J	94.6	2.58 J
DMMU 10	S10-CS	5/17/2016	13.0 J	91.8	2.75
DMMU 11	S11-CS	5/16/2016	7.69 J	86.7	2.65 J
DMMU 12	S12-CS	5/16/2016	14.4 J	84.9	1.44 J
Marina Z sample (-13 to -15 ft MLLW)					
DMMU 9	S9-CS-Z	5/18/2016	10.9 J	93.0	2.36 J
Carr Inlet samples (0 to 10 cm)					
CI-16-1	CI-16-1	5/17/2016	1.75 J	91.3	1.43 J
CI-16-2	CI-16-2	5/17/2016	1.29 J	86.2	1.02 J
CI-16-3	CI-16-3	5/17/2016	1.72 J	92.8	1.75 J
CI-16-4	CI-16-4	5/17/2016	1.10 J	74.9	1.28 J
CI-16-5	CI-16-5	5/17/2016	0.645 J	71.1	0.925 J
CI-16-6	CI-16-6	5/23/2016	4.63 J	89.9	1.93 J
CI-16-7	CI-16-7	5/23/2016	2.57 J	43.2	1.02 J
CI-16-8	CI-16-8	5/23/2016	4.42 J	81.0	1.69 J

[a] This value represents the average of two laboratory replicates.

[b] DMMU 9 was characterized from mudline to -13 ft MLLW.

Axys – Axys Analytical
dw – dry weight
DL – detection limit
DMMU – dredged material management unit
EDL – estimated detection limit
ID – identification
J – estimated concentrations
MLLW – mean lower low water
SAP – sampling and analysis plan
TEQ – toxic equivalent
TOC – total organic carbon

Table 5. Chemistry results for DMMUs 8 and 9 (from Windward, 2017)

Chemical	S8-CS Dredged Material	S9-CS Dredged Material	DMMP 2016 SL	DMMP 2016 BT	DMMP 2016 ML
Metals (mg/kg dw)					
Antimony	0.3 UJ	0.4 U	150	---	200
Arsenic	11.5	11.6	57	507.1	700
Cadmium	0.6	0.8	5.1	---	14
Chromium	49.8	60.9	260	---	---
Copper	66.7	73.4	390	---	1,300
Lead	18.6	18.4	450	975	1,200
Mercury	0.15	0.14	0.41	1.5	2.3
Selenium	0.8 U	0.9 U	---	3	---
Silver	0.300 U	0.400 U	6.1	---	8.4
Zinc	98	110	410	---	3,800
TBT as ion (µg/kg dw)	17 J	5.7	---	73	---
PAHs (µg/kg dw)					
2-Methyl naphthalene	64	94	670	---	1,900
Acenaphthene	79	62	500	---	2,000
Acenaphthylene	41	57	560	---	1,300
Anthracene	120	95	960	---	13,000
Benzo(a)anthracene	340	110	1,300	---	5,100
Benzo(a)pyrene	180	87	1,600	---	3,600
Benzo(g,h,i)perylene	87	48	670	---	3,200
Total benzofluoranthenes	620	220	3,200	---	9,900
Chrysene	650	160	1,400	---	21,000
Dibenzo(a,h)anthracene	26	11	230	---	1,900
Fluoranthene	770	370	1,700	4,600	30,000
Fluorene	95	77	540	---	3,600
Indeno(1,2,3-cd) pyrene	86	38	600	---	4,400
Naphthalene	220	400	2,100	---	2,400
Phenanthrene	320	310	1,500	---	21,000
Pyrene	780	460	2,600	11,980	16,000
Total HPAHs	3,540	1,500	12,000	---	69,000
Total LPAHs	880	1,000	5,200	---	29,000
Phthalates (µg/kg dw)					
Bis(2-ethylhexyl)phthalate	130	57	1,300	---	8,300
Butyl benzyl phthalate	20 U	19 U	63	---	970
Diethyl phthalate	30 J	24 J	200	---	1,200
Dimethyl phthalate	20 U	19 U	71	---	1,400
Di-n-butyl phthalate	20 U	19 U	1,400	---	5,100
Di-n-octyl phthalate	20 U	19 U	6,200	---	6,200

