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Work Plan for the Demonstration of Activated Carbon Amendments

Hunters Point Naval Shipyard
San Francisco, California

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Contents

Section **Page**

Acronyms and Abbreviations ..... **v**

1.0 Introduction **1-1**
1.1 Conceptual Site Model and Study Site Selection 1-1
1.1.1 Study Site Selection 1-2
1.2 Amendment Selection and Placement Design 1-3
1.3 Monitoring Design 1-3

2.0 Amendment Selection and Placement Design **2-1**
2.1 Technology Description 2-1
2.1.1 Contaminated Sediment Remediation 2-2
2.1.2 Contaminant Sorption in Sediments 2-2
2.1.3 In Situ Sorbent (Reactive) Sediment Amendments 2-3
2.1.4 AquaGate Composite Aggregate Technology 2-5
2.1.5 SediMite Technology 2-5
2.1.6 Application Methods 2-6
2.2 Amendment Selection and Placement 2-8

3.0 Monitoring Test Design **3-1**
3.1 Selection of Technology Components 3-1
3.2 Study Design 3-1
3.3 Baseline Characterization and Monitoring Activities 3-2
3.3.1 Characterization and Monitoring Schedule 3-2
3.3.2 Monitoring Design 3-2
3.4 Field Testing 3-4
3.4.1 Physical Characterization 3-4
3.4.2 Chemical Characterization 3-5
3.4.3 Biological Characterization 3-6
3.5 Sampling Plan 3-6
3.5.1 Calibration of Analytical Equipment 3-7
3.5.2 Quality Assurance Sampling 3-7
3.5.3 Decontamination Procedures 3-7
3.5.4 Sample Documentation 3-7

4.0 Field Activities and Data Collection **4-1**
4.1 Site Preparation 4-1
4.1.1 Site Access 4-1
4.1.2 Permitting 4-1
4.1.3 Radiological Work Instructions 4-1
4.1.4 Training 4-2
4.1.5 Subsurface Utility Clearance 4-2
4.1.6 Site Survey 4-2

4.1.7 Equipment Staging / Storage 4-2
4.2 Investigation-Derived Waste Management 4-3
4.3 Pre-Carbon Placement Monitoring Event 4-3
4.3.1 Mobilization 4-3
4.3.2 Sampling Procedures 4-4
4.3.3 Demobilization 4-6
4.4 Carbon Amendment Placement 4-6
4.4.1 Equipment 4-6
4.4.2 Procedures 4-7
4.4.3 Quality Control Procedures 4-7
4.5 Post-Placement Monitoring Events 4-7

5.0 Data Analyses and Reporting 5-1
5.1 Data Validation 5-1
5.2 Data Management 5-1
5.3 Data Evaluation 5-2
5.4 Reporting 5-3

6.0 References 6-1

Tables

2-1 Methods for Placement of Granular Materials
3-1 Sample Analyses Summary
3-2 Analytical Methods Summary

Figures

1-1 Site Location Map
1-2 Map of HPNS with Parcel Boundaries, Including Parcel F with Offshore Sediments
1-3a Proposed Location of 1-acre Amendment Study Site along the MLLW Contour in South Basin, HPNS
1-3b Proposed Location of 1-acre Amendment Study Site along Selected Bathymetry Contours in South Basin, HPNS
1-4 FS Alternative 3: In Situ Stabilization
1-5 FS Alternative 5a: Focused Removal and Backfill with AC Material
1-6 FS Alternative 6a: Focused Removal with Modified Shoreline and Backfill with AC Material
1-7 CSM for South Basin Sediments
1-8 Sediment Transport Processes in South Basin
2-1 Technology Demonstration – Reactive Amendment, Conventional Delivery System, and a Suite of Monitoring Tools
2-2 AquaGate Composite Particle Technology
2-3 AquaGate: Crushed Stone Core Coated with a Combination of Bentonite-Based Clay and Powder-Activated Carbon Materials
2-4 Typical SediMite Pellets Used in Sediment Application

