TECHNICAL REPORT
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Reactive Amendments Treatability Study

Space and Naval Warfare Systems Center Pacific

(Funded by: Naval Facilities Engineering Command (NAVFAC) Northwest)

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1 BACKGROUND

1.1 PROJECT BACKGROUND

Active, deep-water DoD harbor areas pose a number of significant challenges to the effective use of traditional sediment remedies such as dredging, capping and monitored natural recovery (MNR). Successful demonstration of delivery, stability and effectiveness of in-situ treatment materials that can address these challenges has the potential to reduce costs and recovery time frames for a wide range active DoD sites and provide a more effective alternative to traditional methods of remediation.

Reactive amendment technology for contaminated sediments is designed to enhance system recovery by introducing a chemical sorbent to impacted surface sediment. The chemical composition of the sorbent is selected based on the nature of sediment contamination and the extent to which amendment properties require specific implementation strategies. Among the amendments tested, activated carbon (AC) has shown promising results at pilot-scale for reducing the bioavailability of hydrophobic organic contaminants such as PCBs. However, to date most applications have been pilot-scale and used granulated AC which may not be suitable for delivery and stability in deep water active harbors due to its low density.

Due to concern over the elevated polychlorinated biphenyls (PCB) and mercury (Hg) levels discovered during the sampling events associated with Fender Pile Replacement work at Pier 7, Naval Facilities (NAVFAC) NW Remedial Project Managers (RPM) and scientists from Space and Naval Warfare Systems Center (SSC) Pacific discussed the potential to test and evaluate alternative *in situ* sediment treatment methods. Because of SSC's interests in working with and demonstrating the efficacy of reactive amendments in deep-water, active shipyard sites, SSC Pacific was tasked by NAVFAC NW to perform laboratory treatability studies on a reactive amendment, AquaBlok®, for PCB- and Hg-contaminated sediments in the near-pier areas of the Puget Sound Naval Ship Yard and Intermediate Maintenance Facility (PSNS&IMF; Bremerton, WA), which is part of the larger Bremerton Naval Complex (BNC). The general location identified for testing is situated at the southwestern corner of Pier 7, located at the shipyard's eastern end (Figure 1), where both PCBs and Hg (co-located) are listed as contaminants of concern (NAVFAC 2010). All references within this document, to the test site or to samples collected from the site, will be hereafter referred to as Pier 7 (BNC).

AquaBlok® is a patented, composite aggregate technology resembling small stones and typically comprised of a dense aggregate core, clay or clay-sized materials, and polymers (Figure 2). The formulation tested for this study incorporates approximately 2-5% PAC, 10% clay and the remaining fraction of aggregate where the primary reactive amendment is a powdered activated carbon (PAC) bound to the dense aggregate particle with appropriate clay minerals. AquaBlok® utilizes a coated aggregate particle as the means for achieving positive and uniform placement of reactive amendments through a water column. This technology has been used to deliver a range of mineral-based reactive amendments in both freshwater and marine environments (Hawkins 2010; Battelle 2007).

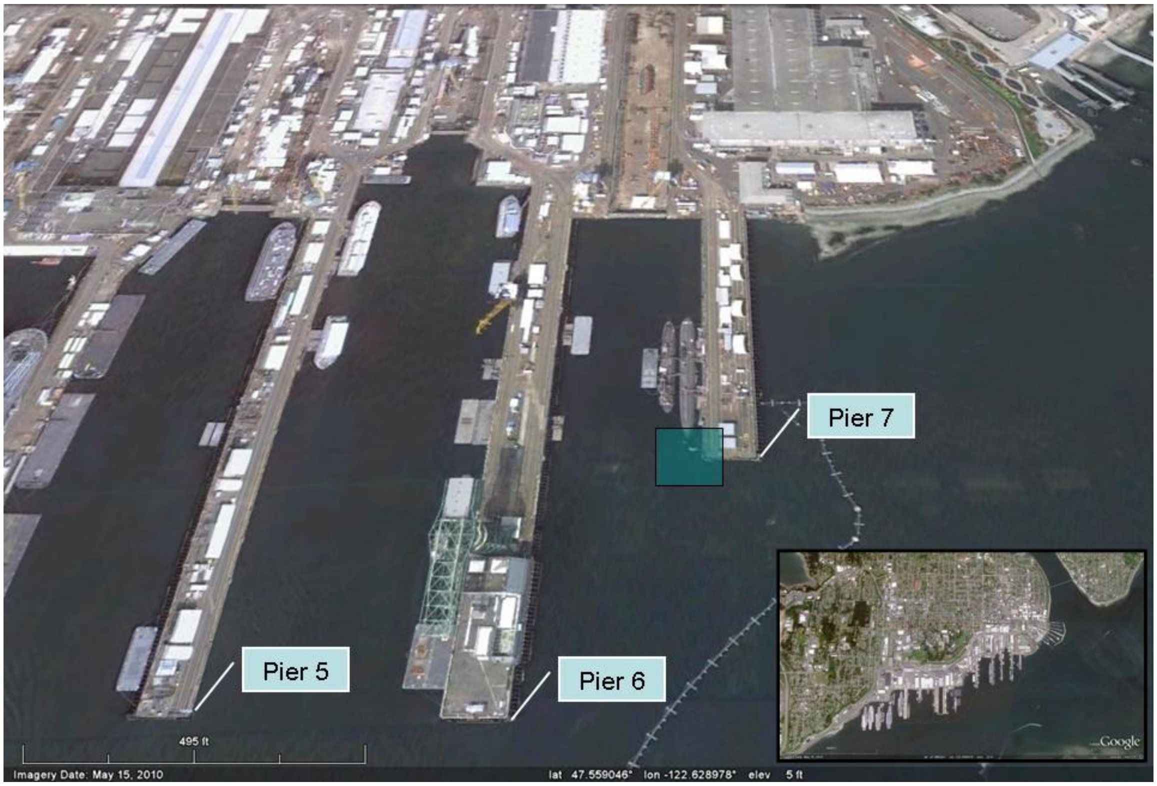
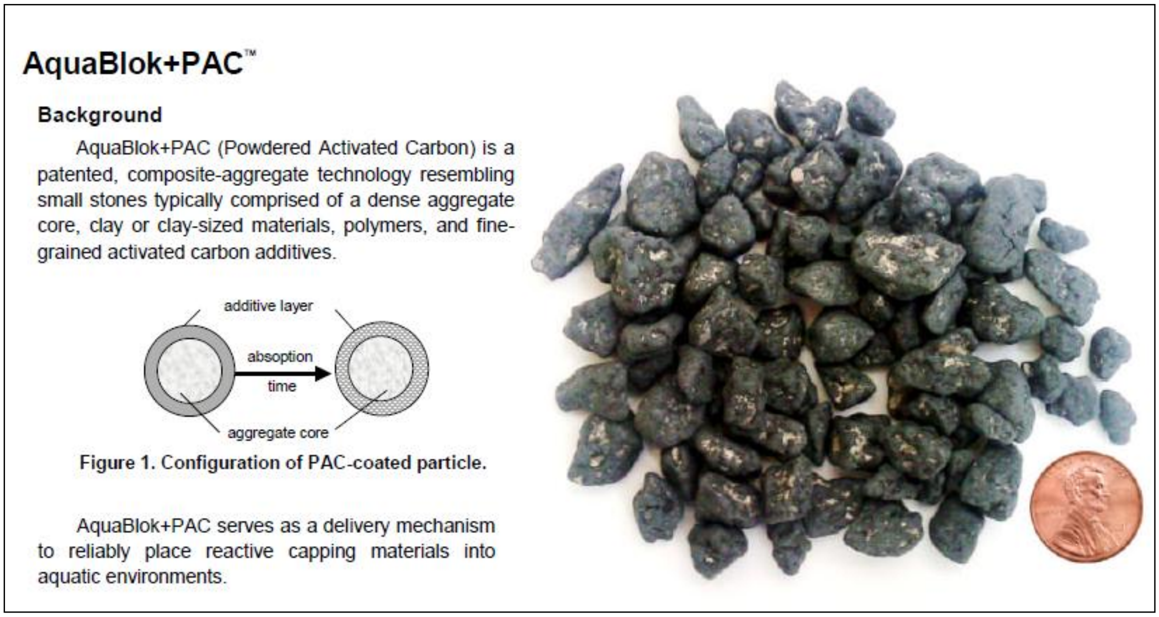


Figure 1. Prospective field demonstration location at Pier 7 (BNC).



AquaBlok+PAC™

Background

AquaBlok+PAC (Powdered Activated Carbon) is a patented, composite-aggregate technology resembling small stones typically comprised of a dense aggregate core, clay or clay-sized materials, polymers, and fine-grained activated carbon additives.

Figure 1. Configuration of PAC-coated particle.

AquaBlok+PAC serves as a delivery mechanism to reliably place reactive capping materials into aquatic environments.

Figure 2. AquaBlok® is a composite aggregate technology with powdered activated carbon (PAC) (AquaBlok®2010).

1.2 SITE BACKGROUND

Pier 7 is part of a naval installation occupied by two separate commands: Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF), Bremerton site, and Naval Base

Kitsap at Bremerton (NBK at Bremerton). The collective area occupied by these two Navy commands is referred as the Bremerton Naval Complex (BNC) (Figure 3).

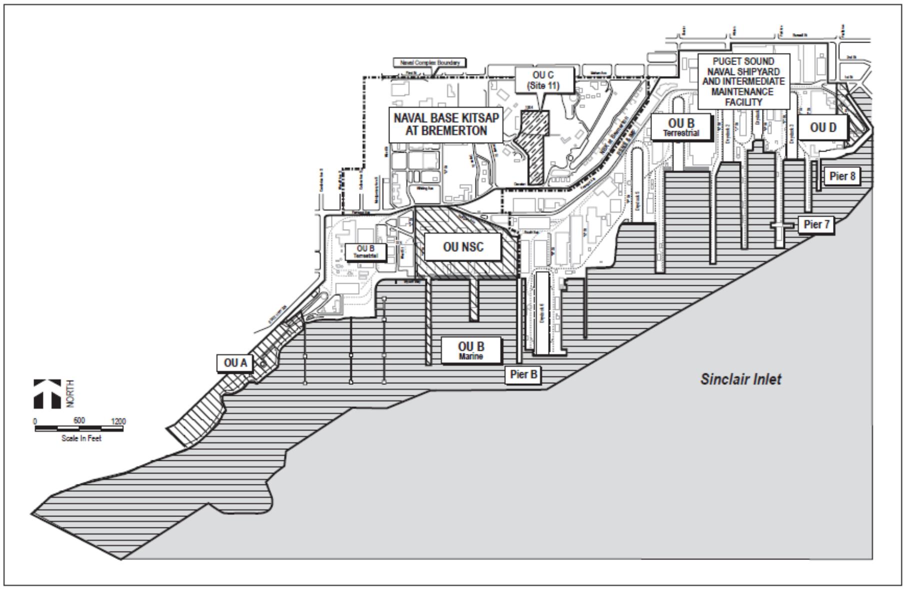


Figure 3. Bremerton Naval Complex operable units (from *Draft Final Pier 7 SMR*; US Navy 2010).

Pier 7 lies within an area known as Operable Unit B Marine (OUB Marine) that was previously subject to a Superfund sediment cleanup (USEPA 2000). The primary components of the remedial action included dredging, disposal in a pit excavated in the sea floor in Sinclair Inlet, capping of contaminated sediments in a small area at the southwest end of the naval complex and placement of a thin layer of clean sediment to promote recovery of sediments (enhanced natural recovery) in the area around the cap, stabilization of a section of shoreline in the center of the naval complex and allowing for the ongoing processes of sediment natural recovery to continue to decrease the residual contamination throughout the area over a period of 10 years (US Navy 2008).

The areas within OU B Marine found to have the highest PCB levels were identified for dredging. The highest levels of PCBs were found mostly in areas along the shoreline or adjacent to the moorings and piers (e.g., Pier 7) of the naval complex. A limited amount of additional dredging was included in the remedial action based on a combination of elevated mercury levels and moderately-elevated levels of PCBs.

Because BNC is an active naval facility, there is on-going maintenance and construction in the area. Sediments near Pier 7 were subject to additional rounds of sampling to document conditions in vicinity of the pier prior to replacement of fender piles associated with the pier. Both pre- and post-sampling was carried out to meet the requirement of state water quality certification for the project (US Navy 2008; US Navy 2010).

The pre-construction sediment sampling involved collection and analysis of 11 sediment samples (0-10 cm) and analysis of these samples for PCBs, Hg, total organic carbon (TOC), and grain size. PCBs were detected in all of the samples. PCB concentrations ranged from 0.12 mg/kg – 35 mg/kg (2.0 – 1,100 mg/kg OC normalized). Mercury was also detected in all of the samples at concentrations ranging from 0.24 – 5.9 mg/kg.

In 2009, work commenced at Pier 7 to remove 325 timber creosote piles and replace them with 166 concrete pilings and place a sand amendment around each replaced piling. Upon completion of this project, post-sampling was carried out. In addition to sampling the same locations again, additional arrays of sampling locations were identified in the vicinity of the locations where elevated PCBs and mercury were observed in the pre-construction samples (Figure 3). PCBs were detected in all but two samples and ranged in concentration from 0.028 mg/kg to 2.0 mg/kg (0.94 to 140 mg/kg OC normalized). In general overall PCB concentrations were lower in the post-construction samples than were measured in the pre-construction samples. However, the highest levels were still observed in the samples collected around locations P7-04 and P7-05 (Figure 4) (US Navy 2010).

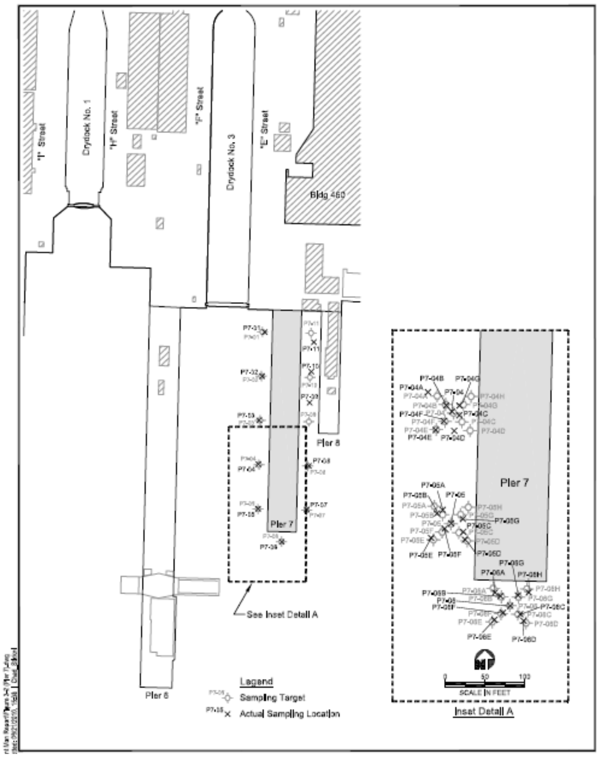


FIGURE 4. PIER 7 FENDER PILE REPLACEMENT SAMPLING LOCATIONS (FROM *DRAFT FINAL PIER 7 SMR*; US NAVY 2010).

Despite a determination that the Pier 7 construction activities would not have a direct impact on achieving the OUB Marine cleanup goals, the continual presence of elevated levels (above Washington State Sediment Quality Standards) of PCBs and Hg in the Pier 7 area, resulted in the desire to test alternative in situ treatment methods, such as reactive amendments, in this area.

2 SCOPE OF WORK

This study addresses several important aspects in the evaluation and optimization of the reactive amendment which will be used to directly support the needs of NAVFAC NW as well as support a larger demonstration and validation project *(Demonstration of In-Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors*) jointly funded by the Navy's Environmental Sustainability Development to Integration Program (NESDI), NAVFAC NW and by the DoD's Environmental Security Technology Certification Program (ESTCP).

Components of this study included pre-screening the site to delineate the nature and extent of contamination, verifying the effectiveness of the amendment in terms of reduction in contaminant bioavailability and testing two different monitoring tools for their ability to distinguish the amendment from native site sediment to support monitoring the placement, stability and mixing of the amendment after installation.

2.1 ON-SITE RAPID SEDIMENT CHARACTERIZATION

A pre-screening survey was conducted to more thoroughly delineate the nature and extent of PCB contamination at the site. This survey included additional sediment sampling and on-site analysis of sediment samples over a 1-acre area. Fifty-one sediment samples (0–6 inches in depth) were collected in an area between Piers 6 and 7 as well as underneath Pier 7 and analyzed on site for total PCBs using USEPA Method 4020 (**Screening for Polychlorinated Biphenyls by Immunoassay**). This screening method has been applied for the determination of total PCBs in sediment, soil, and biological tissue (Wakeman 2006; Kohn et al. 2004) concentrations that are relevant to site conditions at PSNS&IMF, and has been perfected by staff at the Navy's SPAWAR laboratories. The results from this survey were used to identify an area with elevated PCBs for use in the lab treatability studies as well delineate the ½-acre footprint which will be used for the field demonstration and validation of the reactive amendment.

2.2 TREATABILITY STUDIES: CONTAMINANT TOXICITY AND BIOAVAILABILITY

A principal component of the lab study was to verify the effectiveness of the amendment material in terms of reduction in contaminant bioavailability to benthic organisms. The dosing experiments were carried out using a standard formulation of the AquaBlok®, as described above. The tests also evaluated different degrees of mixing including a No Mix, a Partial Mix (24 hour) and a Full Mix (1 month). Toxicity testing involved running standard 10-day amphipod and 28-day polychaete bioassays to assess any potential adverse toxic effects/risk (via growth and mortality endpoints) from a) the unamended sediment, b) the uncoated aggregate that acts as the delivery mechanism for the AquaBlok®, and c) the activated carbon-coated AquaBlok®. Bioaccumulation testing involved running standard 28-day bioaccumulation studies on the reactive amendment/sediment mixtures (Figure 5).

2.3 VERIFICATION OF AMENDMENT PLACEMENT AND MIXING

Laboratory testing also involved evaluating the degree to which various monitoring tools such as the Sediment Profile Imaging (SPI camera) system with digital image analysis and the Friction Sound Probe (FSP) were able to distinguish the amendment from native site sediment post-placement. The ability to monitor the placement and the physical stability of the reactive amendment in deeper water areas that support vessel traffic is a vital component in demonstrating the efficacy of this type of in situ treatment method. Testing was carried out pre- and post-application and mixing of the amendment, via mechanical means, to the native sediment as shown in Figure 6.

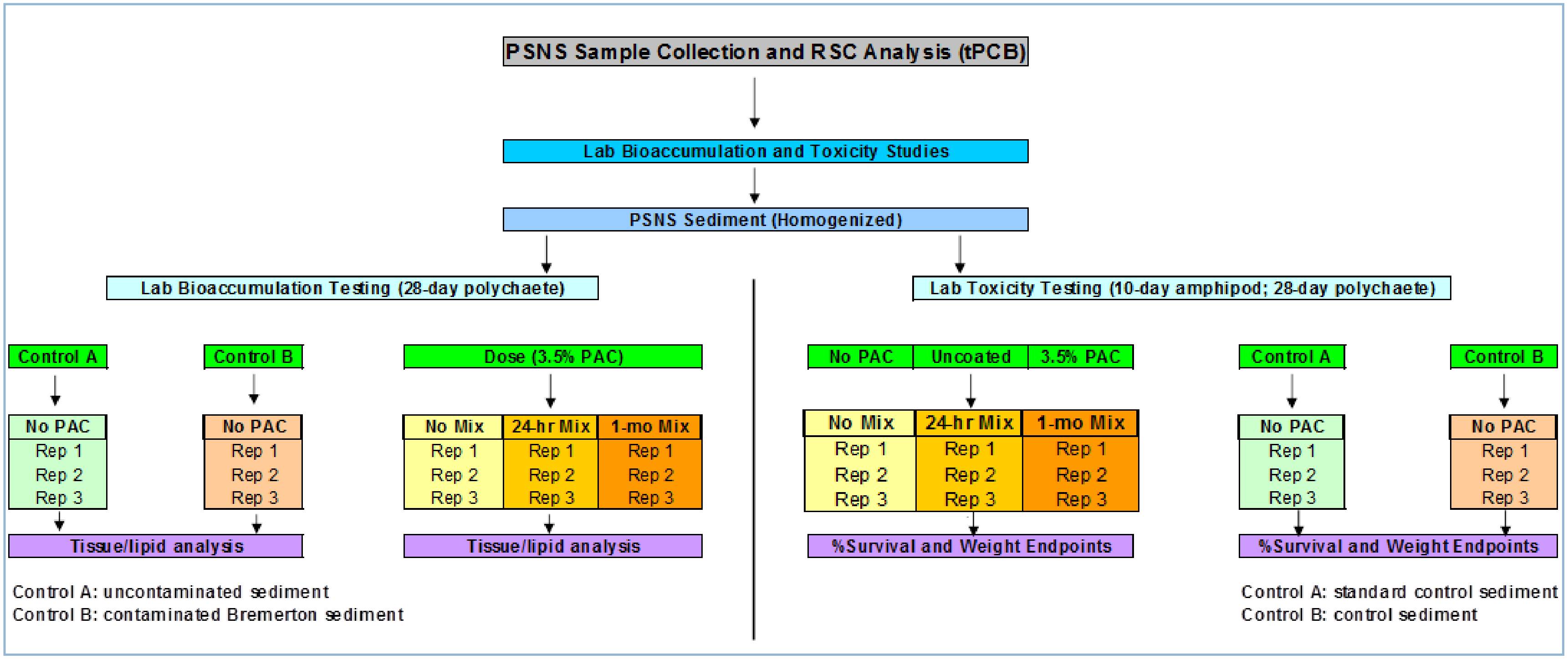


FIGURE 5. LABORATORY TREATABILITY STUDY APPROACHES FOR BNC (PIER 7). TOXICITY AND BIOACCUMULATION STUDIES.

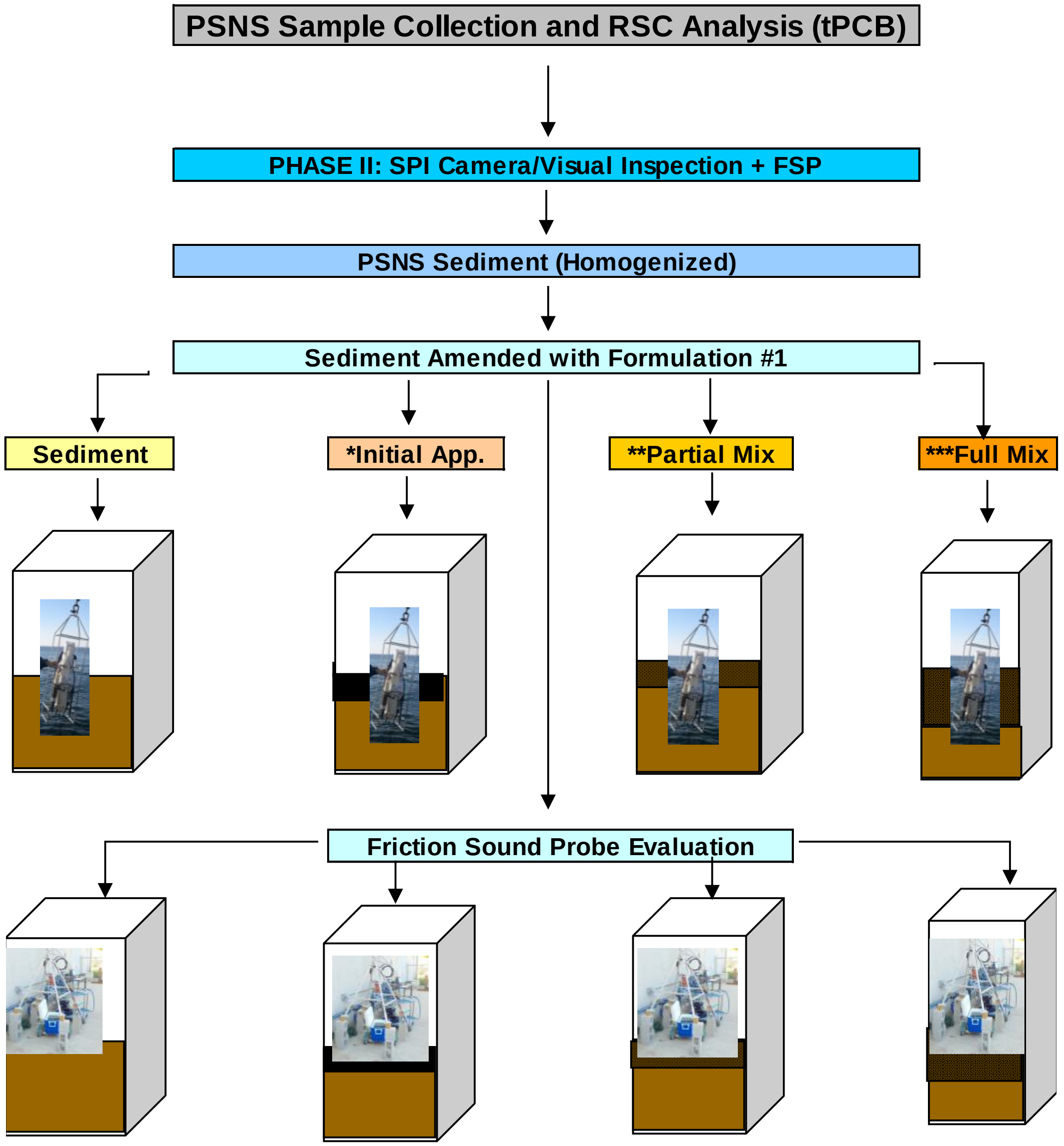
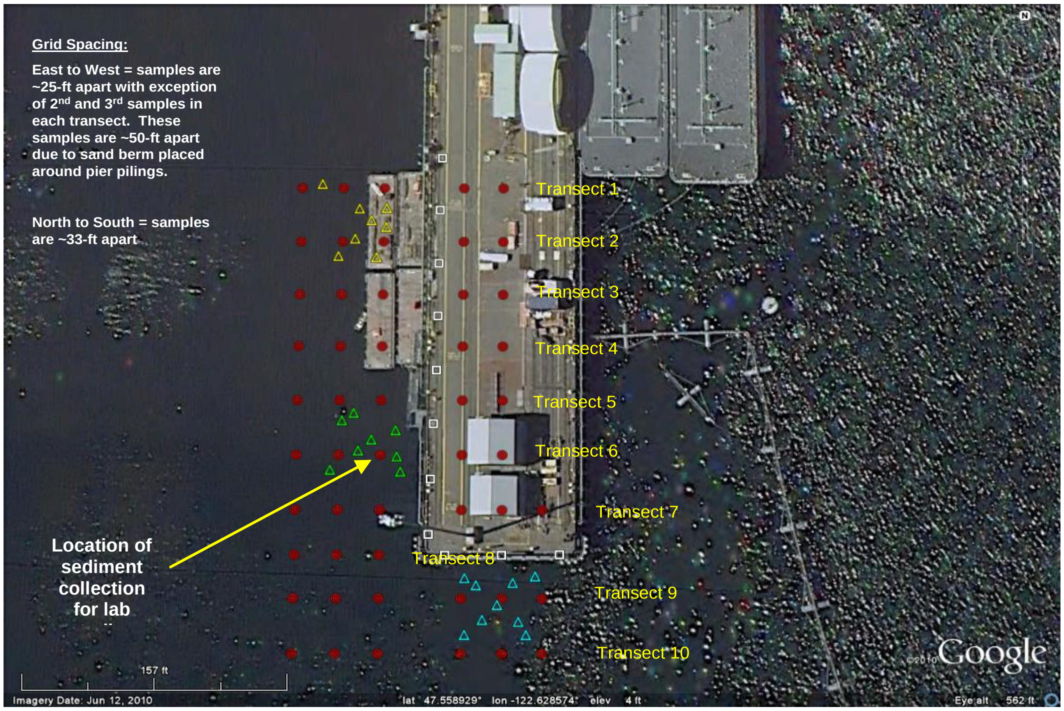


FIGURE 6. LABORATORY TREATABILITY STUDY APPROACHES FOR BNC (PIER 7): SPI CAMERA AND FRICTION SOUND PROBE TESTING.

3 METHODS

3.1 RAPID SEDIMENT CHARACTERIZATION SITE SURVEY

The purpose of the field survey was to collect surface (0-6”) sediment samples from the area around and underneath Pier 7 (BNC) (see Figure 7). Sediment samples were screened for PCBs, on-site, using an Immunoassay. Results from the assay were then used to identify the area(s) with the highest concentrations of PCBs. A subsequent round of sampling was carried out in order to collect a larger volume of sediment for laboratory treatability studies using the reactive amendment. Sampling and analysis was carried out from October 28 - November 01, 2010.



Grid Spacing:

East to West = samples are ~25-ft apart with exception of 2nd and 3rd samples in each transect. These samples are ~50-ft apart due to sand berm placed around pier pilings.

North to South = samples are ~33-ft apart

FIGURE 7. SAMPLING LOCATIONS FOR ON-SITE SURVEY AT PIER 7 BNC (CLOSED RED CIRCLES: RSC SURVEY LOCATIONS; OPEN TRIANGLES: POST-CONSTRUCTION SAMPLING LOCATIONS FOR FENDER PILE REPLACEMENT PROJECT).

3.1.1 IMMUNOASSAY TECHNIQUE

The immunoassay is a technique that makes use of the binding between an antigen and its homologous antibody in order to identify and quantify the specific antigen or antibody in a sample. In the case of environmental samples, **USEPA Method 4020** is used for screening soils, sediments and non-aqueous waste liquids to determine when total polychlorinated biphenyls (PCBs) are present at concentrations above 5, 10 or 50 mg/kg. This method provides an estimate for the concentration of PCBs by comparison with a standard (ref EPA method). The test kits used for this method are commercially available (RaPID^{TM} Assay, Strategic Diagnostics Inc.; **www.sdix.com**). In general, the method is performed using a sample extract. The sample and an enzyme conjugate are added to an antibody. The enzyme conjugate "competes" with the contaminant of interest (PCB) present in the sample for binding to the antibody. The assay test is interpreted by comparing the response produced by the sample test to the response produced by testing a range of kit-supplied standards simultaneously.

3.1.2 SAMPLE LOCATIONS

Using the information obtained for OUB Marine and Pier 7 (BNC), in particular, (US Navy 2010; US Navy 2008) a sampling grid was established over the area of sediment shown to have moderately elevated concentrations of PCBs. Ten transects were placed over the grid so that sediment samples could be collected from underneath the pier extending out into the berthing area between Piers 6 and 7 (Figure 7). A Navy dive team was employed for sample collection. The divers used 1-ft core tubes with caps to collect surface (~ 6") sediment at each of the 51 stations (Table A-1). The sediment samples were homogenized and analyzed on site for bulk PCBs using the Immunoassay technique.

Results from the screening survey were used to identify the area(s) that yielded the highest concentration of PCBs. Navy divers were redeployed to the site and instructed to collect ~ 5 gallons of sediment from this area using a small bucket to scoop the sediment and return it to the surface. Sediment was collected by divers adjacent to Pier 7 (BNC), at a water depth of approximately 40 feet (lat 47.558780; long 122.628896). The BNC sediment was collected with a 5 gallon bucket that skimmed the top 5 cm of sediment surface, with the overlying water removed following settling of fine particles (overnight). Samples were transferred to bags, packed on ice in a cooler and shipped to SSC Pacific for further testing.

3.1.3 TREATABILITY STUDIES: LABORATORY TOXICITY AND BIOACCUMULATION METHODS

3.1.3.1 ***General Sediment Characteristics.*** Sediment was stored at 4 ^{0}C until use, and then sieved to <4 mm to remove shell hash and other indigenous material from interfering with the laboratory bioassays. The Pier 7 (BNC) sediment had a solids content of 33.7%, an initial total organic carbon concentration (TOC) of 2.4%, and consisted of 58.2% silt and clay sized particles (Tables A-2 and A-3). The control sediment utilized was a sandy sediment with a TOC content of 0.06%. The control sediment was collected from an uncontaminated site near Yaquina Bay, OR (collection site of the amphipods used in this study), and is commonly used as a negative control in west coast marine sediment toxicity testing.

3.1.3.2 ***PAC Addition and Sediment Preparation.*** According to the manufacturer, the AquaBlok® formulation consisted of 2-5% particulate activated carbon (PAC), 5-10% Bentonite (clay), a nominal quantity of binder (cellulosic polymer), surrounded by a stone aggregate (approximate diameter = 1 cm) core (85-93%), by weight. Equal parts of AquaBlok® and Pier 7 (BNC) sediment were mixed in 2 L pre-cleaned glass jars to create an estimated 3.5% final PAC concentration, on a dry weight basis. The jars (except for a “No Mix” treatment, as described below in section 3.1.3.5) were then rotated continuously on a roller at a speed of 3 RPM for the designated amount of time.

The final measured sediment TOC concentration (after 1 month of mixing) of 6.6% indicated that the addition of TOC from the AquaBlok® was approximately 4.2%, thereby increased the indigenous sediment concentrations by a factor of 2.75. The target PAC concentration was similar to that used for other recent studies that have demonstrated successful sequestration of nonpolar organics (Millward et al. 2005; Sun and Ghosh 2007; Janssen et al. 2010).

3.1.3.3 ***Test Organisms.*** Two-week old, laboratory cultured *Neanthes arenaceodentata* (marine polychaete) and field-collected, 3-5 mm, *Eohaustorius estuarius* (marine amphipod) were purchased from Aquatic Toxicology Support (Bremerton, WA) and Northwestern Aquatic Sciences (Newport, OR), respectively. Organisms were acclimated to laboratory exposure conditions at SSC Pacific for 3-5 days prior to use in the exposures. During holding, water quality (temperature, salinity, dissolved oxygen, and pH) was monitored daily, and remained within acceptable ranges (Tables A-4 and A-5). Mortality during acclimation was below 5% for all organism batches.

3.1.3.4 ***Preliminary Toxicity Study.*** A preliminary study was conducted as a precursor to the treatability/bioaccumulation study to verify whether the presence of 1) the relatively large aggregate, or 2) the fine particles associated with the PAC might result in adverse effects to two different test organisms, *N. arenaceodentata* and *E. estuarius.* Some bioassays are confounded by grain size incompatibilities of the test organism. Some materials investigated as reactive amendments have also been shown to alter water quality by increasing ammonia or reducing dissolved oxygen concentrations to potentially toxic levels (Burgess et al. 2009; Rosen et al. 2011). Additionally, it was important to verify that unanticipated toxicity from the site sediment would not confound data interpretation for the treatability study. The experimental designs for these studies followed standard methods (USEPA, 1994; ASTM 2000), except that the polychaete was exposed at a density of 20 individuals per replicate rather than the standard five. Treatments included a control sediment from a clean site near Yaquina Bay, OR; unamended BNC sediment, and two different AquaBlok® treatments, one coated with the reactive amendment, and one uncoated (i.e. aggregate only). A summary of the experimental design is shown Figure 5 and Table 3-1. Test conditions for both species are summarized in Tables A-4 and A-5. The exposure conditions, including the supplemental feeding ration, used for *N. arenaceodentata* were similar to other recent studies that have investigated activated carbon (AC) performance with this species (Millward et al. 2005; Janssen et al. 2009).

At the conclusion of each exposure, organisms were recovered from the sediment with a 500 µm stainless steel sieve, enumerated, rinsed in deionized water, gently blotted, and immediately weighed. In addition, the polychaetes were placed in a drying oven overnight at 60 °C prior to dry weight determination.

Daily water quality measurements in the treatments were within target ranges and did not statistically differ among treatments. Summarized conditions for each parameter (mean ± 1 s.d.) were as follows: salinity (33.2 ± 0.34 ‰); temperature (20.1 ± 0.1 °C); dissolved oxygen (6.76 ± 0.68 mg/L); pH (7.91 ± 0.12).

3.1.3.5 ***Treatability Study Approach.*** Overall, the treatability study employed the same exposure approach used in the preliminary toxicity study with the exception that only the polychaete was used. In order to obtain enough tissue for mercury and PCB homolog analysis, 22 organisms were added to each of 9 replicate chambers for each treatment. The different treatments used are summarized in Table 3-1. In addition to control and unamended BNC sediment, three treatments representing differing degrees of mixing (i.e. contact time) with AquaBlok® were created, including a 1-month mix (1 Mo Mix), a 24-hour mix (24 Hr Mix), and No Mix treatments. The mixed treatments were rotated as described previously. The No Mix treatment was created by gently pouring the designated quantity of AquaBlok® on top of unamended BNC sediment directly into organism exposure vessels (1 L glass jars) followed by addition of overlying water, on the day prior to organism exposure initiation (Figure 8). The No Mix treatment relied on worm bioturbation as the primary means of integrating the AquaBlok® into the underlying contaminated sediment, representing a conservative and potentially more realistic means of assessing amendment performance in relatively quiescent locations (Figure 8).

TABLE 3-1. SUMMARY OF APPROACHES USED FOR PRELIMINARY AND TREATABILITY STUDIES. ALL AQUABLOK® ADDITIONS TARGETED A 3.5% POWDERED ACTIVATED CARBON (PAC) CONCENTRATION IN THE BNC SITE SEDIMENT (UNAMENDED). BNC= BREMERTON NAVAL COMPLEX SITE SEDIMENT.

Parameter	Preliminary Study (Toxicity)	Treatability Study (Bioaccumulation)
Species	Polychaete (*Neanthes arenaceodentata*) Amphipod (*Eohaustorius estuarius*)	Polychaete (*N. arenaceodentata*)
Replication	Three per treatment	Nine per treatment
Treatments	1) Control (Yaquina Bay) 2) BNC, unamended 3) BNC + AquaBlok® (BNC + Aq) 4) BNC + uncoated AquaBlok® (BNC + AqNC)	1) Control (Yaquina Bay) 2) BNC, unamended 3) BNC + Aq no mix (No Mix) 4) BNC + Aq 24-hour mix (24-h Mix) 5) BNC + Aq 1-month mix (1-mo Mix)
Mixing period(s)	One month	No Mix; 24-hr Mix; 1-month Mix
Endpoints	Survival, growth only	Survival, growth, bioaccumulation

Following recovery from sediment and enumeration of survivors, polychaetes were transferred to clean seawater to purge ingested sediment overnight. After visual confirmation that sediment was cleared from the gut, polychaetes were rinsed, weighed, and frozen (-20 ^{0}C) in 2 mL microcentrifuge tubes until chemical analysis.

Daily water quality measurements in the treatments were within target ranges and did not statistically differ among treatments. Summarized conditions for each parameter (mean ± 1 s.d.) were as follows: salinity (29.7 ± 0.66 ‰); temperature (20.2 ± 0.2 °C); dissolved oxygen (6.38 ± 0.70 mg/L); pH (7.89 ± 0.14).

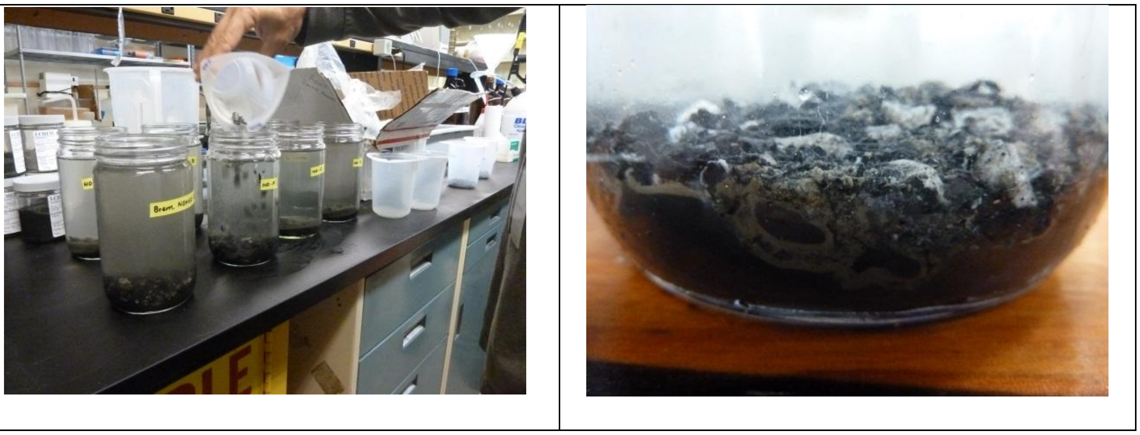


FIGURE 8. PREPARATION OF "NO MIX" TREATMENT SAMPLES FOR BIOACCUMULATION STUDY. ADDING . AQUABLOK® TO BREMERTON SEDIMENT (LEFT), WORM BIOTURBATION MIXING AMENDMENT INTO SEDIMENT (RIGHT).

3.1.3.6 ***Chemical Analyses (PCBs).*** Sediment samples were extracted using pressurized fluid extraction (EPA Method 3545), and analyzed using gas chromatography following EPA Method 8082B. Reporting limits (RL) for PCB congeners in sediment ranged from 0.3 to 0.6 µg/Kg dry wt. Values above the detection limit, but below the RL were included in the sum calculations.

Tissue analysis was conducted using a micro-extraction technique for use with small masses (150-500 mg wet weight; Jones et al. 2006) at the US Army Engineer Research and Development Center (ERDC; Vicksburg, MS, USA). Tissue extracts were analyzed for PCB congeners by gas chromatography (EPA Method 8082B). Tissue PCB concentrations were expressed as the sum of all detected PCB congeners or as the sum of PCB homologs. Reporting limits for PCBs accumulated by *N. arenaceodentata* ranged from 1.0 to 1.8 µg/Kg, wet wt. Values below the reporting limit but above the detection limit were included in the sum concentrations of sediment and tissue data.

Polychaete lipid was analyzed with a spectrophotometer at 490 nm following homogenization and chloroform/methanol extraction, and calibrated using stock solutions of soybean oil.

3.1.3.7 ***Chemical Analyses (Hg, MeHg).*** Sediment and biological tissue samples were homogenized before sub-sampling. Samples were prepared and analyzed by a modified EPA method SW846-7471A . Samples were digested with nitric acid, sulfuric acid, potassium permanganate, and potassium persulfate in Teflon bottles. Samples were then heated to 90-95 C. Before analysis, hydroxylamine hydrochloride is added to reduce the excess permanganate. Samples were diluted with deionized water before analysis by PSA Millenium Merlin atomic fluorescence spectrometer. Methyl mercury was extracted from sediments using acid leaching/solvent extraction/thiourea back-extraction and analyzed using liquid chromatography cold vapor atomic fluorescence spectrometry (LC-CVAF). Detection limits for MeHg in sediment are typically 0.002 ng g-1, with a LOQ of 0.01 ng/g (Quicksilver 2010).

3.1.3.8 ***Data Analysis (PCBs).*** Means and standard deviations of most measurements were reported or graphically displayed. Toxicity test and lipid results were analyzed by one-way analysis of variance ($\alpha = 0.05$) following verification of equal variances and normal distributions. Pairwise comparisons were made using Tukey's HSD tests. Statistical analyses were performed with SigmaStat version 2.03.

3.1.3.9 ***Data Analysis (Hg, MeHg).*** Means and standard deviations for the Hg and MeHg tissue measurements were reported and graphically displayed. Concentrations of mercury and methyl mercury in *Neanthes arenaceodentata* exposed to the Bremerton unamended and Aquablock-amended sediment were compared statistically using JMP 7.0 (SAS Institute Inc., **http://www.jmp.com/**). Prior to comparison, data were analyzed for heterogeneity of variance and log10-transformed to meet statistical assumptions on an add-needed basis. Differences in concentrations among the treatments were evaluated using ANOVA and/or Kruskal-Wallis ranks tests ($\alpha = 0.05$) followed by a posteriori Tukey's Honestly Significant Difference (HSD) test on the data or ranks to separate treatments into statistically-distinct groups.

3.1.4 VERIFICATION OF AMENDMENT PLACEMENT AND MIXING: SPI SYSTEM

3.1.4.1 ***Sediment Profile Imaging (SPI) System.*** A sediment profile imaging (SPI) system uses a camera and prism mounted on a frame to take a picture of where the seafloor and water meet. This instrument is typically lowered to the bottom from a ship, and then takes cross-section photographs of the upper 15-20 cm of the surface of the seafloor, although hand-held camera systems are also utilized for profiling in shallow water as well as for laboratory testing. It is a useful tool for identifying features such as sediment grain size, infauna, sub-surface methane pockets, dredged material deposition, and hypoxic conditions. The imaging faceplate is in direct contact with the sediments, so SPI can be used in turbid waters. The sediment profile imaging (SPI) system is designed to photograph the sediment-water interface without creating disturbance. A sharp-edged prism cuts cleanly into the sediment to a depth of 15 to 20 cm. The camera is mounted in the top of the prism, and a mirror is used to reflect the sediment image to the camera from the vertical faceplate. Since the sediment is right up against the faceplate, lack of water clarity is never a limitation on this optical method.