Chemical	S8-CS Dredged Material	S9-CS Dredged Material	DMMP 2016 SL	DMMP 2016 BT	DMMP 2016 ML
Other SVOCs (µg/kg dw)					
1,2,4-Trichlorobenzene	4.9 U	4.7 U	31	---	64
1,2-Dichlorobenzene	4.9 U	19 U	35	---	110
1,3-Dichlorobenzene	20 U	19 U	---	---	---
1,4-Dichlorobenzene	3.6 J	3.5 J	110	---	120
2,4-Dimethylphenol	24 U	23 U	29	---	210
2-Methylphenol	20 U	19 U	63	---	77
4-Methylphenol	160	380	670	---	3,600
Benzoic acid	91 J	120 J	650	---	760
Benzyl alcohol	20 U	41	57	---	870
Dibenzofuran	77	69	540	---	1,700
Hexachlorobenzene	0.95 U	9.2 U	22	168	230
Hexachlorobutadiene	0.95 U	1.9 U	11	---	270
n-Nitrosodiphenylamine	20 U	19 U	28	---	130
Pentachlorophenol	97 U	93 U	400	504	690
Phenol	52	94	420	---	1,200
PCBs					
Total PCB Aroclors (µg/kg dw)	46	31	130	---	3,100
Total PCB Aroclors (mg/kg OC)	2.8	1.2	---	38	---
Pesticides					
4,4'-DDD	0.95 U	0.96 UJ	16	---	---
4,4'-DDE	0.95 U	0.96 UJ	9	---	---
4,4'-DDT	2.6 U	0.96 U	12	---	---
Total DDTs	2.6 U	0.96 UJ	---	50	69
Aldrin	1.2 U	0.48 U	9.5	---	---
Dieldrin	0.95 U	0.96 UJ	1.9	---	1,700
Total chlordane	0.87 U	17 UJ	2.8	37	---
Heptachlor	0.48 U	2.6 UJ	1.5	---	270

Detection limit exceedance of SL
BT – bioaccumulation trigger
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
DMMP – Dredged Material Management Program
DMMU – dredged material management unit
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
J – estimated concentration
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
ML – maximum level
OC – organic carbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SL – screening level
SVOC – semivolatile organic compound
TBT – tributyltin
U – not detected at given concentration

Table 6. Results for selected SVOCs for subareas 8A and 9A (from Windward, 2017)

Chemical	S8A-CS (0–4 ft)	S8A-CS-Z (-14 to -16 ft MLLW)	S9A-CS (0–4 ft)	S9A-CS-Z (-13 to -15 ft MLLW)	DMMP 2016 SL	DMMP 2016 ML
1,4-Dichlorobenzene	ntr	ntr	3.9 J	66	110	120
2,4-Dimethylphenol	23 U	23 U	ntr	ntr	29	210
Benzyl alcohol	19 U	19 U	ntr	ntr	57	870

DMMP – Dredged Material Management Program
J – estimated concentration
ML – maximum level
MLLW – mean lower low water
ntr – no testing required
SL – screening level
SVOC – semivolatile organic compound
U – not detected at given concentration

Table 7. *Macoma* and *Nephtys* mortality

	mean percent mortality	
	Macoma nasuta	*Nephtys caecoides*
Control	53.3	27.9
M2	23.3	25.2
M3	15.0	18.9
M4	25.0	32.0
Reference	25.0	30.0

Table 8. *Macoma nasuta* tissue dioxin values and lipid content (from Windward, 2017)