2-5 SediMite Pellets Breaking Down into GAC (Step 3) and Mixing into the Sediment (Step 4)
3-1 Example of Cores Used for in Situ Bioaccumulation Analyses
3-2 Petite Ponar Grab Used for the Benthic Invertebrate Surveys
3-3 Passive Samplers Include (But Not Limited to) SPME Technique: Conceptual Model (Left); SPME Fiber and SPMEs in Steel Mesh Envelope Applicator (Right)
3-4 SPI Camera (Left) and SPI Image (Right)
3-5 Conceptual Sampling Location Layout of the 10 Multimetric Sampling Stations within Each Amendment Plot Shown in Figure 1-3
3-6 South Basin Proposed Sampling Locations

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Acronyms and Abbreviations

AC	activated carbon
ANOVA	analysis of variance
APP	Accident Prevention Plan
BC	black carbon
bss	below sediment surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Contract Laboratory Program
cm	centimeter
CQCP	Construction Quality Control Plan
CSM	conceptual site model
CSO	combined sewer overflow
DoD	United States Department of Defense
EDD	electronic data deliverable
EWI	Environmental Work Instruction
FS	feasibility study
GPS	global positioning system
HOC	hydrophobic organic contaminants
HPNS	Hunters Point Naval Shipyard
HSD	Honestly Significant Difference
IDW	investigation-derived waste
KCH	CH2M HILL Kleinfelder, A Joint Venture
LOI	loss on ignition
MLLW	mean lower low water
MNR	monitored natural recovery
NAVFAC	Naval Facilities Engineering Command
Navy	United States Department of the Navy
NIRIS	Naval Installation Restoration Information System
OC	organic carbon
OM	organic matter

PAC	powder activated carbon
PCB	polychlorinated biphenyl
PRC	performance reference compound
QA	quality assurance
QC	quality control
RASO	Radiological Affairs Support Office
ROD	Record of Decision
RPM	Remedial Project Manager
SAP	Sampling and Analysis Plan
SOP	Standard Operating Procedure
SPAWAR	Space and Naval Warfare Systems Center Pacific
SPI	sediment profile imagery
SPME	solid-phase microextraction
SSHP	Site Safety and Health Plan
TOC	total organic carbon
USEPA	United States Environmental Protection Agency

1.0 Introduction

The primary objective of the work described in this plan is to demonstrate and validate placement, stability and performance of reactive amendments for in situ treatment of contaminated sediments at a test site within Parcel F on Hunters Point Naval Shipyard (HPNS; Figures 1-1 and 1-2). This work plan is produced by SPAWAR and the work will be performed by KCH (CH2M HILL-Kleinfelder Contractor group) under contract N62473-09-D-2622 CTO 0059. KCH has developed the Sampling and Analysis Plan (SAP) under a separate cover.

This project expands the pilot-scale testing (Luthy et al., 2009) of the application of activated carbon (AC) to decrease the bioavailability of polychlorinated biphenyls (PCBs) in contaminated sediment to near full-scale demonstration (1 acre test site) under actual field conditions. The evaluation will be conducted under field conditions at the South Basin of HPNS, San Francisco, California (Figures 1-3a and 1-3b). Demonstration and validation will focus on the following monitoring endpoints to evaluate:

- Placement of the amendment in Parcel F sediments in South Basin;
- Physical stability and longevity of the amendment in the sediment following placement; and
- Effectiveness of the amendment in controlling contaminant bioavailability over time.

Performance objectives for this project are specifically designed to assess monitoring physical endpoints (including initial placement, distribution, mixing and stability), chemical monitoring endpoints (including changes in PCB partitioning/sorption in the presence of the amendment), and biological endpoints (including assessment of benthic community effects following placement). This range of monitoring endpoints will allow examination of the amendment performance under several proposed Feasibility Study (FS) remedial options for South Basin. The FS (BAI, 2007) describes six different remedial option alternatives, three of which are summarized in Figures 1-4 to 1-6. These remedial options include Alternative 3 In-Situ Stabilization (AC amendment added to existing sediment with or without mixing) and Alternatives 5a and 6a Focused Removal/Backfill (some sediment removals with backfill of AC amended material). This study will enhance field knowledge of the feasibility of intertidal and subtidal AC material placement, the stability of AC material placement over set periods, and the degree to which AC placement reduces pore water and benthic tissue residue concentrations of PCBs over set periods. Study results should help selection of the preferred remedial alternative in Parcel F sediments at South Basin.