For this study, a lightweight, hand-held profile camera was used (Germano and Associates, Inc., Bellevue, WA). This system is equipped with a Nikon D7000 camera body with 15 megapixel resolution which far surpasses the standard Nikon D200 camera with 10 megapixel resolution which is standard on most SPI camera systems. The hand-held SPI camera with 15 megapixel resolution is the only system currently available that can be used imaging small volumes of sediment.

3.1.4.2 ***Sediment Collection and Preparation.*** In order to carry out the laboratory SPI camera tests, approximately 60 gallons of sediment (silty-sand) was collected from San Diego Bay near the Marine Corp Recruiting Depot (MCRD). The sediment was collected by shovel and placed into 4 coolers of similar size. The coolers were transferred to SSC Pacific and placed in the Cold Room where a 2" layer of overlying seawater was added. The overlying water was bubbled with air. This sediment was meant to act as the native bed sediment upon which the amendment would be placed.

One week prior to testing, four different treatments were prepared as discussed below and summarized in Table 3-2. The treatments included a) no amendment, b) amendment on surface, c) one part sediment to one part amendment, and d) three parts sediment to one part amendment (Figure 9). While it is anticipated that during the field demonstration, a 2" layer (14 lbs/sq. ft) of AquaBlok® will be placed over the surface sediment, due to limitations on the amount of AquaBlok® available for laboratory testing, an amount (grams) of AquaBlok® equivalent to approximately 1" layer (7 lbs/sq. ft) was used for *treatments b, c and d*.

The following steps were taken to set up each of the treatments with the amendment:

i. Determine amount of amendment for 1" layer: Area of each cooler (ft^2) x 7 lb/ft^2 (*treatments b,c,d*)

ii. Determine amount of sediment required to create "mixed" layers: dry weight of sediment in the cooler was determined to calculate the amount of sediment needed from each cooler (*treatments c and d*) to mix with the amendment in order to create a mixed layer (shorter-term/partially mixed versus longer-term/fully mixed) that was placed on top of the sediment in the coolers.

iii. Mixing of sediment and amendment: Based on the results from step ii, the appropriate amount sediment was removed from two coolers (*treatments c and d*) and placed into 4-L glass jars. An equivalent amount of the amendment was then added to each of the jars. The jars were sealed and placed on a tumbler and rotated over night at 3 RPM.

iv. Amendment addition: For each treatment except *treatment a* (no amendment), either the amendment (*treatment b*) or the sediment/amendment mixture (*treatments c and d*) was added to the top of the sediment in the cooler. A 2" layer of overlying seawater was added to each cooler and bubbled with air until the day of testing.

TABLE 3-2. SUMMARY OF TREATMENT SET-UPS FOR SPI CAMERA AND FRICTION SOUND PROBE (FSP) TESTING (MCRD – MARINE CORP RECRUITING DEPOT; WW – WET WEIGHT).

Treatment	Description	Materials: Sediment and Amendment
Treatment A	Unamended sediment. Represents native sediment prior to addition of AquaBlok®.	Sediment from MCRD (~ 15 gallons)
Treatment B	Amended sediment with AquaBlok® placed on sediment surface. Represents initial application of amendment (T=0).	Sediment from MCRD (~15 gallons) + 10lbs of AquaBlok®
Treatment C	Amended sediment with a 1: 1 mixture of sediment and AquaBlok® placed on sediment surface. Represents partial mixing of amendment into sediment surface (short-term mixing).	Sediment from MCRD (~15 gallons) + 13lbs of AquaBlok® (17.5 lbs sediment ww + 13 lbs. amendment)
Treatment D	Amended sediment with a 3: 1 mixture of sediment and AquaBlok® placed on sediment surface. Represents full mixing of amendment into sediment surface (long-term mixing).	Sediment from MCRD (~15 gallons) + 11lbs of AquaBlok® (45lbs sediment ww + 13 lbs. amendment)

3.1.4.3 ***SPI Camera Tests.*** On the day of testing (June 28, 2011), the hand-held SPI camera was set up by Dr. Joe Germano. Testing was carried out by inserting the camera into the surface of the cooler and pushing the camera into the sediment approximately 6-8" before collecting an image. The camera was then pulled out of the sediment and the lens was cleaned before the camera was repositioned to collect another image from the same treatment. The camera was then moved to the next cooler and the process was repeated until images were collected for all of the treatments (Figure 10).

After testing was completed, the images were processed using Nikon image processing software. The images were reviewed to determine if additional imaging was necessary. Two additional images were collected for *treatment c* prior to cleaning and packing the SPI camera for return shipment to Germano and Associates, Inc. (Bellevue, WA).

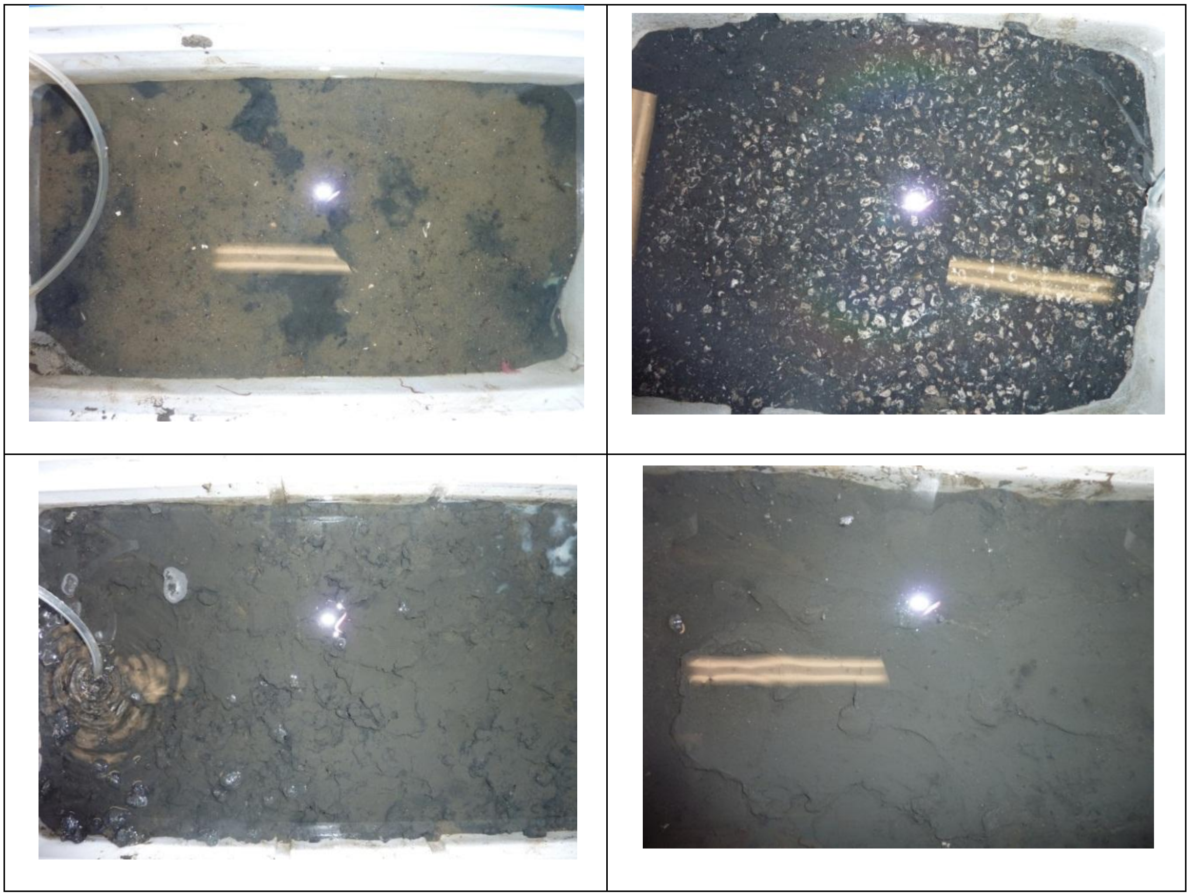


Figure 9. Treatment set-ups for SPI camera and Friction Sound Probe testing. Treatment A - no amendment (top left); Treatment B - amendment on top (top right); treatment C - 1:1 mixture (bottom left); Treatment D - 3:1 mixture (bottom right).

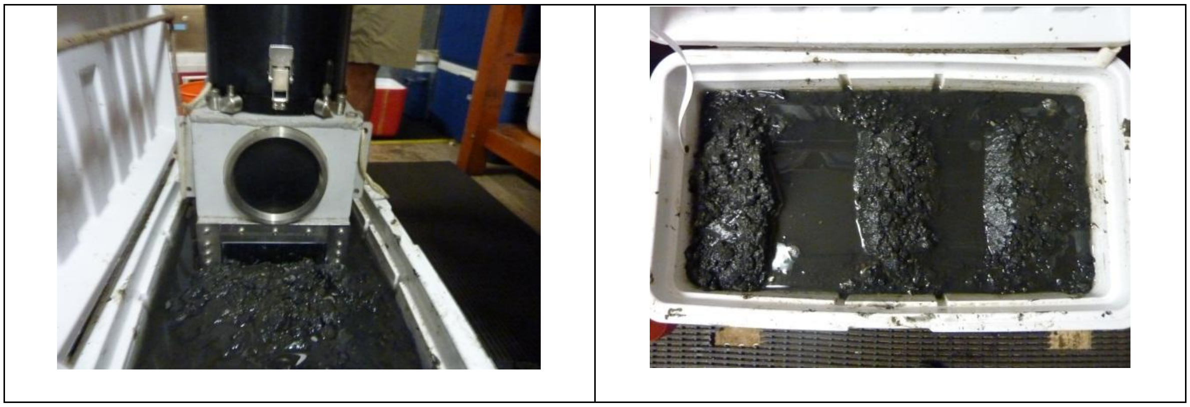


Figure 10. SPI camera testing. Camera push into Treatment C – 1:1 Mixture (left); Treatment C after two SPI camera pushes (right).

3.1.5 VERIFICATION OF AMENDMENT PLACEMENT AND MIXING: FRICTION SOUND PROBE (FSP)

3.1.5.1 ***FSP Technology.*** Friction-sound is a simple and robust technique for in-situ, screening-level measurement of grain size. Friction-sound is believed to be generated when phonons are produced by the breaking or excitation of atomic or molecular bonds as the probe moves over or through the sediment. Theory and previous empirical studies suggest that friction-sound intensity is linearly related to grain size and probe velocity. A prototype SED-FSP has been constructed and tested in the laboratory. In the prototype SED-FSP, the acoustic pickup was integrated into an existing Trident porewater probe that had been sealed to preclude damage to the microphone. The results confirmed that a Trident-based SED-FSP provides a sensitive measure of grain size and that the amplitude of the sound intensity can clearly delineate between sediments with mean diameters in the clay, silt, and sand size ranges (Chadwick 2009).

The SED-FSP probe consists of a stainless steel shaft of 1/2 inch diameter and 1 meter length. The stainless steel probe tip containing the microphone sensor is approximately 1 1/4 inches in length, screwing into a Delrin section 1 1/4 inches length that serves to acoustically isolate the microphone tip assembly from the rest of the SED-FSP unit. The tip assembly has been sealed to preclude damage to the microphone sensor The SED-FSP is coupled to a 5/8 inch diameter pneumatic piston/cylinder drive unit that is vertically mounted onto a submersible frame assembly. The interface incorporates rubber vibration dampeners that serve to acoustically isolate the drive system from the probe sensor. The pneumatic system operates at an air pressure of 85 – 120 psi, controlled by a multiple-valve mechanism that regulates air pressure applied to both the input and output stroke of the piston. The air source is a portable air compressor capable of providing 85 – 120 pounds per square inch gauge (psig) for 10 – 12 seconds duration. For deployments of only a few pushes or where space or utility limitations prevent the use of an air compressor, compressed air tanks (e.g., diver tanks) may be used. When fully retracted the probe tip is near or just in contact to the sediment bed, as the pneumatic cylinder is deployed the SED-FSP extends and penetrates the sediment bed at a controlled and constant speed. The sediment penetration depth of the SED-FSP tip sensor is dependent on the pneumatic piston/cylinder stroke length (the current configuration has a stroke length of 2 feet). The entire SED-FSP assembly weighs around 50 pounds (Figure 11).

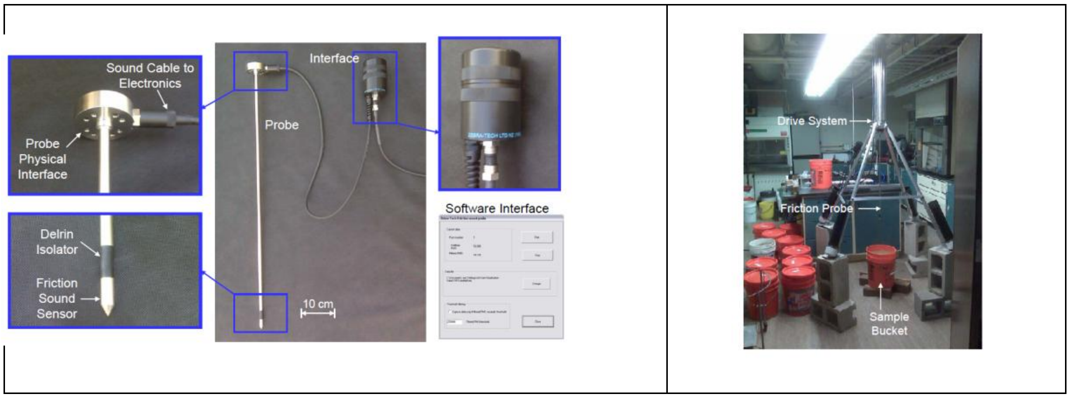


FIGURE 11. SEDIMENT FRICTION SOUND PROBE AND DRIVE PROBE ASSEMBLY (CHADWICK, 2010).

3.1.5.2 ***Test Preparation.*** The SED-FSP testing was carried out using the same treatments set up for the SPI testing. Upon completion of the SPI testing, the coolers were moved outside in order to set up all of the SED-FSP test equipment (Figure 12).

FIGURE 12. SED-FSP SET-UP FOR TESTING REACTIVE AMENDMENT TREATMENTS.

Because the surface of each treatment was disturbed by insertion of the SPI camera, the probe locations were selected in areas around the edges of each cooler/treatment so that the undisturbed sediment could be probed with the SED-FSP. Four to seven pushes into each of the samples were made. Because the coolers ranged in depth from 10-12”, the extent to which the friction sound probe could be pushed into the sediment was limited to ~7-8”, thereby limiting the amount of data that could be collected from each push.

3.1.5.3 ***Data Collection and Analysis.*** The acoustic signal generated at the probe tip is transmitted to an onboard electronics package that filters microphone output and processes the acoustical signal. The electronics package employs a band-pass filter centered around 2 kHz to minimize extraneous and background signals not associated with friction sound generated at the probe tip. The electronics package processes the filtered signal and determines the magnitude of the microphone output at intervals of 160 milli-seconds (msec). The 160 msec interval is a function of the electronic components and numerical processing algorithms that comprise the interface electronics package. The SED-FSP electronics package transmits the processed data to a PC laptop computer running FSP-Talk software developed by the SED-FSP commercial developer, Zebra-Tech, Ltd. of Nelson, New Zealand. FSP-Talk saves the processed signal to data files for later processing and displays a plot of the processed signal as a function of time (Chadwick, 2010).

4 RESULTS AND DISCUSSION

4.1 RSC SITE SURVEY

4.1.1 IMMUNOASSAY RESULTS

Each of the 51 sediment samples collected from the Pier 7 (BNC) site survey (Figure 7) was transported to Building 147, PSNS&IMF former-Foundry, Bremerton (WA) for sample preparation and analysis. The results from the immunoassay are reported as total PCB and are considered equivalent to Aroclor 1254. The tPCB concentration measured in the surface sediments ranged from approximately 50 ppb to 6.6 ppm (Table 4-1). While almost half of the samples were in the 100 ppb or lower range, the remainder of the samples are at concentrations that exceed the clean-up goal for the site which is 3 mg/kg PCB OC normalized (~100 ppb PCB un-normalized assuming nominal 3% TOC) (Figure 13). The location with the highest measured level of PCBs was at station P7-T6-3 (Figure 14). This location corresponds with the area in which elevated levels of PCBs have been repeatedly measured. This location was identified for additional sediment collection for the laboratory treatability studies. As a side note, subsequent to this sampling event, two 55-gallon drums of sediment were collected from this region for research being conducted at ERDC. The concentration of PCBs measured in the subsurface sediments was > 30 ppm.

TABLE 4-1. RAPID SEDIMENT CHARACTERIZATION (RSC) SCREENING RESULTS FOR TOTAL PCBS AT PIER 7 (BNC), OCTOBER 28 – NOVEMBER 01, 2010.

Field ID SAMPLE	tPCB (µg/Kg)	Q	Stdev	%RSD	Field ID SAMPLE	tPCB (µg/Kg)	Q	Stdev	%RSD
P7-T1-1	234				P7-T6-1	243			
P7-T1-2	192				P7-T6-2	262			
P7-T1-3	91				**P7-T6-3**	**6650**	E	1424	21.41%
P7-T1-4	46	U			P7-T6-4	305			
P7-T1-5	152		47	30.74%	P7-T6-5	439			
P7-T2-1	176				P7-T7-1	224			
P7-T2-2	151				P7-T7-2	261			
P7-T2-3	28	U			P7-T7-3	129	J		
P7-T2-4	261				P7-T7-4	655			
P7-T2-5	58	U			P7-T7-5	193			
P7-T3-1	170				P7-T7-6	105	J		
P7-T3-2	96	J			P7-T8-1	227			
P7-T3-3	285				P7-T8-2	129	J		
P7-T3-4	74	U			P7-T8-3	163			
P7-T3-5	48	U	25	51.61%	P7-T9-1	91	J	53	58.25%
P7-T4-1	341				P7-T9-2	74	U		
P7-T4-2	140	J			P7-T9-3	74	U		
P7-T4-3	113	J			P7-T9-4	73	U		
P7-T4-4	133	J			P7-T9-5	84	J		
P7-T4-5	11	U			P7-T9-6	80	J		
P7-T5-1	111	J			P7-T10-1	161			
P7-T5-2	594		76	12.87%	P7-T10-2	24	U		
P7-T5-3	159				P7-T10-3	126	J		
P7-T5-4	150				P7-T10-4	92	J		
P7-T5-5	74	U			P7-T10-5	134	J		
					P7-T10-6	115	J	9	7.75%

Definitions:

***Stdev**:* Standard Deviation from duplicate assay analyses (n=2)

***% RSD**:* Percent Relative Standard Deviation whereby; [{stdev/mean} * 100]

***Q**:* Data Qualifiers: **U** = Non-Detect, **J** = Estimated, **E** = Outside Linear Range, **Blank** = Detect

Label: **P7** = Pier 7; ***Tx-x*** = Transect № (1…10) - Sample № (1…6)

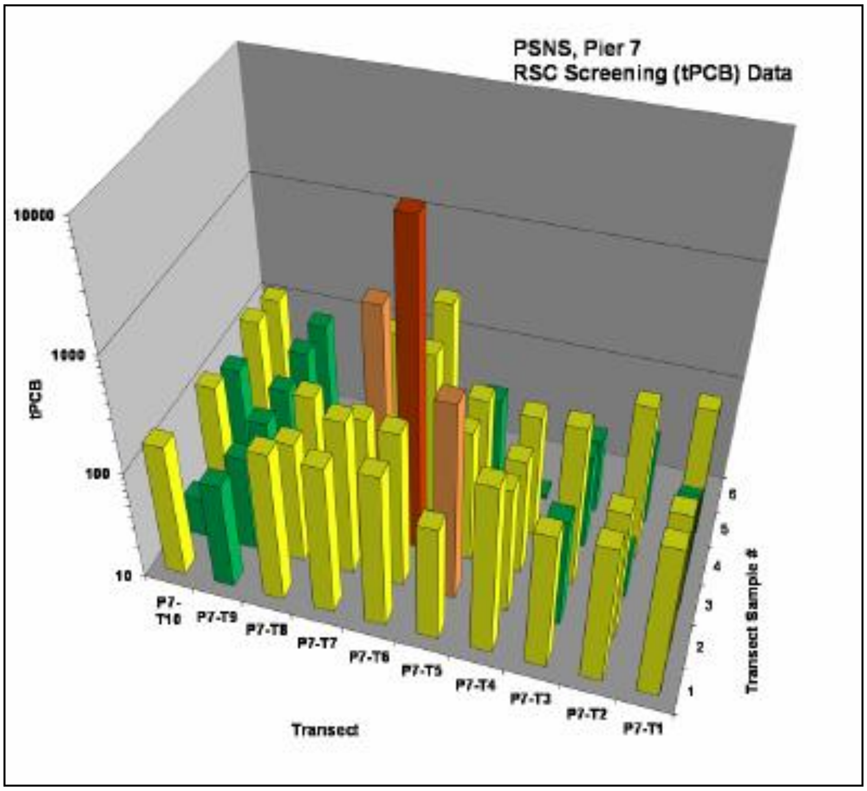


FIGURE 13. RSC IMMUNOASSAY SCREENING LOG-SCALE RESULTS FOR TOTAL PCBS (AROCLOR 1254 EQUIVALENT) AT PIER 7 (BNC) OCTOBER 28 – NOVEMBER 01, 2010.

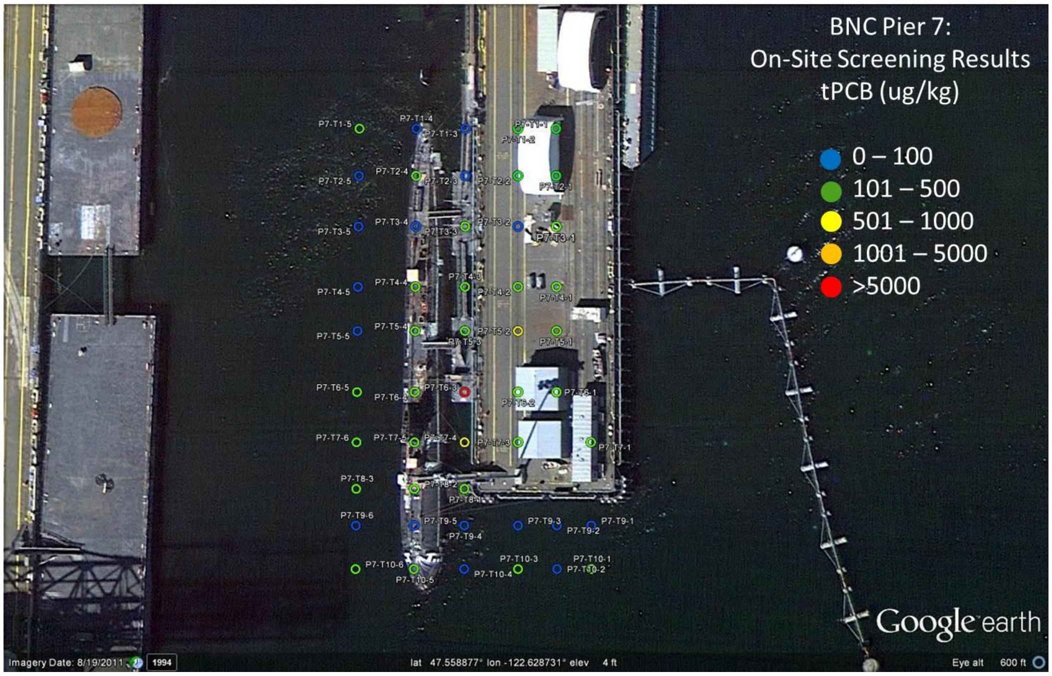


FIGURE 14. RSC IMMUNOASSAY SCREENING RESULTS FOR TOTAL PCBS (AROCLOR 1254 EQUIVALENT) AT PIER 7 (BNC). STATION P7-T6-3 HAD HIGHEST MEASURED LEVELS OF TPCB'S (OCTOBER 28 – NOVEMBER 01, 2010).

4.2 TREATABILITY STUDIES: LABORATORY TOXICITY AND BIOACCUMULATION

4.2.1 PRELIMINARY TOXICITY STUDY

The preliminary toxicity study results are summarized in Tables 4-2 and 4-3, and showed very high survival (≥ 98% for both species) in both the control and unamended Pier 7 (BNC) sediment. No differences in survival or growth were observed between controls consisting of five versus 20 polychaetes, suggesting that the higher worm density (required to obtain enough tissue for bioaccumulation in the treatability study) was acceptable.

No adverse effects, based on survival and growth endpoints, were observed for *N. arenaceodentata* among any of the treatments (Table 4-2). Statistically lower survival ($p < 0.001$) was observed, however, for *E. estuarius* in the presence of AquaBlok® (Table 4-3). Reduced survival was particularly apparent for the AquaBlok® treatment in which the aggregate was coated (BNC + Aq; mean survival = 73%). It is well established that high concentrations of fines have been associated with confounding data interpretation with this amphipod species (USEPA 1994), but it is unclear as to whether particle size was the cause, as reduced survival (mean = 83%) was also observed in the presence of the aggregate without the coating.

Total ammonia concentrations in the AquaBlok® treatments were ≤ 2 mg/L (*E. estuarius* no observed effect concentration = 60 mg/L), therefore ammonia did not contribute to observed adverse effects with AquaBlok®. Although mean wet weight of surviving amphipods was lower in the presence of AquaBlok® (Table 4-3), the difference was not statistically significant ($p=0.08$).

Overall, the results of the preliminary toxicity study indicated that *N. arenaceodentata* was appropriate for use in the treatability study.

TABLE 4-2. PRE-TREATABILITY STUDY RESULTS FROM 28-DAY EXPOSURES WITH THE MARINE POLYCHAETE *NEANTHES ARENACEODENTATA*. N=3 REPLICATES PER TREATMENT. STATISTICAL DIFFERENCES AMONG TREATMENTS ARE INDICATED BY DIFFERENT LETTERS ($P<0.05$). AQ= AQUABLOK®; AQNC= AQUABLOK®, NOT COATED.

Sample ID	% Survival			Wet Weight (mg)			Dry Weight (mg)		
	Mean	s.d.	Sig.	Mean	s.d.	Sig.	Mean	s.d.	Sig.
Control 5	100	0	A	32.5	4.2	A	7.8	0.79	A
Control 20	98	2.9	A	31.4	2.4	A	7.1	0.16	AB
BNC	98	2.9	A	33.9	4.0	A	6.6	0.61	AB
BNC + Aq	98	2.9	A	32.2	4.9	A	6.0	0.50	B
BNC + AqNC	97	2.9	A	35.7	0.4	A	6.8	0.16	AB

TABLE 4-3. PRE-TREATABILITY STUDY RESULTS FROM 10-DAY EXPOSURES WITH THE MARINE AMPHIPOD EOHAUSTORIUS ESTUARIUS. N=3 REPLICATES PER TREATMENT. STATISTICAL DIFFERENCES AMONG TREATMENTS ARE INDICATED BY DIFFERENT LETTERS ($P<0.05$). AQ= AQUABLOK®; AQNC AQUABLOK®, NOT COATED.

Sample ID	% Survival			Wet Weight (mg)		
	Mean	s.d.	Sig.	Mean	s.d.	*p*
Control	99	2.0	A	6.1	0.7	A
BNC	98	2.9	A	5.4	0.5	AB
BNC + Aq	73	2.9	B	4.8	0.2	B
BNC + AqNC	83	10.4	B	4.9	0.5	B

4.2.2 TREATABILITY STUDY: TOXICITY

Polychaete survival was very high (Table 4-4), with ≥ 96% survival in all treatments. Growth was not adversely affected when compared to the control sediment for any treatment, nor when the unamended sediment was compared to the 1 Month Mixed treatment ($p>0.05$). However, the No Mix and 24 Hr Mix treatments did result in statistically lower final weights relative to the unamended BNC treatment (Table 4-4). Millward et al. (2005) reported reduced growth for this species following 1 month contact of 3.4% granular activated carbon (GAC) with PCB contaminated sediment from Hunter's Point, CA, but their experimental design did not include shorter contact time observations. Those authors suggested that ingested organic carbon likely reduced nutrient uptake due to its sorbent properties. That result, however, was not observed by Janssen et al. (2010), who used a similar study design and sediment from nearly the same location. The results of the current study suggest that the lower the contact time, the increased likelihood for potential reduction in growth. It's possible that this could be due to a more concentrated exposure of the PAC to the polychaetes in a less homogeneous exposure. This presents potential concern for short-term effects on the benthic community immediately after application of reactive amendments containing PAC. Lipid content of polychaetes tissues was lowest in the 1 Month Mix treatment (Table 4-4), but the reduced value (1.4%, as a mean of 3 replicates of 6-8 organisms each) was not statistically significant, even though variability within treatments was very low. Janssen et al. (2010) reported lower lipid content of *N. arenaceodentata* following 28 day exposures to AC-amended sediment relative to unamended sediment. Although not conclusive, the authors suggested that natural organic matter in sediment becomes less available after activated carbon addition.

Toxicity results from this treatability study indicate that the amendment was not toxic to the target species, but that consistent with previous studies, there could be some reduction in growth attributed to the more concentrated amendment levels that could occur during a limited time period following the installation.

TABLE 4-4. TREATABILITY STUDY RESULTS FROM 28-DAY EXPOSURES WITH THE MARINE POLYCHAETE *NEANTHES ARENACEODENTATA*. N=9 FOR SURVIVAL AND WET WEIGHT; N=3 FOR LIPID DATA. STATISTICAL DIFFERENCES AMONG TREATMENTS ARE INDICATED BY DIFFERENT LETTERS ($P<0.05$).

	Survival (%)			Individual Wet Wt. (mg)			Lipid (%, wet wt.)		
Sample ID	Mean	s.d.	Sig.	Mean	s.d.	Sig.	Mean	s.d.	Sig.
Control	96	2.7	A	19.6	2.0	A	1.7	0.51	A
Unamended	97	5.1	A	23.5	3.0	B	2.0	0.15	A
No Mix	97	3.9	A	18.4	1.4	A	2.0	0.13	A
24 Hr Mix	96	5.0	A	18.9	1.1	A	1.9	0.69	A
1 Mo Mix	97	3.2	A	22.5	2.7	B	1.4	0.06	A

4.2.3 TREATABILITY STUDY: SEDIMENT PCB CONCENTRATION

Total PCB concentration measured in the unamended BNC sediment was 2,498 µg/Kg, dry weight. Tetra-, Penta-, and Hexa- homologs made up 94% of the detected concentration, with relatively minimal contributions from Di-, Tri-, Hepta-, and Octa- constituents (Figure 14).

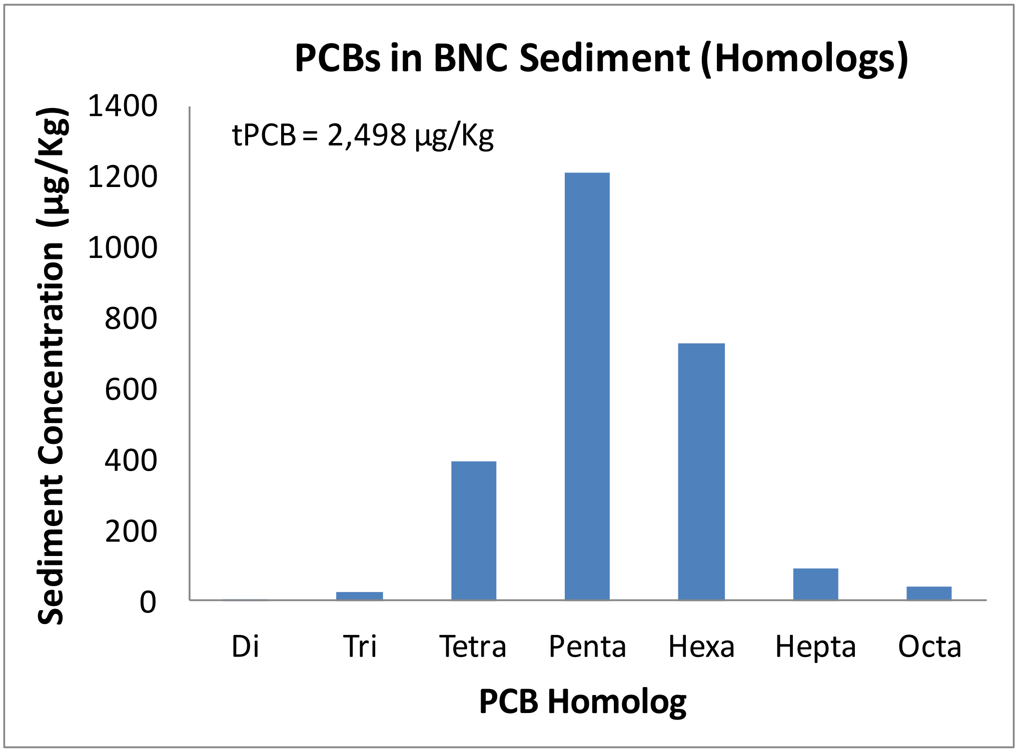


Figure 14. Concentration of PCB homologs in unamended sediment collected from the Bremerton Naval Complex Pier 7 (BNC) and used for the preliminary and treatability studies.

4.2.4 TREATABILITY STUDY: PCB BIOACCUMULATION

Total polychaete tissue PCB concentrations from the control sediment averaged 2.7 µg/Kg, while concentrations in unamended Pier 7 (BNC) sediment averaged 561 µg/Kg (wet weight; Figure 15). The tissue dry/wet ratio ranged from 19-24% (therefore, approximate unamended BNC tissue residue = 2,609 µg/Kg dry wt). Increasing AquaBlok® contact time with the BNC sediment resulted in progressively lower bio-uptake (Figure 15), with up to 94% tPCB reduction for the 1 month mixed treatment. Lipid normalization of the data resulted in similar reductions (Figure 15). The biouptake reduction of tPCBs somewhat exceeds that reported by Millward et al. (2005), where 82% reduction was observed in *N. arenaceodentata* tissues from Hunter's Point Naval Shipyard contaminated sediment following 1 month contact time with GAC (particle size 75-300 µm) and a similar experimental design. The lower biouptake reduction observed with no mixing or following only brief mixing was also reported by Sun and Ghosh (2007) with the oligochaete *Lumbriculus variegatus* exposed to GAC-amended PCB contaminated sediment. The substantial reduction of bioaccumulated PCBs under a worst case scenario (no mixing) and fine particle size associated with the PAC used in AquaBlok® (providing greater surface area and more sorption sites for PCB binding relative to GAC) suggests that field scale applications of AquaBlok® should result in near immediate PCB sequestration to benthic invertebrates.

On a homolog-specific basis, biouptake reduction was inversely correlated PCB chlorination (Figure 16). This observation has also been reported in other investigations employing AC (Millward et al. 2005; Sun and Ghosh 2007; Janssen et al. 2009). Tetra- and Penta- homologs, however, made up 75% of the PCBs detected in tissue exposed to the unamended Pier 7 (BNC) sediment, 97% of which were not detectable in the 1 month mix treatment. Therefore, considering the homolog distribution at the site, the reduced efficiency associated with the highest levels of biphenyl chlorination should be of little concern.

The results from this laboratory study demonstrated that amending the contaminated sediment collected from the BNC Pier 7 site with activated carbon (in the form of AquaBlok® in this study) can effectively reduce the bioavailability of PCBs to the marine polychaete, *Neanthes arenaceodentata*.

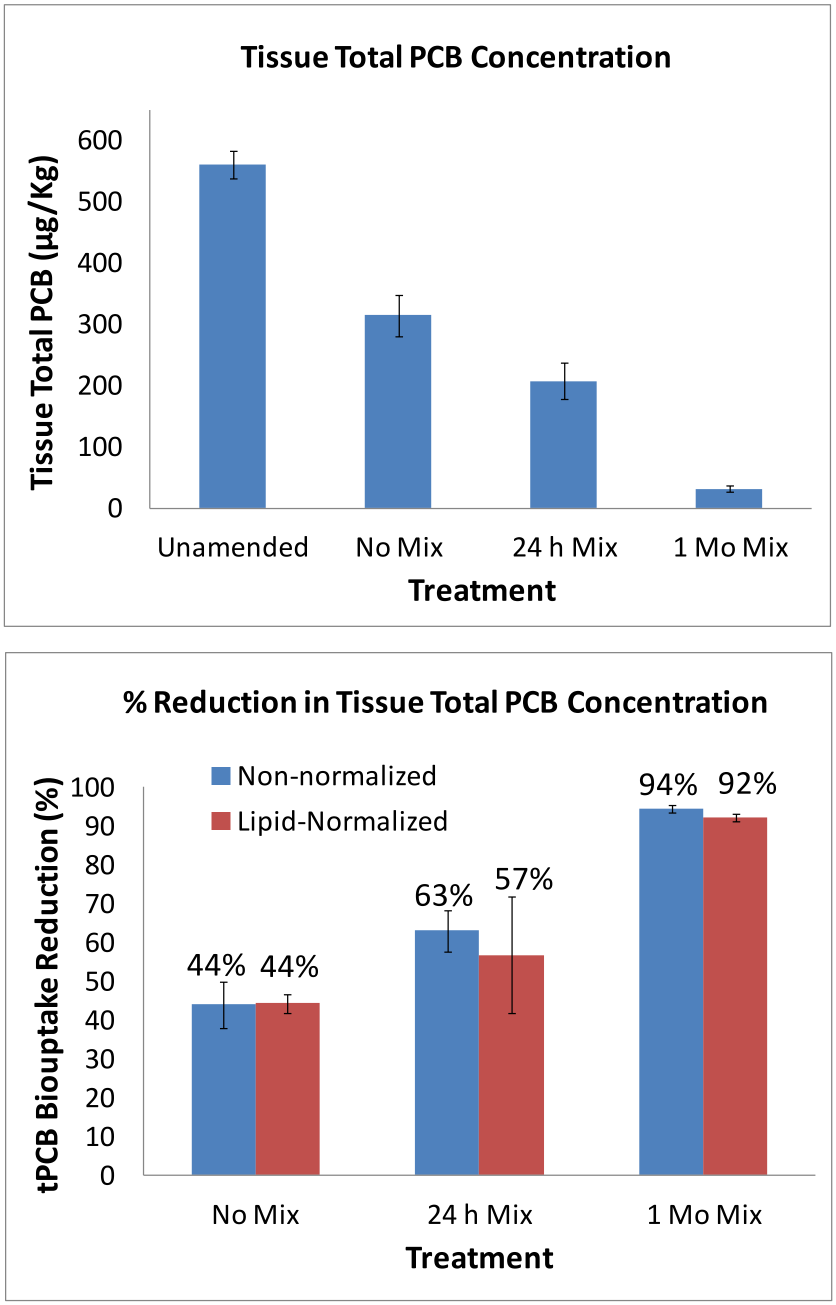
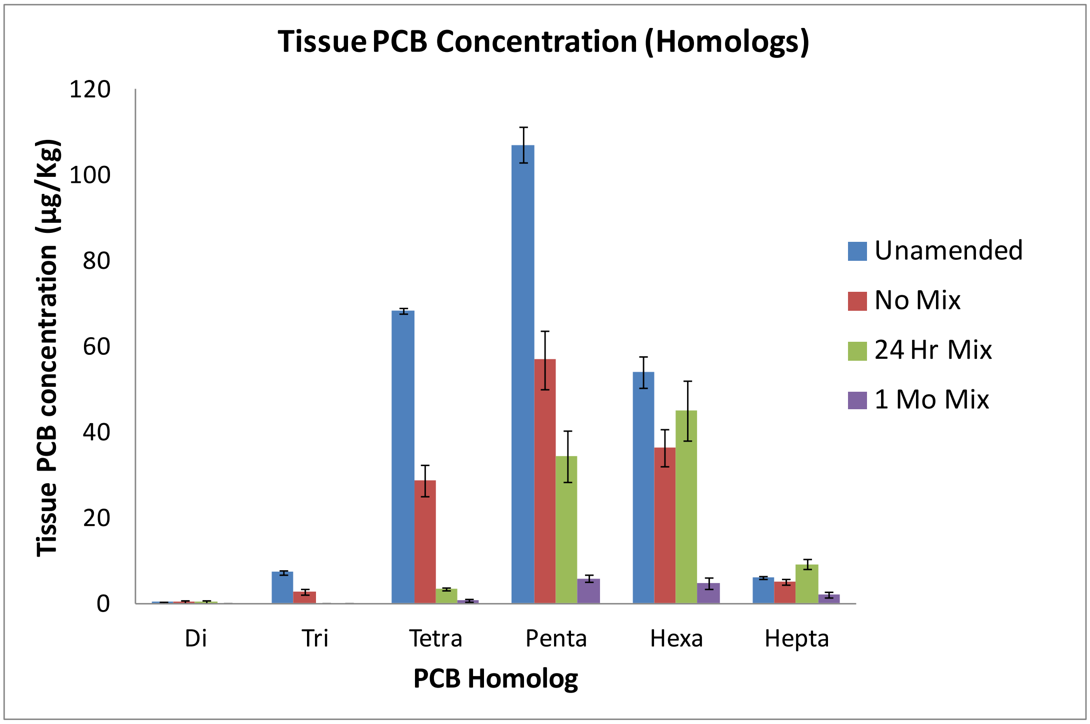


FIGURE 15. TISSUE (WET WEIGHT) TOTAL PCB CONCENTRATION (TOP) AND PERCENT TOTAL PCB TISSUE CONCENTRATION REDUCTION (BOTTOM) IN *NEANTHES ARENACEODENTATA* FOLLOWING 28-DAY LABORATORY EXPOSURES FOLLOWING DIFFERENT MIXING DURATION OF BNC SEDIMENT AQUABLOK®. N= 3 REPLICATES PER TREATMENT.



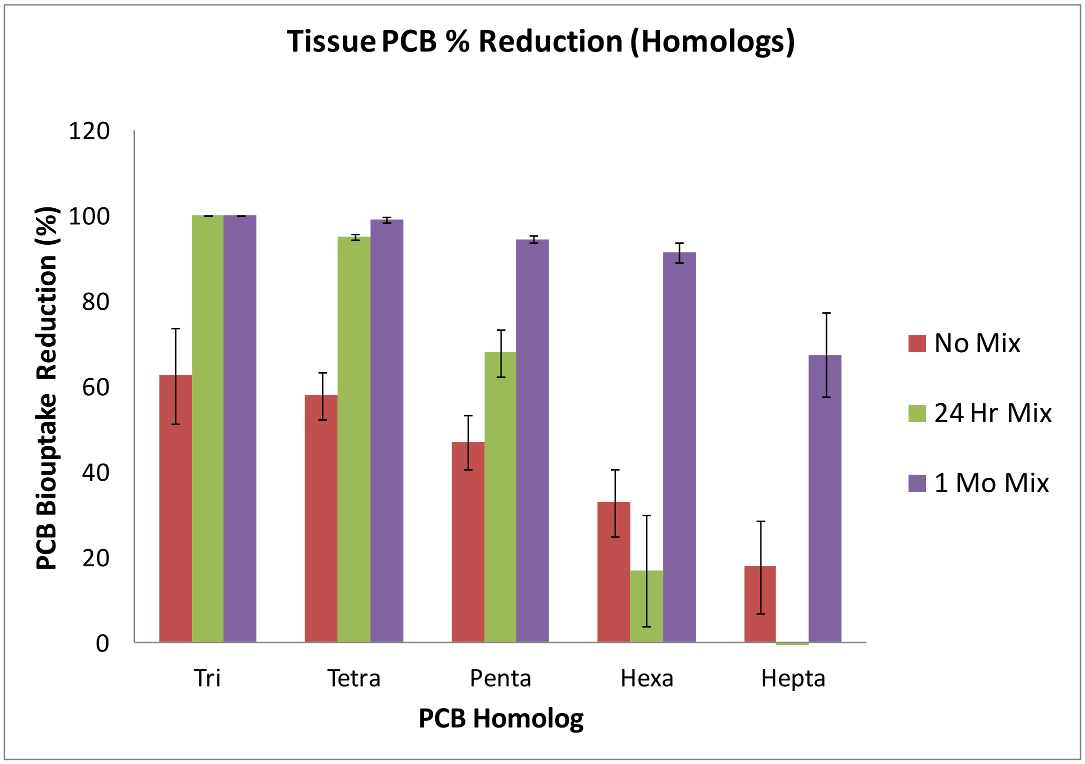


FIGURE 16. TISSUE (WET WEIGHT) PCB CONCENTRATION, EXPRESSED AS SUM OF CONGENERS IN EACH HOMOLOG (TOP) AND PERCENT TOTAL PCB TISSUE CONCENTRATION REDUCTION, BY HOMOLOG (BOTTOM), IN *NEANTHES ARENACEODENTATA* FOLLOWING 28-DAY LABORATORY EXPOSURES FOLLOWING DIFFERENT MIXING DURATION OF BNC SEDIMENT WITH AQUABLOK®. N= 3 REPLICATES PER TREATMENT.