Sample Name	Dioxin/Furan TEQ Mammal – Half DL (ng/kg ww)	Dioxin/Furan TEQ Mammal – zero DL (ng/kg ww)	Lipid (% ww)
Tissue collected prior to testing			
T0-Mac-01	0.0902 U	0.000 U	0.20
Carr Inlet samples			
CIREF-Mac-01	0.112 J	0.008 J	0.35
CIREF-Mac-02	0.111 J	0.018 J	0.32
CIREF-Mac-03	0.115 J	0.032 J	0.34
CIREF-Mac-04	0.112 J	0.040 J	0.45
CIREF-Mac-05	0.101 J	0.017 J	0.38
Marina samples			
M2-Mac-01	0.119 J	0.018 J	0.28
M2-Mac-02	0.153 J	0.042 J	0.21
M2-Mac-03	0.135 J	0.035 J	0.20
M2-Mac-04	0.158 J	0.068 J	0.24
M2-Mac-05	0.151 J	0.065 J	0.30
M3-Mac-01	0.141 J	0.043 J	0.29
M3-Mac-02	0.132 J	0.036 J	0.38
M3-Mac-03	0.162 J	0.051 J	0.21
M3-Mac-04	0.171 J	0.085 J	0.37
M3-Mac-05	0.158 J	0.053 J	1.93
M4-Mac-01	0.227 J	0.119 J	0.47
M4-Mac-02	0.150 J	0.036 J	0.13
M4-Mac-03	0.264 J	0.188 J	0.061
M4-Mac-04	0.173 J	0.093 J	0.25
M4-Mac-05	0.175 J	0.114 J	0.35

DL – detection limit
J – estimated concentrations
TEQ – toxic equivalent
U – result undetected at reporting limit shown
ww – wet weight

Table 9. *Nephtys caecoides* tissue dioxin values and lipid content (from Windward, 2017)

Sample Name	Dioxin/Furan TEQ Mammal – Half DL (ng/kg ww)	Dioxin/Furan TEQ Mammal – zero DL (ng/kg ww)	Lipid (% ww)
Tissue collected prior to testing			
T0-Nep-01	0.0915 U	0.000 U	1.26
Carr Inlet samples			
CIREF-Nep-01	0.103 J	0.014 J	1.17
CIREF-Nep-02	0.108 J	0.022 J	1.17
CIREF-Nep-03	0.104 J	0.008 J	1.44
CIREF-Nep-04	0.116 J	0.038 J	0.97
CIREF-Nep-05	0.105 J	0.023 J	1.34
Marina samples			
M2-Nep-01	0.168 J	0.078 J	1.04
M2-Nep-02	0.204 J	0.155 J	0.98
M2-Nep-03	0.159 J	0.062 J	0.87
M2-Nep-04	0.234 J	0.187 J	1.10
M2-Nep-05	0.200 J	0.094 J	0.86
M3-Nep-01	0.215 J	0.115 J	0.90
M3-Nep-02	0.193 J	0.116 J	1.01
M3-Nep-03	0.172 J	0.082 J	0.86
M3-Nep-04	0.180 J	0.078 J	1.09
M3-Nep-05	0.182 J	0.082 J	1.00
M4-Nep-01	0.193 J	0.104 J	0.95
M4-Nep-02	0.223 J	0.165 J	0.84
M4-Nep-03	0.201 J	0.116 J	1.01
M4-Nep-04	0.241 J	0.149 J	1.07
M4-Nep-05	0.227 J	0.131 J	0.97

DL – detection limit
J – estimated concentrations
TEQ – toxic equivalent
U – result undetected at reporting limit shown
ww – wet weight

Table 10. Results of the t-tests comparing mean dioxin/furan TEQs in organisms exposed to Marina Management Area sediments with mean dioxin/furan TEQs in organisms exposed to Carr Inlet sediment (alpha=0.1) (from Windward, 2017)

Test Organism	Dioxin/Furan TEQ	p Value Difference (one-sided)		
		M2	M3	M4
Macoma nasuta	zero DL	0.034	0.008	0.011
	half DL	0.001	0	0.002
	full DL	0.001	0	0.007
Nephtys caecoides	zero DL	0.008	0	0
	half DL	0.001	0	0
	full DL	0.001	0	0

Note: p values < 0.10 indicate a value significantly greater than the Carr Inlet value.
DL – detection limit
TEQ – toxic equivalent

Table 11. Congener-specific PQLs (from Windward, 2017)