1.1 Conceptual Site Model and Study Site Selection

The FS (BAI, 2007) and FS Data Gaps Investigation (Battelle et al., 2006) provide a conceptual site model (CSM) for the South Basin contaminated sediments that can serve to assist the site selection process for this amendment study. The CSM, summarized in

Figure 1-7, indicates that the primary exposure pathway for ecological receptors is the ingestion of contaminated sediment and prey. PCBs enter the food chain through this pathway and bioaccumulate in upper trophic level receptors (e.g., piscivorous and invertebrate-eating birds, fish, and shellfish). PCBs also contribute to an unacceptable potential human health risk from the consumption of shellfish.

Two apparent major source areas of PCBs to South Basin have been identified: the Parcel E-2 landfill area to the north and Yosemite Creek to the west.

There appears to be a physically separate plume of PCB contaminated sediments coming from Yosemite Creek (also known as Slough) on the west side of South Basin.

Because PCBs tend to adsorb to fine-grained sediment particles and organic matter, sediment transport processes (i.e., re-suspension, transport, and deposition) are important contaminant transport pathways in South Basin. Bioturbation is also an important fate and transport process. The smooth vertical PCB profiles in sediment cores indicate that overall, the sediment bed in South Basin is relatively stable and undisturbed. Sediment stability analyses support this observation; scour depths of less than 10 centimeters (cm) are predicted in large storm events (i.e., those with a 25-year return period), and little evidence of past erosion is apparent in the sediment cores (Battelle et al., 2006).

Sediment transport processes in South Basin are shown in Figure 1-8. Because of its restricted circulation, tidal currents in South Basin are very weak. Waves are likely to be the dominant sediment resuspension mechanism because the basin is shallow and open to the southeast, which is the direction of the prevailing winds during winter storms. The dispersal pattern of PCBs, with higher concentrations nearshore and decreasing concentrations offshore, is consistent with wave-influenced and tidally influenced sediment transport. Storm waves breaking along the shoreline suspend fine, low-density sediments in the nearshore region. A return flow near the bottom of the water column (balancing the shoreward flow due to waves at the surface of the water column) transports the sediments away from the shoreline and into South Basin.

Biological activity mixes the newly deposited surface sediment into the sediment bed. The majority of the biological activity takes place in the upper 10 cm of sediment, with decreasing biological activity with increasing depth below 10 cm. The mixing of surface and subsurface sediments via bioturbation tends to produce a smooth PCB profile (i.e., gradually increasing concentrations with increasing depth in the sediment to a subsurface peak, and a gradual decrease in concentration below the peak). PCB flux calculations indicate that the mass of dissolved-phase PCBs released to the water column from the sediment bed from bioturbation, diffusion, and porewater advection is small compared to the estimated average annual PCB load to San Francisco Bay from urban runoff (Barajas, 2007).

1.1.1 Study Site Selection

The proposed general study location shown in Figure 1-3 was selected to meet several criteria that are important for a successful demonstration of the technology. The surface sediments on the north side of South Basin contain a range in PCB levels that are sufficient for this demonstration. The study area shows a range of surface sediment concentrations around 1,000 micrograms per kilogram total PCB so that any reductions in tissue PCB

concentration can be demonstrated, with few non-detects for the lower concentration congeners. The physical and chemical properties of the sediment in this area are also similar to the sediments targeted for potential in situ within the proposed remedial footprints in the feasibility study (as illustrated on Figures 1-4, 1-5, and 1-6). This general pilot area was also located in an area unlikely to be affected by potential contamination from offsite sources.