4.2.5 TREATABILITY STUDY: SEDIMENT HG AND MEHG CONCENTRATIONS

The total mercury (Hg) concentration measured in the unamended Pier 7 (BNC) sediment was 0.72 mg/Kg, dry weight and the methyl mercury (MeHg) concentration in the unamended sediment was 0.26 ng/g, dry weight.

4.2.6 TREATABILITY STUDY: HG AND MEHG BIOACCUMULATION

No statistically-significant differences were observed among treatments for concentration of total mercury (P = 0.11, Kruskal-Wallis). Differences were observed among treatments for concentration of methyl mercury (P = 0.02, Kruskal-Wallis). Tukey's HSD indicated that concentrations of methyl mercury in the 24-h mixing treatment were highest and distinct from all other treatments. Concentrations in the 1-month mixing treatment were significantly higher than the unamended treatment, although they were not significantly different from the unmixed treatment. Concentrations in the unmixed treatment were not statistically different from those in the unamended treatment (Figures 17 and 18).

Although the concentrations of mercury and methyl mercury in *Neanthes arenaceodentata* exposed to AquaBlok®-amended Bremerton Pier 7 sediment increased relative to the unamended Bremerton Pier 7 sediment, these differences are all within the range of values observed at "clean" reference areas (Figures 17 and 18). For example, all Bremerton Pier 7 results (unamended or AquaBlok®-amended) were lower than the concentrations of mercury and methyl mercury observed in *N. arenaceodentata* exposed to reference sediment obtained from Yaquina Bay, OR. Bremerton results are also below the range of concentrations of total mercury in tissue observed in *Nereis virens* (a marine polychaete similar to N. arenaceodentata) exposed for 28 days to sediment from coastal marshes at China Camp, San Pablo Bay, CA (Best et al. 2007) and another study with sediment from Long Island Sound (Burgess et al. 2009) as shown in Figure 17. These sites were used as reference sites by Best et al. (2007) and Burgess et al. (2009), respectively. Concentrations of methyl mercury in tissue are comparable for exposures to unamended Bremerton Pier 7 sediment and China Camp (2.63 ng/g ww and 1.17 ng/g ww, respectively). Although concentrations of methyl mercury are higher in the AquaBlok®-amended treatments (compared to the unamended sediment), concentrations are within the range of methyl mercury observed in the Yaquina Bay and other reference sediments. Both methyl mercury and mercury occur naturally throughout the environment and the range of analytically-detectable concentrations shown in Figures 17 and 18 do not indicate that Bremerton Pier 7 sediment or Bremerton Pier 7 sediment amended with AquaBlok® are outside the range of expected background levels.

Despite the apparent uptake of Hg and MeHg by the polychaete, the concentrations are very low and are not outside the range of expected background levels. We don't have an expectation that the amendment is going to have a beneficial or adverse impact on bioavailability. However, we plan to monitor both Hg and MeHg throughout the course of the field demonstration to assess the amendments impact on biouptake under field conditions.

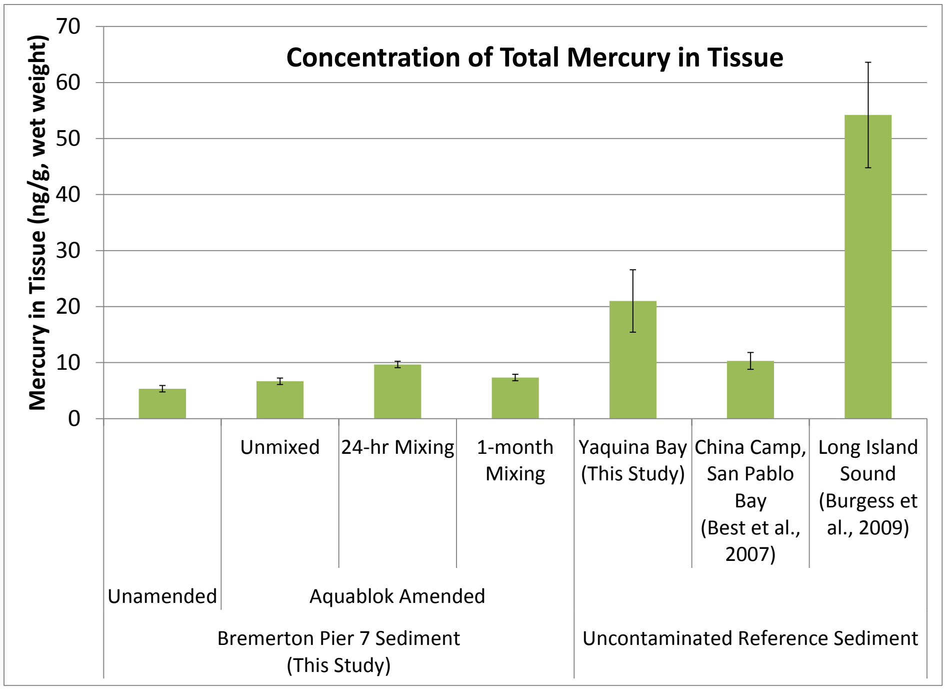


FIGURE 17. TISSUE (WET WEIGHT) MERCURY (NG/G) IN *NEANTHES ARENACEODENTATA* FOLLOWING 28-DAY LABORATORY EXPOSURES FOLLOWING DIFFERENT MIXING DURATION OF BNC SEDIMENT AQUABLOK®. N= 3 REPLICATES PER TREATMENT.

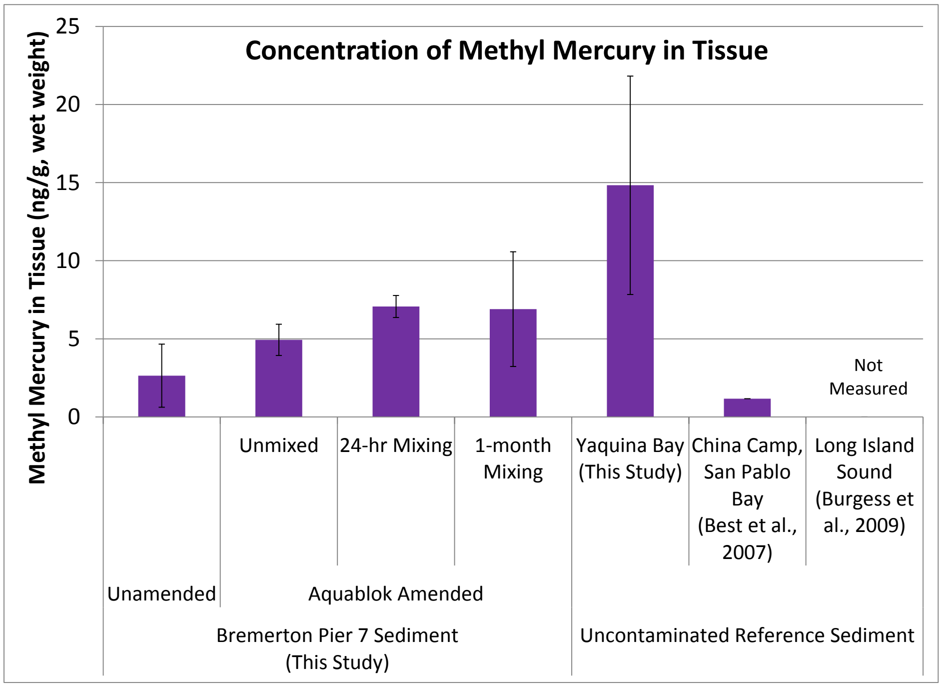


FIGURE 18. TISSUE (WET WEIGHT) METHYL MERCURY (NG/G) IN *NEANTHES ARENACEODENTATA* FOLLOWING 28-DAY LABORATORY EXPOSURES FOLLOWING DIFFERENT MIXING DURATION OF BNC SEDIMENT AQUABLOK®. N= 3 REPLICATES PER TREATMENT.

4.3 VERIFICATION OF AMENDMENT PLACEMENT AND MIXING: SPI SYSTEM

4.3.1 SEDIMENT PROFILE IMAGING RESULTS

The SPI camera system was deployed a total of 10 times over the course of two hours to image four different sediment treatments, as described in section 2.2.4.2 above. Prior to testing the SPI Images collected from all of the four treatments are shown in Figure 19 through Figure 22.

Figure 19 shows the images from two pushes into *treatment a* (unamended sediment). Slight variations in sediment texture in the unamended sediment can be observed, ranging from coarser-grained sediment on the top to finer-grained sediment on the bottom. Figure 20 shows the images of two pushed into *treatment b* (amendment placed on top). A clear distinction between the AquaBlok and the underlying sediment below can be observed with the much darker layer comprised of the aggregate and PAC on top of the “native” sediment. It can also be observed that the PAC has started to fall of the aggregate (small, whitish rocks) on deposit onto the surface of the sediment. Figure 21 shows the images of two SPI camera pushes into *treatment c* (1:1 sediment to amendment mixture). While the distinction between the amended layer and the underlying sediment is less obvious than in *treatment b*, two layers can be observed. The amended layer appears as a thicker, darker, more consolidated layer on top of the coarse-grained sediment below. Prior to testing, it was thought that the aggregate itself (whitish-rocks) would be observed during the testing and could be used as a means of identifying where the amendment was placed. However, it appears as if during the process of pushing the camera into the sediment, the finer-grained materials (PAC mixed with sediment) fill any voids and that is what is captured by the camera.

Figure 22 shows the two SPI camera images taken from *treatment d* (3:1 sediment to amendment mixture). The results are similar to those observed for treatment c, however, the amended layer extends deeper into the “native” sediment. Again, the upper amended layer appears as a more consolidated darker layer on top of the coarser-grained, lighter-colored material below.

The SPI camera was able to distinguish between unamended and amended sediment layers in this lab study. This tool will be important for verifying placement, stability and mixing of amendment post-placement.

4.4 VERIFICATION OF AMENDMENT PLACEMENT AND MIXING: FRICTION SOUND PROBE

4.4.1 FRICTION SOUND PROBE (FSP) RESULTS

The same treatments used for the SPI camera testing were used for the Friction Sound Probe tests. The treatments, which were prepared in ice chests (~ 8-10 inches depth of sediment/mixture with approximately 2 inches of overlying water), were transferred outside for testing. They were identified for SED-FSP testing as: “No Treatment” (*treatment a*), “Initial Treatment” (*treatment b*), “San Diego Bay Partial Treatment” (*treatment d*, 3:1 sediment to amendment) and “San Diego Bay Full Treatment” (*treatment c*, 1:1 sediment to amendment). The probe locations were selected as much as possible around the edges of the coolers so that the undisturbed sediment was probed. Four to seven pushes into each of the treatments were made. Four plots of signal amplitude per times are shown in Figures 23 – 26. The data are presented so that the encounter of the SED-FSP probe with the sediment surface is at data point 5000 (5 seconds). The probe speed is 2.1 in/sec (5.3 cm/sec); the data resolution is 0.166 seconds, corresponding to 0.35 cm/data interval or 0.88 in/interval.

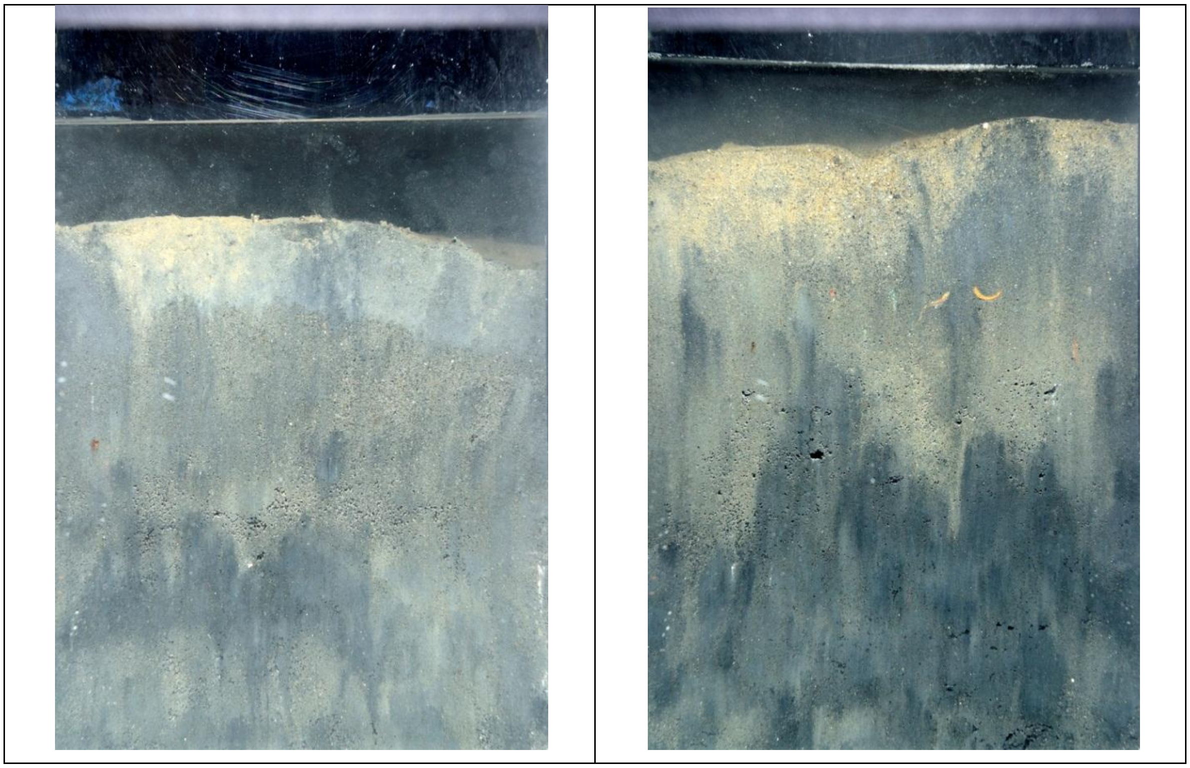


FIGURE 19. SPI CAMERA IMAGES FROM TWO PUSHES INTO TREATMENT A (UNAMENDED SEDIMENT).

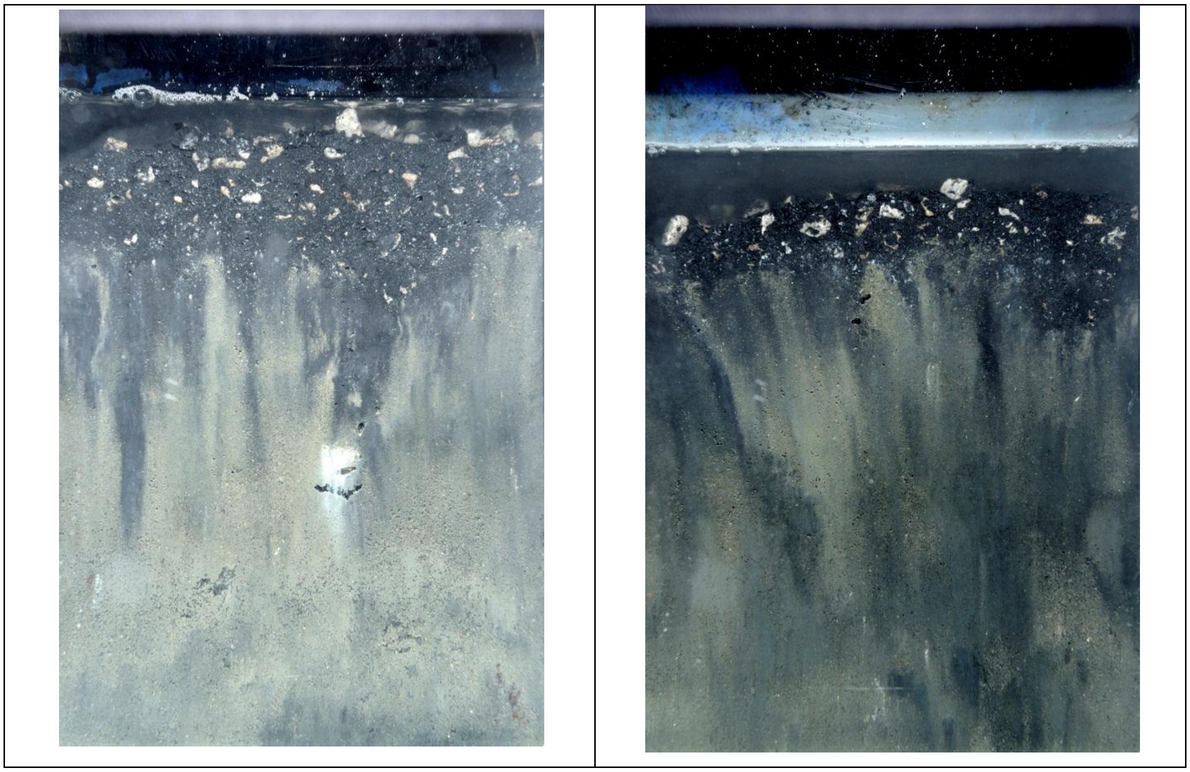


FIGURE 20. SPI CAMERA IMAGES FROM TWO PUSHES INTO TREATMENT C (AMENDMENT ON TOP).

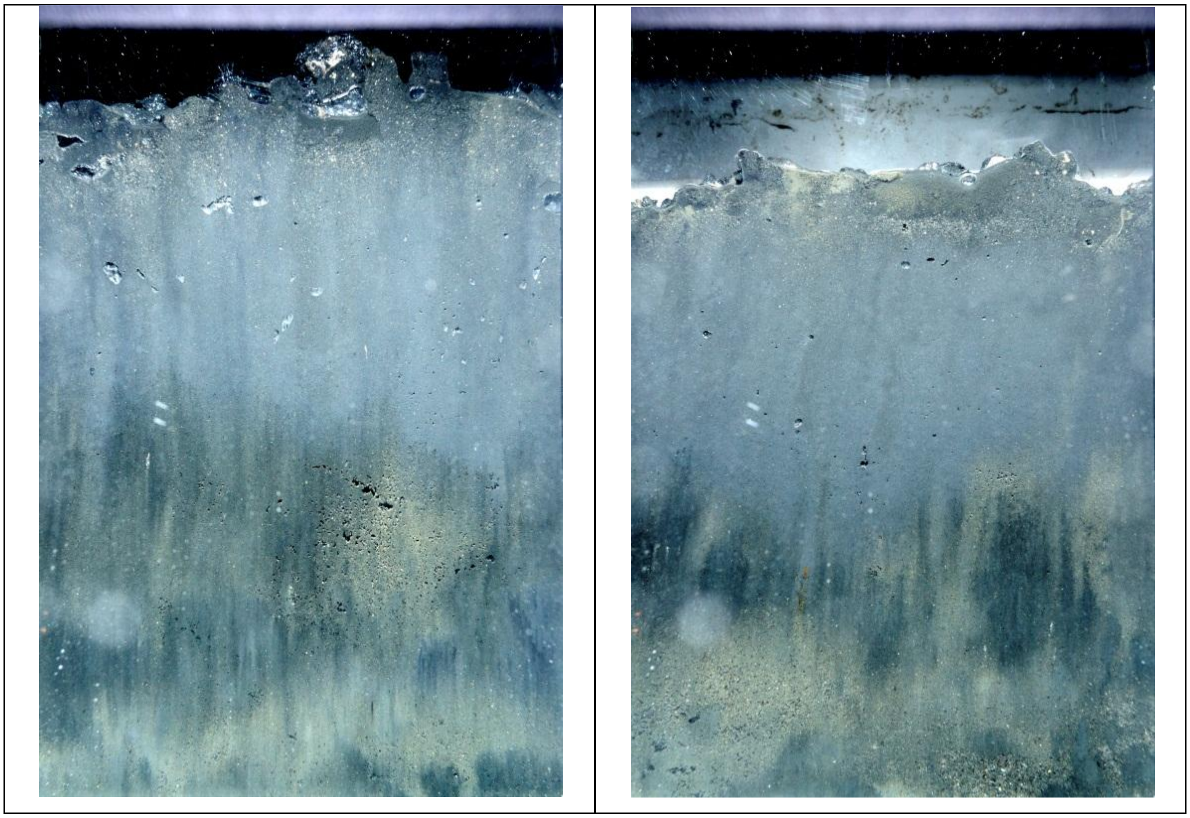


Figure 21. SPI camera images from two pushes into treatment C (1:1 sediment to amendment mixture on top).

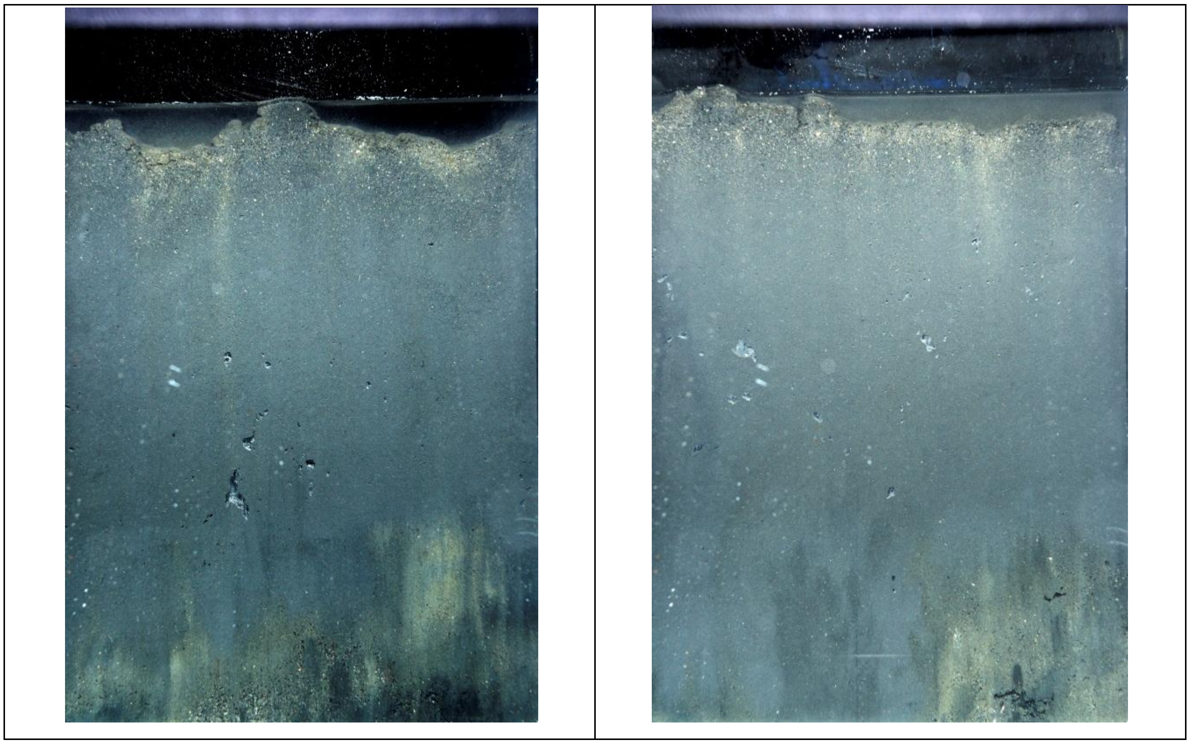


Figure 22. SPI camera images from two pushes into treatment D (3:1 sediment to amendment mixture on top).

Figure 23 shows the plots of signal amplitude for treatment a (sediment only, no amendment). The sample amplitude corresponds to sand of around 100 µm diameter. Observation of the sediment shows this to be approximately correct, the sediment is silty sand. The signal corresponds to a sandy sample. Seven pushes were made into *treatment b* (Figure 24). The large spikes indicate encounter of the probe with AquaBlok® pebbles. The pebble size is on the order of 0.5 – 1 cm diameter. The AquaBlok® layer on top of the sample can’t be distinguished from the rest of the sediment with the exception of SDBIT07 where the signal does return to background after the initial push through the pebbly top layer. For *treatment d*, elevation of signal above “no treatment” background is seen (Figure 25). The signal starts elevated then returns to background levels. The amplitude of the peaks is less than expected if the probe had “fully” encountered a pebble. The spikes aren’t as large as was seen for the “initial treatment” sample. For the final test, *treatment c* was probed with the SED-FSP. Greater amplitude of spikes in comparison to “partial mix” samples was observed (Figure 26). It appears that spiking is encountered at the top of the sample versus the bottom. This treatment seems to exhibit layering behavior.

As with the SPI camera, the Friction Sound Probe was also able to distinguish between unamended and amended sediment layers. This tool, coupled with the SPI camera and core samples will be important in verifying placement, stability and mixing of amendment post-placement.

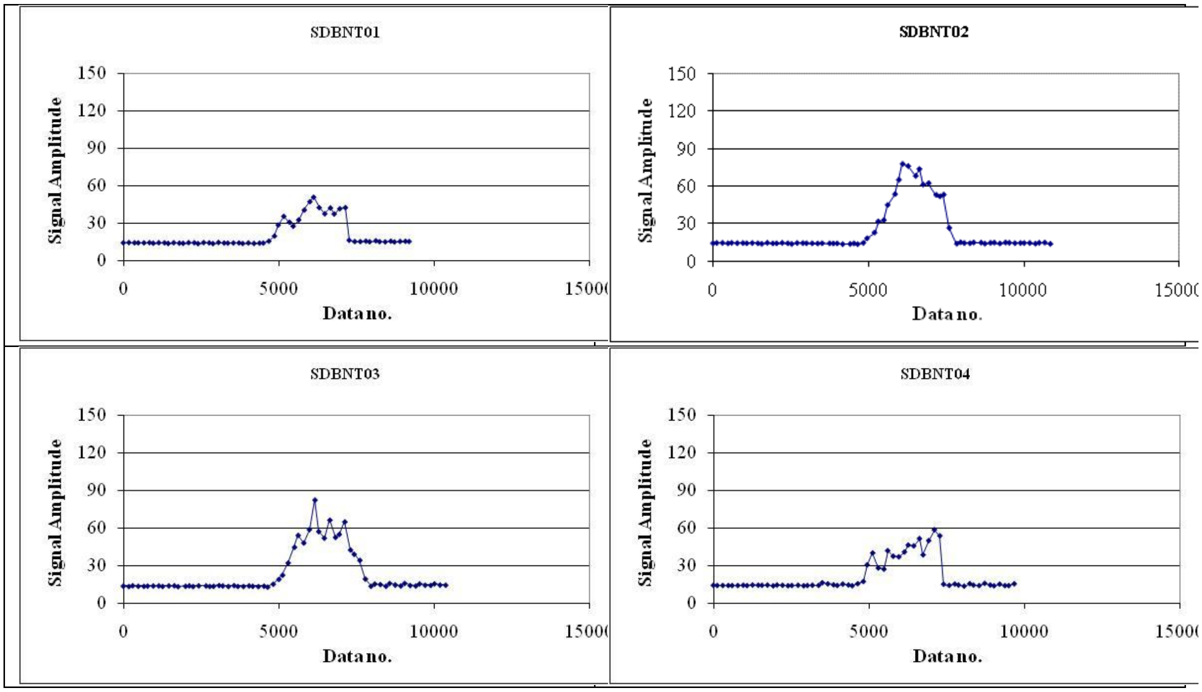


Figure 23. “No Treatment” Sample: Sediment without AquaBlok® (Total sediment depth = 7.5 inches).

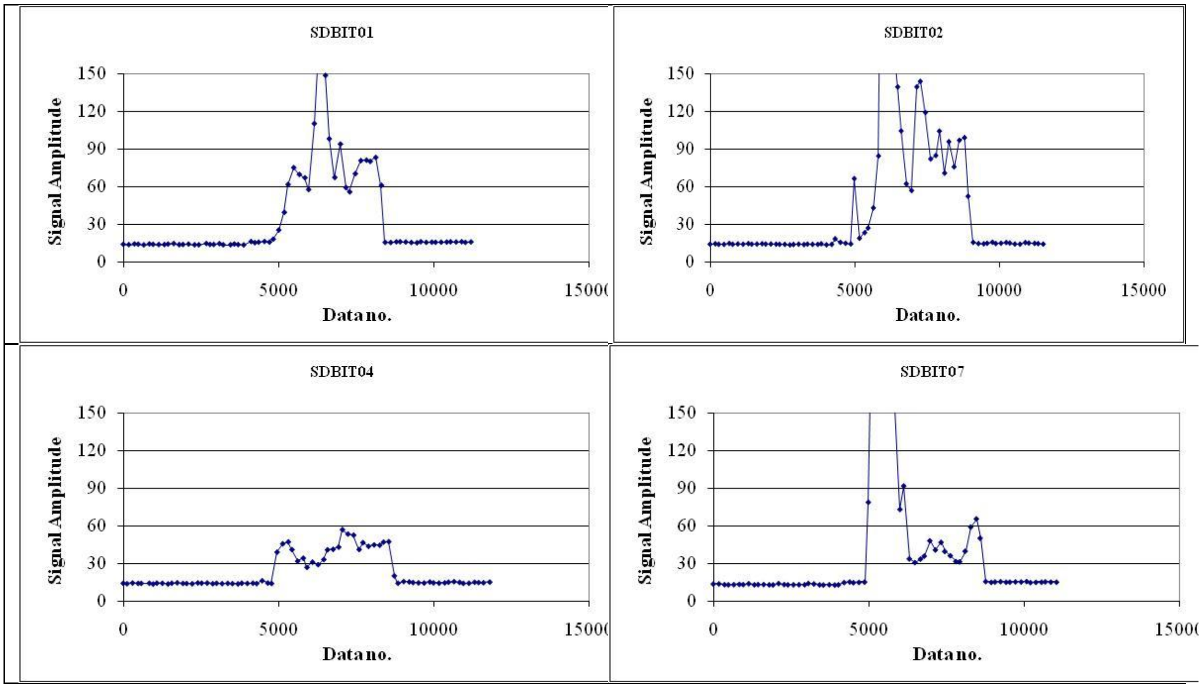


FIGURE 24. "INITIAL TREATMENT" SAMPLE: AQUABLOK® ON TOP OF SEDIMENT (TOTAL SEDIMENT DEPTH = 8 INCHES).

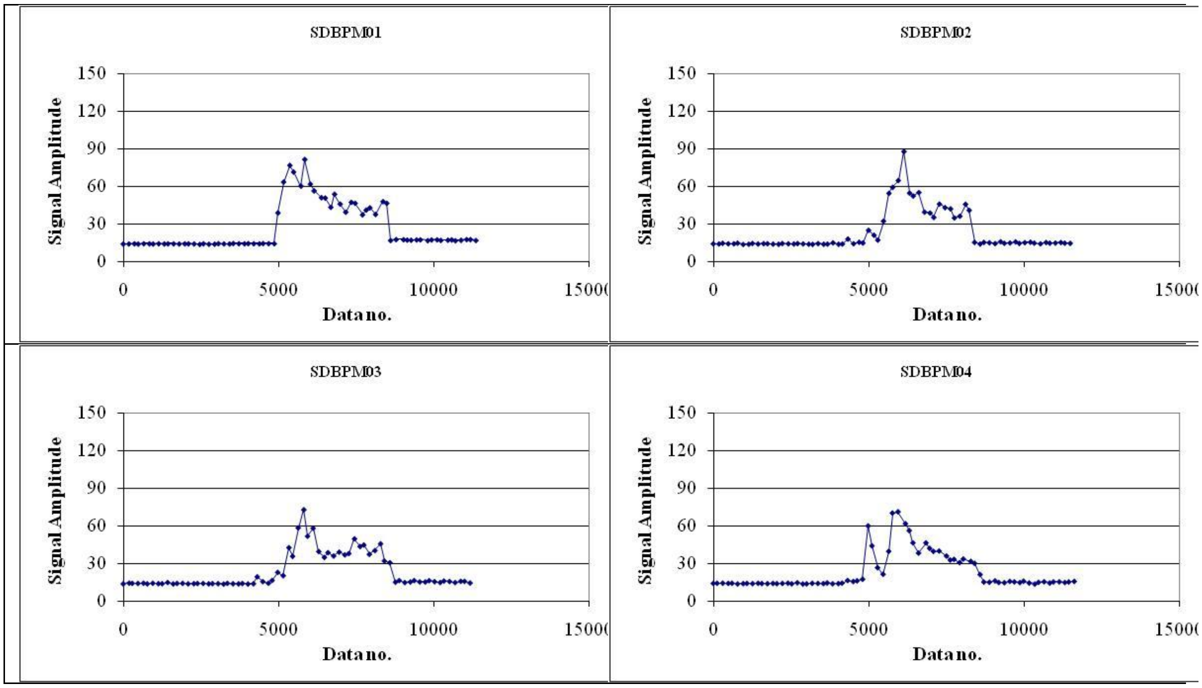


FIGURE 25. "PARTIAL MIX" SAMPLE: MIXTURE OF 1:3 AQUABLOK® TO SEDIMENT RATIO. TOTAL SEDIMENT DEPTH = 9.25 INCHES).

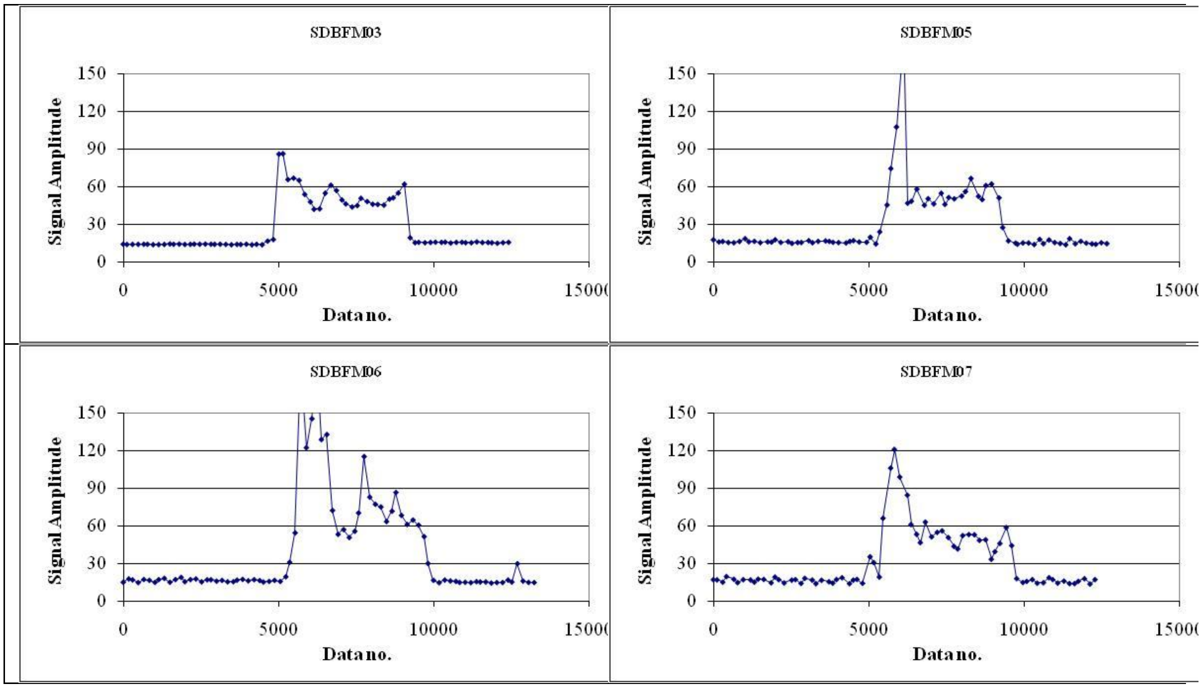


FIGURE 26. "FULL MIX" SAMPLE: MIXTURE OF 1:1 AQUABLOK® TO SEDIMENT RATIO. (TOTAL SEDIMENT DEPTH = 9.5 INCHES).

5 CONCLUSIONS

The results from this laboratory study demonstrated that amending the contaminated sediment collected from the BNC Pier 7 site with activated carbon (in the form of AquaBlok® in this study) can effectively reduce the bioavailability of PCBs to the marine polychaete, *Neanthes arenaceodentata*. Increasing AquaBlok® contact time with the BNC sediment resulted in progressively lower bio-uptake with up to 94% tPCB reduction for the 1 month mixed treatment. Lipid normalization of the data resulted in similar reductions. While one of the main goals of this study was to verify the effectiveness of the amendment material in terms of reduction in contaminant bioavailability to benthic organisms, laboratory toxicity testing was also carried out to assess any potential adverse toxic effects from the unamended as well as amended sediment. Polychaete survival was very high with ≥ 96% survival in all treatments. Growth was not adversely affected when compared to the control sediment for any treatment, nor when the unamended sediment was compared to the 1 Month Mixed treatment ($p>0.05$). However, the No Mix and 24 Hr Mix treatments did result in statistically lower final weights relative to the unamended BNC treatment. These results suggest that there is an increased likelihood for reduction in growth immediately following amendment addition, possibly due to a more concentrated exposure, less homogeneous exposure of the PAC to the polychaetes initially. However, over time growth does not appear to be adversely affected.

Because the bentonite-based clay minerals present in the amendment formulation tested in this study are known to have a high cation exchange and binding capacity for metals, the composite amendment was also evaluated for its effectiveness for the co-occurring mercury contamination in the site sediments. While a dramatic reduction in uptake of the Hg and MeHg was not expected, it was assumed that the tissue concentrations from the amended sediments would decrease. Conversely, the concentrations of mercury and methyl mercury in *Neanthes arenaceodentata* exposed to AquaBlok®-amended Bremerton Pier 7 sediment increased relative to the unamended Bremerton Pier 7 sediment. However, further comparison of these results to other studies showed that the Bremerton results were below the range of concentrations of total mercury in tissue observed in marine polychaetes exposed for 28 days to reference sediments from other study locations. Similarly, while the concentrations of methyl mercury were higher in the AquaBlok®-amended treatments (compared to the unamended sediment), concentrations were within the range of methyl mercury observed in the Yaquina Bay reference sediment used in this study and other reference sediments. It should be noted that both methyl mercury and mercury occur naturally throughout the environment and the range of analytically-detectable concentrations observed in this study do not indicate that Bremerton Pier 7 sediment or Bremerton Pier 7 sediment amended with AquaBlok® are outside the range of expected background levels.

The secondary objective of this study was to evaluate the degree to which various monitoring tools such as the Sediment Profile Imaging (SPI camera) system with digital image analysis and the Friction Sound Probe (FSP) could distinguish the amendment from native site sediment post-placement. The ability to monitor the placement and the physical stability of the reactive amendment in deeper water areas that support vessel traffic is a vital component in demonstrating the efficacy of this type of in situ treatment method. A hand-held Sediment Profile Imaging system (SPI camera) was tested in the laboratory on four different sediment treatments: 1) unamended sediment, 2) sediment with 1” layer of AquaBlok® placed on top, 3) amended sediment with a 1: 1 mixture of sediment and AquaBlok® placed on sediment surface and 4) Amended sediment with a 3: 1 mixture of sediment and AquaBlok® placed on sediment surface. In each of the amended treatments, two distinct layers could be observed in the SPI images. While the distinction between the amended layer and the underlying sediment was less obvious in the 1:1 and 3:1 mixtures as compared to the initial treatment (AquaBlok® placed on sediment surface), the amended layer could be distinguished as a thicker, darker, more consolidated layer on top of the coarse-grained sediment below. Another monitoring tool, the Friction Sound Probe (FSP) was also tested on the four sediment treatments used for the SPI camera testing. Because the FSP testing was carried out after the SPI camera testing, the sediment treatments were quite disturbed. The probe locations were selected as much as possible around the edges of the coolers so that the undisturbed sediment was probed. In general, the FSP was able to distinguish between the different sediment layers (e.g., coarse versus fine) in each of the treatments. In each of the amended treatments, a spike in amplitude (which corresponds to larger grain-size) was observed.

The purpose of this study was to address several important aspects in the evaluation and optimization of the reactive amendment which will be used to directly support the needs of NAVFAC NW as well as support a larger demonstration and validation project (Demonstration of In-Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors) jointly funded by the Navy’s Environmental Sustainability Development to Integration Program (NESDI), NAVFAC NW and by the DoD’s Environmental Security Technology Certification Program (ESTCP). The results from this study suggest that the amendment, AquaBlok, will be effective at reducing the PCB bioavailability. While the results for Hg and MeHg were not as anticipated, the comparison of these results to other background/reference sites suggest that despite the apparent uptake of Hg and MeHg by the polychaete, the concentrations are very low and are not outside the range of expected background levels. Results from testing two different placement/stability verification monitoring tools also yielded promising results as each tool was able to distinguish the amendment from the native sediment.

6 GO/NO-GO DECISION

As part of the ESTCP project, a Go/No-Go decision point to move forward with the field demonstration was requested based on the results of the lab study. The results from this study suggest that a **GO** decision is warranted. Therefore, a demonstration plan, based on the original proposal (Appendix E) and the lessons learned from this study will be developed in order to examine multiple facets of the amendment performance under an active harbor setting, including the feasibility of deep water material placement, the stability of material placement, the extent to which material placement reduces tissue residue concentrations of PCBs and mercury, together with the observable impact or enhancement of the structure, diversity, or density of the benthic community.

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APPENDIX A

RSC SAMPLING LOCATIONS

TABLE A-1. SAMPLING LOCATIONS FOR RSC IMMUNOASSAY SURVEY, PIER 7 (BNC).

Transect	Sample ID	Latitude	Longitude	Notes
Transect 1	P7-T1-1	47.559226	-122.628651°	Under Pier
Transect 1	P7-T1-2	47.559226	-122.628750°	Under Pier
Transect 1	P7-T1-3	47.559226	-122.628950°	Away from Pier
Transect 1	P7-T1-4	47.559226	-122.629053°	Away from Pier
Transect 1	P7-T1-5	47.559226	-122.629157°	Away from Pier
Transect 2	P7-T2-1	47.559130	-122.628651°	Under Pier
Transect 2	P7-T2-2	47.559130	-122.628750°	Under Pier
Transect 2	P7-T2-3	47.559130	-122.628950°	Away from Pier
Transect 2	P7-T2-4	47.559130	-122.629053°	Away from Pier
Transect 2	P7-T2-5	47.559130	-122.628651°	Away from Pier
Transect 3	P7-T3-1	47.559036	-122.628651°	Under Pier
Transect 3	P7-T3-2	47.559036	-122.628750°	Under Pier
Transect 3	P7-T3-3	47.559036	-122.628950°	Away from Pier
Transect 3	P7-T3-4	47.559036	-122.629053°	Away from Pier
Transect 3	P7-T3-5	47.559036	-122.629157°	Away from Pier
Transect 4	P7-T4-1	47.558945	-122.628651°	Under Pier
Transect 4	P7-T4-2	47.558945	-122.628750°	Under Pier
Transect 4	P7-T4-3	47.558945	-122.628950°	Away from Pier
Transect 4	P7-T4-4	47.558945	-122.629053°	Away from Pier
Transect 4	P7-T4-5	47.558945	-122.629157°	Away from Pier
Transect 5	P7-T5-1	47.558851	-122.628651°	Under Pier
Transect 5	P7-T5-2	47.558851	-122.628750°	Under Pier
Transect 5	P7-T5-3	47.558851	-122.628950°	Away from Pier
Transect 5	P7-T5-4	47.558851	-122.629053°	Away from Pier
Transect 5	P7-T5-5	47.558851	-122.629157°	Away from Pier
Transect 6	P7-T6-1	47.558757	-122.628651°	Under Pier
Transect 6	P7-T6-2	47.558757	-122.628750°	Under Pier
Transect 6	P7-T6-3	47.558757	-122.628950°	Under Pier
Transect 6	P7-T6-4	47.558757	-122.629053°	Away from Pier
Transect 6	P7-T6-5	47.558757	-122.629157°	Away from Pier
Transect 7	P7-T7-1	47.558663	-122.628553°	Under Pier
Transect 7	P7-T7-2	47.558663	-122.628651°	Under Pier
Transect 7	P7-T7-3	47.558663	-122.628750°	Under Pier
Transect 7	P7-T7-4	47.558663	-122.628950°	Away from Pier
Transect 7	P7-T7-5	47.558663	-122.629053°	Away from Pier
Transect 7	P7-T7-6	47.558663	-122.629157°	Away from Pier
Transect 8	P7-T8-1	47.558587	-122.628950°	Away from Pier
Transect 8	P7-T8-2	47.558587	-122.629053°	Away from Pier
Transect 8	P7-T8-3	47.558587	-122.629157°	Away from Pier
Transect 9	P7-T9-1	47.558514	-122.628553°	Away from Pier
Transect 9	P7-T9-2	47.558514	-122.628651°	Away from Pier
Transect 9	P7-T9-3	47.558514	-122.628750°	Away from Pier
Transect 9	P7-T9-4	47.558514	-122.628950°	Away from Pier
Transect 9	P7-T9-5	47.558514	-122.629053°	Away from Pier
Transect 9	P7-T9-6	47.558514	-122.629157°	Away from Pier
Transect 10	P7-T10-1	47.558422	-122.628553°	Away from Pier
Transect 10	P7-T10-2	47.558422	-122.628651°	Away from Pier
Transect 10	P7-T10-3	47.558422	-122.628750°	Away from Pier
Transect 10	P7-T10-4	47.558422	-122.628950°	Away from Pier
Transect 10	P7-T10-5	47.558422	-122.629053°	Away from Pier
Transect 10	P7-T10-6	47.558422	-122.629157°	Away from Pier

APPENDIX B

TOC AND GRAINSIZE SUMMARY

TABLE A-2. TOTAL ORGANIC CARBON ANALYSIS RESULTS FOR LABORATORY TREATABILITY SAMPLES.