Congener	PQL (ng/kg ww)	TEF	TEF-weighted Concentration (ng/kg ww)
1,2,3,4,6,7,8-HpCDD	1	0.01	0.01
1,2,3,4,6,7,8-HpCDF	1	0.01	0.01
1,2,3,4,7,8,9-HpCDF	1	0.01	0.01
1,2,3,4,7,8-HxCDD	1	0.1	0.1
1,2,3,4,7,8-HxCDF	1	0.1	0.1
1,2,3,6,7,8-HxCDD	1	0.1	0.1
1,2,3,6,7,8-HxCDF	1	0.1	0.1
1,2,3,7,8,9-HxCDD	1	0.1	0.1
1,2,3,7,8,9-HxCDF	1	0.1	0.1
1,2,3,7,8-PeCDD	1	1	1
1,2,3,7,8-PeCDF	1	0.03	0.03
2,3,4,6,7,8-HxCDF	1	0.1	0.1
2,3,4,7,8-PeCDF	1	0.3	0.3
2,3,7,8-TCDD	0.2	1	0.2
2,3,7,8-TCDF	0.2	0.1	0.02
OCDD	2	0.0003	0.0006
OCDF	2	0.0003	0.0006

Note: The PQLs in this table are equal to the LMCLs provided by Axys.

Axys – Axys Analytical
HpCDD – heptachlorodibenzo-*p*-dioxin
HpCDF – heptachlorodibenzofuran
HxCDD – hexachlorodibenzo-*p*-dioxin
HxCDF – hexachlorodibenzofuran
LMCL – lowest method calibration level
na – not applicable
OCDD – octachlorodibenzo-*p*-dioxin
OCDF – octachlorodibenzofuran
PeCDD – pentachlorodibenzo-*p*-dioxin
PeCDF – pentachlorodibenzofuran
PQL – practical quantitation limit
TCDD – tetrachlorodibenzo-*p*-dioxin
TCDF – tetrachlorodibenzofuran
TEF – toxic equivalence factor
ww – wet weight

Attachment 1

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MEMORANDUM

To: DMMP

From: Susie McGroddy and Kathy Godtfredsen behalf of Port of Everett

Subject: Port of Everett Marina Preliminary Results

Date: June 15, 2016

This memorandum presents the preliminary results of the dioxin/furan analyses conducted on the dredged material management unit (DMMU) composites collected from the Port of Everett Marina (Marina) in May 2016 and proposes management areas options for bioaccumulation testing. In addition, the results of the reference area sampling are presented.

The unvalidated results from the Marina sampling are provided in the attached Excel® file. The dioxin/furan toxic equivalent (TEQ), total organic carbon (TOC), and grain size for all Marina DMMU composite samples are summarized in Table 1. The target and actual individual core locations within the Marina are provided on Map 1. Three options have been identified to combine the DMMUs into management area composites for bioaccumulation testing. The purpose of the call between the Dredged Material Management Program (DMMP) and the Port of Everett on Tuesday, June 14, 2016, is to finalize the composites for bioaccumulation testing in order to ship the samples and begin testing within the sample hold times. Bioaccumulation testing must be initiated between July 5 and July 12, 2016.

Table 1. Dioxin/furan TEQ, TOC, and grain size results for the Marina DMMU composites

DMMU	Volume (cubic yards)	Dioxin/furan TEQ (ng/kg, dw)	TOC (% dw)	Grain size (% fines)
DMMU 4	17,242	7.79	1.99	84.00
DMMU 5	11,250	5.21	2.11	68.90
DMMU 6	8,259	3.86	1.80	99.90
DMMU 7	12,790	8.16	2.23	91.60
DMMU 8	7,047	9.27	1.62	77.00
DMMU 9	9,368	8.67	2.58	94.60
DMMU 10	18,566	13.0	2.75	91.80
DMMU 11	17,978	7.69	2.65	86.70
DMMU 12	8,126	14.4	1.44	84.90

DMMU – dredged material management unit
dw – dry weight
Marina – Port of Everett Marina
TEQ – toxic equivalent
TOC – total organic carbon

After reviewing the preliminary data, the grouping of DMMUs into management areas was evaluated. Two of the DMMUs (DMMU 5 and DMMU 6) are proposed to be combined with what was previously characterized as Management Area 1 (DMMUs 1, 2, and 3). The volume-weighted average of the revised Management Area 1 is 3.40, which is below the DMMP threshold of 4 for dioxin/furan TEQ, so sediment from DMMUs 1, 2, 3, 5, and 6 can be disposed of at the Port Gardner open-water disposal site (Table 2).