Earlier work (Luthy et al., 2009) was done in very shallow intertidal areas. This study will be conducted in deeper water farther offshore that will be more representative of the depths where the United States Department of the Navy (Navy) may utilize the full-scale technology (near the mean low water level and some combination of intertidal and subtidal areas). This will allow the placement techniques to be appropriately assessed relative to conditions that will be encountered during full-scale implementation. Luthy et al. (2009) proposed that the small size of his test plots (370 square feet) allowed recontamination from the surrounding outside unamended sediments to confound his later monitoring results. By utilizing a larger area (1 acre), the study will attempt to reduce the impact of any recontamination to the margins of the test site. The study area is also outside most of the areas considered for dredging, but still within areas considered under Remedial Alternatives 3, 5, and 6 (additions of AC amendment). The 1-acre box shown in Figure 1-3 will be split into two halves (one north and one south, each with both intertidal and subtidal components) with each half demonstrating a different type of amendment (see Section 2). Each half-acre plot does not need to be contiguous with the other but may be connected or separated to facilitate amendment placement or other design requirements. The precise location and configuration of the pilot test plot (and sampling locations) will be established after a pre-mobilization site walk with the selected contractor(s), which will allow specific equipment and access issues to be considered for implementation.

1.2 Amendment Selection and Placement Design

Two different amendment types will be demonstrated (see Section 2) to provide a contrast to earlier amendment studies at HPNS (Luthy et al., 2009). The carbon amendments selected are commercially available and have been used at other locations throughout the United States. This demonstration will provide site-specific data to allow the Navy to select which types of amendments might be applicable to various South Basin areas under remedial consideration. Placement design will be specific to the type of amendment, but it is expected that a barge-based delivery system will be used since the site is so far offshore. Instead of actively mixing the amendment into the sediment, a thin layer of the materials will be mixed into the surface sediments by bioturbation.

1.3 Monitoring Design

The objective of this phase of work (see Section 3) is to demonstrate and validate placement, stability, and performance of reactive amendments for in situ treatment of contaminated sediments. The approach to demonstration and validation of in situ treatment using reactive amendments will focus specifically on key technical performance criteria including:

- Proper design and selection of the amendments
- Placement and physical stability of the reactive amendments

- Effectiveness of the amendments in reducing contaminant bioavailability over time
- Quantification of changes to benthic habitat and benthic community structure

These demonstration and validation criteria form the basis of the performance objectives for this project. The monitoring 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.

2.0 Amendment Selection and Placement Design

2.1 Technology Description

In an effort to provide some background on these types of sediment amendments, a brief discussion of standard sediment remediation is provided (Sections 2.1.1 and 2.1.2) followed by an introduction to these more innovative in situ methods (Section 2.1.3). This is followed by a description of two amendment technologies (Sections 2.1.4 and 2.1.5) and potential application methods (Section 2.1.6).

The technology to be demonstrated incorporates a combination of a reactive amendment, a conventional delivery system, and a suite of monitoring tools (Figure 2-1). A 1-acre test plot will be divided in half to compare two different types of AC amendments. These two amendment technologies have also been selected for comparison to earlier work done at HPNS with granular activated carbon (Luthy et al., 2009).

The first proposed amendment will be placed using a composite particle system based on the AquaGate + PAC™ (henceforward referred to as AquaGate) technology platform (AquaBlok Ltd., Toledo, Ohio). This reactive amendment will be a powdered activated carbon (PAC) bound to a dense aggregate particle with appropriate clay minerals. AquaGate 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 (AquaBlok Ltd., 2010). The anticipated formulation for this demonstration incorporates approximately 5 to 10 percent PAC, 10 percent clay (calcium bentonite), and the remaining fraction of aggregate. Thus, from a placement perspective, the AquaGate particles resemble small stones and can be handled and applied with a wide range of conventional construction equipment.

The second proposed amendment technology will be a SediMite™ application (henceforward referred to as SediMite). It is an agglomerate comprised of a treatment agent (typically AC), a weighting agent (to enable it to sink and resist resuspension), and an inert binder. It is pressed into pellets up to an inch in length so it too can be applied with a wide range of dispersal options. AC levels in SediMite can be up to 50 percent by weight. SediMite is designed to withstand dispersal through the water column with minimal release of active ingredients followed by slow disintegration and mixing into the bioactive zone of sediments through natural sediment mixing processes such as bioturbation.

Due to the physical setting at this site, it has been determined that broadcast application with conveyor belt-type equipment (e.g., telebelt) or clamshell dredge type equipment provide a suitable option for rapid, relatively uniform placement (see Section 2.2). Due to the site location farther offshore and in deeper water than the earlier Luthy et al. (2009) site, it is also expected that land-based delivery options will not be possible.