Sample ID	TOC	Units
Control Sediment	550	mg/kg
Bremerton Unamended	24000	mg/kg
Bremerton No Mix	59000	mg/kg
Bremerton 24-hr Mix	34000	mg/kg
Bremerton 1-month Mix	66000	mg/kg

TABLE A-3. GRAINSIZE DATA FOR UNAMENDED BREMERTON SEDIMENT.

Sample ID	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Bremerton Unamended	0	35.7	45.8	12.4
Bremerton Unamended (duplicate)	0	35.7	45.8	12.4

APPENDIX C

TEST CONDITIONS AND ACCEPTABILITY CRITERIA FOR LABORATORY BIOACCUMULATION AND TOXICITY TESTING

TABLE A-4. TEST CONDITIONS AND ACCEPTABILITY CRITERIA FOR LABORATORY 28-DAY SURVIVAL AND GROWTH TESTING WITH THE MARINE POLYCHAETE *NEANTHES ARENACEODENTATA*.

Parameter	**Conditions**
Test Type	Solid phase, static-renewal
Test Species	*Neanthes arenaceodentata*
Method	ASTM (2000)
Exposure Duration	28 days
Organism Source	Lab culture from Aquatic Toxicity Support, Bremerton, WA
Organism Age at test initiation	2 weeks
Approx. weight each at 6 weeks	25 mg wet wt.
Renewal frequency	2 times/week
Salinity	30 or 33 ± 2 ppt, adjusted with Milli-Q water
Temperature	20 ± 1 ºC
Feeding	2 mg ground Tetramin/worm/week
Light Intensity	50-100 lux
Photoperiod	16 h light: 8 h dark
Replication	9 per treatment (3 per treatment for screening evaluation)
No. organisms/vessel	5 (standard method), 20 (this study)
Test vessel	1 L glass Mason jars
Sediment volume	2 cm sediment
Overlying water volume	700 mL uncontaminated dilution water
Dilution water	0.45 µm filtered natural seawater (SSC Pacific)
Aeration	~100 bubbles/min, filtered lab air
Water quality	pH, salinity, temperature, dissolved oxygen measured daily; ammonia measured at exposure initiation.
Endpoints Measured	Survival, growth, bioaccumulation
Test Acceptability	Mean survival ≥ 80%, and positive growth, in controls

TABLE A-5. TEST CONDITIONS AND TEST ACCEPTABILITY REQUIREMENTS FOR ACUTE (10-DAY) SOLID PHASE SEDIMENT TOXICITY TESTS WITH THE MARINE AMPHIPOD *EOHAUSTORIUS ESTUARIUS*.

Parameter	Conditions
Test Type	Solid phase sediment toxicity, static, non-renewal
Test species	*Eohaustorius estuarius*
Test Method	USEPA (1994)
Test Duration	10 days
Organism Source	Northwestern Aquatic Sciences, Newport, OR
Age/size at test initiation	Adult 3-5 mm
Salinity	33 ± 2 ppt
Temperature	15 ± 1 ^{o}C
Light quality	Wide-spectrum fluorescent lights
Light intensity	50-1000 lux
Photoperiod	24 hours light: 0 hours dark
Test vessel	1 L glass jar with ~10 cm I.D.
Sediment volume	2 cm sediment
Overlying water volume	700 mL uncontaminated dilution water
Dilution water	0.45 µm filtered natural seawater (SSC Pacific)
No. organisms/chamber	20
No. replicate chambers/concentration	5
Feeding	None
Aeration	~100 bubbles filtered lab air per minute
Water quality	pH, salinity, temperature, dissolved oxygen measured daily; ammonia measured at exposure initiation.
Endpoints Measured	Survival, bioaccumulation (preliminary test only)
Test Acceptability Criteria	Mean control survival ≥ 90%

APPENDIX D

ANALYTICAL RESULTS (ERDC)

ARDL REPORT NO: 6310
U.S. ARMY ERDC-EP-C
BPA CALL NO: 82

INORGANIC ANALYSIS DATA PACKAGE

Corps of Engineers – Vicksburg, MS

Report Date: 06/22/11

Lab Name: ARDL, Inc.
Samples Received at ARDL: 27-May-11
Project Name: 1052502
BPA Call No. 082

ARDL Report No.: 6310

CASE NARRATIVE

Sample ID No.	Date Collected	Lab ID No.	Analysis Requested
Control Sediment	05/24/11	6310-01	Methyl Mercury, TOC
Bremerton Unamended	05/24/11	6310-02	Methyl Mercury, TOC
Bremerton – No Mix	05/24/11	6310-03	Methyl Mercury, TOC
Bremerton – 24 Hr Mix	05/24/11	6310-04	Methyl Mercury, TOC
Bremerton – 1 Month Mix	05/24/11	6310-05	Methyl Mercury, TOC
Bremerton – Sediment (GS)	05/24/11	6310-06	Grain Size
Santos Estuary	05/27/11	6310-07	Methyl Mercury

NOTE: The methyl mercury analyses were subcontracted to Quicksilver Scientific. A summary page of their results has been generated and immediately follows this case narrative.

The quality control data are summarized as follows:

LABORATORY CONTROL SAMPLES

Percent recovery of all LCS analyses were within control limits.

PREPARATION BLANKS

The results of all preparation blanks were within acceptable limits.

MATRIX SPIKES

Percent recovery of all matrix spikes and matrix spike duplicates were within control limits.

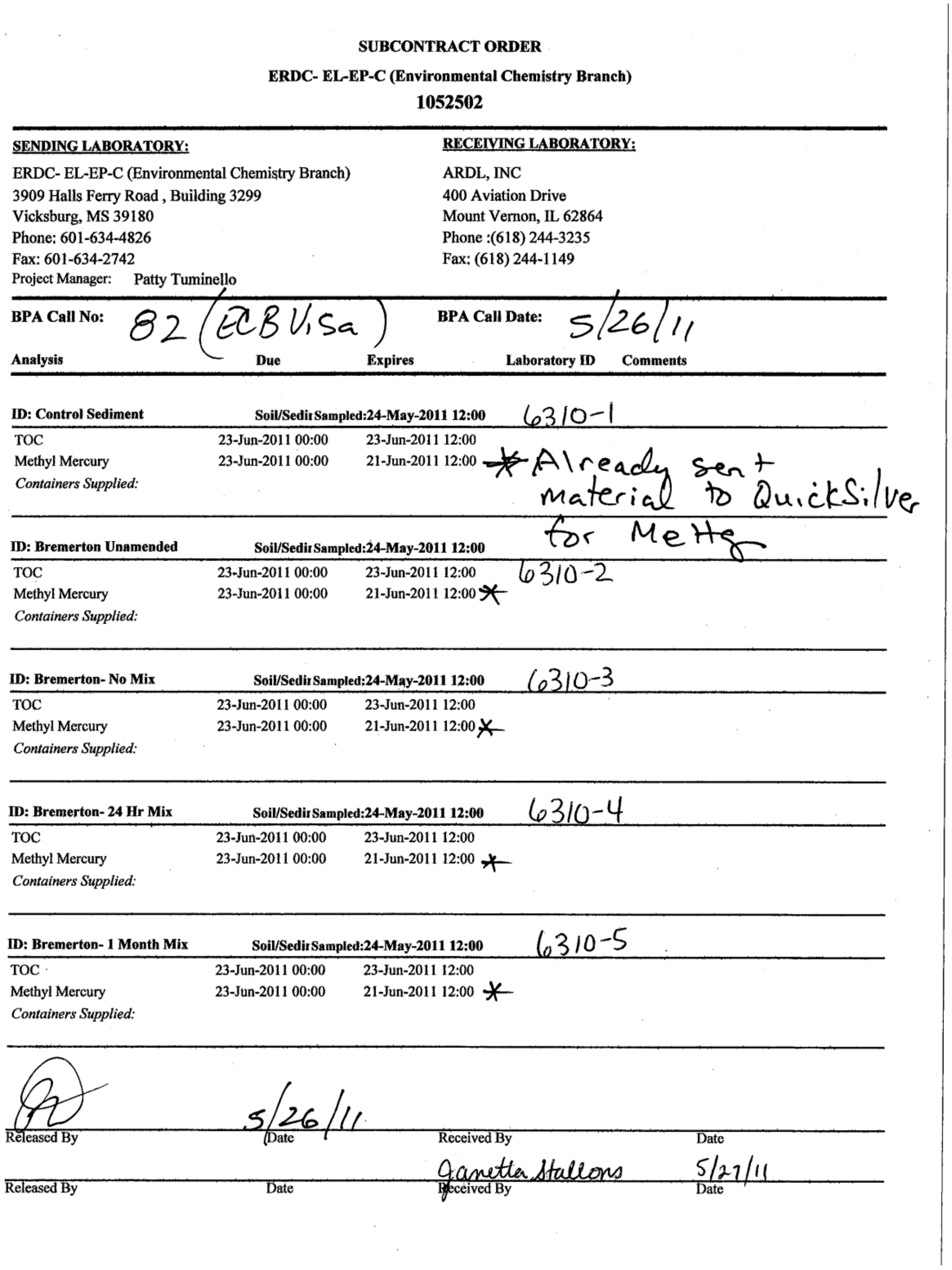
DUPLICATES

RPD on all duplicate analyses were within control limits. All duplicate analyses are reported as MS/MSD except grain size which is reported as sample/duplicate.

Release of the data contained in this package has been authorized by the Technical Services Manager or his designee as verified by the following signature.

Dean S. Dickerson
Technical Services Manager

CHAIN-OF-CUSTODY DOCUMENTATION



SUBCONTRACT ORDER

ERDC- EL-EP-C (Environmental Chemistry Branch)

1052502

SENDING LABORATORY:

ERDC- EL-EP-C (Environmental Chemistry Branch)
3909 Halls Ferry Road , Building 3299
Vicksburg, MS 39180
Phone: 601-634-4826
Fax: 601-634-2742
Project Manager: Patty Tuminello

RECEIVING LABORATORY:

ARDL, INC
400 Aviation Drive
Mount Vernon, IL 62864
Phone :(618) 244-3235
Fax: (618) 244-1149

BPA Call No: 82 (ECB Visa)

BPA Call Date: 5/26/11

Analysis	Due	Expires	Laboratory ID	Comments
ID: Control Sediment	**Soil/Sedir Sampled:24-May-2011 12:00**		6310-1	
TOC	23-Jun-2011 00:00	23-Jun-2011 12:00		
Methyl Mercury	23-Jun-2011 00:00	21-Jun-2011 12:00 *		*Already sent material to QuickSilver for MeHg
Containers Supplied:				
ID: Bremerton Unamended	**Soil/Sedir Sampled:24-May-2011 12:00**		6310-2	
TOC	23-Jun-2011 00:00	23-Jun-2011 12:00		
Methyl Mercury	23-Jun-2011 00:00	21-Jun-2011 12:00 *		
Containers Supplied:				
ID: Bremerton- No Mix	**Soil/Sedir Sampled:24-May-2011 12:00**		6310-3	
TOC	23-Jun-2011 00:00	23-Jun-2011 12:00		
Methyl Mercury	23-Jun-2011 00:00	21-Jun-2011 12:00 *		
Containers Supplied:				
ID: Bremerton- 24 Hr Mix	**Soil/Sedir Sampled:24-May-2011 12:00**		6310-4	
TOC	23-Jun-2011 00:00	23-Jun-2011 12:00		
Methyl Mercury	23-Jun-2011 00:00	21-Jun-2011 12:00 *		
Containers Supplied:				
ID: Bremerton- 1 Month Mix	**Soil/Sedir Sampled:24-May-2011 12:00**		6310-5	
TOC	23-Jun-2011 00:00	23-Jun-2011 12:00		
Methyl Mercury	23-Jun-2011 00:00	21-Jun-2011 12:00 *		
Containers Supplied:				

Released By:
Date: 5/26/11
Received By:
Date:

Released By:
Date:
Received By: Janetta Stallons
Date: 5/27/11

SUBCONTRACT ORDER

ERDC- EL-EP-C (Environmental Chemistry Branch)

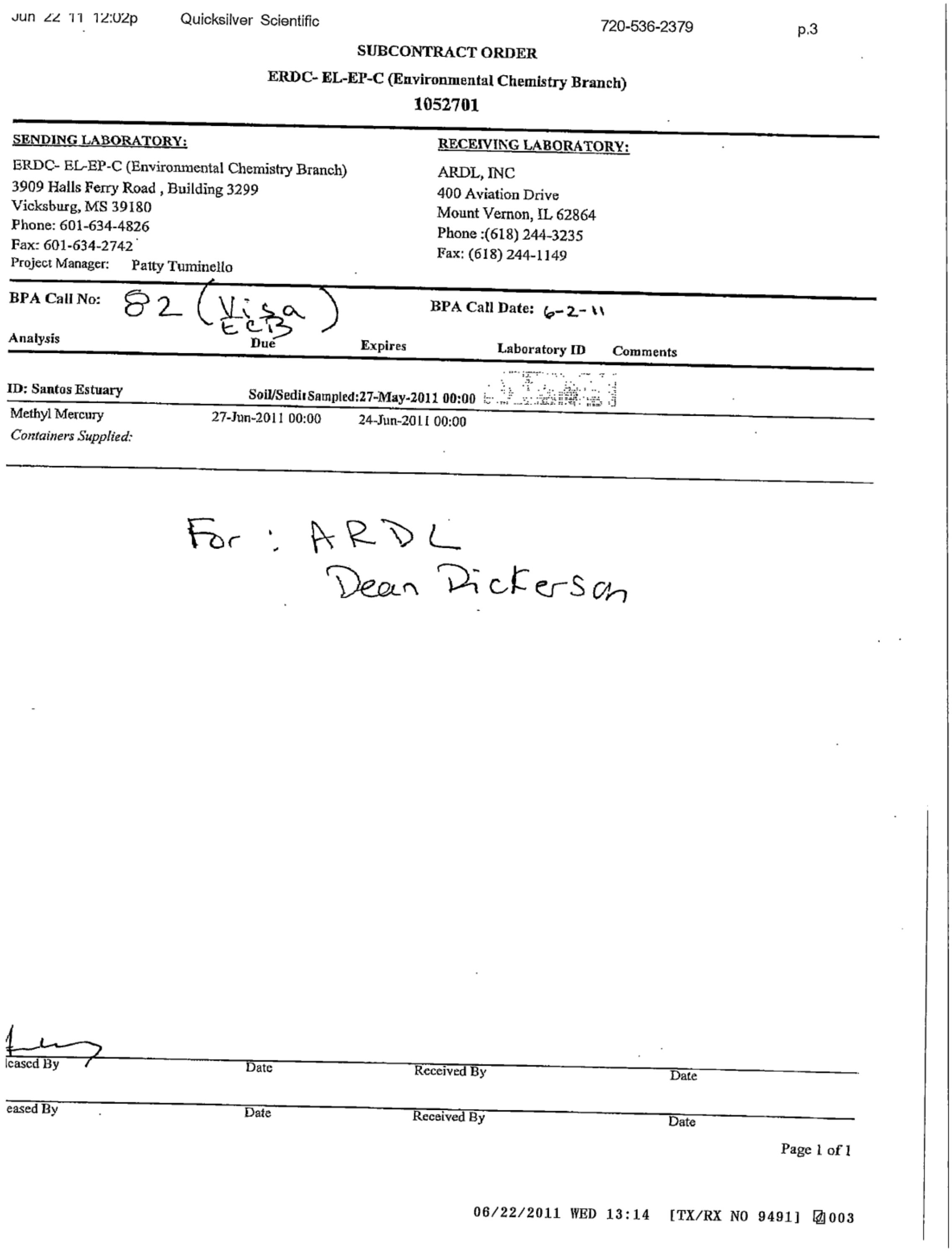
1052502

Analysis	Due	Expires	Laboratory ID	Comments
ID: Bremerton Sediment (GS)	**Soil/Sedir**	**Sampled:24-May-2011 12:00**	6310-6	
Particle Size - Sieve	26-May-2011 00:00	07-Jun-2011 12:00		
Particle Size - Hydrometer	26-May-2011 00:00	07-Jun-2011 12:00		
Containers Supplied:				

* Please note that small rock like pieces in the TOC samples are AquaBok and should be removed.

Released By 5/26/11 Date Received By Date

Released By Date Janetta Stullons Received By 5/27/11 Date



Jun 22 11 12:02p Quicksilver Scientific 720-536-2379 p.3

SUBCONTRACT ORDER

ERDC- EL-EP-C (Environmental Chemistry Branch)

1052701

SENDING LABORATORY:

ERDC- EL-EP-C (Environmental Chemistry Branch)
3909 Halls Ferry Road , Building 3299
Vicksburg, MS 39180
Phone: 601-634-4826
Fax: 601-634-2742
Project Manager: Patty Tuminello

RECEIVING LABORATORY:

ARDL, INC
400 Aviation Drive
Mount Vernon, IL 62864
Phone :(618) 244-3235
Fax: (618) 244-1149

BPA Call No: 82 (Visa ECB)

BPA Call Date: 6-2-11

Analysis	**Due**	**Expires**	**Laboratory ID**	**Comments**
ID: Santos Estuary	**Soil/Sedit Sampled:27-May-2011 00:00**		[illegible]	
Methyl Mercury	27-Jun-2011 00:00	24-Jun-2011 00:00		
Containers Supplied:				

For : ARDL
Dean Dickerson

leased By	Date	Received By	Date
eased By	Date	Received By	Date

Page 1 of 1

06/22/2011 WED 13:14 [TX/RX NO 9491] ☑003

COOLER RECEIPT REPORT
ARDL, INC.

original in 6311
dlc
5-27-11

ARDL #: 6309, 6310, 6311

Cooler # KPRIME

Number of Coolers in Shipment: 1

Project: 35 Millington, 68 Millington / 82 ECBVisa

Date Received: 5/27/11

A. **PRELIMINARY EXAMINATION PHASE:** Date cooler was opened: 5/27/11 (Signature) J Stallons

1. Did cooler come with a shipping slip (airbill, etc.)?.......... [✓ YES] NO

If YES, enter carrier name and airbill number here: Fed Ex 7971 4123 8416

2. Were custody seals on outside of cooler?.......... YES [✓ NO] N/A

How many and where?__________, Seal Date:__________, Seal Name:__________

3. Were custody seals unbroken and intact at the date and time of arrival?.......... N/A .....YES NO

4. Did you screen samples for radioactivity using a Geiger Counter?.......... [✓ YES] NO

5. Were custody papers sealed in a plastic bag and taped inside to the lid?.......... [✓ YES] NO

6. Were custody papers filled out properly (ink, signed, etc.)?..... 2nd page of Call 68 not signed ..... YES [✓ NO] N/A

7. Were custody papers signed in appropriate place by ARDL personnel?.......... [✓ YES] NO N/A

8. Was project identifiable from custody papers? If YES, enter project name at the top of this form.......... [✓ YES] NO N/A

9. Was a separate container provided for measuring temperature? YES____ NO X Cooler Temp. 9.5 C ambient

B. **LOG-IN PHASE:** Date samples were logged-in: 5/27/11 (Signature) J Stallons

10. Describe type of packing in cooler: (Melted) Bagged Ice + Bubble Wrap

11. Were all bottles sealed in separate plastic bags?.......... YES [✓ NO] N/A

12. Did all bottles arrive unbroken and were labels in good condition?.......... [✓ YES] NO

13. Were bottle labels complete?.......... [✓ YES] NO

14. Did all bottle labels agree with custody papers?.......... [✓ YES] NO

15. Were correct containers used for the tests indicated?.......... [✓ YES] NO

16. Was pH correct on preserved water samples?.......... [✓ YES] NO N/A

17. Was a sufficient amount of sample sent for tests indicated?..... except -06 - low volume ..... [✓ YES] NO

18. Were bubbles absent in VOA samples? If NO, list by sample #:__________ YES NO [✓ N/A]

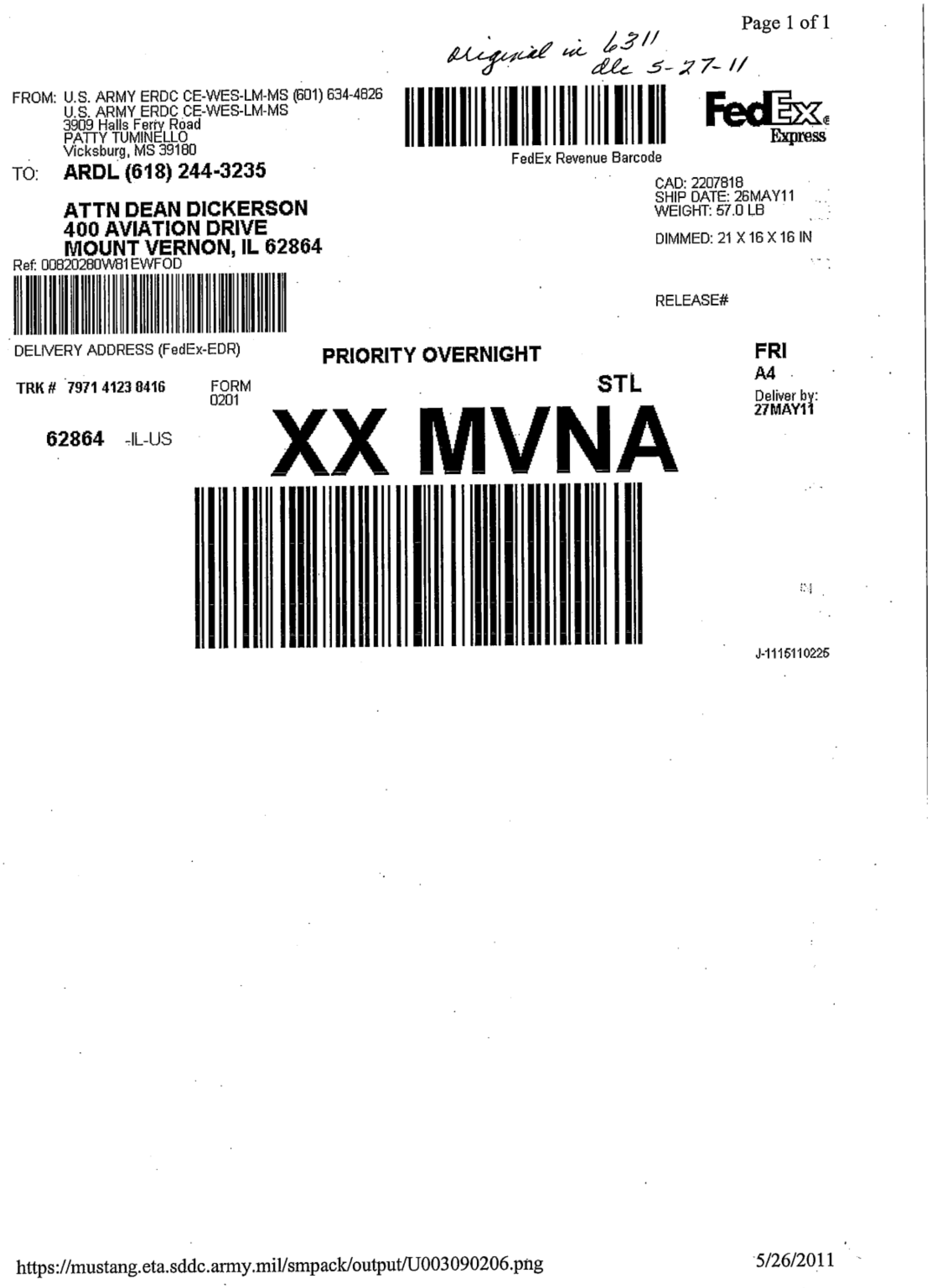
19. Was the ARDL project coordinator notified of any deficiencies?.......... [✓ YES] NO N/A

Comments and/or Corrective Action:	
(By: Signature)	Date:

Sample Transfer

Fraction All	Fraction
Area # Walkin	Area #
By dlc	By
On 5-27-11	On

M:\ADMIN\FORMS\COOLER RECEIPT REPORT.doc Rev. 05/07/07



Page 1 of 1

original in 6311
dlc 5-27-11

FROM: U.S. ARMY ERDC CE-WES-LM-MS (601) 634-4626
U.S. ARMY ERDC CE-WES-LM-MS
3909 Halls Ferry Road
PATTY TUMINELLO
Vicksburg, MS 39180

FedEx Revenue Barcode

FedEx Express

TO: **ARDL (618) 244-3235**

ATTN DEAN DICKERSON
400 AVIATION DRIVE
MOUNT VERNON, IL 62864
Ref: 00820280W81EWFOD

CAD: 2207818
SHIP DATE: 26MAY11
WEIGHT: 57.0 LB

DIMMED: 21 X 16 X 16 IN

RELEASE#

DELIVERY ADDRESS (FedEx-EDR)

PRIORITY OVERNIGHT

FRI
A4
Deliver by:
27MAY11

TRK # 7971 4123 8416

FORM
0201

STL

62864 -IL-US

XX MVNA

J-1115110225

https://mustang.eta.sddc.army.mil/smpack/output/U003090206.png

5/26/2011

SAMPLE RESULTS
QUALITY ASSURANCE DATA

ARDL Subcontracted Work Report
Vicksburg 6310

Methyl Mercury (MeHg) Analysis - Quicksilver Scientific

Sample Results Summary

ARDL ID	Vicksburg ID	Quicksilver ID	Sample Type	MeHg (as Hg)
6310-01	Control Sediment	201130-1	Sample	0.015 ng/g
6310-02	Bremerton Unamended	201130-2	Sample	0.26 ng/g
6310-03	Bremerton - No Mix	201130-3	Sample	0.18 ng/g
6310-04	Bremerton - 24 Hr Mix	201130-4	Sample	0.17 ng/g
6310-05	Bremerton - 1 Month Mix	201130-5	Sample	0.37 ng/g
6310-07	Santos Estuary	201130-6	Sample	0.62 ng/g

QC Results Summary

ARDL ID	Vicksburg ID	Quicksilver ID	Sample Type	Result
6310-03	Bremerton - No Mix	201130-8 MS	Matrix Spike	87.0% Rec
6310-03	Bremerton - No Mix	301130-9 MSD	Matrix Spike Duplicate	88.5% Rec
		201130-11 LCS1	Laboratory Control Sample	99.3% Rec
		201130-12 LCS2	Laboratory Control Sample	102.0% Rec
		201130-14 MBL	Method Blank	<0.0056 ng/g
		201130-15 PBL	Process Blank	<0.0056 ng/g
		201130-17 REF	Reference	109.9% Rec

ARDL, INC.
400 Aviation Drive; P.O. Box 1566
Mt. Vernon, Illinois 62864

Lab Report No: 006310 Report Date: 06/22/2011

Project Name: 1052502
Project No: CALL #82

Analysis: Inorganics
NELAC Certified - IL100308

Field ID: CONTROL SEDIMENT
Sampling Loc'n: 1052502
Sampling Date: 05/24/2011
Sampling Time: 1200

ARDL No: 006310-01
Received: 05/27/2011
Matrix: SOIL
Moisture: No Moisture Present

Analyte	Detection Limit	Result	Units	Prep Method	Analysis Method	Prep Date	Analysis Date	Run Number
Total Organic Carbon	120	550	MG/KG	NONE	LYDKHN	NA	06/07/11	06225329

ARDL, INC.
400 Aviation Drive; P.O. Box 1566
Mt. Vernon, Illinois 62864

Lab Report No: 006310 Report Date: 06/22/2011

Project Name: 1052502
Project No: CALL #82

Analysis: Inorganics
NELAC Certified - IL100308

Field ID: BREMERTON UNAMENDED
Sampling Loc'n: 1052502
Sampling Date: 05/24/2011
Sampling Time: 1200

ARDL No: 006310-02
Received: 05/27/2011
Matrix: SOIL
Moisture: No Moisture Present

Analyte	Detection Limit	Result	Units	Prep Method	Analysis Method	Prep Date	Analysis Date	Run Number
Total Organic Carbon	120	24000	MG/KG	NONE	LYDKHN	NA	06/07/11	06225329

ARDL, INC.
400 Aviation Drive; P.O. Box 1566
Mt. Vernon, Illinois 62864

Lab Report No: 006310 Report Date: 06/22/2011

Project Name: 1052502
Project No: CALL #82
Analysis: Inorganics
NELAC Certified - IL100308

Field ID: BREMERTON-NO MIX
Sampling Loc'n: 1052502
Sampling Date: 05/24/2011
Sampling Time: 1200
ARDL No: 006310-03
Received: 05/27/2011
Matrix: SOIL
Moisture: No Moisture Present

Analyte	Detection Limit	Result	Units	Prep Method	Analysis Method	Prep Date	Analysis Date	Run Number
Total Organic Carbon	120	59000	MG/KG	NONE	LYDKHN	NA	06/07/11	06225329

Sample 006310-03, Inorganic Analyses Page 1 of 1

ARDL, INC.
400 Aviation Drive; P.O. Box 1566
Mt. Vernon, Illinois 62864

Lab Report No: 006310   Report Date: 06/22/2011

Project Name: 1052502   Analysis: Inorganics
Project No: CALL #82   NELAC Certified - IL100308

Field ID: BREMERTON-24 HR MIX   ARDL No: 006310-04
Sampling Loc'n: 1052502   Received: 05/27/2011
Sampling Date: 05/24/2011   Matrix: SOIL
Sampling Time: 1200   Moisture: No Moisture Present

Analyte	Detection Limit	Result	Units	Prep Method	Analysis Method	Prep Date	Analysis Date	Run Number
Total Organic Carbon	120	34000	MG/KG	NONE	LYDKHN	NA	06/07/11	06225329

ARDL, INC.
400 Aviation Drive; P.O. Box 1566
Mt. Vernon, Illinois 62864

Lab Report No: 006310
Report Date: 06/22/2011

Project Name: 1052502
Project No: CALL #82
Analysis: Inorganics
NELAC Certified - IL100308

Field ID: BREMERTON-1 MONTH MX
Sampling Loc'n: 1052502
Sampling Date: 05/24/2011
Sampling Time: 1200
ARDL No: 006310-05
Received: 05/27/2011
Matrix: SOIL
Moisture: No Moisture Present

Analyte	Detection Limit	Result	Units	Prep Method	Analysis Method	Prep Date	Analysis Date	Run Number
Total Organic Carbon	120	66000	MG/KG	NONE	LYDKHN	NA	06/07/11	06225329

ARDL, INC.
400 Aviation Drive; P.O. Box 1566
Mt. Vernon, Illinois 62864

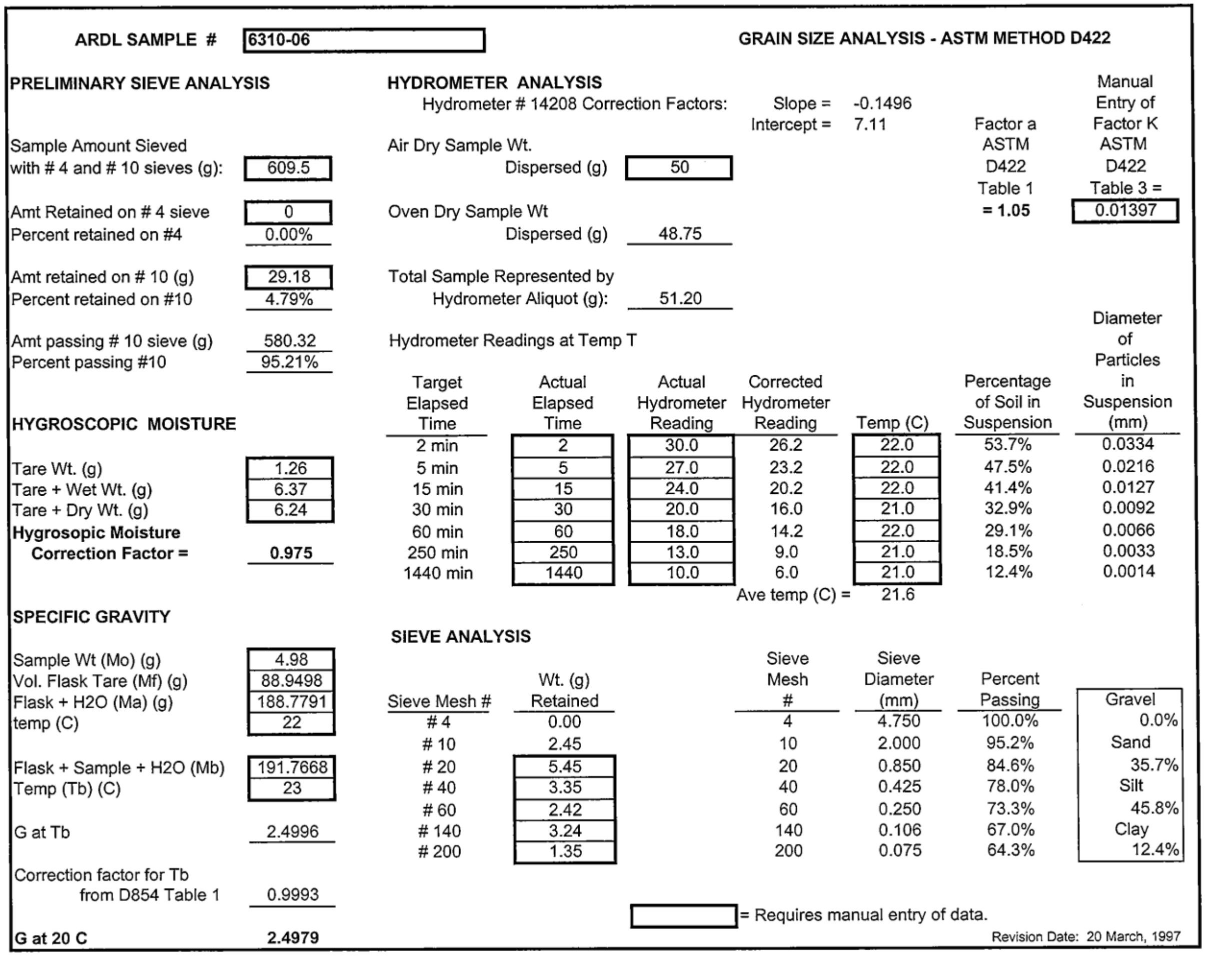
Lab Report No: 006310 Report Date: 06/22/2011

Project Name:	1052502	Analysis:	Inorganics
Project No:	CALL #82		NELAC Certified - IL100308

Field ID:	BREMERTON-SED(GS)	ARDL No:	006310-06
Sampling Loc'n:	1052502	Received:	05/27/2011
Sampling Date:	05/24/2011	Matrix:	SOIL
Sampling Time:	1200	Moisture:	No Moisture Present

Analyte	Detection Limit	Result	Units	Prep Method	Analysis Method	Prep Date	Analysis Date	Run Number
Grain Size		ATTACHED			ASTM D422			

Sample 006310-06, Inorganic Analyses Page 1 of 1



ARDL SAMPLE # 6310-06

GRAIN SIZE ANALYSIS - ASTM METHOD D422

PRELIMINARY SIEVE ANALYSIS

Sample Amount Sieved with # 4 and # 10 sieves (g): 609.5

Amt Retained on # 4 sieve 0
Percent retained on #4 0.00%

Amt retained on # 10 (g) 29.18
Percent retained on #10 4.79%

Amt passing # 10 sieve (g) 580.32
Percent passing #10 95.21%

HYGROSCOPIC MOISTURE

Tare Wt. (g) 1.26
Tare + Wet Wt. (g) 6.37
Tare + Dry Wt. (g) 6.24
Hygrosopic Moisture Correction Factor = **0.975**

SPECIFIC GRAVITY

Sample Wt (Mo) (g) 4.98
Vol. Flask Tare (Mf) (g) 88.9498
Flask + H2O (Ma) (g) 188.7791
temp (C) 22

Flask + Sample + H2O (Mb) 191.7668
Temp (Tb) (C) 23

G at Tb 2.4996

Correction factor for Tb from D854 Table 1 0.9993

G at 20 C **2.4979**

HYDROMETER ANALYSIS

Hydrometer # 14208 Correction Factors: Slope = -0.1496
Intercept = 7.11

Factor a ASTM D422 Table 1 **= 1.05**

Manual Entry of Factor K ASTM D422 Table 3 = 0.01397

Air Dry Sample Wt. Dispersed (g) 50

Oven Dry Sample Wt Dispersed (g) 48.75

Total Sample Represented by Hydrometer Aliquot (g): 51.20

Hydrometer Readings at Temp T

Target Elapsed Time	Actual Elapsed Time	Actual Hydrometer Reading	Corrected Hydrometer Reading	Temp (C)	Percentage of Soil in Suspension	Diameter of Particles in Suspension (mm)
2 min	2	30.0	26.2	22.0	53.7%	0.0334
5 min	5	27.0	23.2	22.0	47.5%	0.0216
15 min	15	24.0	20.2	22.0	41.4%	0.0127
30 min	30	20.0	16.0	21.0	32.9%	0.0092
60 min	60	18.0	14.2	22.0	29.1%	0.0066
250 min	250	13.0	9.0	21.0	18.5%	0.0033
1440 min	1440	10.0	6.0	21.0	12.4%	0.0014
			Ave temp (C) =	21.6		

SIEVE ANALYSIS

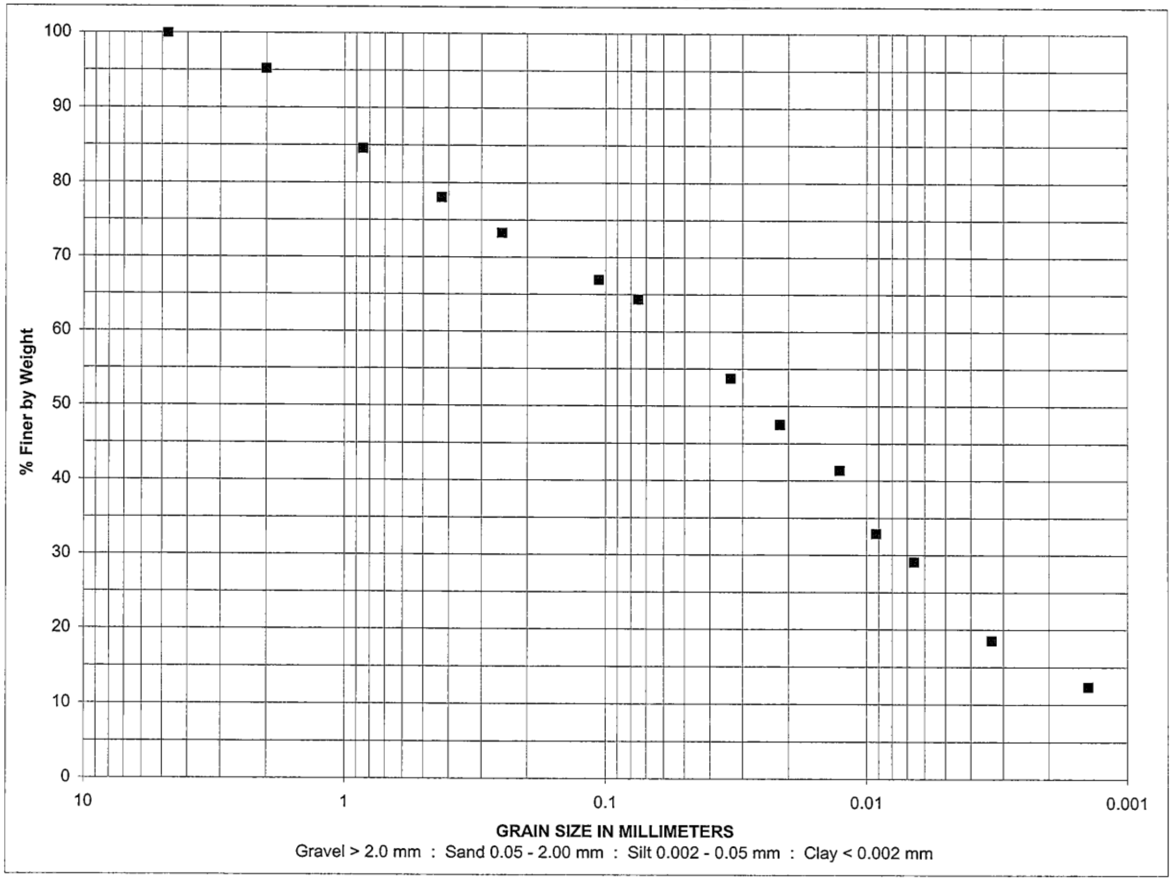
Sieve Mesh #	Wt. (g) Retained	Sieve Mesh #	Sieve Diameter (mm)	Percent Passing
# 4	0.00	4	4.750	100.0%
# 10	2.45	10	2.000	95.2%
# 20	5.45	20	0.850	84.6%
# 40	3.35	40	0.425	78.0%
# 60	2.42	60	0.250	73.3%
# 140	3.24	140	0.106	67.0%
# 200	1.35	200	0.075	64.3%

Gravel	0.0%
Sand	35.7%
Silt	45.8%
Clay	12.4%

☐ = Requires manual entry of data.

Revision Date: 20 March, 1997

ARDL SAMPLE # 6310-06 **GRAIN SIZE ANALYSIS - ASTM METHOD D422**



MATRIX SPIKE/SPIKE DUPLICATE REPORT

ARDL, INC. 400 Aviation Drive; P.O. Box 1566 Mt. Vernon, IL 62864

Lab Report No: 006310

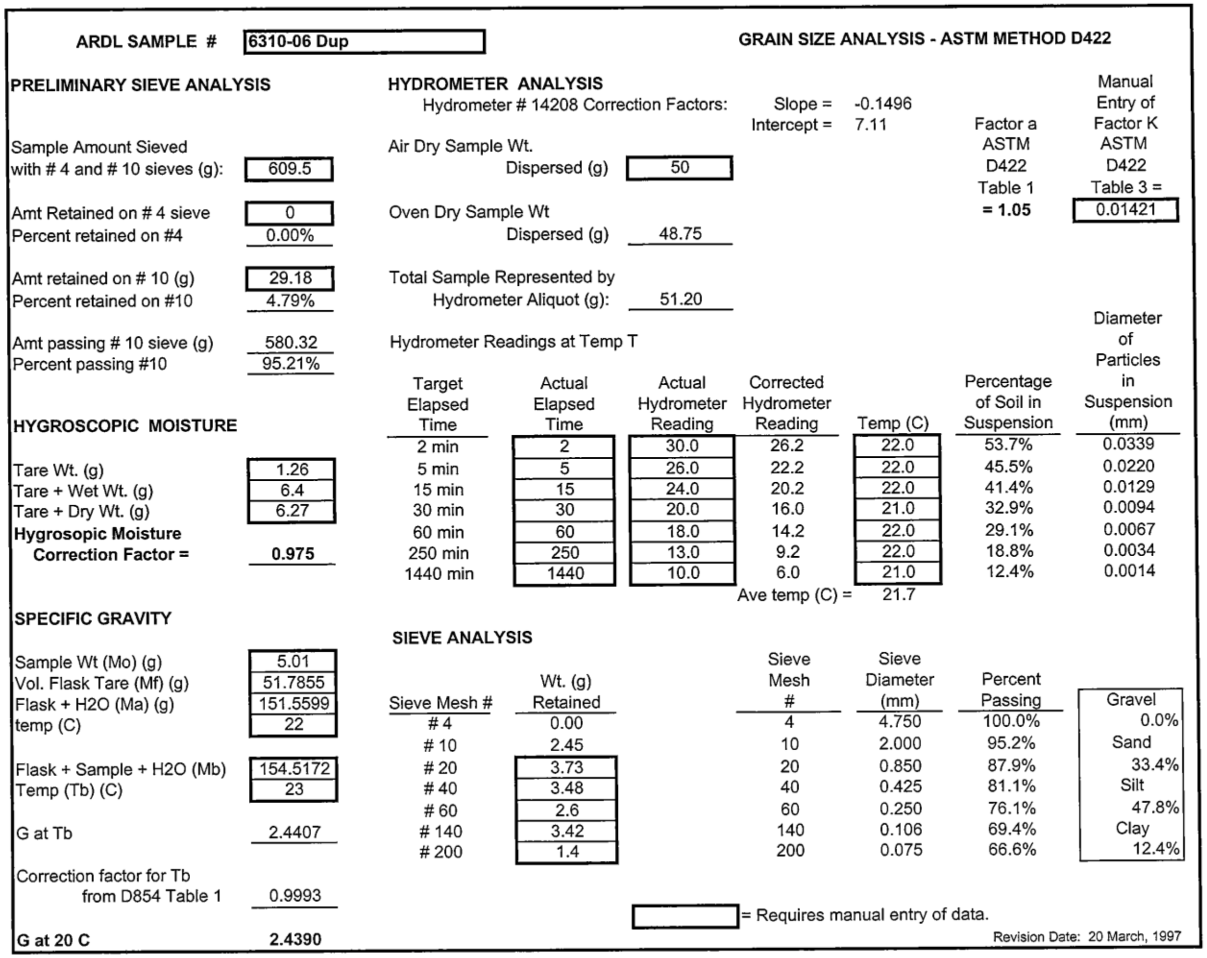
Report Date: 06/22/2011

Project Name: 1052502
Project No.: CALL #82

NELAC Certified - IL100308

Analyte	Sample Matrix	Sample Result	MS Result	MS Level	MS % Rec	MSD Result	MSD Level	MSD % Rec	% Rec Limits	RPD	RPD Limit	Run	QC Lab Number
Total Organic Carbon	SOIL	24000	68700	38500	116	57700	34500	98	75-125	17	20	06225329	006310-02MS

NOTE: Any values tabulated above marked with an asterisk are outside of acceptable limits.