Table 2. DMMUs in revised Management Area 1

Management Area	DMMU	Dioxin/furan TEQ (ng/kg dw)	Volume (cubic yards)	Volume-weighted Average Dioxin/furan TEQ (ng/kg dw)
M1	DMMU 1	5.47	6,936	3.40
	DMMU 2	5.14	20,456	
	DMMU 3	0.06	22,233	
	DMMU 5	5.21	11,250	
	DMMU 6	3.86	8,259	

DMMU – dredged material management unit
dw – dry weight
TEQ – toxic equivalent

Options for management areas for the remaining DMMUs are presented in Table 3. These options will be discussed during the call on Tuesday, June 14, 2016.

Table 3. Options for DMMU compositing into management areas for bioaccumulation testing

Option	Management Area	Compositing Plan	Volume-weighted Average TEQ (ng/kg dw)	Pro	Con
A	M2	DMMUs 4, 7, 8, 9	8.47	only testing two samples spatially grouped samples	DMMU 11 has a lower TEQ than DMMUs 10 and 12
	M3	DMMUs 10,11,12	11.7		
B	M2	DMMUs 4 and 11	7.74	two highest concentrations are combined smaller composites spatially grouped samples (except DMMUs 4 and 11)	essentially testing the same concentrations in two of the composites Separates DMMUs 11 from DMMUs 10 and 12
	M3	DMMUs 7, 8, 9	8.59		
	M4	DMMUs 10, 12	13.5		
C	M2	DMMUs 4, 7, 8, 9, 11	8.13	samples grouped by TEQ	five DMMUs combined in one composite sample
	M3	DMMUs 10, 12	13.4		

DMMU – dredged material management unit
dw – dry weight
TEQ – toxic equivalent

Eight reference area samples were collected (Map 2). The first five samples were collected from areas outside of the target reference area because the sampling vessel was not able to sample sediment from depths greater than 100 ft. A second day of sampling was conducted with this ability, and three samples were collected from the target reference area (CI-6, CI-7, CI-8). The dioxin/furan TEQ, TOC, and percent fines for each of the reference area samples are provided in Table 4.

Table 4. Carr Inlet reference samples

Reference Area Sample Location	Dioxin/furan TEQ (ng/kg)	TOC (% dw)	Grain Size (% fines)
CI-1	1.81	1.43	91.30
CI-2	1.29	1.02	86.20
CI- 3	1.71	1.75	92.80
CI- 4	1.15	1.28	74.90
CI-5	0.73	0.93	71.10
CI- 6	5.21	2.19	89.90
CI- 7	2.57	1.02	43.20
CI-8	4.43	1.69	81.00

Note: The average TOC and percent fines in the Marina samples were 2.18% and 87.23 percent fines, respectively.
dw – dry weight
Marina – Port of Everett Marina
TEQ – toxic equivalent
TOC – total organic carbon

Per the sampling and analysis plan, the reference area sample selected for bioaccumulation testing should provide as similar TOC and grain size as possible to the Marina samples, with a dioxin/furan TEQ less than or equal to the DMMP threshold of 4 ng TEQ/kg. CI-6 provides the closest match in terms of TOC and grain size; however, the TEQ for this sample is 5.21 ng/kg, greater than the DMMP threshold. We propose CI-8 as the reference sediment sample for the bioaccumulation testing. CI-8 provides similar TOC and grain size and the dioxin/furan TEQ meets the DMMP threshold of 4.[1]

[1] Specifically, 4 parts per trillion (pptr) is the nonparametric estimation of the 90% upper confidence limit for the 90thpercentile of the distribution of the background Puget Sound Main Basin dataset, rounded up to the nearest whole digit.