2.1.1 Contaminated Sediment Remediation

Persistent hydrophobic organic contaminants (HOCs) such as PCBs, when released into the aqueous environment eventually become associated with sediment, where they may reside for long periods of time due to a combination of strong sorption and slow degradation (Millward et al., 2005). PCBs have been identified as the most common chemicals of concern in contaminated sediments in the United States (NRC, 2007). These contaminants pose long-term risks to ecosystems and human health.

The most widely used approach for remediating contaminated sediments is dredging and disposal. This approach can be expensive and disruptive to existing ecosystems. Numerous dredging projects have failed to achieve their cleanup goals because they were carried out when site conditions were unfavorable or because of dredging residual contamination, an inevitable side effect of dredging (NRC, 2007). In addition, dredging is not always feasible (e.g., low contaminant concentrations and/or valuable subtidal habitat). Capping with clean sediments, another widely used remedial option, is not always practical in sensitive environments such as wetlands or in areas where changes to the sediment bathymetry are of concern. Finally, monitored natural recovery (MNR) of sediments, a risk management alternative that relies upon natural environmental processes to permanently reduce risk to the environment (Magar et al., 2009), is generally targeted to low levels of contamination not requiring active remediation. At HPNS, the use of AC as a sediment amendment provides an additional option for sediment remediation. The amendment may be used in combination with other remedial options to provide the best remedial solution. This study will assist the Navy in evaluating this remedial option under site-specific conditions at HPNS.

While existing remedial options continue to be important and effective strategies under suitable conditions, numerous United States Department of Defense (DoD) and non-DoD sites face increasing demands to address contaminated sediment issues, particularly in areas where traditional remedial options such as dredging, capping, and monitored natural recovery (MNR) may be limited in effectiveness. Due to the complexity and heterogeneity of many sites, a combination of approaches and new technologies are needed to develop economic and effective ways to treat sediment contamination. More recently, research in contaminated sediment management has been moving towards the use of in situ sorbent (reactive) amendments as a means of altering sediment geochemistry and increasing contaminant binding to reduce contaminant exposure (Ghosh et al., 2011).

2.1.2 Contaminant Sorption in Sediments

It has long been understood that the organic matter (OM) in soils and sediments is the principal factor controlling sorption of organic compounds (Lambert, 1968). Sorption to sediment is a key process in determining the actual fate and risk of HOCs in aquatic environments. It lowers aqueous concentrations and therefore reduces mobility, bioavailability, and chemical and biological degradation processes (Jonker and Koelmans, 2002). Because of their hydrophobic nature, HOCs predominantly sorb to the hydrophobic regions of sediments. The volumetrically most important sedimentary hydrophobic domain is natural organic carbon, the degradation product of dead biomass. Therefore, sorption is commonly described as being a function of the organic carbon content in sediments (Jonker and Koelmans, 2002). Historically, researchers have estimated the sorption of HOCs to

solids (K_d, L/kg_{solid}) using the organic carbon (OC) content (f_{oc}, k_{goc}/kg_{solid}) and the OC-normalized distribution coefficient (K_{oc}, L/k_{goc}). This model assumes that all hydrophobic chemicals partition into organic matter. However, some reported sorption data do not conform to this partitioning model, and researchers have observed K_d values that are greater than predicted by f_{oc} or K_{oc}. To explain this discrepancy, it has been proposed that sediments and soils contain more than one carbon fraction, each sorbing chemicals with a different affinity (Accardi-Dey and Gschwend, 2002).