ARDL SAMPLE # 6310-06 Dup

GRAIN SIZE ANALYSIS - ASTM METHOD D422

PRELIMINARY SIEVE ANALYSIS

Sample Amount Sieved with # 4 and # 10 sieves (g): 609.5

Amt Retained on # 4 sieve: 0
Percent retained on #4: 0.00%

Amt retained on # 10 (g): 29.18
Percent retained on #10: 4.79%

Amt passing # 10 sieve (g): 580.32
Percent passing #10: 95.21%

HYGROSCOPIC MOISTURE

Tare Wt. (g): 1.26
Tare + Wet Wt. (g): 6.4
Tare + Dry Wt. (g): 6.27
Hygrosopic Moisture Correction Factor = **0.975**

SPECIFIC GRAVITY

Sample Wt (Mo) (g): 5.01
Vol. Flask Tare (Mf) (g): 51.7855
Flask + H2O (Ma) (g): 151.5599
temp (C): 22

Flask + Sample + H2O (Mb): 154.5172
Temp (Tb) (C): 23

G at Tb: 2.4407

Correction factor for Tb from D854 Table 1: 0.9993

G at 20 C **2.4390**

HYDROMETER ANALYSIS

Hydrometer # 14208 Correction Factors: Slope = -0.1496
Intercept = 7.11

Factor a ASTM D422 Table 1 **= 1.05**

Manual Entry of Factor K ASTM D422 Table 3 = 0.01421

Air Dry Sample Wt. Dispersed (g): 50

Oven Dry Sample Wt Dispersed (g): 48.75

Total Sample Represented by Hydrometer Aliquot (g): 51.20

Hydrometer Readings at Temp T

Target Elapsed Time	Actual Elapsed Time	Actual Hydrometer Reading	Corrected Hydrometer Reading	Temp (C)	Percentage of Soil in Suspension	Diameter of Particles in Suspension (mm)
2 min	2	30.0	26.2	22.0	53.7%	0.0339
5 min	5	26.0	22.2	22.0	45.5%	0.0220
15 min	15	24.0	20.2	22.0	41.4%	0.0129
30 min	30	20.0	16.0	21.0	32.9%	0.0094
60 min	60	18.0	14.2	22.0	29.1%	0.0067
250 min	250	13.0	9.2	22.0	18.8%	0.0034
1440 min	1440	10.0	6.0	21.0	12.4%	0.0014

Ave temp (C) = 21.7

SIEVE ANALYSIS

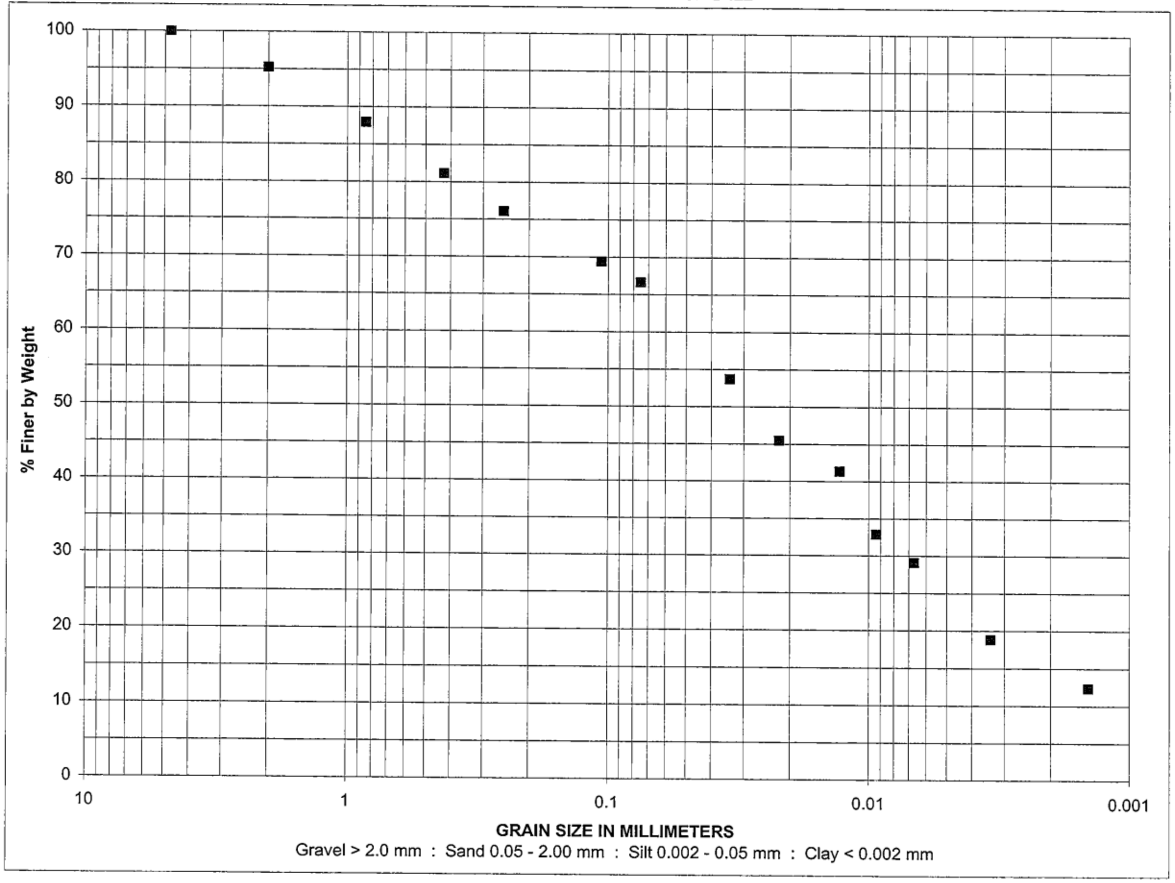
Sieve Mesh #	Wt. (g) Retained	Sieve Mesh #	Sieve Diameter (mm)	Percent Passing
# 4	0.00	4	4.750	100.0%
# 10	2.45	10	2.000	95.2%
# 20	3.73	20	0.850	87.9%
# 40	3.48	40	0.425	81.1%
# 60	2.6	60	0.250	76.1%
# 140	3.42	140	0.106	69.4%
# 200	1.4	200	0.075	66.6%

Gravel	0.0%
Sand	33.4%
Silt	47.8%
Clay	12.4%

☐ = Requires manual entry of data.

Revision Date: 20 March, 1997

ARDL SAMPLE # 6310-06 Dup GRAIN SIZE ANALYSIS - ASTM METHOD D422



BLANK SUMMARY REPORT

ARDL, INC. 400 Aviation Drive; P.O. Box 1566 Mt. Vernon, IL 62864

Lab Report No: 006310

Report Date: 06/22/2011

Project Name: 1052502
Project No.: CALL #82

NELAC Certified - IL100308

Analyte	Detect Limit	Blank Result	Units	Prep Method	Analysis Method	Prep Date	Analysis Date	Run	QC Lab Number
Total Organic Carbon	120	ND	MG/KG	NONE	LYDKHN	NA	06/07/11	06225329	006310-02B1

LABORATORY CONTROL SAMPLE REPORT

ARDL, INC. 400 Aviation Drive; P.O. Box 1566 Mt. Vernon, IL 62864

Lab Report No: 006310

Report Date: 06/22/2011

Project Name: 1052502
Project No.: CALL #82

NELAC Certified - IL100308

Analyte	LCS 1 Result	LCS 1 Level	LCS 1 % Rec	LCS 2 Result	LCS 2 Level	LCS 2 % Rec	% Rec Limits	Mean % Rec	Analytical Run	QC Lab Number
Total Organic Carbon	5580	4110	136	--	--	--	33-167	--	06225329	006310-02C1

NOTE: Any values tabulated above marked with an asterisk are outside of acceptable limits.

Inorganic LCS Results for 006310

1052502 BREMERTON SEDIMENT DATA.PDF

USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

21 July 2011

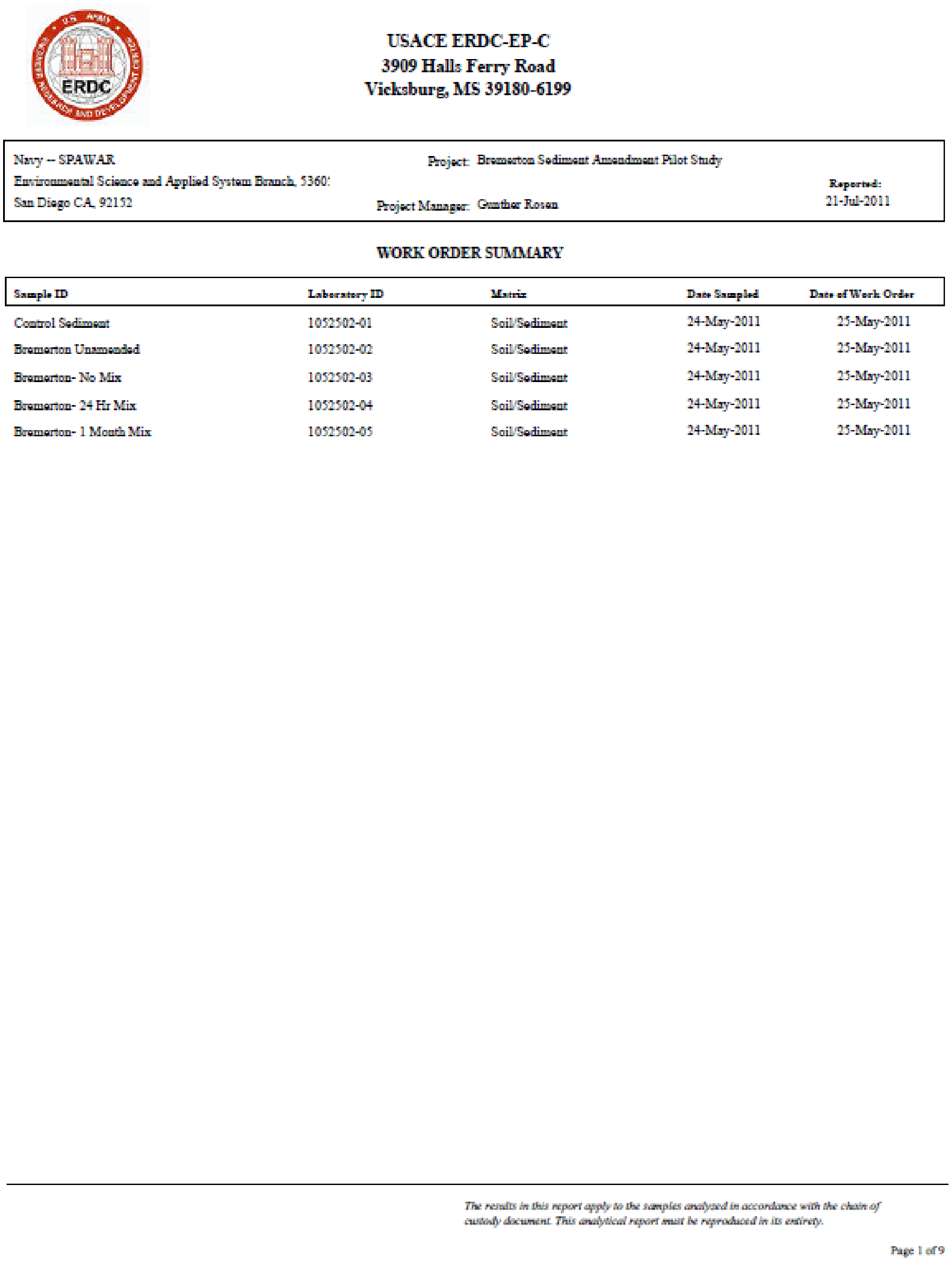
Gunther Rosen
Navy – SPAWAR
Environmental Science and Applied System Branch, 536
San Diego, CA 92152

RE: Bremerton Sediment Amendment Pilot Study

Enclosed are the results of analyses for samples received by the laboratory on 25-May-2011. The samples associated with this report will be held for 90 days from the date of this report. The raw data associated with this report will be held for 5 years from the date of this report. If you need us to hold onto the samples or the data longer then these specified times, you will need to notify us in writing at least 30 days before the expiration dates. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Patty Tuminello
Project Coordinator



USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Navy -- SPAWAR
Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

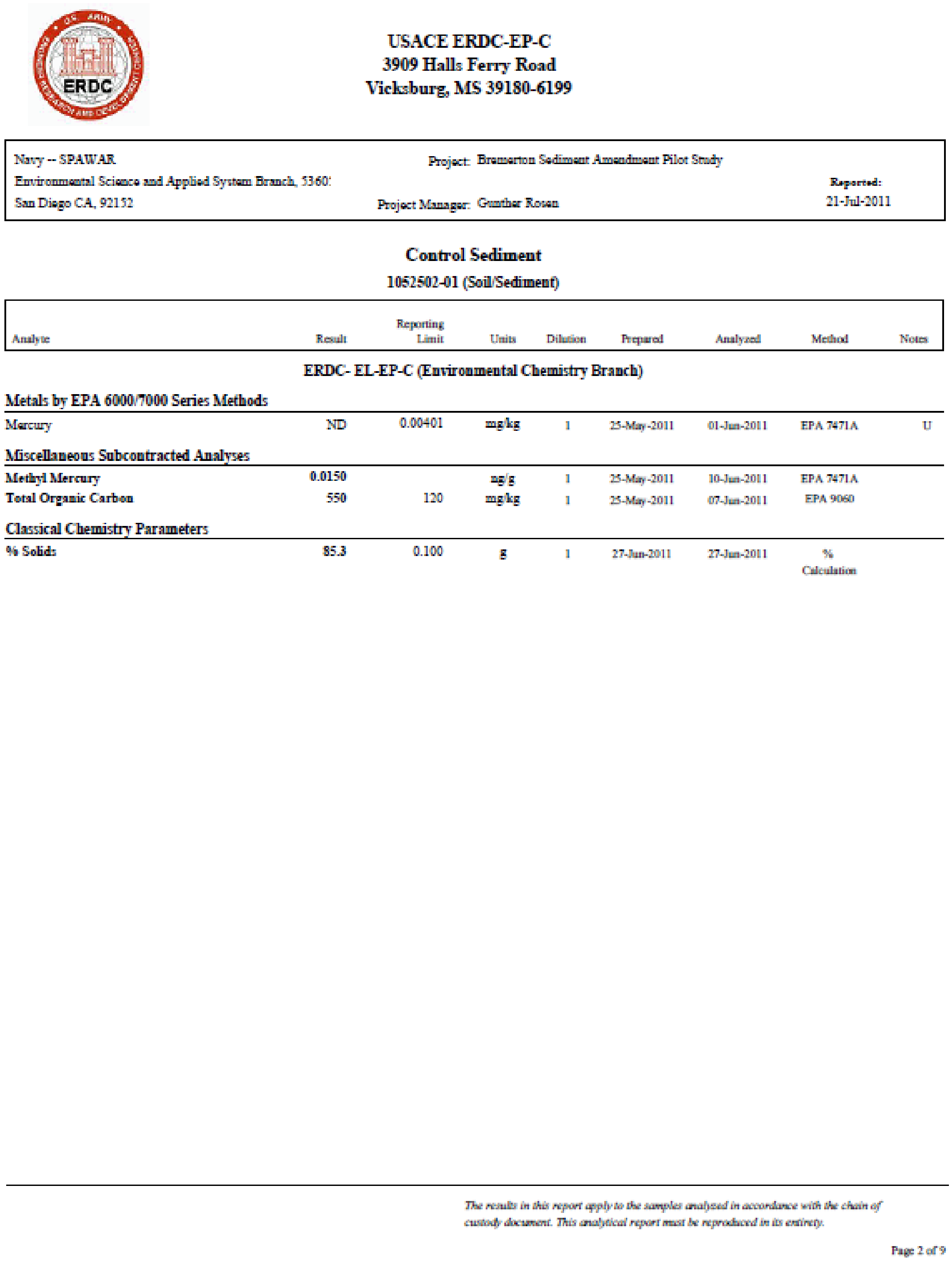
Reported:
21-Jul-2011

WORK ORDER SUMMARY

Sample ID	Laboratory ID	Matrix	Date Sampled	Date of Work Order
Control Sediment	1052502-01	Soil/Sediment	24-May-2011	25-May-2011
Bremerton Unamended	1052502-02	Soil/Sediment	24-May-2011	25-May-2011
Bremerton- No Mix	1052502-03	Soil/Sediment	24-May-2011	25-May-2011
Bremerton- 24 Hr Mix	1052502-04	Soil/Sediment	24-May-2011	25-May-2011
Bremerton- 1 Month Mix	1052502-05	Soil/Sediment	24-May-2011	25-May-2011

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Page 1 of 9



USACE ERDC-EP-C
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Vicksburg, MS 39180-6199

Navy -- SPAWAR
Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
21-Jul-2011

Control Sediment

1052502-01 (Soil/Sediment)

ERDC- EL-EP-C (Environmental Chemistry Branch)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
Metals by EPA 6000/7000 Series Methods								
Mercury	ND	0.00401	mg/kg	1	25-May-2011	01-Jun-2011	EPA 7471A	U
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0150**		ng/g	1	25-May-2011	10-Jun-2011	EPA 7471A	
Total Organic Carbon	550	120	mg/kg	1	25-May-2011	07-Jun-2011	EPA 9060	
Classical Chemistry Parameters								
% Solids	85.3	0.100	g	1	27-Jun-2011	27-Jun-2011	% Calculation	

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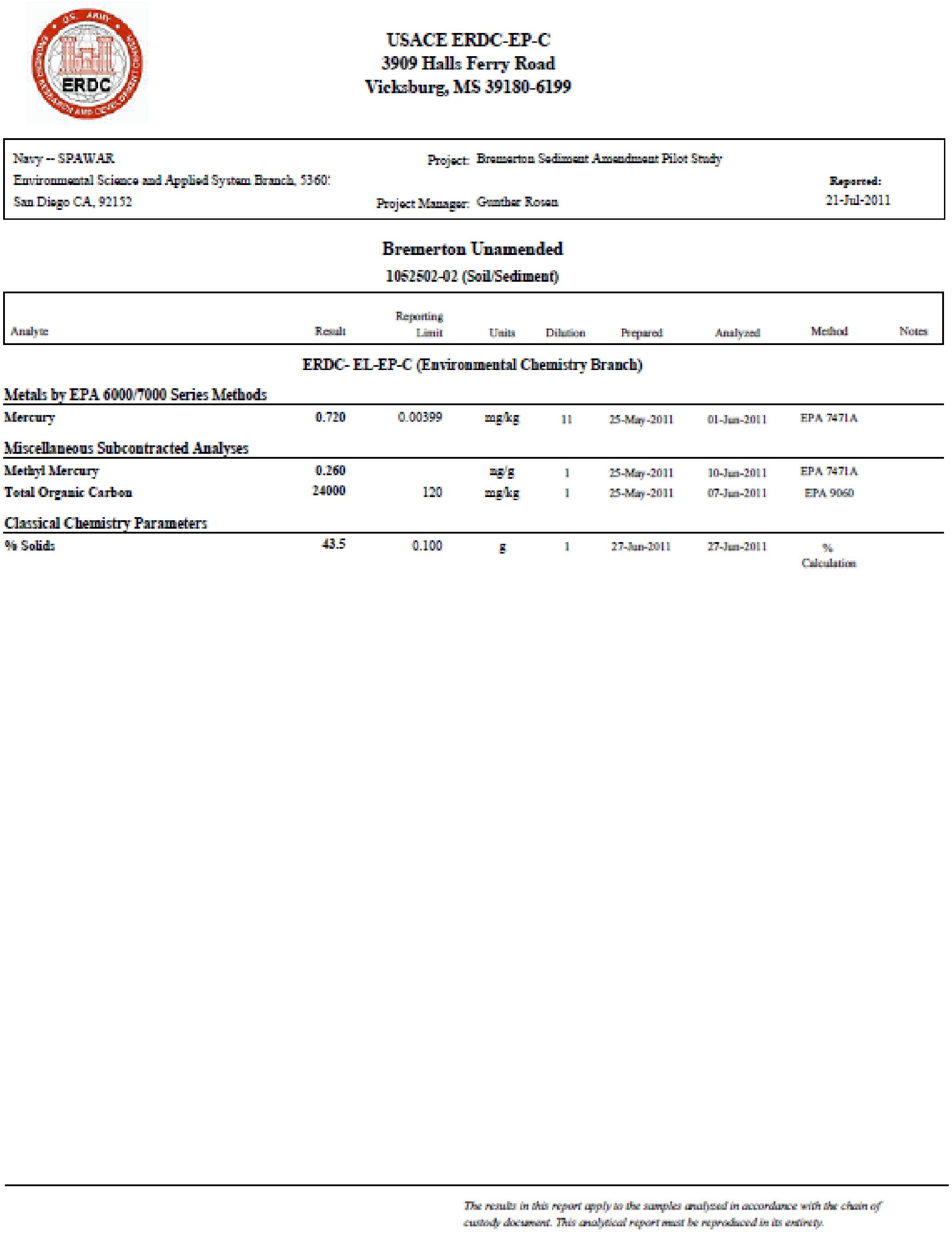

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Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
21-Jul-2011

Bremerton Unamended

1052502-02 (Soil/Sediment)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.720**	0.00399	mg/kg	11	25-May-2011	01-Jun-2011	EPA 7471A	
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.260**		ng/g	1	25-May-2011	10-Jun-2011	EPA 7471A	
Total Organic Carbon	**24000**	120	mg/kg	1	25-May-2011	07-Jun-2011	EPA 9060	
Classical Chemistry Parameters								
% Solids	**43.5**	0.100	g	1	27-Jun-2011	27-Jun-2011	% Calculation	

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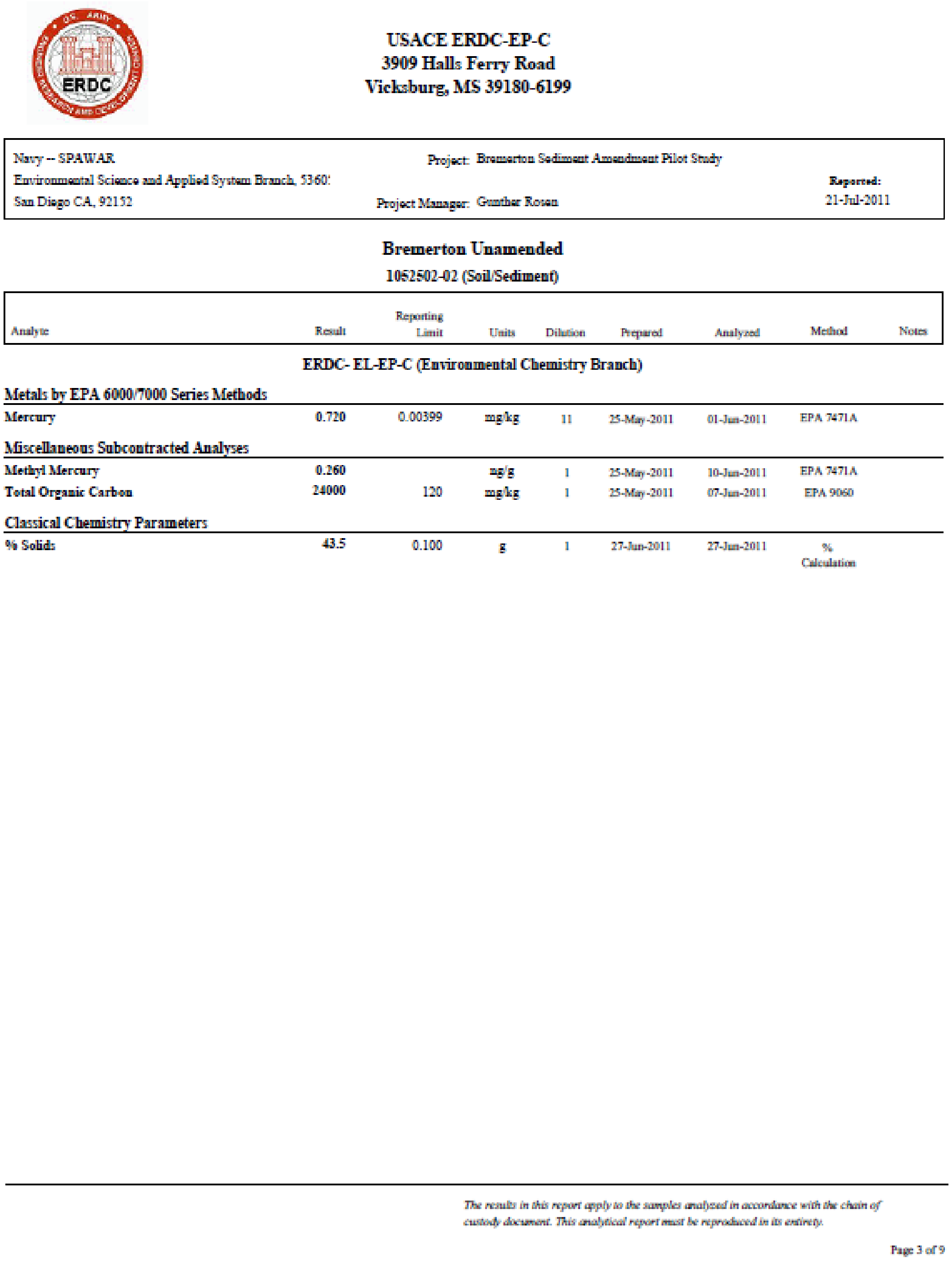

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Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
21-Jul-2011

Bremerton Unamended

1052502-02 (Soil/Sediment)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.720**	0.00399	mg/kg	11	25-May-2011	01-Jun-2011	EPA 7471A	
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.260**		ng/g	1	25-May-2011	10-Jun-2011	EPA 7471A	
Total Organic Carbon	**24000**	120	mg/kg	1	25-May-2011	07-Jun-2011	EPA 9060	
Classical Chemistry Parameters								
% Solids	**43.5**	0.100	g	1	27-Jun-2011	27-Jun-2011	% Calculation	

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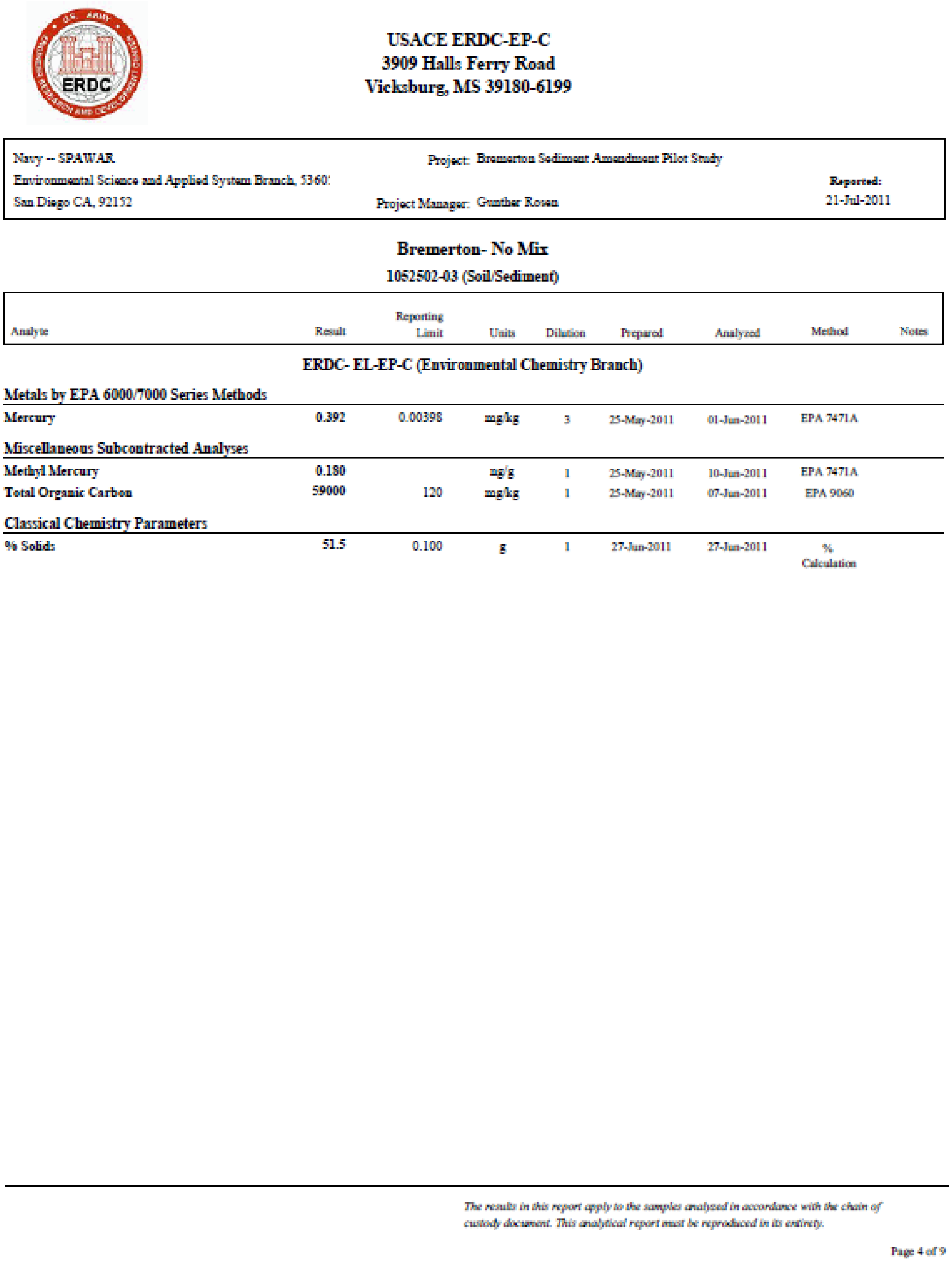

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San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study
Project Manager: Gunther Rosen

Reported:
21-Jul-2011

Bremerton- No Mix

1052502-03 (Soil/Sediment)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.392**	0.00398	**mg/kg**	3	25-May-2011	01-Jun-2011	EPA 7471A	
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.180**		**ng/g**	1	25-May-2011	10-Jun-2011	EPA 7471A	
Total Organic Carbon	**59000**	120	**mg/kg**	1	25-May-2011	07-Jun-2011	EPA 9060	
Classical Chemistry Parameters								
% Solids	**51.5**	0.100	**g**	1	27-Jun-2011	27-Jun-2011	% Calculation	

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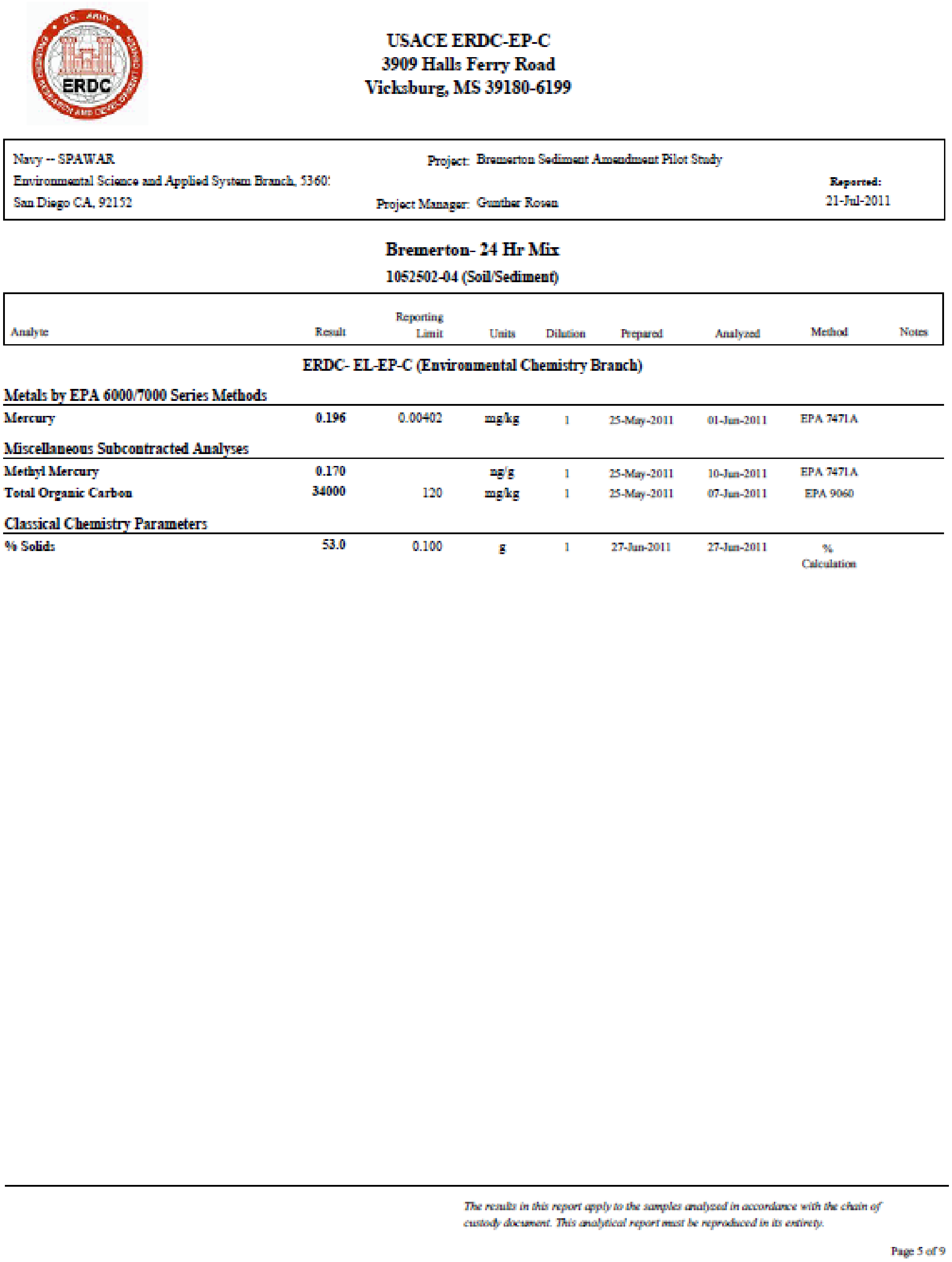

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Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported: 21-Jul-2011

Bremerton- 24 Hr Mix

1052502-04 (Soil/Sediment)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.196**	0.00402	mg/kg	1	25-May-2011	01-Jun-2011	EPA 7471A	
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.170**		ng/g	1	25-May-2011	10-Jun-2011	EPA 7471A	
Total Organic Carbon	**34000**	120	mg/kg	1	25-May-2011	07-Jun-2011	EPA 9060	
Classical Chemistry Parameters								
% Solids	**53.0**	0.100	g	1	27-Jun-2011	27-Jun-2011	% Calculation	

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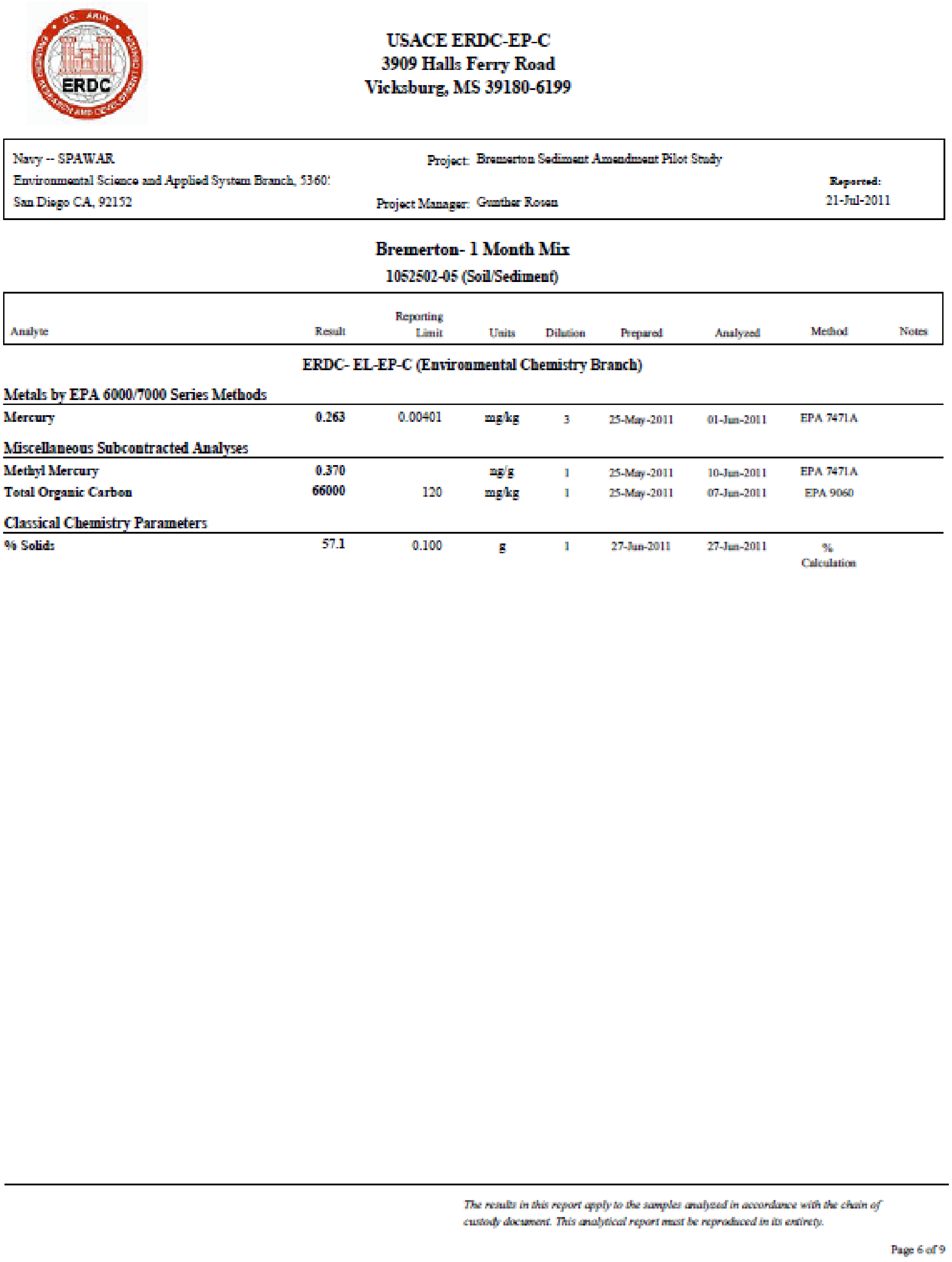

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Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
21-Jul-2011

Bremerton- 1 Month Mix

1052502-05 (Soil/Sediment)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.263**	0.00401	mg/kg	3	25-May-2011	01-Jun-2011	EPA 7471A	
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.370**		ng/g	1	25-May-2011	10-Jun-2011	EPA 7471A	
Total Organic Carbon	**66000**	120	mg/kg	1	25-May-2011	07-Jun-2011	EPA 9060	
Classical Chemistry Parameters								
% Solids	57.1	0.100	g	1	27-Jun-2011	27-Jun-2011	% Calculation	

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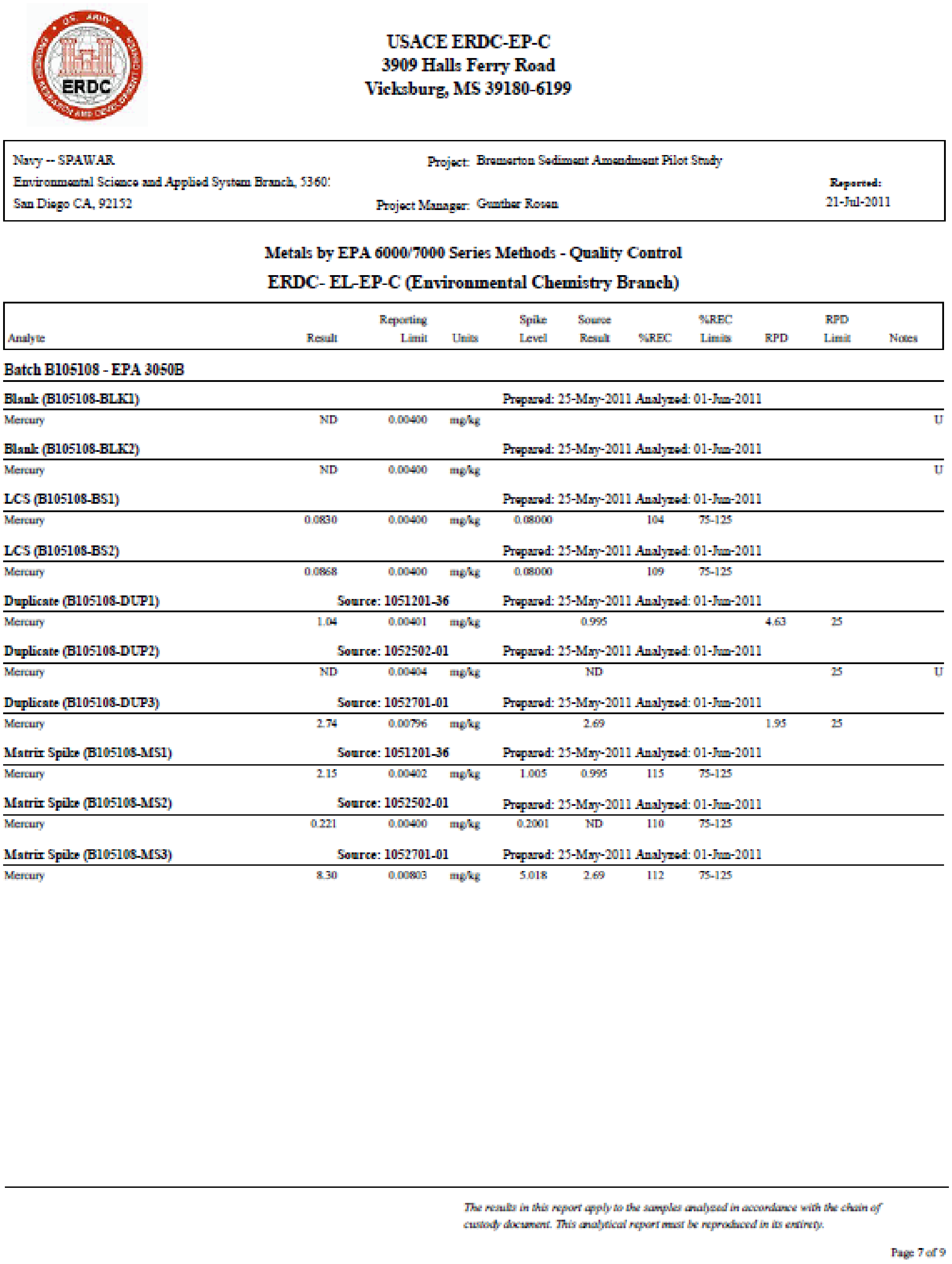