Attachment 2

Screen shots from BioStat statistical comparisons of Everett Marina management areas to the Carr Inlet reference

Bio STAT

File Edit Log Options Help

Project Information

Project Name: Port of Everett Marina - Macoma

Test Data (x1)

Sample ID: M2

Alias: Management Area 2

Rep	Data	Transform
1	.119	0.119
2	.153	0.153
3	.135	0.135
4	.158	0.158
5	.151	0.151
6		~
7		~
8		~
9		~
10		~

Clear

Reference Data (x2)

Reference ID: CIREF

Alias: Carr Inlet Reference

Rep	Data	Transform
1	.112	0.112
2	.111	0.111
3	.115	0.115
4	.112	0.112
5	.101	0.101
6		~
7		~
8		~
9		~
10		~

Clear

Transformation Method: No Transformation

Experimental Alpha Level: 0.1

Execute Statistics

Experimental Hypothesis

Null: x1 <= x2

Alternate: x1 > x2

Messages

```
*** Stats complete.
*** Executing Stats ...
    Conducting Shapiro-Wilk Normality Test...
    Conducting Levene's Homoscedasticity Test
    Conducting Approximate t-Test
*** Stats complete.
```

Statistical Results

Test Treatment

Number of Reps:	5
Test Mean:	0.143
Test SD:	0.016
Transform Mean:	0.143
Transform SD:	0.016

Reference Treatment

Number of Reps:	5
Reference Mean:	0.11
Reference SD:	0.005
Transform Mean:	0.11
Transform SD:	0.005

Normality (Shapiro-Wilk)

Critical W Value:	<= 0.842
Calculated W Value:	0.9265
Alpha:	0.05
Override:	
Normal:	✓

Homoscedasticity (Levene's)

Critical Student's t:	>= 1.860
Calculated Student's t:	2.7011
Alpha:	0.1
Homoscedastic:	✗

Test of Experimental Hypothesis

Statistic:	Approximate t	Calculated Statistic:	4.3641
Critical Value:	>= 1.476	Transform Type:	No Transformation
Alpha Level:	0.1	df:	5
Power:		Accept Null Hypothesis:	✗

Bio STAT

File Edit Log Options Help

Project Information

Project Name: Port of Everett Marina - Nephtys

Test Data (x1)

Sample ID: M2

Alias: Management Area 2

Rep	Data	Transform
1	.168	0.168
2	.204	0.204
3	.159	0.159
4	.234	0.234
5	.200	0.2
6		~
7		~
8		~
9		~
10		~

Clear

Reference Data (x2)

Reference ID: CIREF

Alias: Carr Inlet Reference

Rep	Data	Transform
1	.103	0.103
2	.108	0.108
3	.104	0.104
4	.116	0.116
5	.105	0.105
6		~
7		~
8		~
9		~
10		~

Clear

Transformation Method: No Transformation

Experimental Alpha Level: 0.1

Execute Statistics

Experimental Hypothesis
Null: x1 <= x2
Alternate: x1 > x2

Messages

```
*** Stats complete.
*** Executing Stats ...
    Conducting Shapiro-Wilk Normality Test...
    Conducting Levene's Homoscedasticity Test
    Conducting Approximate t-Test
*** Stats complete.
```

Statistical Results

Test Treatment

Number of Reps:	5
Test Mean:	0.193
Test SD:	0.03
Transform Mean:	0.193
Transform SD:	0.03

Reference Treatment

Number of Reps:	5
Reference Mean:	0.107
Reference SD:	0.005
Transform Mean:	0.107
Transform SD:	0.005

Normality (Shapiro-Wilk)

Critical W Value:	<= 0.842
Calculated W Value:	0.9314
Alpha:	0.05
Override:	
Normal:	✓

Homoscedasticity (Levene's)

Critical Student's t:	>= 1.860
Calculated Student's t:	2.9717
Alpha:	0.1
Homoscedastic:	✗

Test of Experimental Hypothesis

Statistic:	Approximate t	Calculated Statistic:	6.2720
Critical Value:	>= 1.533	Transform Type:	No Transformation
Alpha Level:	0.1	df:	4
Power:		Accept Null Hypothesis:	✗