For regulatory purposes, the organic carbon fraction is typically taken as a measure of the sorption capacity that enables normalization of the aqueous equilibrium relationship for sediments containing different amounts of organic carbon. However, as mentioned above, it is now understood that this approach is too simplistic because organic carbon in sediment comes in different forms that may have very different sorption capacities for HOCs (Ghosh et al., 2003). As shown by numerous research studies (Lohmann et al., 2005; Cornelissen et al., 2005; Cornelissen et al., 2004; Ghosh et al., 2003; Jonker and Koelmans, 2002; Kraaij et al., 2002), in addition to natural materials such as decayed remains of plants and animals, and humic matter, sediment organic carbon also comprises particles such as coal, coke, charcoal, and soot (often referred to as black carbon (BC)[1]) that are known to have extremely high sorption capacities. For example, the log K_{oc} values for phenanthrene spans several orders of magnitude: non-BC lignin=5 and humic acid=5; BC-derived particulate charcoal=5.5, soot carbon=6.5 and AC=7 (Ghosh et al., 2003). The possible importance of BC in sorption processes in sediment has led to an increasing body of research into the use of carbon sorbents to reduce HOC bioavailability in sediments (Ghosh et al., 2011; Oen et al., 2011; Werner et al., 2010; Cho et al., 2009).

2.1.3 In Situ Sorbent (Reactive) Sediment Amendments

Reactive amendments are chemical or mineral-based materials designed to react in situ with sediments and porewater through direct contact or emplacement in caps or barriers. They do not decrease the total sediment concentrations of contaminants but rather decrease contaminant bioavailability and transport to surface- and groundwater. As more emphasis is being placed on the development of alternative in situ sediment remedial technologies (SERDP, 2004; USEPA, 2005; 2013) and research has demonstrated strong binding of HOCs in anthropogenic and naturally occurring particulate, black carbonaceous matter in sediments (Zimmerman et al., 2004), there is a growing movement towards the development and application of in situ sorbent amendments for contaminated sediment management.

Numerous reactive amendments - both natural mineral sorbents (e.g. apatite, barite, and bentonite) as well as engineered materials (e.g. ATS, Thiol-SAMMS) – have been bench scale tested for their organic and metal sorption capacity (Ghosh et al., 2011; Ghosh et al., 2008). For HOCs such as PCBs, AC has been demonstrated to be the most effective type of sorbent. Other carbon types such as coke, charcoal, and organoclays have been suggested, but the

[1] Black Carbon is generally defined as a carbonaceous material formed during the incomplete combustion of plant or other organic materials (Grossman and Ghosh, 2009).

sorption capacity for PCBs in activated carbons[2] is at least an order of magnitude higher than in the other sorbents (Ghosh et al., 2003).

Laboratory studies have demonstrated that contaminated field sediment amended with AC amendments in the range of 1 to 5 percent reduced the equilibrium pore water concentrations of HOCs in the range of 70 to 99 percent, thereby reducing the diffusive flux of the HOCs into the water column and transfer into organisms (Hale and Werner, 2010). Most studies (Ghosh et al., 2011 and references therein) using benthic organisms show a reduction of bio-uptake of HOCs in the range of 70 to 90 percent compared to untreated control sediment. Similar results have recently been observed in laboratory studies investigating biouptake reduction with AquaGate in PCB contaminated sediments from the Puget Sound Naval Shipyard (Kirtay et al., in prep). The results from this laboratory study demonstrated that amending the contaminated sediment collected from the Bremerton Naval Complex Pier 7 site with activated carbon (in the form of AquaGate) could effectively reduce the bioavailability of PCBs to the marine polychaete (*Neanthes arenaceodentata*). Increasing AquaGate contact time with the BNC sediment resulted in progressively lower bio-uptake with up to 94 percent total PCB reduction for the one month mixed treatment (Kirtay et al., in prep).

A recent publication by Ghosh et al. (2011) provides a brief summary of five ongoing pilot-scale field studies in which AC was applied to the sediment to reduce the bioavailability of hydrophobic contaminants. The field sites include a tidal mudflat, a freshwater river, a marine harbor, a deep-water fjord, and a tidal creek and marsh. In each case, the form of AC used, the application technique employed and suite of contaminants was different. However, each study had similar objectives, to assess and evaluate the following:

- Feasibility of field-scale application using large equipment;
- Persistence of AC and binding capacity in the natural environment;
- Effectiveness of the AC in reducing contaminant bioavailability;
- Reduction in pore water concentrations and sediment-to-water fluxes; and
- Effects of AC addition on the existing benthic community.

Results from the previous tidal mudflat demonstration at HPNS in San Francisco Bay showed that AC can be placed in sediment in large scale, is physically stable in the environment and remains effective in binding contaminants in sediments several years after application (Ghosh et al., 2011; Cho et al., 2009).