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Project: Bremerton Sediment Amendment Pilot Study
Project Manager: Gunther Rosen

Reported:
21-Jul-2011

Metals by EPA 6000/7000 Series Methods - Quality Control

ERDC- EL-EP-C (Environmental Chemistry Branch)

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B105108 - EPA 3050B										
Blank (B105108-BLK1)				**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	ND	0.00400	mg/kg							U
Blank (B105108-BLK2)				**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	ND	0.00400	mg/kg							U
LCS (B105108-BS1)				**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	0.0830	0.00400	mg/kg	0.08000		104	75-125			
LCS (B105108-BS2)				**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	0.0868	0.00400	mg/kg	0.08000		109	75-125			
Duplicate (B105108-DUP1)		**Source: 1051201-36**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	1.04	0.00401	mg/kg		0.995			4.63	25	
Duplicate (B105108-DUP2)		**Source: 1052502-01**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	ND	0.00404	mg/kg		ND				25	U
Duplicate (B105108-DUP3)		**Source: 1052701-01**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	2.74	0.00796	mg/kg		2.69			1.95	25	
Matrix Spike (B105108-MS1)		**Source: 1051201-36**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	2.15	0.00402	mg/kg	1.005	0.995	115	75-125			
Matrix Spike (B105108-MS2)		**Source: 1052502-01**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	0.221	0.00400	mg/kg	0.2001	ND	110	75-125			
Matrix Spike (B105108-MS3)		**Source: 1052701-01**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	8.30	0.00803	mg/kg	5.018	2.69	112	75-125			

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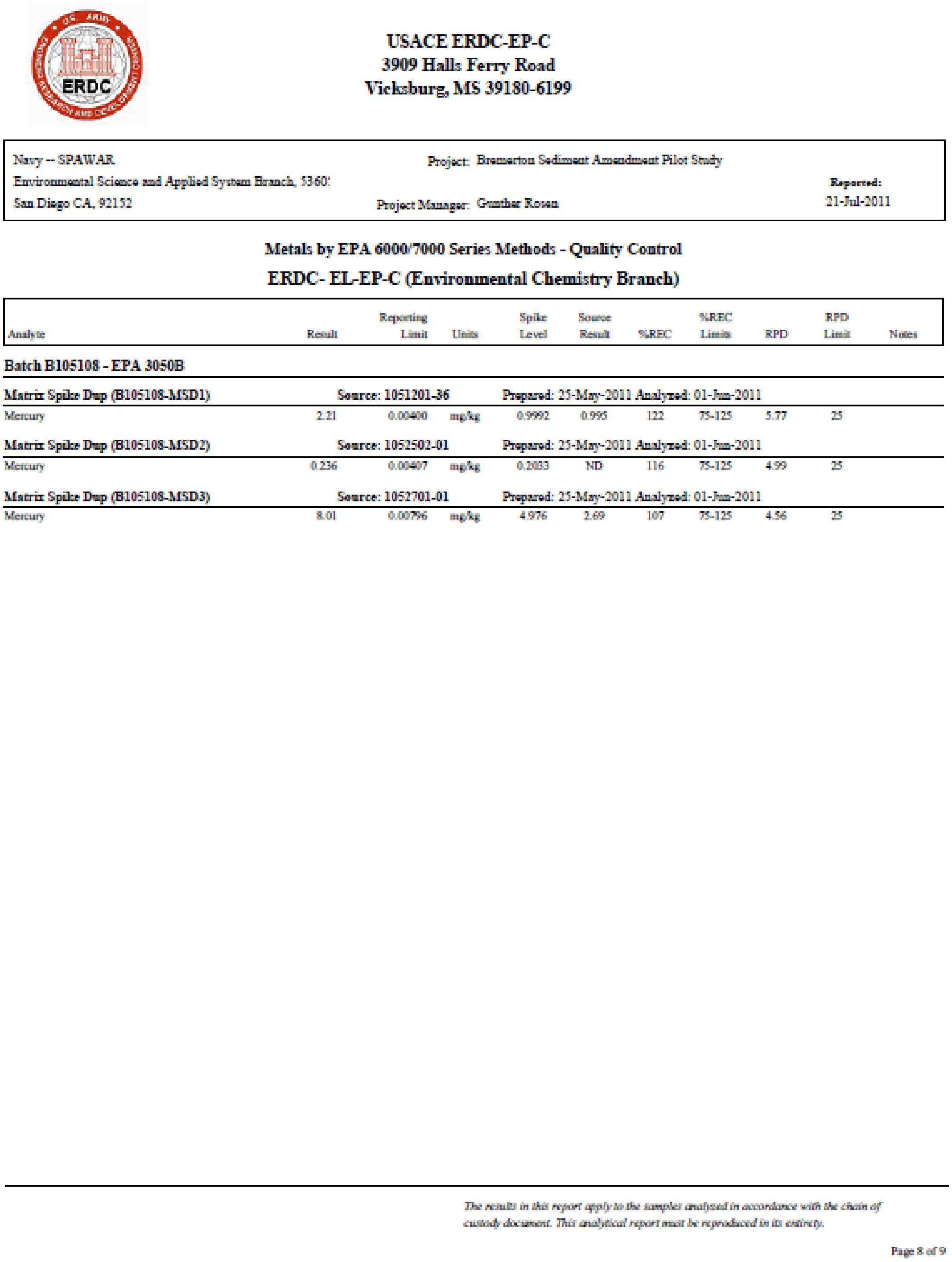

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San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study
Project Manager: Gunther Rosen

Reported:
21-Jul-2011

Metals by EPA 6000/7000 Series Methods - Quality Control

ERDC- EL-EP-C (Environmental Chemistry Branch)

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B105108 - EPA 3050B										
Matrix Spike Dup (B105108-MSD1)		**Source: 1051201-36**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	2.21	0.00400	mg/kg	0.9992	0.995	122	75-125	5.77	25	
Matrix Spike Dup (B105108-MSD2)		**Source: 1052502-01**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	0.236	0.00407	mg/kg	0.2033	ND	116	75-125	4.99	25	
Matrix Spike Dup (B105108-MSD3)		**Source: 1052701-01**		**Prepared: 25-May-2011 Analyzed: 01-Jun-2011**						
Mercury	8.01	0.00796	mg/kg	4.976	2.69	107	75-125	4.56	25	

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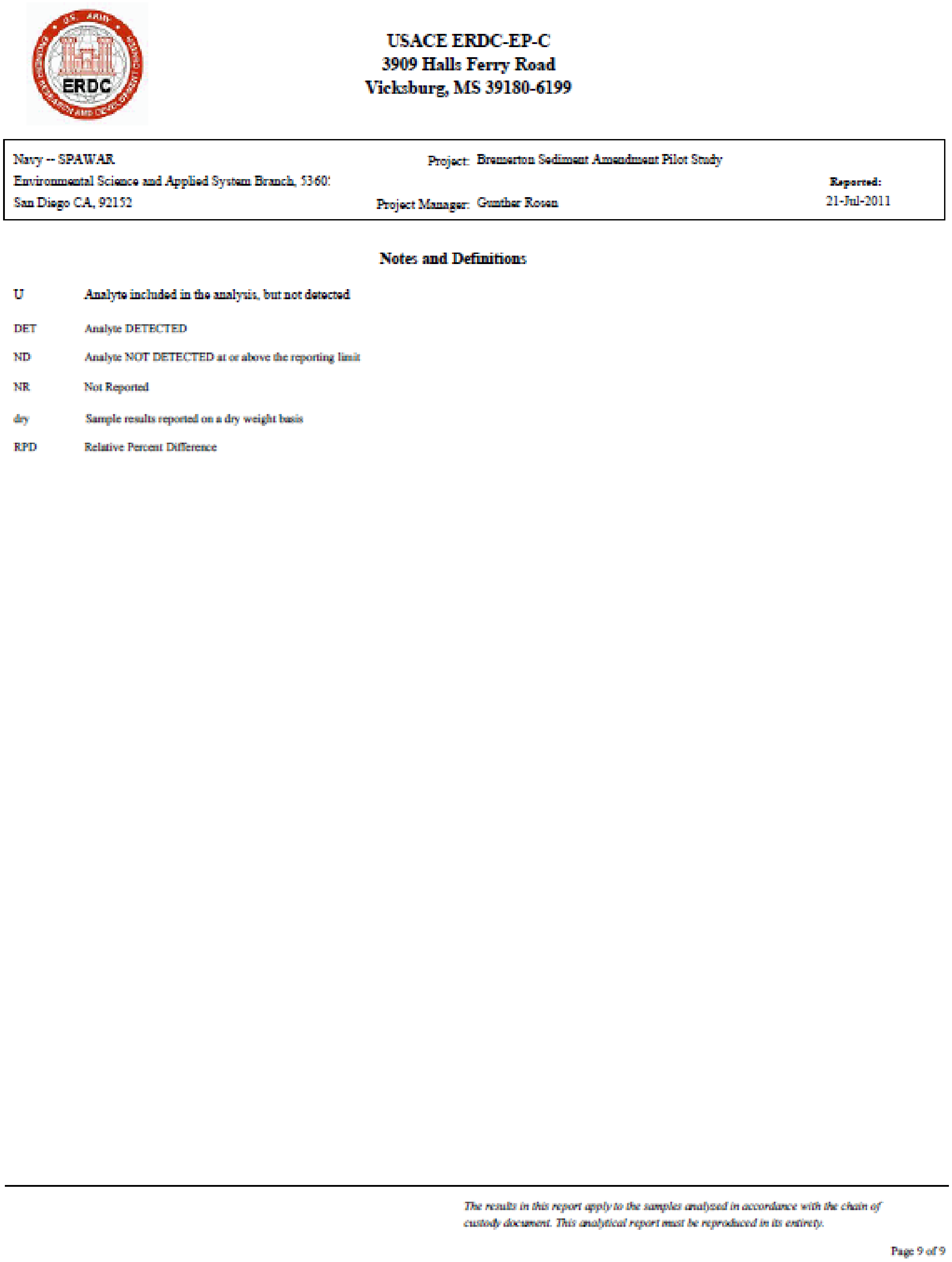

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3909 Halls Ferry Road
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Navy -- SPAWAR	Project: Bremerton Sediment Amendment Pilot Study	
Environmental Science and Applied System Branch, 5360		**Reported:**
San Diego CA, 92152	Project Manager: Gunther Rosen	21-Jul-2011

Notes and Definitions

U	**Analyte included in the analysis, but not detected**
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference

1061704 BREMERTON SEDIMENT AMENDMENT STUDY 01 AUG 2011.PDF

USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

01 August 2011

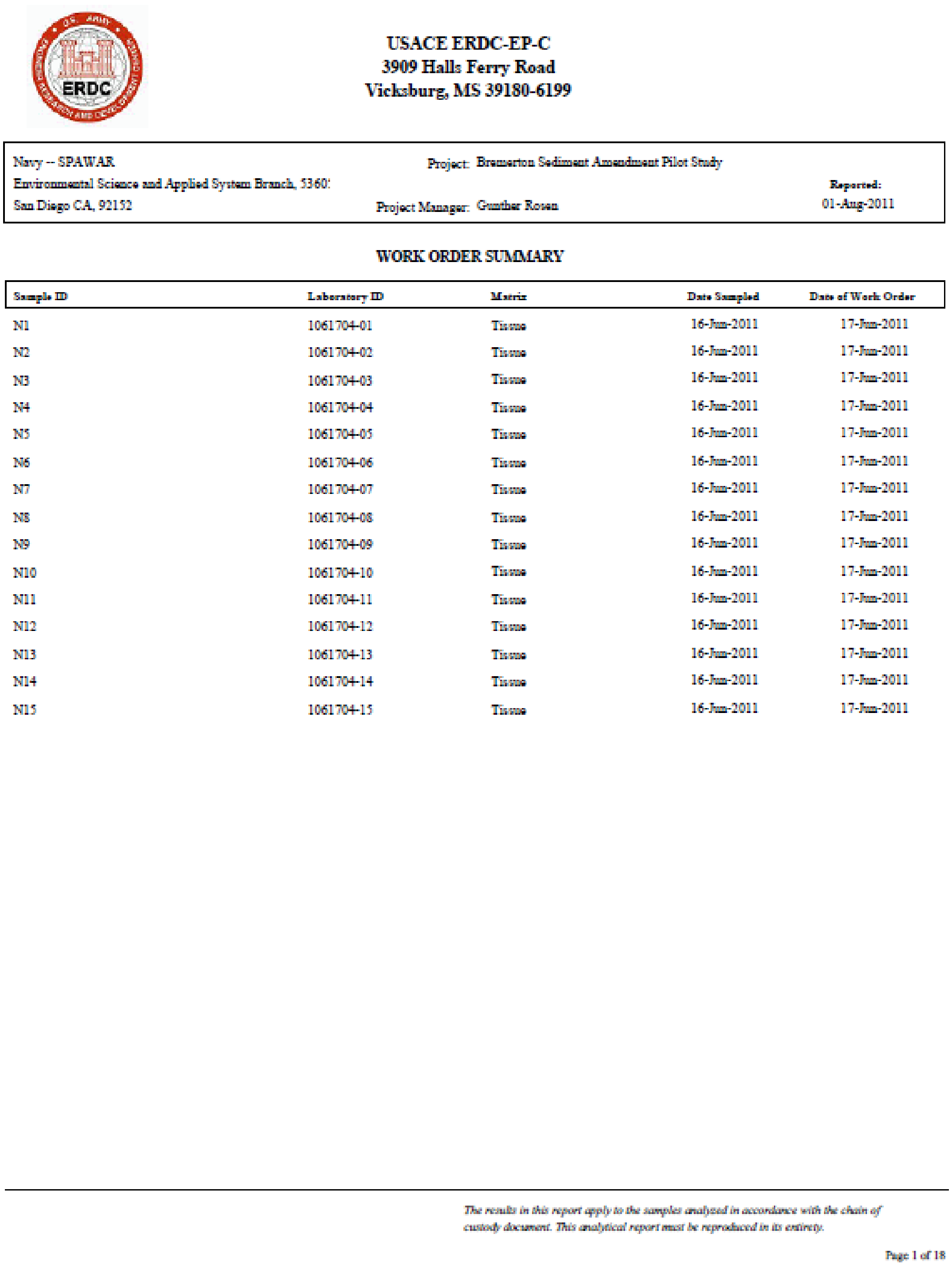
Gunther Rosen
Navy – SPAWAR
Environmental Science and Applied System Branch, 536
San Diego, CA 92152

RE: Bremerton Sediment Amendment Pilot Study

Enclosed are the results of analyses for samples received by the laboratory on 17-Jun-2011. The samples associated with this report will be held for 90 days from the date of this report. The raw data associated with this report will be held for 5 years from the date of this report. If you need us to hold onto the samples or the data longer then these specified times, you will need to notify us in writing at least 30 days before the expiration dates. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Patty Tuminello
Project Coordinator



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Navy -- SPAWAR
Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

WORK ORDER SUMMARY

Sample ID	Laboratory ID	Matrix	Date Sampled	Date of Work Order
N1	1061704-01	Tissue	16-Jun-2011	17-Jun-2011
N2	1061704-02	Tissue	16-Jun-2011	17-Jun-2011
N3	1061704-03	Tissue	16-Jun-2011	17-Jun-2011
N4	1061704-04	Tissue	16-Jun-2011	17-Jun-2011
N5	1061704-05	Tissue	16-Jun-2011	17-Jun-2011
N6	1061704-06	Tissue	16-Jun-2011	17-Jun-2011
N7	1061704-07	Tissue	16-Jun-2011	17-Jun-2011
N8	1061704-08	Tissue	16-Jun-2011	17-Jun-2011
N9	1061704-09	Tissue	16-Jun-2011	17-Jun-2011
N10	1061704-10	Tissue	16-Jun-2011	17-Jun-2011
N11	1061704-11	Tissue	16-Jun-2011	17-Jun-2011
N12	1061704-12	Tissue	16-Jun-2011	17-Jun-2011
N13	1061704-13	Tissue	16-Jun-2011	17-Jun-2011
N14	1061704-14	Tissue	16-Jun-2011	17-Jun-2011
N15	1061704-15	Tissue	16-Jun-2011	17-Jun-2011

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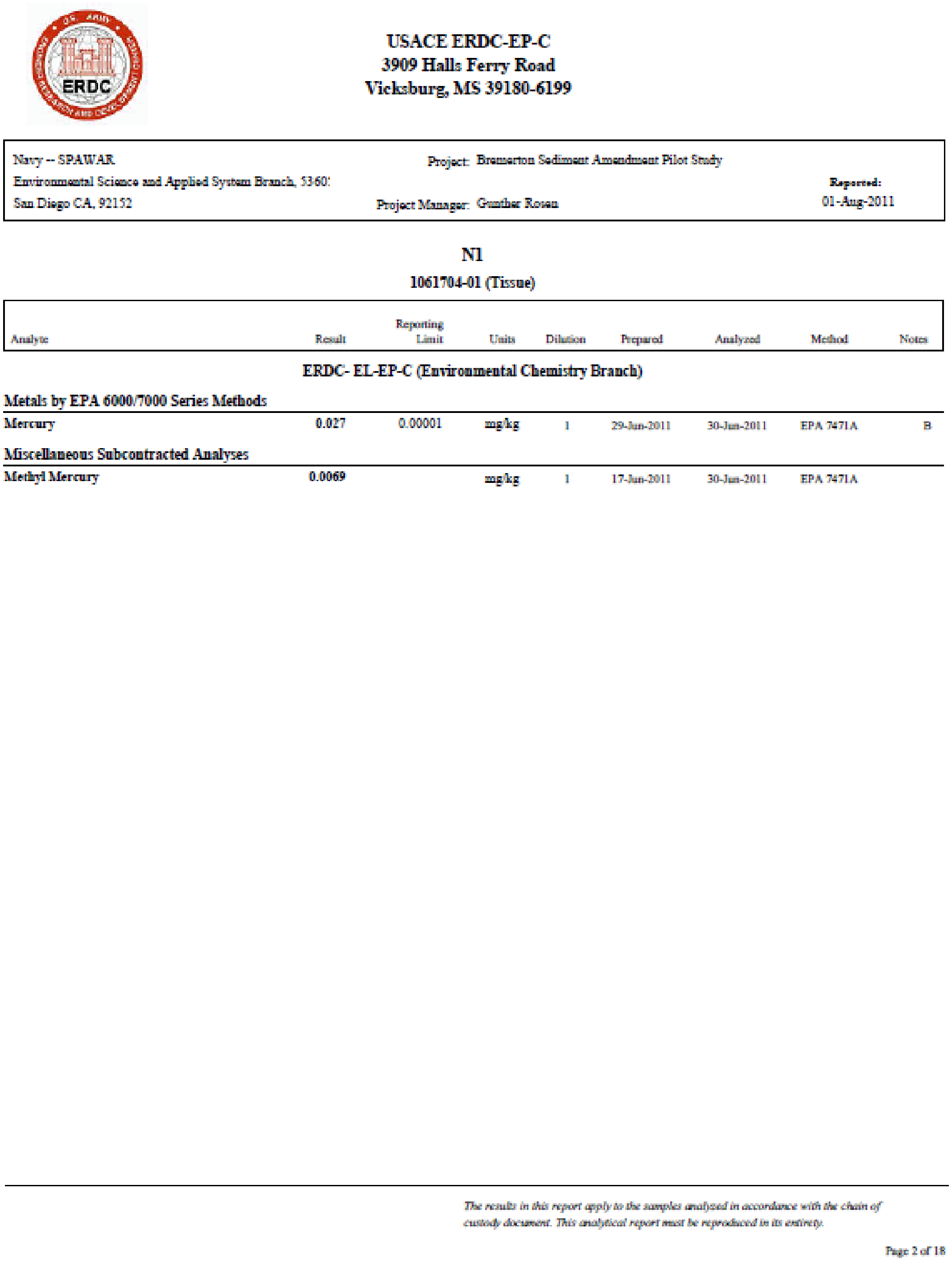

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San Diego CA, 92152

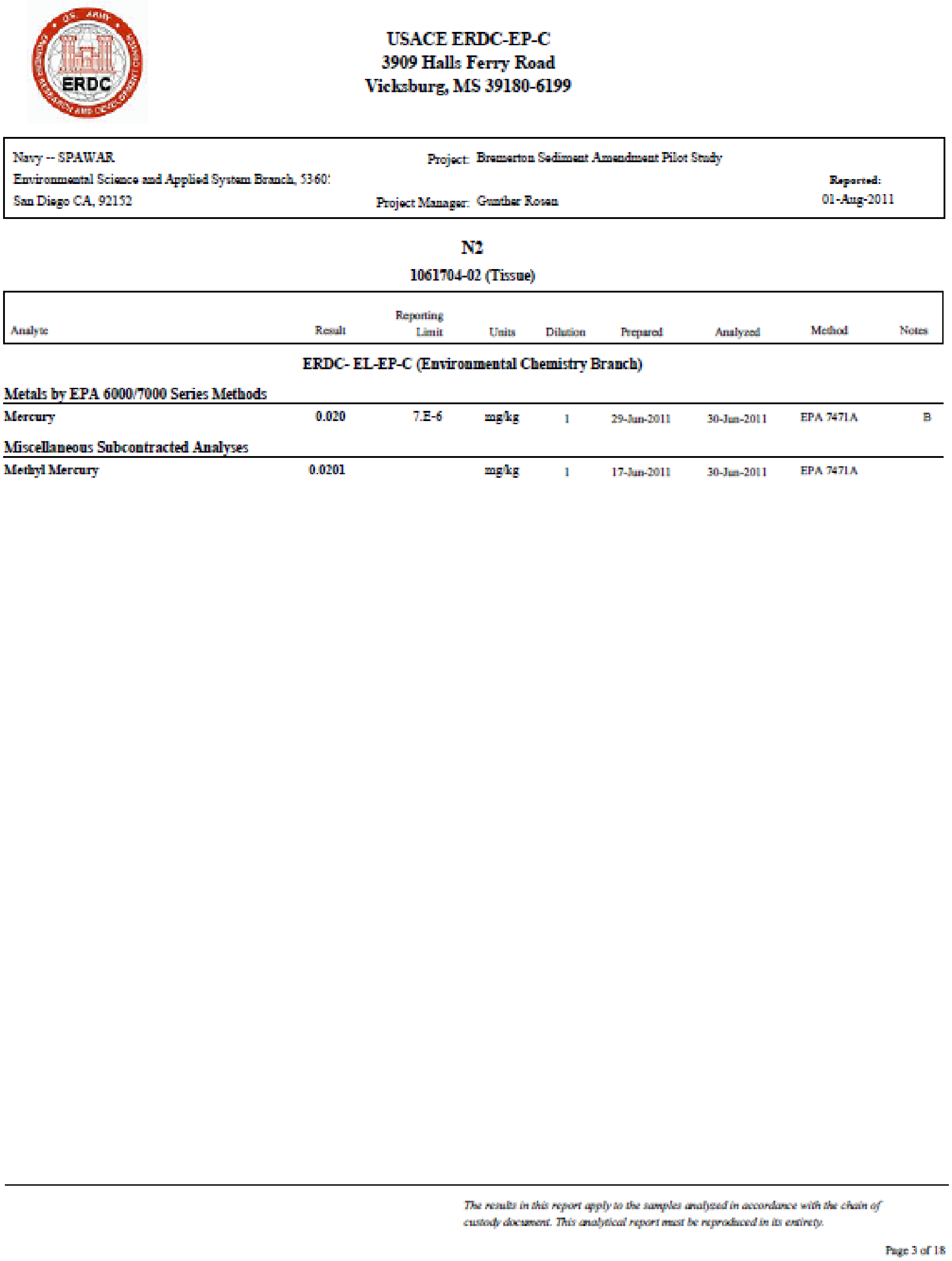
Project: Bremerton Sediment Amendment Pilot Study
Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N1

1061704-01 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.027**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0069**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	



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San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study
Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N2

1061704-02 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.020**	7.E-6	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0201**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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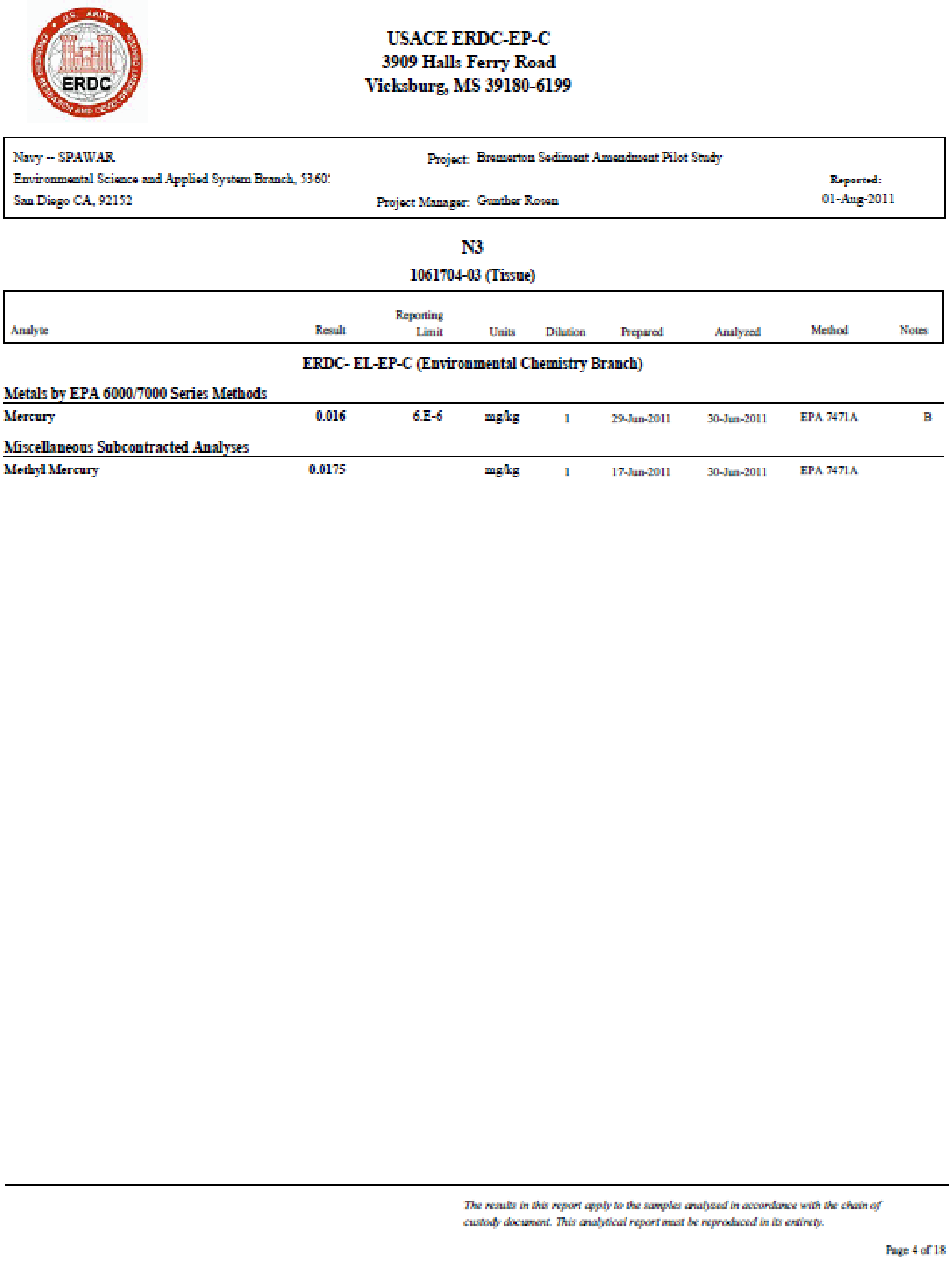

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Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N3

1061704-03 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.016**	6.E-6	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0175**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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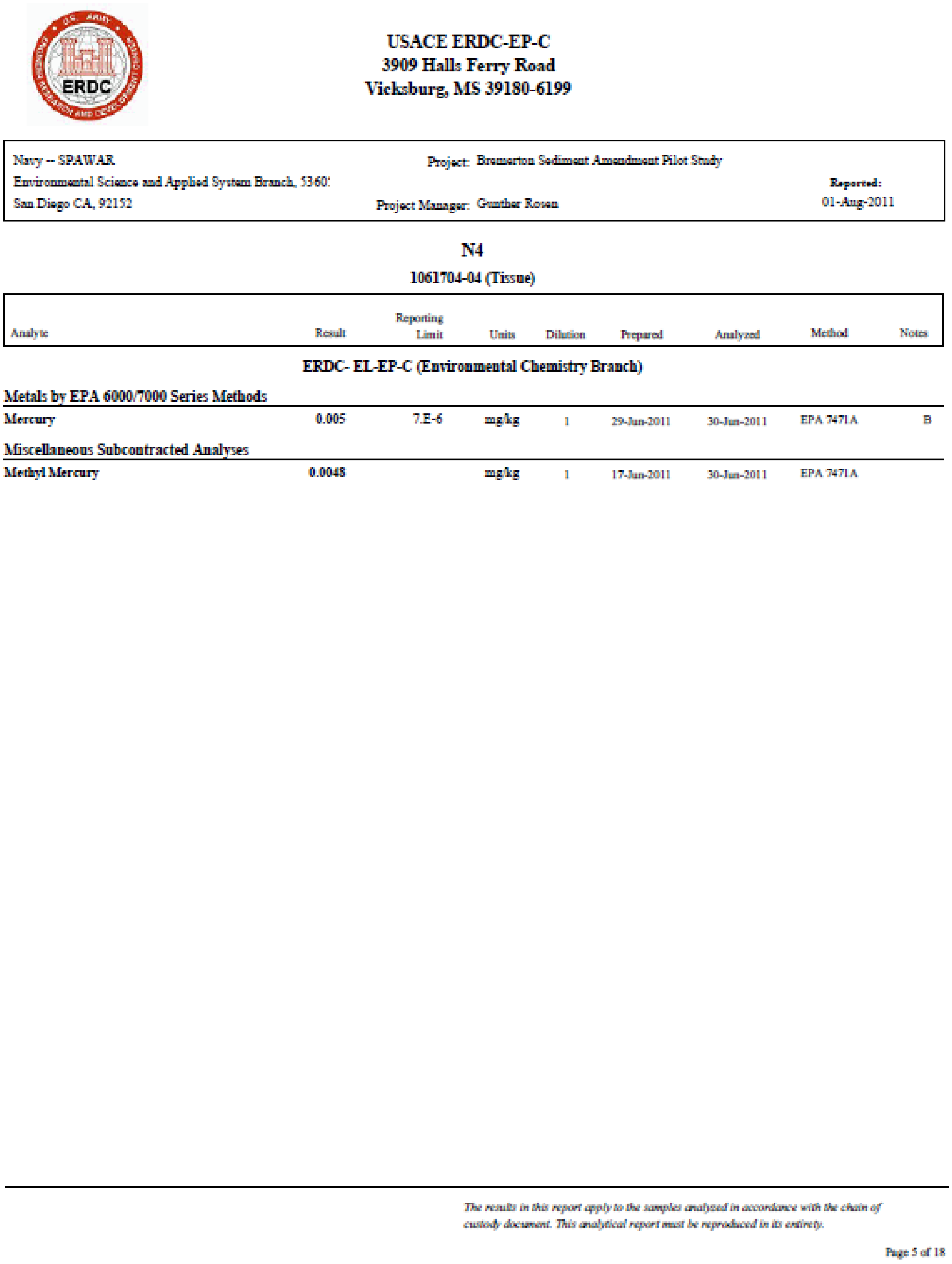

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Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N4

1061704-04 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes

ERDC- EL-EP-C (Environmental Chemistry Branch)

Metals by EPA 6000/7000 Series Methods

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
Mercury	0.005	7.E-6	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B

Miscellaneous Subcontracted Analyses

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
Methyl Mercury	0.0048		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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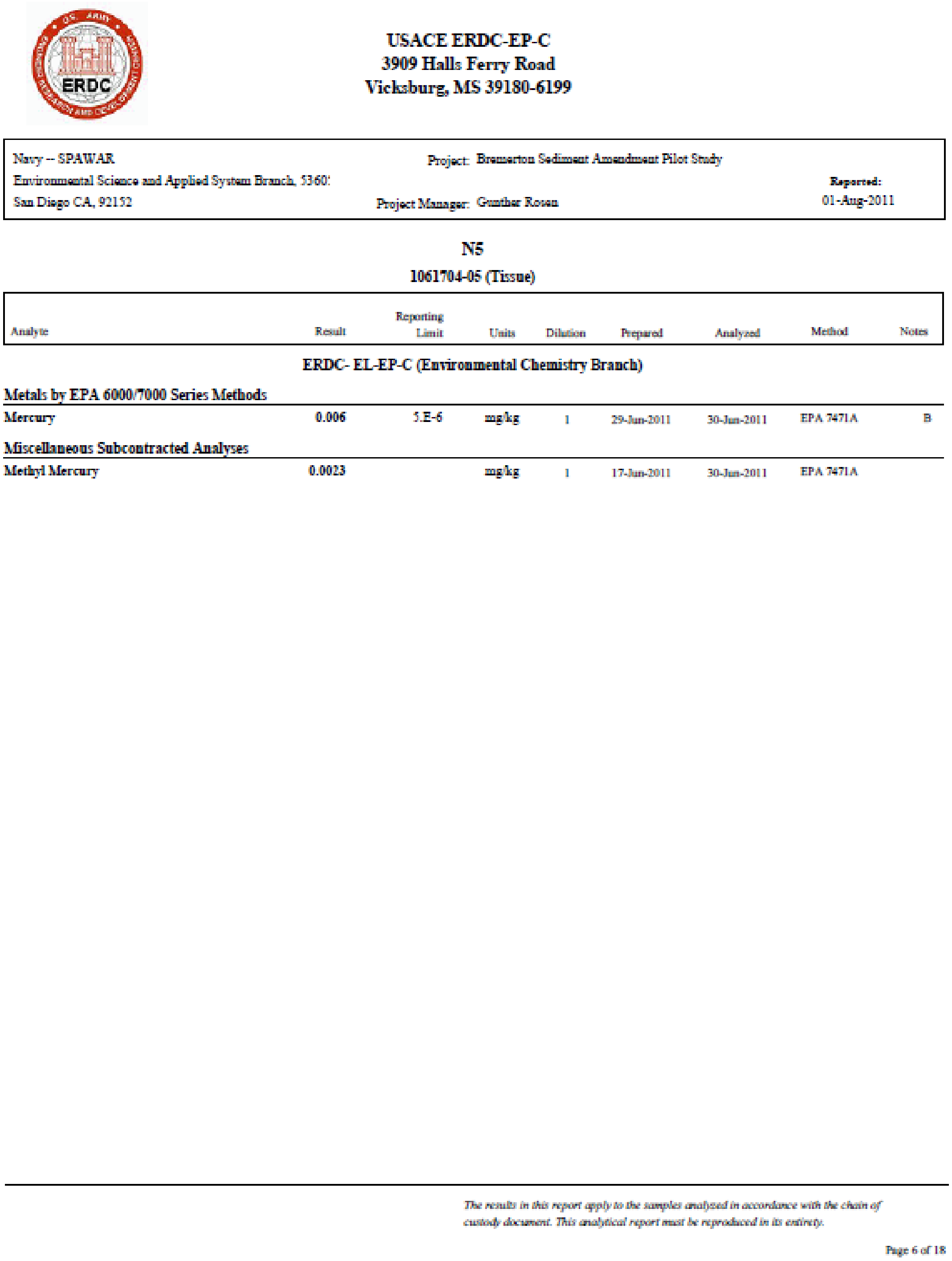

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San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

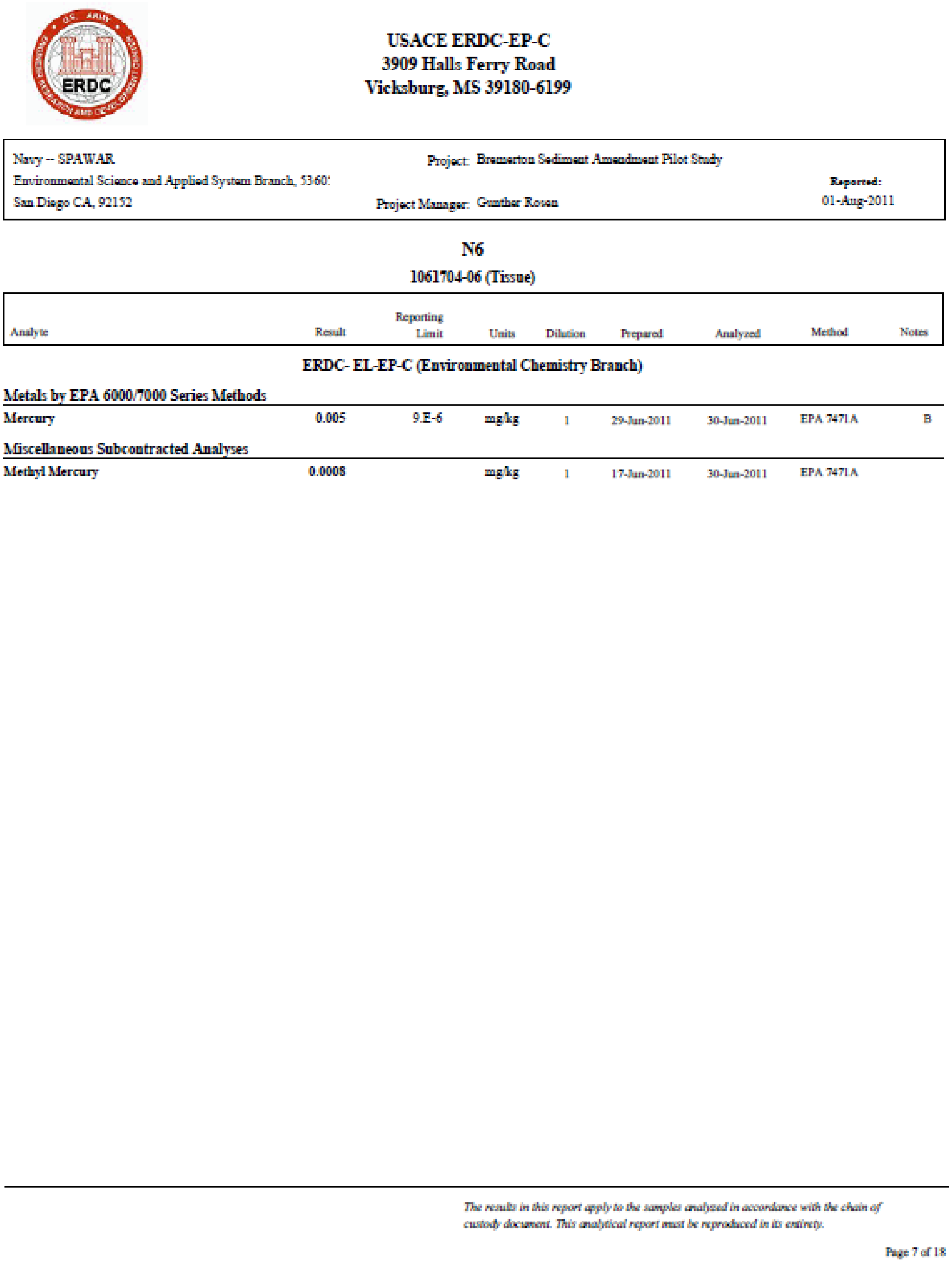
Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N5

1061704-05 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.006**	5.E-6	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0023**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	



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San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N6

1061704-06 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.005**	**9.E-6**	**mg/kg**	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0008**		**mg/kg**	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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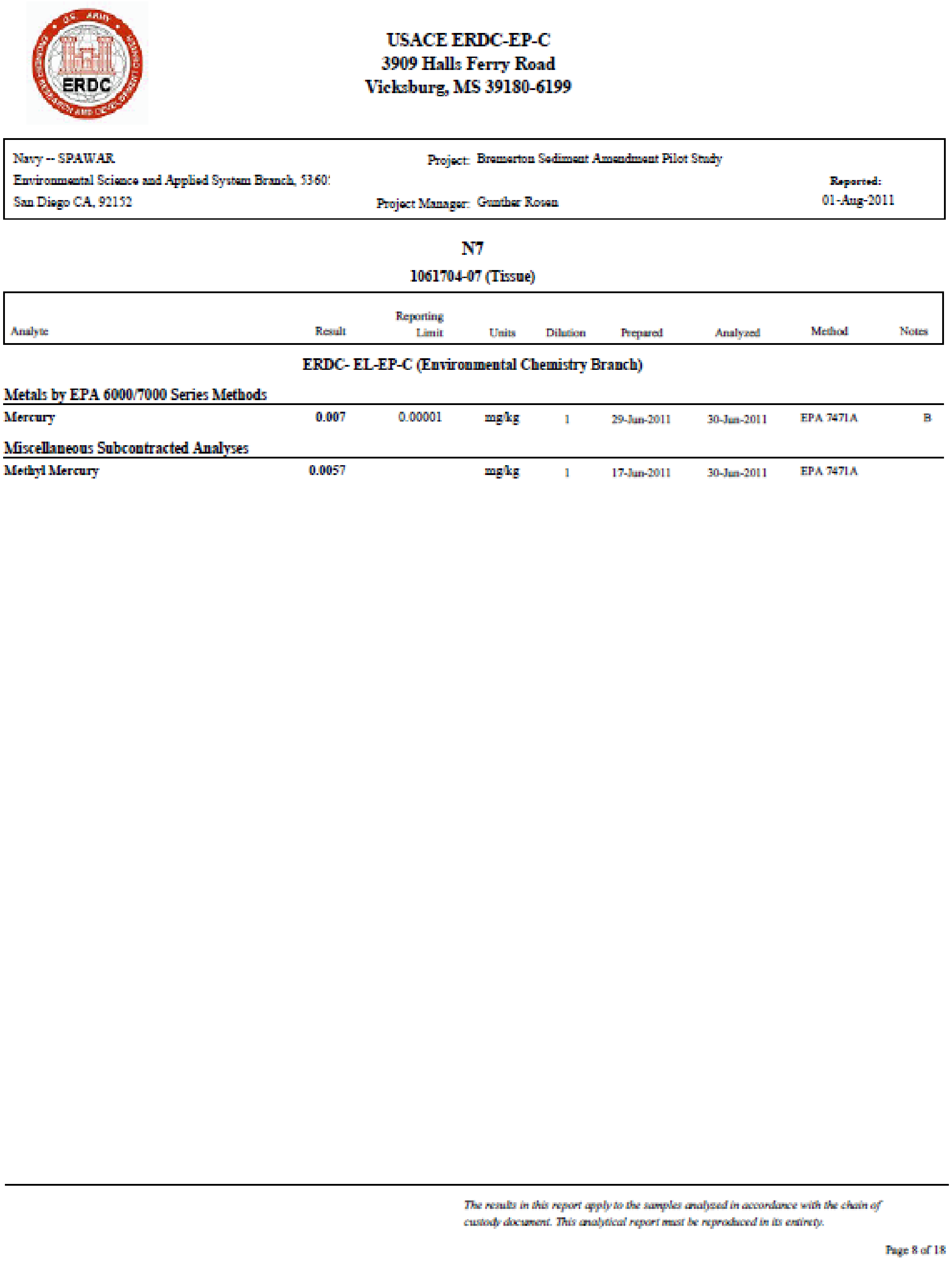

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Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N7