Bio STAT

File Edit Log Options Help

Project Information

Project Name: Port of Everett Marina - Macoma

Test Data (x1)

Sample ID: M3

Alias: Management Area 3

Rep	Data	Transform
1	.141	0.141
2	.132	0.132
3	.162	0.162
4	.171	0.171
5	.158	0.158
6		~
7		~
8		~
9		~
10		~

Clear

Reference Data (x2)

Reference ID: CIREF

Alias: Carr Inlet Reference

Rep	Data	Transform
1	.112	0.112
2	.111	0.111
3	.115	0.115
4	.112	0.112
5	.101	0.101
6		~
7		~
8		~
9		~
10		~

Clear

Transformation Method: No Transformation

Execute Statistics

Experimental Alpha Level: 0.1

Experimental Hypothesis

Null: x1 <= x2

Alternate: x1 > x2

Messages

```
*** Stats complete.
*** Executing Stats ...
    Conducting Shapiro-Wilk Normality Test...
    Conducting Levene's Homoscedasticity Test
    Conducting Approximate t-Test
*** Stats complete.
```

Statistical Results

Test Treatment

Number of Reps:	5
Test Mean:	0.153
Test SD:	0.016
Transform Mean:	0.153
Transform SD:	0.016

Reference Treatment

Number of Reps:	5
Reference Mean:	0.11
Reference SD:	0.005
Transform Mean:	0.11
Transform SD:	0.005

Normality (Shapiro-Wilk)

Critical W Value:	<= 0.842
Calculated W Value:	0.9562
Alpha:	0.05
Normal:	✓
Override:	

Homoscedasticity (Levene's)

Critical Student's t:	>= 1.860
Calculated Student's t:	2.8771
Alpha:	0.1
Homoscedastic:	✗

Test of Experimental Hypothesis

Statistic:	Approximate t	Calculated Statistic:	5.6684
Critical Value:	>= 1.476	Transform Type:	No Transformation
Alpha Level:	0.1	df:	5
Power:		Accept Null Hypothesis:	✗

Bio STAT

File Edit Log Options Help

Project Information

Project Name: Port of Everett Marina - Nephtys

Test Data (x1)

Sample ID: M3

Alias: Management Area 3

Rep	Data	Transform
1	.215	0.215
2	.193	0.193
3	.172	0.172
4	.180	0.18
5	.182	0.182
6		~
7		~
8		~
9		~
10		~

Clear

Reference Data (x2)

Reference ID: CIREF

Alias: Carr Inlet Reference

Rep	Data	Transform
1	.103	0.103
2	.108	0.108
3	.104	0.104
4	.116	0.116
5	.105	0.105
6		~
7		~
8		~
9		~
10		~

Clear

Transformation Method: No Transformation

Experimental Alpha Level: 0.1

Execute Statistics

Experimental Hypothesis
Null: x1 <= x2
Alternate: x1 > x2

Messages

```
*** Stats complete.
*** Executing Stats ...
    Conducting Shapiro-Wilk Normality Test...
    Conducting Levene's Homoscedasticity Test
    Conducting Approximate t-Test
*** Stats complete.
```

Statistical Results

Test Treatment

Number of Reps:	5
Test Mean:	0.188
Test SD:	0.017
Transform Mean:	0.188
Transform SD:	0.017

Reference Treatment

Number of Reps:	5
Reference Mean:	0.107
Reference SD:	0.005
Transform Mean:	0.107
Transform SD:	0.005

Normality (Shapiro-Wilk)

Critical W Value:	<= 0.842
Calculated W Value:	0.9114
Alpha:	0.05
Override:	
Normal:	✓

Homoscedasticity (Levene's)

Critical Student's t:	>= 1.860
Calculated Student's t:	2.0155
Alpha:	0.1
Homoscedastic:	✗

Test of Experimental Hypothesis

Statistic:	Approximate t	Calculated Statistic:	10.3966
Critical Value:	>= 1.476	Transform Type:	No Transformation
Alpha Level:	0.1	df:	5
Power:		Accept Null Hypothesis:	✗