Results from the above studies are starting to provide valuable information about the long-term effectiveness of the physical stability of the AC and the chemical permanence of the remedy. However, further testing is needed to evaluate AC long-term effectiveness and placement processes on a large scale at HPNS.

The goal of reactive amendment technology, specifically in situ remediation approaches, for contaminated sediments is to reduce bioavailability and contaminant transport by

[2] Activated Carbon is produced from coal or biomass feedstock and treated with high temperature to produce a highly porous structure with greater sorption capacity (Ghosh et al., 2011).

introducing a small amount of a chemical sorbent to the contaminated surface sediment. Significant bench scale testing of AC has demonstrated its applicability for binding contaminants into matrices that reduce aqueous phase concentrations and bioavailability (Ghosh et al., 2000; Ghosh et al., 2003; Ghosh et al., 2009; Merritt et al., 2009; Millward et al., 2005; USEPA, 2005; Zimmerman et al., 2005). For HOCs such as PCBs, AC has shown consistently positive results (Luthy et al., 2004; Magar et al., 2003). However, AC has a very low bulk density and readily floats in fresh and saline waters. This property limits the ability for AC to be applied to sediments that are underwater continuously (i.e., sediments in areas below the low-water tide line) because AC added directly to underwater sediment tends to float upwards into the water column rather than remain within the sediment. Previously successful applications of AC to aquatic sediment have been primarily limited to sediment in shallow areas that were exposed to the air at low tide, allowing manual mixing of the AC into the sediment using land-based equipment before the tide covered the area with water. A range of approaches for applying AC to underwater sediments have recently been demonstrated (Ghosh et al., 2011), and two are discussed in the following sections.

2.1.4 AquaGate Composite Aggregate Technology

AquaBlok initially applied its composite particle technology to the delivery of a bentonite-based material to form a low-permeability cap over contaminated sediments. This technology is now well proven, having been successfully evaluated under the United States Environmental Protection Agency (USEPA) SITE (Superfund Innovative Technology Evaluation) program. In 2007, AquaBlok began working in Norway and the United States to adapt its technology for the delivery of powdered activated carbon (PAC) through the water. This product is called AquaGate+PAC (AquaBlok, 2010). AquaGate differs from traditional AquaBlok by using non-swelling reactive phases that remain more permeable and allow the sediments to maintain their physical properties better. Figure 2-2 provides a schematic representation of the composite particle approach employed for AquaGate+ PAC.

The AquaGate composite particle is manufactured using a crushed stone core coated with a combination of clay and PAC materials (Figure 2-3). Because the lighter powder materials are bound to an aggregate substrate to form the composite particle, the particle has a very high specific gravity (compared to the coating materials) and it will fall rapidly through the water, either alone or in combination with other granular materials.

As shown in Figure 2-2, after placement, the coating materials containing the carbon amendment will disaggregate from the stone core and mix with the underlying sediment. It is expected that natural mixing (bioturbation) will take place over time and incorporate the PAC material into the surface sediment layer allowing it to adsorb target contaminants, providing reduction in bioavailability over time. The period for the disaggregation is site-specific; however, at a similar pilot study in Puget Sound, the AquaGate+PAC was observed to have disaggregated within two weeks of initial placement (Chadwick et al., 2014).

2.1.5 SediMite Technology

SediMite is a granular material that is pressed into pellets of sufficient density to sink through the water column and disintegrate at the sediment surface. It was developed to deliver treatment materials to sediments contaminated by organic chemicals and metals. The material can be applied at the water surface and is designed to sink to the bottom,

where it slowly releases the treatment material. The material is designed to enable native benthic organisms to perform the mixing into the biologically active zone, thus obviating the need for mechanical mixing. Thus, the approach limits the potential for sediment re-suspension and habitat impacts. Unlike many capping technologies, the approach also has minimal impact on the existing habitat. Because it is not designed to cover the sediments physically, there are no issues associated with trapped gases. SediMite amendments with AC have performed well to date in bench-scale testing, both in terms of treatment efficacy and in mixing to the desired treatment depths by benthic invertebrates. Exposures to PCBs are reduced by 70 percent to 90 percent in the bench-scale demonstrations, as measured by sediment chemistry and bioaccumulation (Ghosh et al., 2011).