1061704-07 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
		ERDC- EL-EP-C (Environmental Chemistry Branch)						
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.007**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0057**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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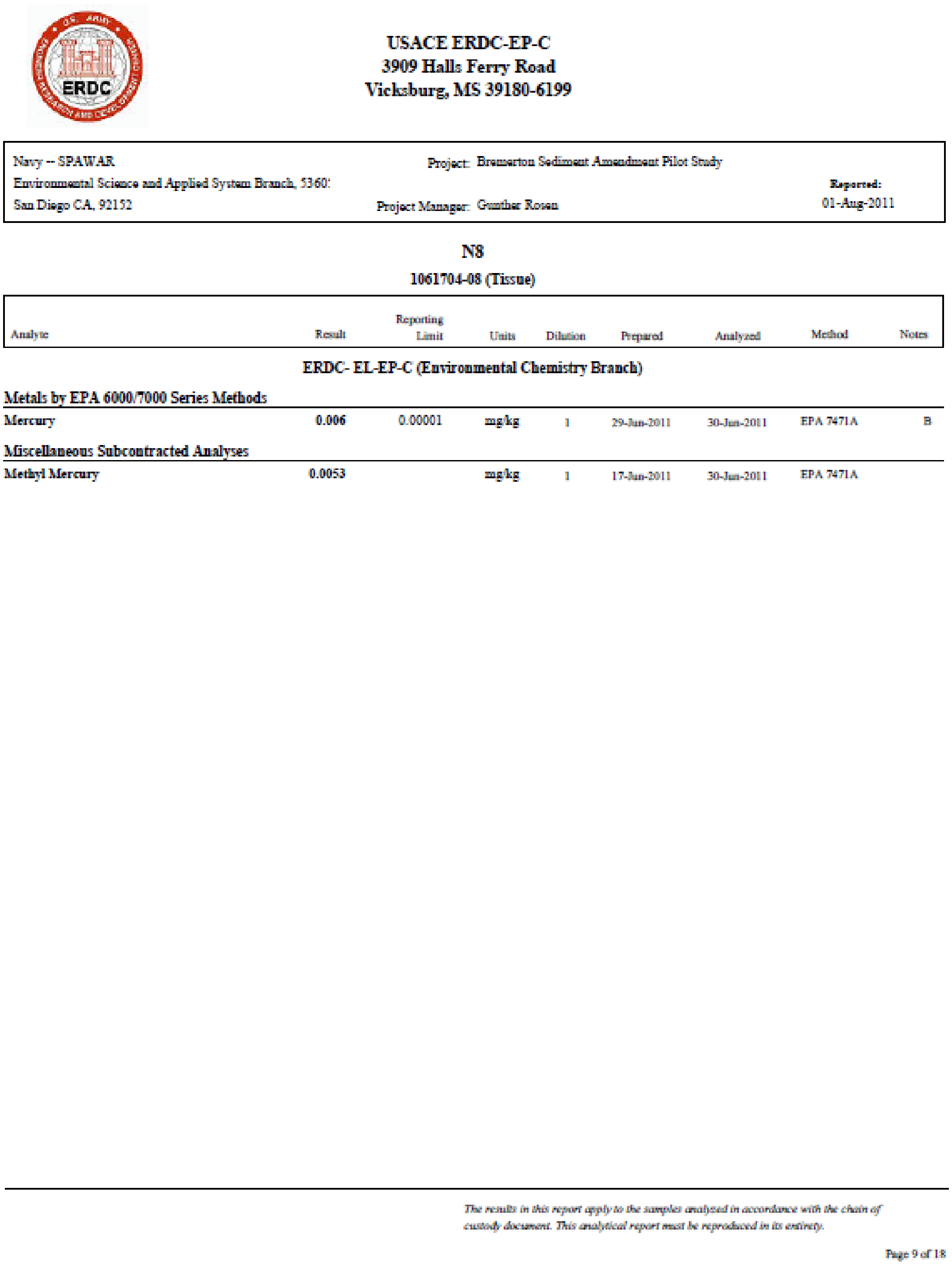

USACE ERDC-EP-C
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Navy -- SPAWAR
Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N8

1061704-08 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.006**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0053**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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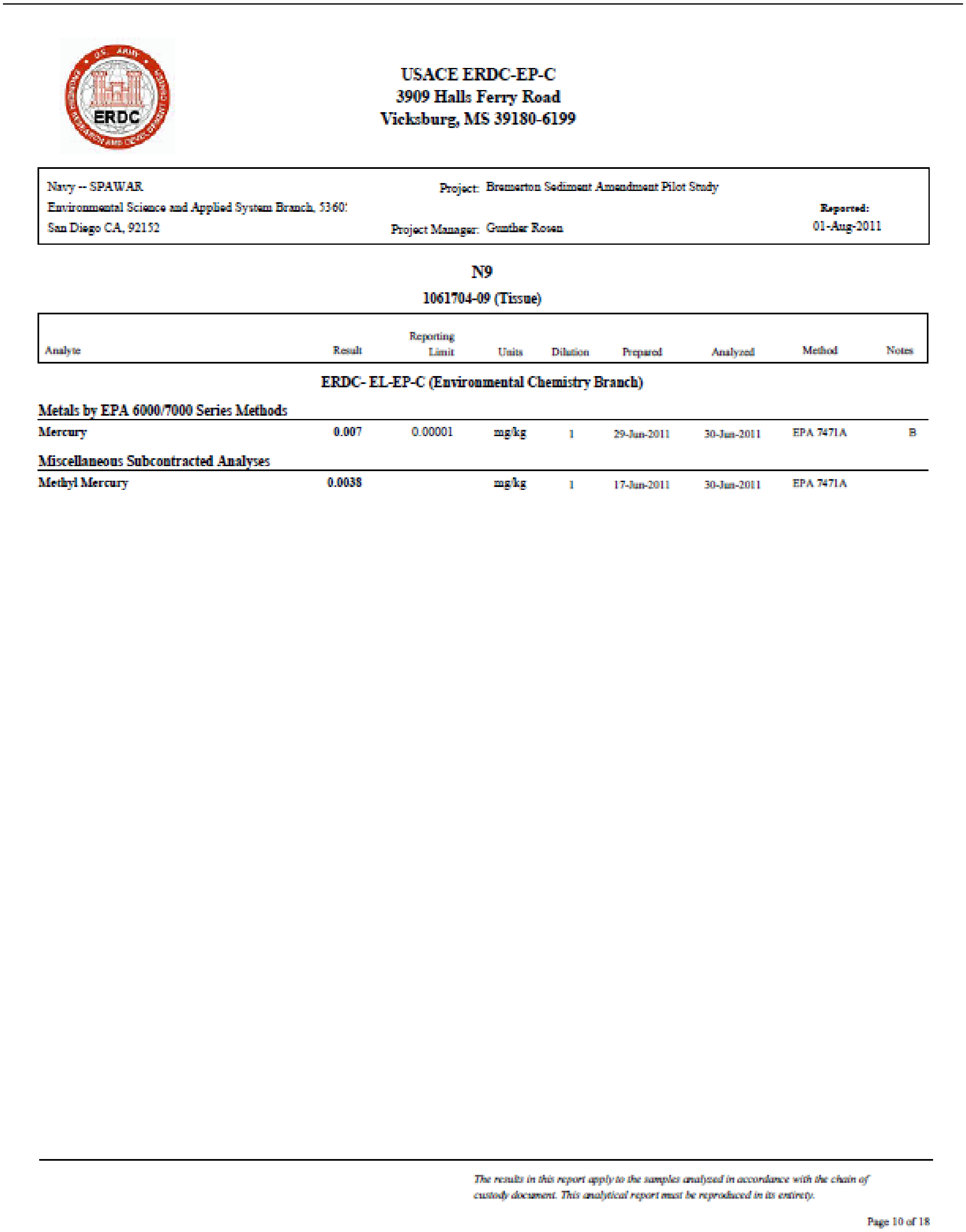

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Navy -- SPAWAR Environmental Science and Applied System Branch, 5360 San Diego CA, 92152	Project: Bremerton Sediment Amendment Pilot Study Project Manager: Gunther Rosen	**Reported:** 01-Aug-2011

N9

1061704-09 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.007**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0038**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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San Diego CA, 92152

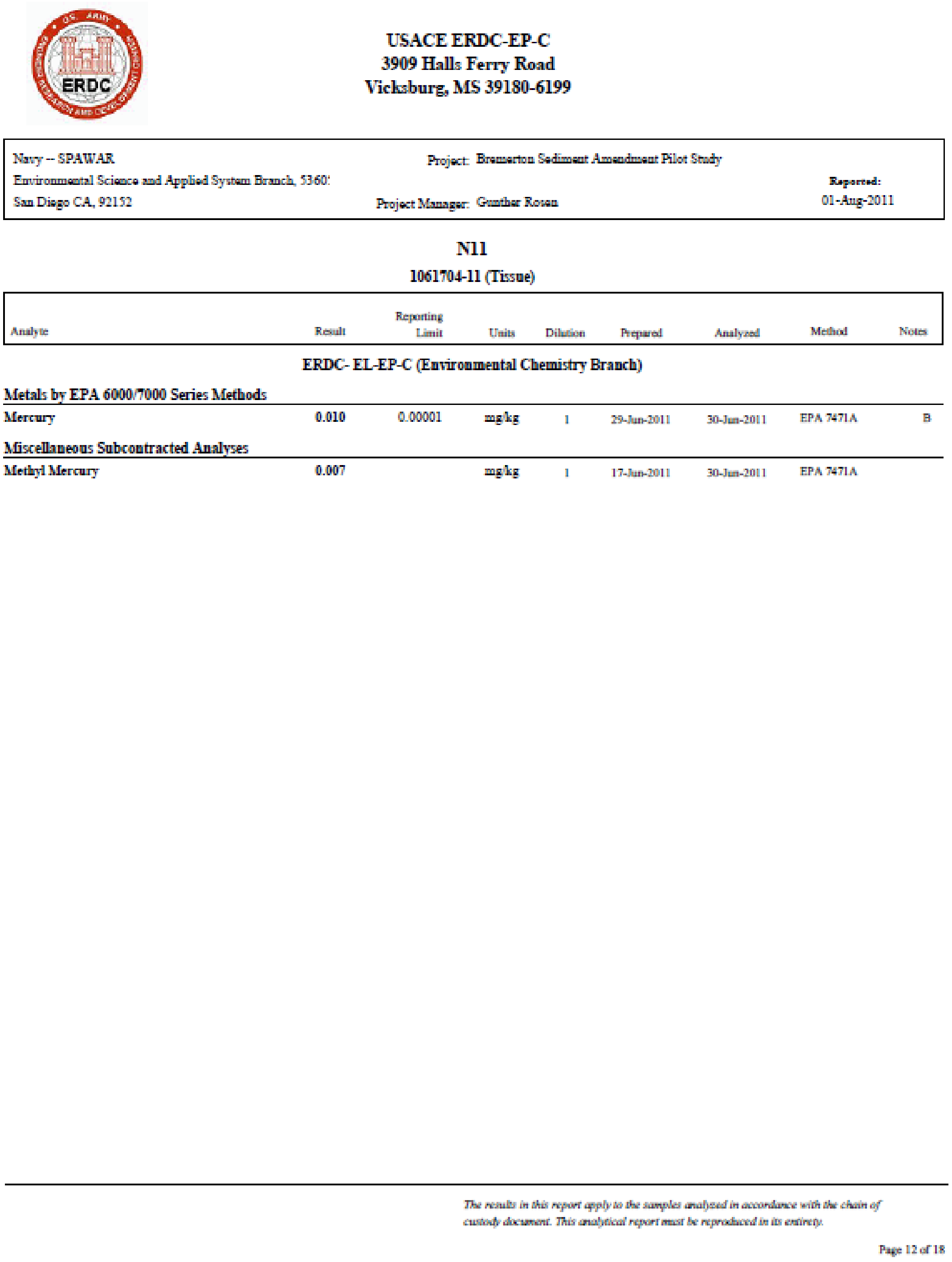
Project: Bremerton Sediment Amendment Pilot Study
Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N10

1061704-10 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.010**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0064**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	



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Navy -- SPAWAR
Environmental Science and Applied System Branch, 5360:
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported: 01-Aug-2011

N11

1061704-11 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.010**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.007**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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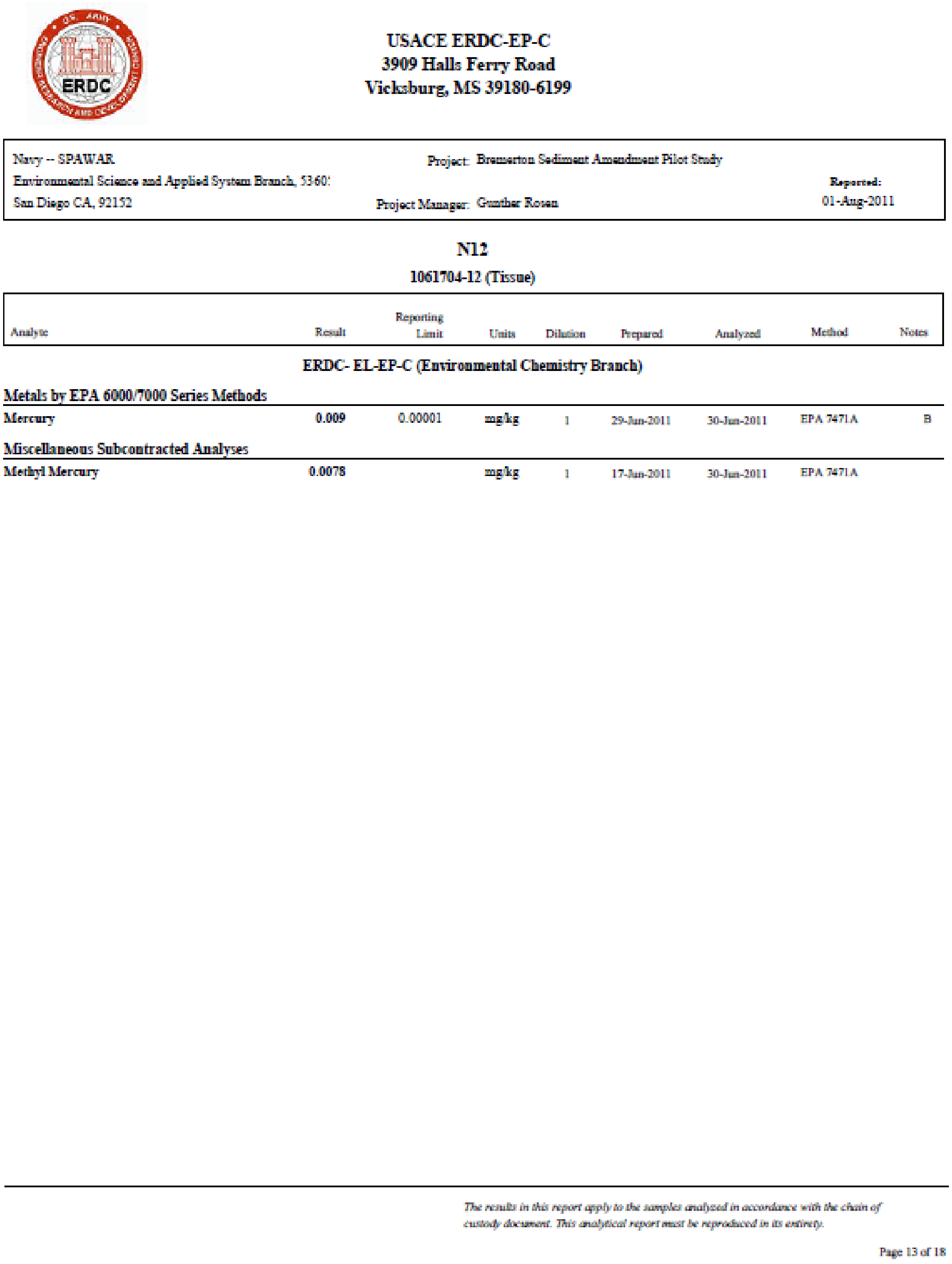

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Navy -- SPAWAR
Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N12

1061704-12 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.009**	0.00001	**mg/kg**	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0078**		**mg/kg**	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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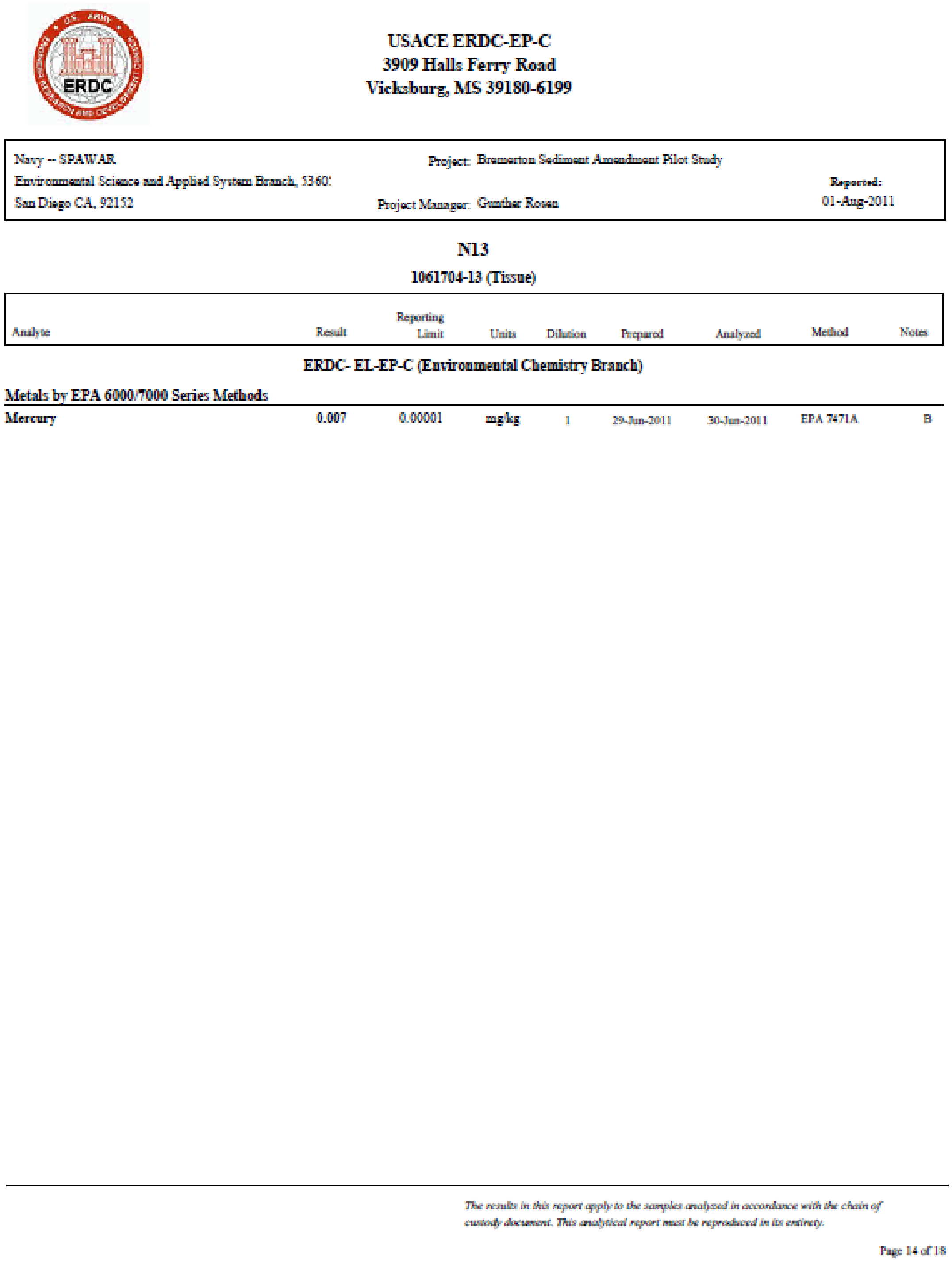

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Navy -- SPAWAR Environmental Science and Applied System Branch, 5360: San Diego CA, 92152	Project: Bremerton Sediment Amendment Pilot Study Project Manager: Gunther Rosen	**Reported:** 01-Aug-2011

N13

1061704-13 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.007**	0.00001	**mg/kg**	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B

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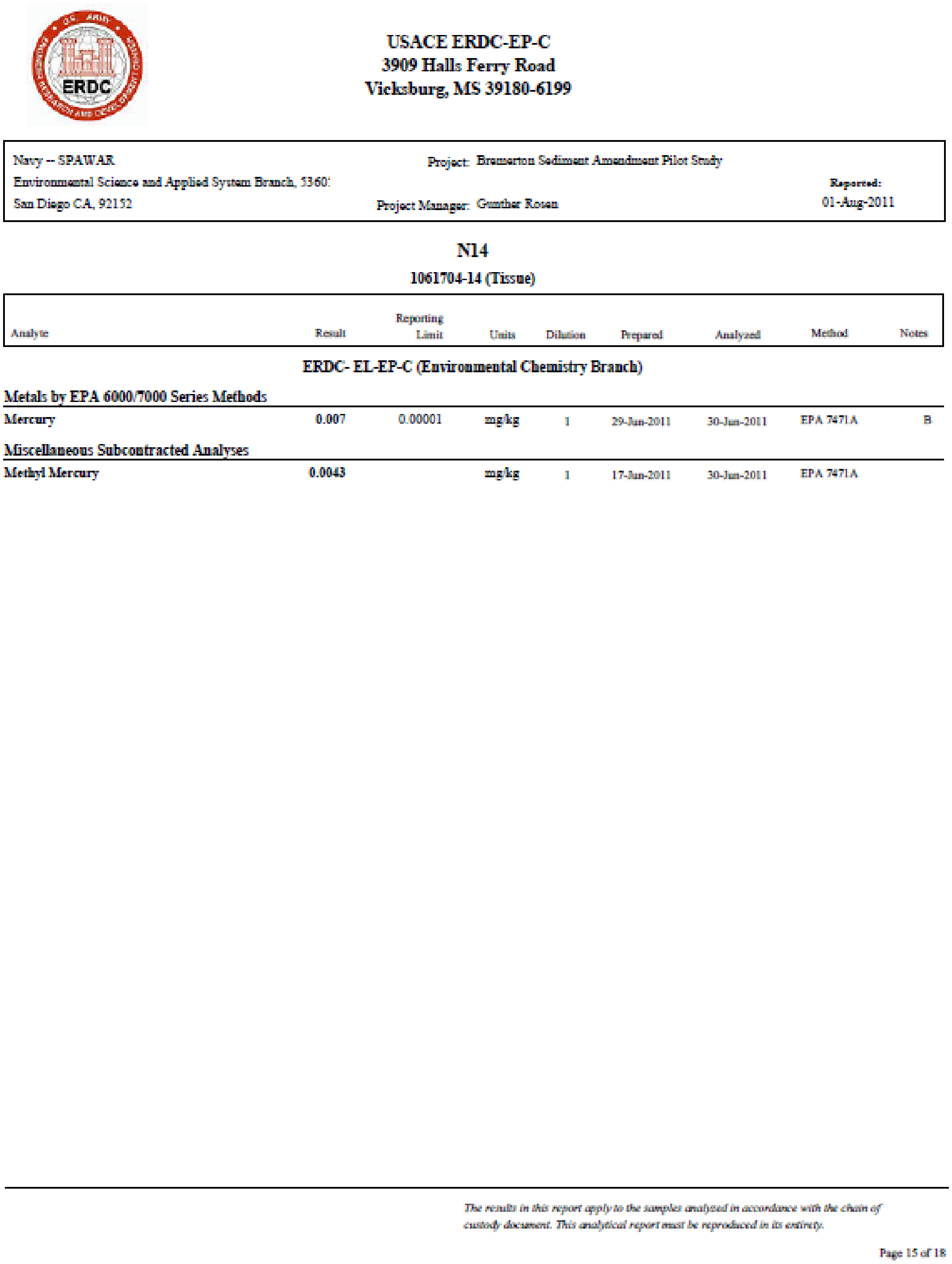

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Navy -- SPAWAR Environmental Science and Applied System Branch, 5360 San Diego CA, 92152	Project: Bremerton Sediment Amendment Pilot Study Project Manager: Gunther Rosen	**Reported:** 01-Aug-2011

N14

1061704-14 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
ERDC- EL-EP-C (Environmental Chemistry Branch)								
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.007**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0043**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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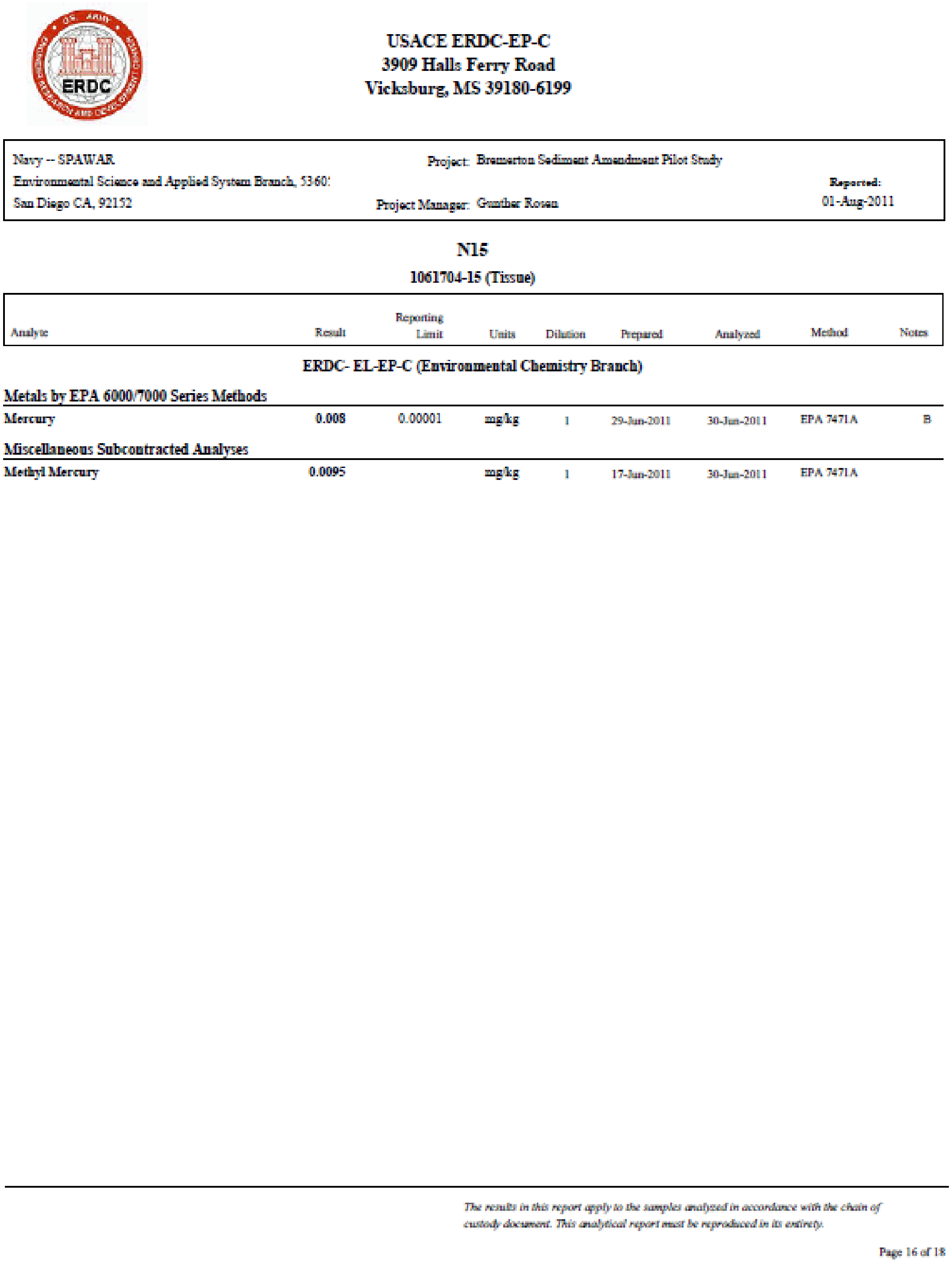

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Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

N15

1061704-15 (Tissue)

Analyte	Result	Reporting Limit	Units	Dilution	Prepared	Analyzed	Method	Notes
			ERDC- EL-EP-C (Environmental Chemistry Branch)					
Metals by EPA 6000/7000 Series Methods								
Mercury	**0.008**	0.00001	mg/kg	1	29-Jun-2011	30-Jun-2011	EPA 7471A	B
Miscellaneous Subcontracted Analyses								
Methyl Mercury	**0.0095**		mg/kg	1	17-Jun-2011	30-Jun-2011	EPA 7471A	

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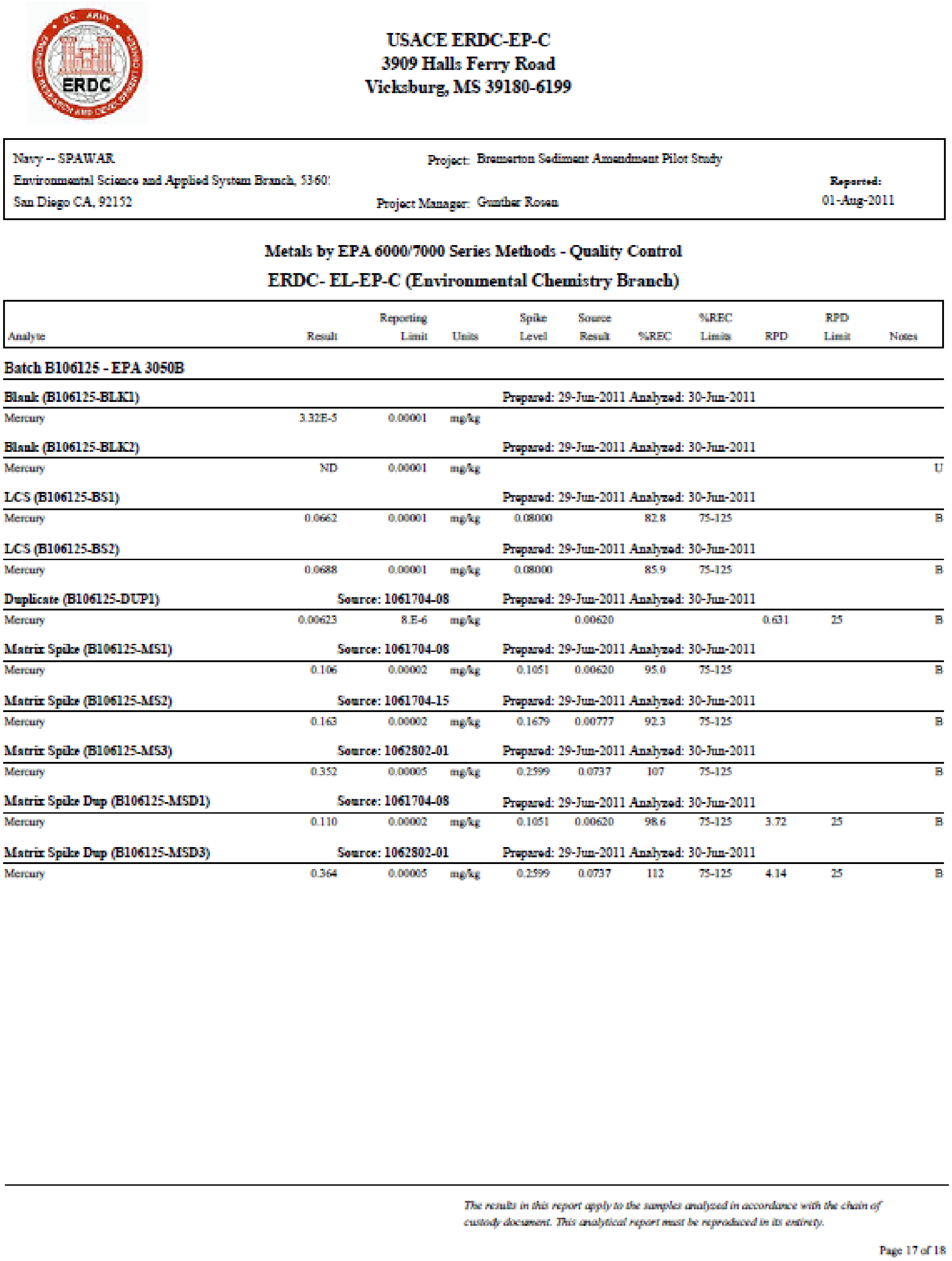

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3909 Halls Ferry Road
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Environmental Science and Applied System Branch, 5360:
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study

Project Manager: Gunther Rosen

Reported:
01-Aug-2011

Metals by EPA 6000/7000 Series Methods - Quality Control

ERDC- EL-EP-C (Environmental Chemistry Branch)

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B106125 - EPA 3050B										
Blank (B106125-BLK1)				**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	3.32E-5	0.00001	mg/kg							
Blank (B106125-BLK2)				**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	ND	0.00001	mg/kg							U
LCS (B106125-BS1)				**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.0662	0.00001	mg/kg	0.08000		82.8	75-125			B
LCS (B106125-BS2)				**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.0688	0.00001	mg/kg	0.08000		85.9	75-125			B
Duplicate (B106125-DUP1)		**Source: 1061704-08**		**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.00623	8.E-6	mg/kg		0.00620			0.631	25	B
Matrix Spike (B106125-MS1)		**Source: 1061704-08**		**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.106	0.00002	mg/kg	0.1051	0.00620	95.0	75-125			B
Matrix Spike (B106125-MS2)		**Source: 1061704-15**		**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.163	0.00002	mg/kg	0.1679	0.00777	92.3	75-125			B
Matrix Spike (B106125-MS3)		**Source: 1062802-01**		**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.352	0.00005	mg/kg	0.2599	0.0737	107	75-125			B
Matrix Spike Dup (B106125-MSD1)		**Source: 1061704-08**		**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.110	0.00002	mg/kg	0.1051	0.00620	98.6	75-125	3.72	25	B
Matrix Spike Dup (B106125-MSD3)		**Source: 1062802-01**		**Prepared:** 29-Jun-2011 **Analyzed:** 30-Jun-2011						
Mercury	0.364	0.00005	mg/kg	0.2599	0.0737	112	75-125	4.14	25	B

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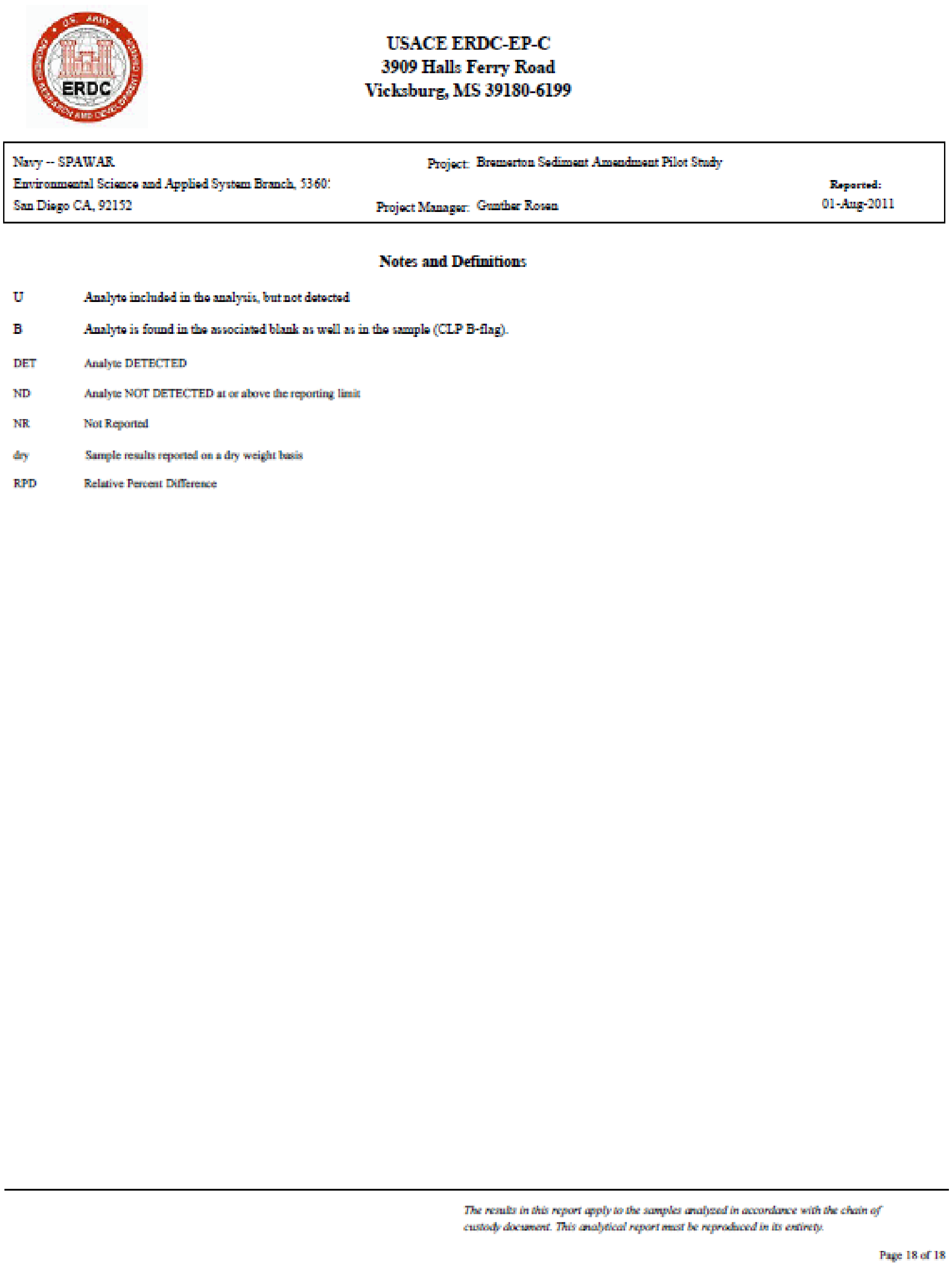

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Environmental Science and Applied System Branch, 5360
San Diego CA, 92152

Project: Bremerton Sediment Amendment Pilot Study
Project Manager: Gunther Rosen

Reported:
01-Aug-2011

Notes and Definitions

U	Analyte included in the analysis, but not detected
B	Analyte is found in the associated blank as well as in the sample (CLP B-flag).
DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference

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INORGANIC ANALYSIS DATA PACKAGE

Corps of Engineers – Vicksburg, MS
Report Date: 07/22/11

Lab Name: ARDL, Inc.
ARDL Report No.: 6323
Samples Received: 29-Jun-11
Project Name: 1061704

CASE NARRATIVE

Sample ID No.	Date Collected	Lab ID No.	Analysis Requested
N1	06/16/11	6323-01	Methyl Mercury
N2	06/16/11	6323-02	Methyl Mercury
N3	06/16/11	6323-03	Methyl Mercury
N4	06/16/11	6323-04	Methyl Mercury
N5	06/16/11	6323-05	Methyl Mercury
N6	06/16/11	6323-06	Methyl Mercury
N7	06/16/11	6323-07	Methyl Mercury
N8	06/16/11	6323-08	Methyl Mercury
N9	06/16/11	6323-09	Methyl Mercury
N10	06/16/11	6323-10	Methyl Mercury
N11	06/16/11	6323-11	Methyl Mercury
N12	06/16/11	6323-12	Methyl Mercury
N14	06/16/11	6323-13	Methyl Mercury
N15	06/16/11	6323-14	Methyl Mercury

NOTE: The methyl mercury analyses were subcontracted to Quicksilver Scientific. A summary page of their results has been generated and immediately follows this case narrative.

Sample N13 was compromised during shipment. No sample remained to be analyzed.

The quality control data are summarized as follows:

PREPARATION BLANKS
The results of all preparation blanks were within acceptable limits.

DUPLICATES
RPD on the duplicate analysis was within control limits.

Release of the data contained in this package has been authorized by the Technical Services Manager or his designee as verified by the following signature.

Dean S. Dickerson
Technical Services Manager

ARDL Subcontracted Work Report
Vicksburg 6323

Methyl Mercury (MeHg) Analysis - Quicksilver Scientific

Sample Results Summary

ARDL ID	Vicksburg ID	Quicksilver ID	Sample Type	MeHg (as Hg)
6323-01	N1	201135-1	Sample	6.9 ng/g (ww)
6323-02	N2	201135-2	Sample	20.1 ng/g (ww)
6323-03	N3	201135-3	Sample	17.5 ng/g (ww)
6323-04	N4	201135-4	Sample	4.8 ng/g (ww)
6323-05	N5	201135-5	Sample	2.3 ng/g (ww)
6323-06	N6	201135-6	Sample	0.8 ng/g (ww)
6323-07	N7	201135-7	Sample	5.7 ng/g (ww)
6323-08	N8	201135-8	Sample	5.3 ng/g (ww)
6323-09	N9	201135-9	Sample	3.8 ng/g (ww)
6323-10	N10	201135-10	Sample	6.4 ng/g (ww)
6323-11	N11	201135-11	Sample	7.0 ng/g (ww)
6323-12	N12	201135-12	Sample	7.8 ng/g (ww)
6323-13	N14	201135-14	Sample	4.3 ng/g (ww)
6323-14	N15	201135-15	Sample	9.5 ng/g (ww)

QC Results Summary

ARDL ID	Vicksburg ID	Quicksilver ID	Sample Type	Result	
6323-14	N15	201135-15	Duplicate	9.4 ng/mL	(CV - 0.9)
6323-14	N15	201135-16	Duplicate	9.5 ng/mL	
		201135-25	Reference	110.3 % Rec	
		201135-20	Blank	<0.00295 ng/mL	
		201135-21	Blank	<0.00295 ng/mL	

APPENDIX E

ESTCP PROJECT PROPOSAL: ER201131

1. TITLE: Demonstration of In-Situ Treatment with Reactive Amendments for Contaminated Sediments in Active DoD Harbors

2. ESTCP TOPIC AREAS: Topic 1: Environmental Restoration

3. LEAD ORGANIZATION: US Navy, SPAWAR Systems Center Pacific

Project Lead: Bart Chadwick	(619) 553-5333
Environmental Sciences Branch, Code 71750	(619) 553-6305 (fax)
53475 Strothe Rd., San Diego, CA 92152	bart.chadwick@navy.mil

4. ABSTRACT

a) *Objective*. The primary and unique objective of this work is to demonstrate and validate placement, stability and performance of reactive amendments for treatment of contaminated sediments in ***active Department of Defense (DoD) harbor settings***. This project extends current pilot-scale testing of the application of activated carbon (AC) to decrease the bioavailability of polychlorinated biphenyls (PCBs) in contaminated sediment to near full-scale demonstration under realistic conditions at an active DoD harbor site. Because AC and the clay mineral associated with the proposed amendment may also sorb methylmercury (MeHg), thereby reducing its bioavailability, a subset of the data collected to meet biological and chemical performance objectives for this project will also focus on effectiveness of this amendment for MeHg-related endpoints. Demonstration and validation will focus on: placement of the amendment in deeper water areas that support vessel traffic; physical stability and longevity of the amendment in the sediment following placement; effectiveness of the amendment in controlling contaminant bioavailability over time; and response of the benthic community to the amendment application. Performance objectives for this project are specifically designed to assess physical endpoints (including placement, distribution, mixing and stability), chemical endpoints (including changes in PCB partitioning/sorption in the presence of the amendment), and biological endpoints (including tissue concentrations of contaminants and assessment of benthic community effects following placement). This range of monitoring endpoints will allow us to examine multiple facets of the amendment performance under an active harbor setting, including the feasibility of deep water material placement, the stability of material placement, the extent to which material placement reduces tissue residue concentrations of PCBs and mercury, together with the observable impact or enhancement of the structure, diversity, or density of the benthic community.

b) *Technology Description*. Reactive amendment technology for contaminated sediments is designed to enhance system recovery by introducing a chemical sorbent to impacted surface sediment. The chemical composition of the sorbent is selected based on the nature of sediment contamination and the extent to which amendment properties require specific implementation strategies. Among the amendments tested, AC has shown promising results at pilot-scale for reducing the bioavailability of hydrophobic organic contaminants such as PCBs. However, to date most applications have been pilot-scale and used granulated AC which may not be suitable for delivery and stability in deep water active harbors due to its low density. Instead, we intend to demonstrate an AC amendment over a relatively large-scale footprint (~20,000 ft^2) in an active DoD harbor area using a delivery method that has been proven effective in a wide range

of applications for the placement of various powder adsorptive and treatment materials (AquaBlok-based technology). The AC will be combined with a clay and aggregate substrate to form a composite particle that will readily fall through the water. The bentonite-based clay minerals are also known to have a high cation exchange and binding capacity for metals. Therefore, the composite amendment may also be effective for the co-occurring mercury contamination at the site. These particles will be installed using conventional deep water capping technology. The placement process, followed by natural (bioturbation) and ship-driven mixing will be relied on to incorporate the material into the surface sediment layer and we will monitor the subsequent degree of transport, mixing and reduction in bioavailability over time. Thus, the placement strategy developed for this demonstration project will be consistent with the general characteristics of the amendment and tailored to requirements for large-scale application of AC by conventional/proven technology. Our preliminary design calls for placement of the amendment as an initial surface sediment layer approximately 1 centimeter (cm) in thickness (or as determined appropriate following Task 1), using conventional cap placement methods. The initial layer is expected to be mixed vertically into the sediment by natural bioturbation and physical mixing by propeller wash. During this mixing period, we anticipate that the AC and clay mineral components will separate from the aggregate, distribute into the sediment and bind the target contaminants. The extent to which the amendment redistributes laterally and is mixed vertically after placement, and the extent to which this results in the anticipated reduction in bioavailability will be assessed at multiple post-placement sampling intervals and compared to conditions immediately following placement.

c) *Expected Benefits*. DoD faces increasing demands to address contaminated sediment sites, particularly for active harbor areas. In 2004, SERDP/ESTCP convened an expert panel workshop and identified high priority DoD needs with respect to in situ treatment [1]. This project represents an important effort to formalize the development, validation and implementation of in situ treatment technology in response to these needs identified by DoD. This capability has potentially far-reaching benefits for DoD and through successful demonstration and implementation is expected to result in (1) significantly improved remedy performance compared to conventional isolation capping, reduced construction costs compared to dredging, and reduced long-term monitoring costs compared to MNR, and (2) reduced carbon footprint and improved sustainability as compared to removal, transport and disposal associated with dredging, minimization of impacts to benthic communities as compared to conventional isolation capping and dredging approaches, and the potential to treat isolated areas such as beneath piers that are currently difficult to remediate and constitute high potential risks for recontamination of areas remediated through other more expensive approaches, such as conventional dredging. Because many of the DoDs contaminated sediment sites are only moderately contaminated, reactive amendments have the potential to find widespread application. Demonstration of these amendments with bioavailability-based monitoring techniques will form the basis for an integrated remedy strategy that can be duplicated at future sites. If sediment amendments such as AC can be easily delivered in composite particle form and be demonstrated to remain stable and perform effectively to reduce PCB and/or mercury bioavailability in active DoD harbors, the potential to the projected $1B DoD sediment clean up costs will be substantial.