Bio STAT

File Edit Log Options Help

Project Information

Project Name: Port of Everett Marina - Macoma

Test Data (x1)

Sample ID: M4

Alias: Management Area 4

Rep	Data	Transform
1	.227	0.227
2	.150	0.15
3	.264	0.264
4	.173	0.173
5	.175	0.175
6		~
7		~
8		~
9		~
10		~

Clear

Reference Data (x2)

Reference ID: CIREF

Alias: Carr Inlet Reference

Rep	Data	Transform
1	.112	0.112
2	.111	0.111
3	.115	0.115
4	.112	0.112
5	.101	0.101
6		~
7		~
8		~
9		~
10		~

Clear

Transformation Method: No Transformation

Experimental Alpha Level: 0.1

Execute Statistics

Experimental Hypothesis

Null: x1 <= x2

Alternate: x1 > x2

Messages

```
*** Stats complete.
*** Executing Stats ...
    Conducting Shapiro-Wilk Normality Test...
    Conducting Levene's Homoscedasticity Test
    Conducting Approximate t-Test
*** Stats complete.
```

Statistical Results

Test Treatment

Number of Reps:	5
Test Mean:	0.198
Test SD:	0.047
Transform Mean:	0.198
Transform SD:	0.047

Reference Treatment

Number of Reps:	5
Reference Mean:	0.11
Reference SD:	0.005
Transform Mean:	0.11
Transform SD:	0.005

Normality (Shapiro-Wilk)

Critical W Value:	<= 0.842
Calculated W Value:	0.9338
Alpha:	0.05
Override:	
Normal:	✓

Homoscedasticity (Levene's)

Critical Student's t:	>= 1.860
Calculated Student's t:	4.0906
Alpha:	0.1
Homoscedastic:	✗

Test of Experimental Hypothesis

Statistic:	Approximate t	Calculated Statistic:	4.1834
Critical Value:	>= 1.533	Transform Type:	No Transformation
Alpha Level:	0.1	df:	4
Power:		Accept Null Hypothesis:	✗

Bio STAT

File Edit Log Options Help

Project Information

Project Name: Port of Everett Marina - Nephtys

Test Data (x1)

Sample ID: M4

Alias: Management Area 4

Rep	Data	Transform
1	.193	0.193
2	.223	0.223
3	.201	0.201
4	.241	0.241
5	.227	0.227
6		~
7		~
8		~
9		~
10		~

Clear

Reference Data (x2)

Reference ID: CIREF

Alias: Carr Inlet Reference

Rep	Data	Transform
1	.103	0.103
2	.108	0.108
3	.104	0.104
4	.116	0.116
5	.105	0.105
6		~
7		~
8		~
9		~
10		~

Clear

Transformation Method: No Transformation

Experimental Alpha Level: 0.1

Execute Statistics

Experimental Hypothesis
Null: x1 <= x2
Alternate: x1 > x2

Messages

```
*** Stats complete.
*** Executing Stats ...
    Conducting Shapiro-Wilk Normality Test...
    Conducting Levene's Homoscedasticity Test
    Conducting Approximate t-Test
*** Stats complete.
```

Statistical Results

Test Treatment

Number of Reps:	5
Test Mean:	0.217
Test SD:	0.02
Transform Mean:	0.217
Transform SD:	0.02

Reference Treatment

Number of Reps:	5
Reference Mean:	0.107
Reference SD:	0.005
Transform Mean:	0.107
Transform SD:	0.005

Normality (Shapiro-Wilk)

Critical W Value:	<= 0.842
Calculated W Value:	0.9733
Alpha:	0.05
Override:	
Normal:	✓

Homoscedasticity (Levene's)

Critical Student's t:	>= 1.860
Calculated Student's t:	3.1341
Alpha:	0.1
Homoscedastic:	✗

Test of Experimental Hypothesis

Statistic:	Approximate t	Calculated Statistic:	12.0710
Critical Value:	>= 1.476	Transform Type:	No Transformation
Alpha Level:	0.1	df:	5
Power:		Accept Null Hypothesis:	✗