5. PROBLEM STATEMENT

Active, deep-water DoD harbor areas pose a number of significant challenges to the effective use of traditional sediment remedies such as dredging, capping and monitored natural recovery

(MNR). Successful demonstration of delivery, stability and effectiveness of in-situ treatment materials that can address these challenges has the potential to reduce costs and recovery time frames for a wide range active DoD sites and provide a more effective alternative to traditional methods of remediation. Cleanup costs for contaminated sediments at DoD sites are estimated to exceed $1B. Cost effective remedies for sediment remediation at contaminated DoD sites are limited, particularly for active harbor areas. Currently, the primary remedial options for DoD sites include dredging, isolation capping, and Monitored Natural Recovery (MNR) [2]. Although in-situ treatment is described in EPA Guidance for Contaminated Sediment Remediation [2], large scale demonstrations, implementation and acceptance are generally lacking, and there have been no demonstrations in active DoD harbors. Dredging is expensive, energy intensive, can have adverse short-term effects, severely impacts the benthic community, can negatively impact surface water, cannot be applied near structural bulkheads and beneath piers, and its effectiveness is often hampered by the inability to remove contaminated sediments in and around the pier and structural areas that are common to active DoD harbors. Conventional sand-based isolation capping also impacts the benthic community, may be limited by vessel draft requirements, can be unstable in the face of ship and tug movements, and has minimal capacity to control sources. MNR is generally targeted to quiescent, depositional environments and is generally thought to be poorly suited to high-energy environments subject to significant vessel traffic. To date, the majority of the in situ reactive amendment applications have been small, pilot-scale efforts generally targeted to areas with minimal vessel traffic, obstructions or harbor activities. In addition, most of these efforts have focused on the use of granulated AC which may not be suitable for delivery and stability in deep water active harbors due to its low density. Extending these efforts to an active DoD harbor area where propeller wash, piers, bulkheads, deep water and a range of other common challenges associated with coastal installations is necessary to demonstrate the broader, more critical application for solving DoD's contaminated sediment challenge. Currently, no cost effective technology has been demonstrated that can meet this range of challenges.

6. TECHNOLOGY DESCRIPTION

a) *Technical Objectives*. The objective of this work is to demonstrate and validate placement, stability and performance of reactive amendments for in-situ treatment of contaminated sediments in active DoD harbor settings. Demonstration and validation will focus on: (1) proper design and selection of the amendment, (2) placement and physical stability of the reactive amendment in deeper water areas that support vessel traffic, (3) effectiveness of the amendment in reducing contaminant bioavailability over time and (4) quantification of changes to benthic habitat and benthic community structure. These demonstration and validation criteria will form the basis of the performance objectives for this project. Data collected in support of these performance objectives will provide multiple lines of evidence for assessing the effectiveness of amendment placement as an in situ strategy for limiting chemical bioavailability at contaminated sediment sites.

b) *Technology Description*. The technology to be demonstrated incorporates a combination of a reactive amendment, a conventional delivery system, and a suite of monitoring tools (Figure 1). The novel aspect of the technology involves the demonstration of a composite particle system which enables the delivery of a known and effective amendment in an active DoD harbor environment, particularly in areas where piers and structures limit traditional dredging and capping methods. The proposed amendments will be placed using a composite particle system (subject to pre-project phase lab optimization and verification) based on the AquaBlok, Ltd. technology platform. The primary reactive amendment will be a powder activated carbon (PAC) bound to a dense aggregate particle with appropriate clay minerals. AquaBlok utilizes a coated aggregate particle as the means for achieving positive and uniform placement of reactive amendments through a water column. This technology has been used to deliver a range of mineral-based reactive amendments. The anticipated formulation for this demonstration incorporates approximately 5% PAC, 10% clay and the remaining fraction of aggregate. Thus, from a placement perspective, the AquaBlok particles resemble small stones and can be handled and applied with a wide range of conventional construction equipment. Based on previous applications, we anticipate that the installation/application approach will allow utilization of conventional belt conveyor and/or long-stick excavator methods. The final amendment formulation and placement method will be optimized based on a range of factors, including chemical sorbent properties, system hydrodynamics, water depth, native sediment geotechnical properties, requirements for introducing the amendment directly into sediment versus as a component of a thin-layer cap and access to the areas where placement is required. The concurrent demonstration of robust monitoring techniques for assessing delivery, stability, and effectiveness in reducing bioavailability will be integrated within the project.

c) *Technical Maturity.* Based on a number of research and demonstration projects supported by SERDP/ESTCP and industry, reactive sediment amendments have emerged as an attractive remediation strategy. Significant bench scale testing of reactive amendments has demonstrated their applicability for binding contaminants into matrices that reduce aqueous phase concentrations and bioavailability [3-9]. Among the amendments tested, activated carbon has shown promising results for hydrophobic organic contaminants such as polychlorinated biphenyls (PCBs) [10-11]; where as other materials such as bentonite have shown a degree of effectiveness for binding/sorbing metals, such as mercury. Placement of amendments has been tested using a number of strategies including applied mixing [12], surface application (e.g., www.grasseriver.com), thin layer caps and geofabric mats [13], and natural mixing both as pure amendments or amendment mixtures [14] and in combination with a delivery matrix [15]. AquaBlok, as a technology to deliver powdered materials to sediments in the form of a coated particle, has been evaluated and demonstrated (US EPA SITE Program) and other projects have been performed which illustrate the capability of the technology to deliver reactive amendment materials through a water column. AquaBlok-based PAC materials are also being surface applied in a marsh setting under an existing ESTCP project [16]. However, this delivery technology has not been used to place PAC in a deep water setting. In addition to the PAC amendment, it is possible to engineer a particle to carry additional materials which could improve the sorptive capacity to bind metals, such as mercury. A number of new tools have also been developed to provide measures of the reduction in bioavailability achieved by the placement of these amendments, ranging from passive sampling devices [17-18] to integrated exposure and effects systems that combine sediment, porewater bioavailability, and biological metrics [1918]. To date, the majority of the in situ amendment efforts have been small, pilot-scale efforts in areas without limits to access and generally targeted to low velocity waters with minimal vessel traffic or harbor activities. Extending these efforts to larger scale footprints in active DoD harbor areas will demonstrate the broader and more critical application for solving DoDs contaminated sediment challenge.

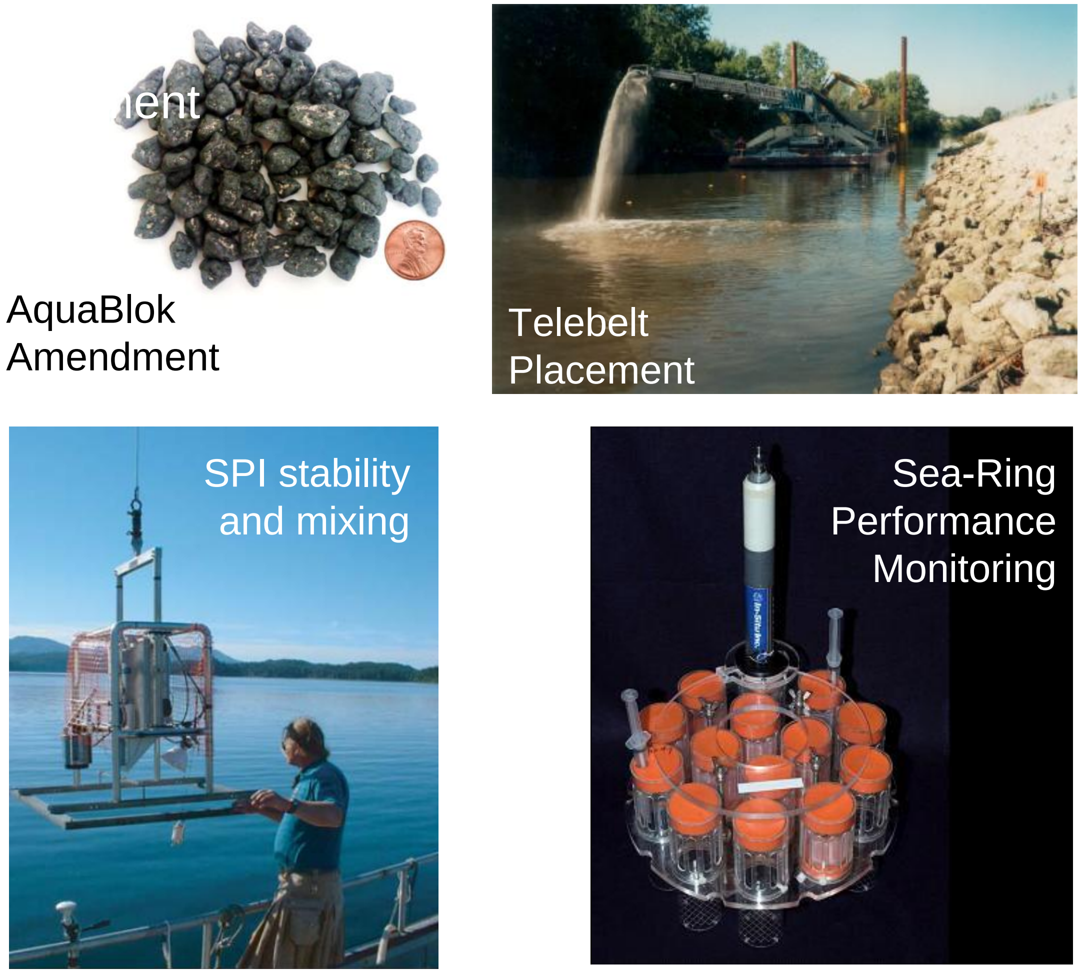


Figure 1. Components of the integrated remedy demonstration for active DoD harbors including the reactive AquaBlok amendment, a conventional Telebelt delivery system, the SPI profiling camera, and the SEA Ring monitoring suite.

d) *Technical Approach*. The technical approach for the project consists of four primary tasks including: Task 1 - Laboratory Amendment Treatability Studies with a Go/No-Go Decision; Task 2 - Full-Scale Field Demonstration; Task 3 - Post-Placement Monitoring; and Task 4 - Performance and Cost Analysis and Reporting. Based on a preliminary survey of potential Navy sites, field-scale demonstration of reactive amendment addition would occur in near-pier areas of the Puget Sound Naval Ship Yard and Intermediate Maintenance Facility (PSNS&IMF; Bremerton, WA). The site Remedial Project Manager has expressed interest in and agreed to support the work defined in this proposal. A suitable location has been identified at the SW corner of Pier 7, located at the shipyard's eastern end (Figure 2), where both PCBs and Hg (which is co-located with the PCBs) are listed as contaminants of concern. Site managers from other facilities (e.g., Pearl Harbor, Naval Station San Diego) have also expressed interest in the application of reactive amendments in active shipyard areas. At all of these sites elevated surface sediment concentrations of polychlorinated biphenyls (PCBs) and metals, such as Hg, are of concern and physical disturbance is dominated by ship and tug activity. A brief overview of each task is described below.

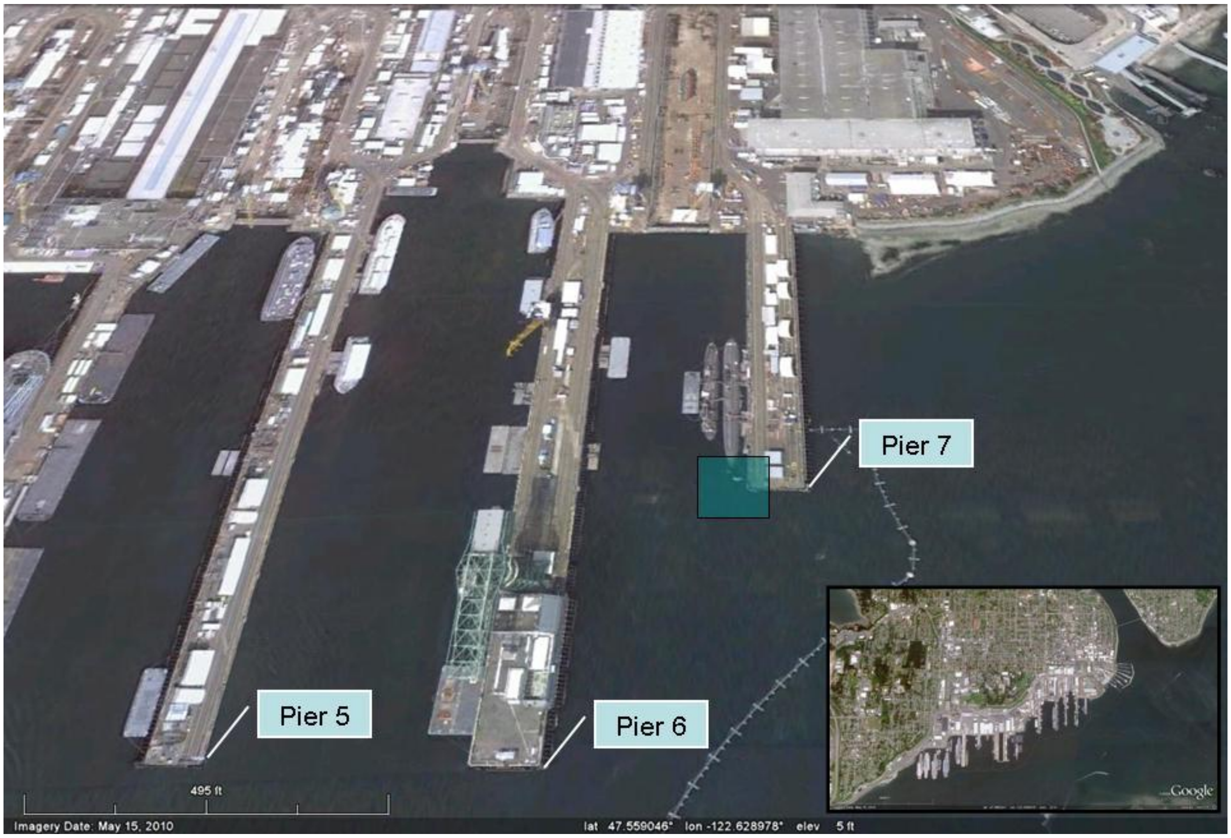


Figure 2. Puget Sound Naval Shipyard and Intermediate Maintenance Facility and Proposed Demonstration Site.

__Task 1 - Laboratory Amendment Treatability Studies.__ This effort, supported by leveraged funding from Puget Sound Naval Shipyard, will address several important aspects in selection and optimization of the amendment prior to a field demonstration. This task will incorporate:

i) On-site pre-screening that will include additional sediment sampling and analysis to further delineate contaminant concentrations in the near pier area (Pier 7). Twenty-five surface sediment samples (0–6 inches in depth) will be collected in areas between Piers 6 and 7, and analyzed for total PCBs using USEPA Method 4020 (the immunoassay method). This screening method has been applied to the determination of total PCBs in sediment, soil, and biological tissue [20-21] concentrations that are relevant to site conditions at PSNS&IMF, and has been perfected by staff at the Navy's SPAWAR laboratories. Results of this analysis will rapidly provide further delineation of total PCB concentrations and will allow for collection of sediment suitable for the laboratory studies as well as ensure the area selected for amendment placement contains sufficient sediment PCB concentrations so that potential changes in concentrations following amendment placement will be detected over time.

ii) Pre-demonstration testing to verify the effectiveness of different combinations of amendment materials in terms of reduction in contaminant bioavailability. The primary reactive amendment under consideration is powdered activated carbon (PAC) with a secondary clay mineral component. The dosing experiments will explore a range of anticipated formulations from approximately 2-5% PAC, 5-10% clay and the remaining fraction of aggregate. The tests will also evaluate two levels of mixing including a partial mix of the initial 1 cm layer to about 2 cm, and a fuller mix to about 5 cm. Testing will involve running standard 10-day amphipod and 28-day oligocheate bioassays to assess any potential adverse toxic effects/risk (via growth and mortality endpoints) from a) the unamended sediment, b) the uncoated aggregate that acts as the delivery mechanism for the AquaBlok, and c) the activated carbon-coated AquaBlok. Laboratory testing will also involve running standard 28-day bioaccumulation studies on site sediment treated with the reactive amendment formulations (Figure 3) as well as measuring any reduction in the diffusive flux of the contaminants to the overlying water using XAD beads, as described by Luthy et al, 2004 [10] and Zimmerman et al, 2004 [22]

iii) Pre-demonstration testing to verify potential visual monitoring tools such as the SPI camera system (including digital image analysis) for distinguishing the amendment from native site sediment. Testing will be carried out pre- and post-application and mixing of the amendment, via mechanical means, to the native sediment as shown in Figure 3.

Initial cost analysis and delivery system design will also be performed during this task.

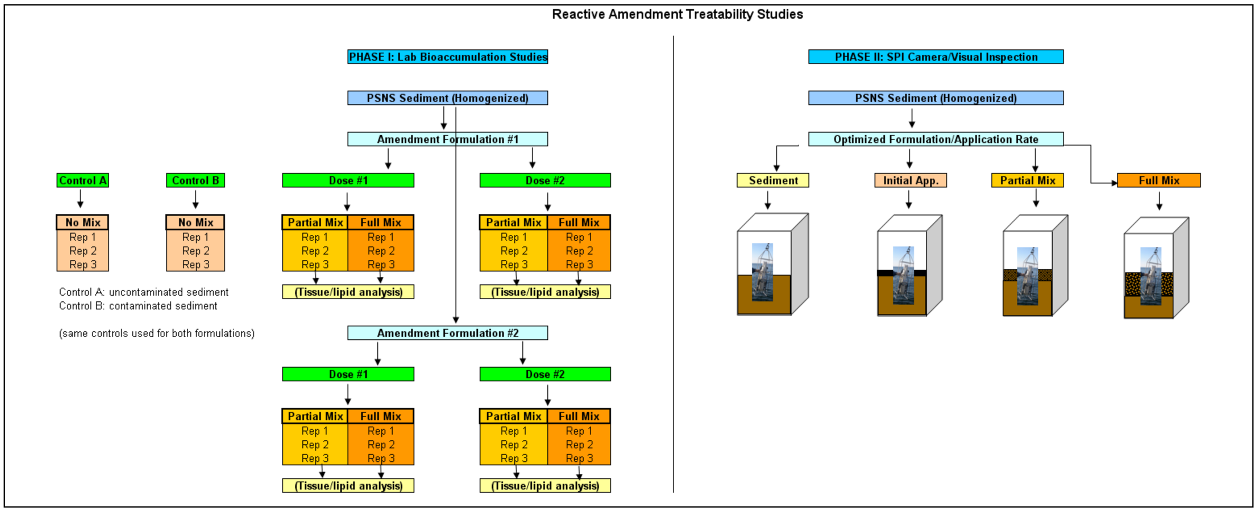


Figure 3. Laboratory Reactive Amendment Treatability Studies

Go/No-Go Decision – The results from Task 1 will provide the basis for the Go/No-Go decision point in the project. The purpose of the Go/No-Go is to provide a recommendation as to whether the full scale demonstration should move forward. If Task 1 is successful, then the amendment will have been shown to be effective in the lab thus significantly reducing potential risks for the full-scale demonstration. Thus lab effectiveness in reducing bioavailability of PCBs and mercury, and effective placement and short-term stability in the field will be the primary metrics for the Go/No-Go decision.

Task 2 - Full-Scale Demonstration. Based on the results from Task 1, the Demonstration Plan will be developed for the full-scale demonstration. Any final changes to the engineering design for the delivery and placement of the amendment will be determined during the development of the Demonstration Plan. Task 2 will entail *i*) a baseline monitoring event to establish current conditions and to define a performance baseline for comparison of post-amendment monitoring events and *ii*) delivery and placement of the selected amendment to a target footprint of ~1/2-acre. Incorporating any final optimization, the full-scale demonstration will utilize the amendment formulation defined in Task 1. The full-scale application will incorporate design considerations for placement of material in pier and structural areas where dredging is not a viable remediation option.

i. Baseline Monitoring. Prior to placement, baseline monitoring within the footprint will include chemical and biological characterization at 10 target stations, and broader geophysical mapping for specific measurements including bathymetry, current measurements, and SPI camera imagery of sediment composition. Geophysical data, which is available from previous investigations at PSNS [23-24], will be evaluated throughout the region of the amendment addition, whereas SPI data will be collected at ~50 stations. Sediment geotechnical characteristics will be performed at the 10 target stations and will include grain size, permeability and bulk density. Chemical characterization will be performed at the 10 stations and will include total organic carbon (TOC) analysis as well as whole-sediment PCBs and Hg/MeHg by conventional analyses and porewater PCB and Hg/MeHg using passive samplers at up to 10 target stations. Biological characterization at the 10 stations will include benthic tissue lipid content, and PCB congener and Hg/MeHg concentrations in tissue of native infauna and caged organisms. Additionally, benthic community composition will be performed at up to 10 target stations. We anticipate that this monitoring will take advantage of emerging SERDP technologies for passive sampling [19] and in situ exposures [25], and will be collaborative with the ongoing ESTCP propeller wash modeling project [26] and the proposed reactive mat project [27]. The following components are contemplated, subject to the findings of Task 1 and optimization during the development of the demonstration plan:

- Baseline geophysical conditions will be determined prior to final placement of the amendment. Baseline geophysical monitoring within the footprint will include targeted discrete characterization at 10 stations (corresponding to the chemistry stations), and broader geophysical mapping for specific measurements including bathymetry, current measurements, grain size analysis and SPI camera imagery of sediment composition. SPI data will be collected at ~50 stations. Physical stability analysis will be performed at the 10 stations and will include grain size, permeability and bulk density measurements. These measurements will support refinements to the amendment delivery/placement design as well as support broader understanding of amendment behavior at the site. We anticipate that portions of this characterization will be developed in collaboration with propeller wash project team.
- Sediment chemical characterization will be performed at a total of 10 stations. At these stations, undisturbed shallow (20 cm) surface sediment cores will be collected via a multicorer device (Ocean Instruments Inc.) and will be analyzed for total organic carbon (TOC) (Lloyd-Kahn method, modified 9060), black carbon, whole-sediment PCB congeners (SW-846 3545/8082) and whole-sediment Hg/MeHg (method). Sediment black carbon concentrations will be measured through a chemical and thermal oxidation method [28-29]. This method has been used to measure activated carbon concentrations at other amended sites (Grasse River, NY). The chemical and thermal oxidation method reduces significant losses of activated carbon that results from the commonly used low temperature thermal oxidation method and allows quantification of GAC at as low as 0.5%, depending on background carbon concentration and composition at the selected field site [28]. Native bulk sediment samples will be also be collected from these stations from a deployed Sediment Ecotoxicity Assessment Ring (SEA Ring) device developed under SERDP ER-1550 [25] (Figure 1). The SEA Ring is a multi-compartment, deep-water deployable, integrated system for accurately assessing exposure and effects in marine and estuarine systems. Exposure can be compartmentalized into water column, sediment-water interface, or surficial sediment exposures depending on variations of the inner chamber design, and the unit supports

passive samplers and water quality sensors capable of measuring a variety of important physical parameters. At the Bremerton site, the deployed SEA Ring device will house native bulk sediment, passive pore water sampling devices, and caged benthic organisms, and will deployed for a 28-day period. The use of this device ensures co-location of bulk sediment, pore water, and caged benthic organisms. Bulk sediment, pore water and caged benthic organisms will all be analyzed for PCB congener concentrations, as well as, potentially, for MeHg concentrations (discussed further below). Bulk sediment samples collected from the SEA Ring devices also will be analyzed for TOC and black carbon concentration. Concentrations of PCB congeners in sediment pore water will be evaluated through the deployment of polyethylene film devices housed within surface sediment exposure chambers on the SEA Ring apparatus. Polyethylene films have been shown as an inexpensive in situ method for measuring small changes in sediment pore water PCB congener concentrations over time [30-31]. Concentrations of MeHg in sediment pore water will be evaluated through the deployment of mercury-specific hydrogels, if hydrogel technology has advanced suitably to allow for ready deployment at this site. A recently funded SERDP research project (ER-1771; *Assessing Mercury and Methylmercury Bioavailability in Sediment Porewater Using Mercury-Specific Hydrogels*) to optimize their utility for field application. If the SERDP project deliverables have advanced to the stage that hydrogels could be deployed within the SEA Ring apparatus, then pore water MeHg assessment analogous to pore water PCB assessment will be possible. Currently there are no standard passive sampling strategies for MeHg that allow integrated measurement of changes in pore water concentration over time, therefore any hydrogel data would be considered proof-of-concept data for this project and support the development of hydrogels as a field-based bioavailability screening tool.

- Biological characterization will include the analysis of PCB congener and Hg/MeHg concentrations in tissue of caged test organisms indigenous to the area, including amphipods, mysids, and bivalves. Native benthic community composition will also be included as part of the biological characterization. For infaunal organisms, Ponar grab samples will be collected from the five locations targeted for SEA Ring deployment. Benthic invertebrate community census will be evaluated prior to cap placement to establish baseline conditions and will be compared to surveys post-amendment placement to assess potential impacts of amendment material on the native benthic communities. Invertebrates will be identified to the lowest possible taxonomic level and enumerated, with results used to compute comparative parameters such as organism density, species richness or evenness, and various benthic community indices such as Benthic Index of Biotic Integrity [B-IBI] [32]. These comparative parameters will allow for evaluation of potential impacts that may result from placement of GAC at the sediment surface.

ii. *Amendment Placement.* Following baseline data collection, a final evaluation of the installation and placement requirements will be performed. Baseline monitoring data, including bathymetry will be evaluated together with under pier conditions, including spacing of pilings, physical stability of the sediments, anticipated ship traffic, prop wash issues, etc. The team will carefully evaluate physical site limitations as they relate to potential equipment that may be utilized in the full-scale demonstration. With this analysis, a final placement footprint will be determined and all installation control measures will be evaluated (i.e. silt curtains, etc.). The following components are contemplated, subject to the findings of Task 1, the baseline monitoring and optimization during the development of the demonstration plan:

- The physical installation of the composite particle reactive amendment materials will utilize commercially available equipment that can be sourced in the region. Material will be placed by an articulated conveyor (telebelt or similar) operating from a flat deck barge. Figure 1 shows this equipment during the field installation of AquaBlok material on the Ottawa River in Toledo, Ohio. During this project, it was demonstrated that this equipment could place very thin layers of dry bulk materials through the water on a uniform basis. The equipment was used for application from both the shore and from a barge in the river. This is a proven method that has been successfully used on sediment capping projects within Puget Sound. The telebelt is a telescoping conveyor with hopper. A loader on the barge will be used to feed material to the telebelt hopper. The operator will then move the telebelt discharge point throughout the placement operation to achieve a relatively uniform application rate throughout the placement area. Material will be discharged from the telebelt just above the water surface. The material will then fall through the water column to the sediment. This method will allow placement of material in both open water areas adjacent to the dock and to areas under the dock (based on clearances provided by NAVFAC). The telebelt will be equipped with DGPS for positioning in open water areas. This will allow tracking of actual placement location throughout the placement process. The material will be dispersed throughout the placement area in a relatively uniform fashion. In the underdock areas, a predetermined amount of material will be placed between adjacent piling bents, based on the pre-determined application rate and area between adjacent piling bents. Engineering services will be provided by Dalton, Olmsted & Fuglevand Inc. (DOF). DOF has a local office in Silverdale Washington, approximately 15 minutes from the site. Engineering plans and specifications will be prepared for the work. A contractor bid package will be prepared and circulated to qualified contractors. DOF will assist with review of contractor submittals.
- During placement, optical backscatter instruments and current meters will be deployed near the down-current boundary of the target area to detect any significant off-site transport of the amendment.

Task 3. Post-Placement Monitoring. Four post placement monitoring events will be conducted over the two years following placement (T=0-1-mo, T=6-mo, T=18-mo and T=30-mo). Monitoring will include physical, chemical and biological characterization matched to the same target stations used during baseline monitoring; in addition, the monitoring will allow for adaptation in the event that measurements indicate significant movement or off-footprint transport of the amendment. Finally, specific monitoring including bathymetry and SPI may be conducted to target ship/tug movement events to evaluate the level of localized disturbance to the amendment associated with these disturbance activities. The disturbance assessment will be coordinated and leveraged with ESTCP Project ER-1031.

- *T=0 to 1-mo*. Immediately following placement, SPI imagery will be collected at the same 50 locations that formed the baseline survey to characterize the thickness (up to 20 cm) and spatial uniformity of the placement, and the surface area covered during the initial placement. Placement will be evaluated through the SPI images and collection of core samples. The core samples will be evaluated for the applied layer thickness (visual measurement). Results from the immediate post-placement monitoring will serve as a baseline from which to evaluate the potential redistribution of amendment material over time. Post-placement monitoring will allow for evaluation of the "physical endpoint" performance objectives, including the feasibility of uniform amendment placement in deeper water areas that support vessel traffic. In addition, post-placement monitoring will allow for evaluation of gas formation (ebullition) after amendment placement. While gas ebullition has been observed at various freshwater sites where either reactive mats or sand caps have been used, the goal of this demonstration project is to place a thin layer (~1 inch) of the amendment over the 20,000 ft^2 demonstration site and allow natural (bioturbation) and ship-driven mixing to incorporate the material into the surface sediment layer as opposed to placing a reactive mat or a cap at the site. Additionally, the formulation of the amendment will utilize a non-swelling type of bentonite therefore decreasing the likelihood of mat-like layer forming after placement. Because of the nature of the amendment placement and site characteristics – thin-layer, non-swelling, natural mixing processes – the likelihood of gas formation is minimal.

- *T= 6-mo, 18-mo and 30-mo*. Post-placement monitoring will follow the same physical, chemical, and biological monitoring as the preplacement baseline monitoring. In summary, bulk sediment samples will be collected from 10 stations and analyzed for TOC and black carbon. At the stations at which the SEA Ring device is deployed, sediment will be analyzed for PCB congeners and MeHg. Pore water concentrations of PCB congeners will be measured at the same five stations through the deployment of polyethylene film devices housed within the surface sediment in the SEA Ring apparatus. As discussed under Task 2, porewater MeHg concentrations will be measured by mercury-specific hydrogels if the hydrogel technology (analogous to the polyethylene film devices for PCB determination) has advanced to a deployable stage by this point in the project. The tissue of caged benthic organisms within the deployed SEA Rings will be analyzed for concentrations of PCB congeners and MeHg. Native benthic community surveys for infauna will be conducted on ponar sediment grab samples collected from the five locations targeted for SEA Ring deployment.

  The analysis of post-placement contaminant concentrations in pore water and caged benthic organisms will be used to evaluate a potential reduction in contaminant bioavailability over time, as a result of the AC placement. In turn, this will allow for an evaluation of the performance objectives that are designed to asses "chemical endpoints", including PCB partitioning to AC and to polyethylene samplers, and "biological endpoints", including benthic tissue concentrations of PCBs and mercury. Benthic community assessments conducted pre- and post-placement also will contribute to the "biological endpoint" objective through an evaluation of a potential change in the benthic community following amendment placement.

  If the SPI camera is shown to be effective at distinguishing the amendment from the native sediment (Task 1), SPI camera imagery will also be conducted within the study cell, post GAC placement. The post-placement images will be compared the SPI camera images collected immediately following placement. These images, in addition to the analysis of black carbon concentrations from sediments collected within the cell will be used to evaluate the lateral and vertical changes in GAC distribution over time. This will contribute to the evaluation of the "physical endpoint" performance objective relating to the placement and distribution of the GAC over time.

Task 4 - Performance and Cost Analysis and Reporting. Performance analysis and reporting will utilize the baseline and post-placement monitoring relative to the metrics described below to document the effectiveness of the amendment under active DoD harbor conditions. Performance is expected to be determined by factors associated with the placement and the subsequent redistribution of the amendment into native sediment (physical endpoint objectives), the partitioning of PCBs to GAC and polyethylene passive samplers (chemical endpoint objectives), and tissue concentrations of contaminants in benthos and changes in the benthic community following amendment placement (biological endpoint objectives). The range of monitoring endpoints will allow us to examine multiple facets of GAC placement, including the feasibility of material placement, the stability of material placement, the vertical mixing of the GAC with surface sediments, the reduction in pore water concentration and bioavailability of target chemicals in benthic organisms, and the degree of any deleterious effects observed for the benthic community. Cost analysis and reporting will utilize data generated for the construction and monitoring phases to estimate fixed and unit area costs for the remedy. All costs will be monitored and reported throughout the duration of the project. Costs will be reported via the SEMS reporting tool, Program Reviews and Final Technical and Cost and Performance Reports. In collaboration with our partners, we will adjust this analysis to provide estimates for scaling up the remedy to larger areas. Monitoring costs will be evaluated for both the demonstration design, and other scaled designs using a subset of the techniques to be employed here. Cost details are provided in Table 1.

e) *Technical Risks.* Potential concerns associated with placement and performance of in situ amendments includes placement accuracy, degree of mixing, and short- and long-term stability and effectiveness of the remedy. Previous applications suggest that the placement accuracy and stability under relatively quiescent conditions is acceptable, but it is known that placement under piers and around obstructions presents significant challenges, which are common to many military and commercial shipyards. Task 1 and the associated Go/No-Go decision point are designed to reduce these risks prior to full-scale demonstration. Monitoring and performance metrics for the project are designed to assess the feasibility and effectiveness of the amendment directly for a representative active DoD harbor environment.

Table 1. Cost Tracking

Remedy Implementation	▪ Costs associated with remedy installation design ▪ Costs associated with reactive amendment placement, including material costs
Baseline Characterization	▪ Costs associated with labor ▪ Costs associated with material purchase and rentals ▪ Analytical costs ▪ Costs associated with analysis and data interpretation
Post-Remedy Monitoring	▪ Costs associated with labor ▪ Costs associated with material purchase and rentals ▪ Analytical costs ▪ Costs associated with analysis and data interpretation
Waste Disposal	▪ Costs associated with IDW disposal; the reactive amendment remedy does not involve material removal or disposal
Operation and Maintenance	▪ In general, these costs are borne by the base and are not

Costs	part of this study. If available, these costs will be obtained by the project team and will be reported in the final report. If unavailable, literature-reported costs may be used to supplement our understanding of costs.
Long-term Monitoring	▪ In general, these costs are borne by the base and are not part of this study. If available, these costs will be obtained by the project team and will be reported in the final report. If unavailable, literature-reported costs may be used to supplement our understanding of costs.

f) *Related Efforts.* This work builds on and integrates recent research and development projects for amendments, passive sampling, and in situ monitoring funded by SERDP and ESTCP, as well as industry funded studies. It also builds on extensive site characterization and ongoing work to characterize the fate and transport of PCBs and other chemicals at the Bremerton and Pearl Harbor sites. We anticipate that this project will build on laboratory treatability studies of amendments and verification of the amendment delivery system and stability, funded primarily by funds sought from the NESDI program. Baseline characterization of sediment contaminant concentrations, sediment physical characteristics, bathymetry, and hydrodynamic conditions establish a strong foundation for the work proposed herein. We anticipate that this effort may also serve as a significant opportunity for collaboration with complimentary demonstrations recently funded under ESTCP (i.e., Evaluation of Resuspension from Dredging, Extreme Storm Events, and Propeller Wash in DoD Harbors (ER-1031)). Additionally, if funded, an opportunity will exist to work with and leverage against two other related projects (Demonstration of a Reactive Mat System for Capping Contaminated Sediments [11 E-ER1-004] and Demonstration and Commercialization of the Sediment Ecosystem Assessment Protocol (SEAP) [11 E-ER1-012] and provide the added benefit of comparing two promising reactive amendment approaches simultaneously and allow for cost- and resource-sharing at the same site.

Supplemental funding will also be available from the site manager (via the Navy's ER-N program) as well as from the Navy's Environmental Sustainability Development to Integration program (NESDI) for the NESDI project entitled *Demonstration of Reactive Amendments for Contaminated Sediments in Near Structures and Piers.* This funded project specifically aims to demonstrate that the addition of reactive amendments to sediment will be effective for addressing contamination concerns in active Navy harbors and shipyards. Particularly, the project funded through NESDI will focus on those areas in shipyards and harbors that cannot be dredged easily because of limited access or concerns regarding impacts of dredge activity on the structural integrity of piers, docks, or bulkheads.

7. EXPECTED DOD BENEFIT

DoD faces increasing demands to address contaminated sediment sites, particularly for active harbor areas where traditional low-impact remedial options such as capping and monitored natural recovery (MNR) may be limited in effectiveness. In 2004, SERDP/ESTCP convened an expert panel workshop on "Research and Development Needs for the In Situ Management of Contaminated Sediments" [1]. High priority DoD needs identified with respect to in situ treatment included: A21. Develop and demonstrate engineering platforms for amendment delivery and treatment; A22. Perform parallel field demonstrations of multiple in situ treatment technologies to provide performance comparison; A23. Refine and demonstrate tools and metrics to evaluate pre- and post-remedial impacts of in situ treatment; A24. Develop and assess innovative in situ amendments under a range of sediment conditions; and A25. Develop and/or modify equipment for implementation of in situ treatment that minimizes contaminant release during deployment.

This project represents an important effort to formalize the development, validation and implementation of in situ treatment technology in response the needs identified above. This capability has potentially far-reaching benefits for DoD and through successful demonstration and implementation is expected to result in:

- Significantly improved remedy performance compared to conventional isolation capping, reduced construction costs compared to dredging, and reduced long-term monitoring costs compared to MNR.
- Reduced carbon footprint and improved sustainability as compared to removal, transport and disposal associated with dredging, minimization of impacts to benthic communities as compared to conventional isolation capping and dredging approaches, and the potential to treat isolated areas such as beneath piers that are currently difficult to remediate and constitute high potential risks for recontamination of areas remediated through other more expensive approaches, such as conventional dredging.

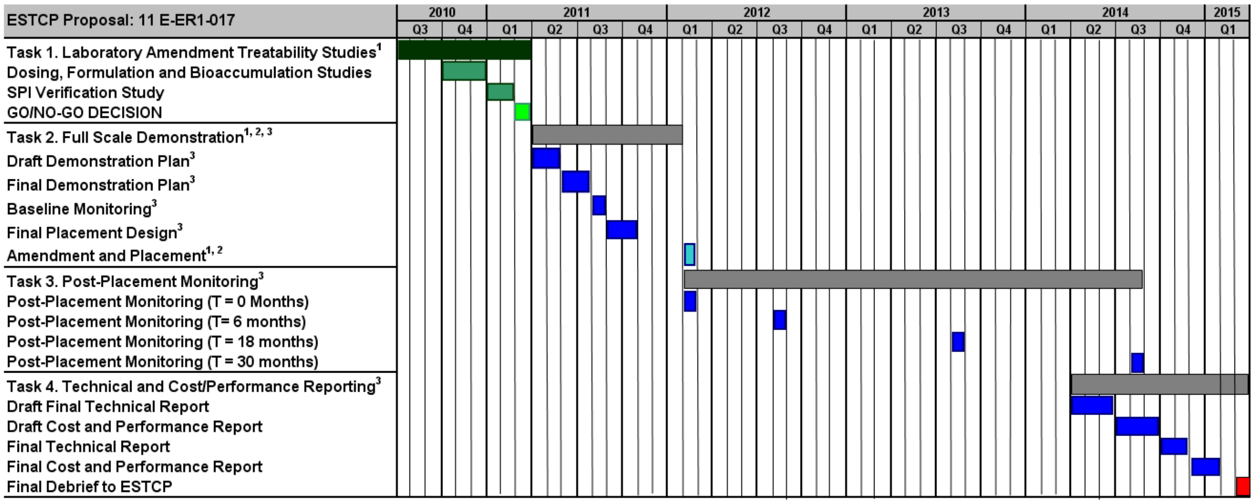
Because many of the DoDs contaminated sediment sites are only moderately contaminated, reactive amendments have the potential to find widespread application. Demonstration of these amendments with bioavailability-based monitoring techniques will form the basis for an integrated remedy strategy that can be duplicated at future sites. If sediment amendments such as AC can be easily delivered in composite particle form and be demonstrated to remain stable and perform effectively to reduce PCB and/or mercury bioavailability in active DoD harbors, the potential to the projected $1B DoD sediment clean up costs will be substantial.

8. SCHEDULE OF MILESTONES

The project schedule, milestones and deliverables are summarized in the Gantt chart in Figure 4. The predemonstration tasks (Task 1), supported with leveraged funded by PSNS include the Amendment Laboratory Treatability studies and a go/no-go decision point. The Full Demonstration tasks (Task 2) will preparation of the Demonstration Plan, baseline monitoring within the footprint and placement of the amendment at the site. Post placement monitoring events (Task 3) will be conducted over the two years following placement (T=0-1-mo, T=12-mo, T=24-mo). The post-demonstration tasks (Task 4) include final report and cost and performance reporting and a final debrief to ESTCP upon completion of the project.

9. TECHNOLOGY TRANSITION

The in-situ treatment approach using reactive amendments will be integrated into DoD operations through various publication and seminar-related opportunities such as the Navy RPM Newsletter and Currents Magazine, EPA Tech Trends Newsletter, Navy RITs Seminar Series, Navy CECOS program, and EPA Clu-in.org web seminars. Regulatory acceptance will be sought by working with the USEPA Contaminated Sediments Advisory Group. In the Puget Sound, King County regulators have expressed strong interest in the use of reactive caps for contaminated sediment. This project activity, combined with existing regulatory interest and approval will greatly accelerate acceptance of this technology. It is anticipated that validated methodologies will also be transferred via our industry partner (AquaBlok, Ltd.), and future field applications will be supported via existing DoD contractors and subcontractors. The technical guidance will be peer reviewed within Navy Workgroups, USEPA, and USACoE (ERDC) and with selected site regulatory entities. Results will be published.



Note: Monthly financial reports, quarterly progress reports and annual In Progress Reviews (IPR) are accounted for but not shown on Gannt Chart.

Figure 4. Schedule of Milestones.

10. DISPOSITION OF EQUIPMENT

It is not expected that any major equipment will be purchased for this project.

11. PERFORMERS

Dr. Bart Chadwick (Navy) will be the principal investigator (PI) for this project. With over 20 years of experience, he brings knowledge of contaminant fate and transport, sediment dynamics, and sampling technologies/methodologies to the project. Ph (619) 553-5333; bart.chadwick@navy.mil.

Dr. Dick Luthy (Stanford Univ.) will be senior advisor to the project and will also be the senior scientist in charge of bioavailability studies using passive sampling devices. Dr. Luthy has focused much of his research on amendments and the environmental behavior and availability of organic contaminants and the application of these approaches to the control of contaminant bioavailability and the improvement of water and sediment quality. Ph (650) 725-9720; luthy@standford.edu.

Dr. Joe Germano (Germano & Associates) will be the senior scientist in charge of SPI investigations. He has over two decades of experience working with capping projects and studying benthic recolonization an ecosystem recovery of aquatic sediment sites. Ph (425) 865-0199; joe@remots.com

Mr. John Collins (Aquablok, Ltd.) will provide technical support for amendment formulation and placement design. Aquablok will also serve as our industry partners and lead the effort to transfer the technology to the commercial sector. Ph (419) 385-2980; JCollins@aquablokinfo.com

Mr. Robb Webb (Dalton, Olmstead, and Fuglevand (DOF) will be the lead design engineer for the placement of the amendment at the site and will oversee the contractor team during placement. DOF services will be provided by Rob Webb PE, Nancy Case O'Bourke PE and Rich

May PE, all of whom have extensive experience in sediment remediation and marine construction. Additionally, Mr. Webb and Mr. May have experience working at the Bremerton Naval Complex and are very familiar with conditions within Sinclair Inlet. DOF has significant experience with many of the marine contractor’s active within the Puget Sound region.