SediMite is a low-impact system for delivering treatment materials to sediment for in-situ remediation. It is an agglomerate comprised of a treatment agent (typically AC), a weighting agent (to enable it to sink and resist re-suspension), and an inert binder. The inert materials are comprised of sand and bentonite clay (approximately 50±5 percent dry weight, based on the published specifications sheet). SediMite pellets (Figure 2-4) can be manufactured with different shapes and material properties to target specific field applications. In the commonly used form, the product is designed to withstand dispersal through the water column with minimal release of active ingredients followed by slow disintegration (on the order of days to weeks, depending upon the site) and mixing into the bioactive zone of sediments through natural sediment mixing processes such as bioturbation (Figure 2-5).

2.1.6 Application Methods

A range of conventional installation/application methods have been used to place thin uniform layers of dry granular materials through a water column. Many of these have been used to place various AquaBlok and SediMite products during full-scale installations. Examples of these methods include belt conveyors, aggregate stone slinger type systems, clamshell buckets from a conventional derrick, and excavators.

Various application methods have been considered for this specific project including various mechanical methods such as clamshell bucket or conveyor, hydraulic placement, and pneumatic placement (see comparisons in Table 2-1). A portion of the site will be subtidal and the application will be primarily barge-based. This may also require a second barge used to supply material to the delivery system.

Both the AquaGate and SediMite materials are granular in nature and can be applied using many of the same technologies that can be used for placing materials such as sand or gravel. There are numerous proven and available methods that can be used for the placement of granular materials within the marine environment. The specific equipment viability for any given project is then determined by the actual site conditions and requirements, where the materials are to be placed and the properties of the material to be placed. Site conditions and requirements affecting material placement equipment selection include:

- Site access including access from land or water, ability of heavy equipment to access site, location of underwater structures that interfere with placement
- Water depth
- Bathymetry

- Current velocities
- Accuracy and precision of placement including allowable variability in placement

Table 2-1 lists some of the various methods that can be used for the placement of granular materials, their limitations, and the applicability to the site conditions and requirements listed below. Key considerations are discussed in detail below:

- Application of these amendment materials requires site access considerations for the heavy machinery needed to introduce the material to the site. Access from water is most efficient and allows application equipment and materials to be efficiently loaded onto barges at another location for travel to the site. Once on site, the equipment can be easily maneuvered in close proximity to the placement area. For areas only accessible from land, floating equipment can be craned in and used during placement.
- Water depth at the site can affect material placement ability and accuracy of placement, especially when combined with extreme low tides. If barges are used then water depth must be sufficient to allow navigation of barges to allow equal distribution of material across the site.
- Various equipment has the ability to place the material to varying levels of accuracy and degrees of uniformity. Accuracy refers to the ability to place the material within the given target area. Both equipment type and water conditions at the site can affect placement accuracy. The global positioning system (GPS) and other methods can be used to monitor equipment location at time material is discharged, but currents can cause material to drift once released creating uncertainty in actual placement location. GPS receivers and other positioning equipment can be mounted on the boom of a crane, on an excavator or on the end of an articulated conveyor.
- Due to its composition, both the AquaGate and SediMite materials require some specialized handling in order to maintain the integrity and viability of the material. These specialized handling techniques are not uncommon to other construction materials and can be accommodated using conventional construction material management and placement methods. The main material handling considerations when working with both amendments are similar and are related to keeping the reagent pellets (SediMite) or the coating on the aggregate particle (AquaGate) intact and dry until time of actual placement, allowing the particle with as high a percentage of its full composition of added ingredients to reach the sediment surface as practicable. This requires keeping the material dry until time of placement and avoiding unnecessarily rough or redundant handling of the material using equipment such as loaders and excavators or similar that can cause the coating of added ingredients to abrade or crack off the aggregate particle. These are not uncommon handling requirements. Dry cement and many other materials must be kept dry during handling. Larger sizes of stone and riprap require special handling to prevent the materials from breaking and becoming smaller than specified. Many of these issues have been investigated in previous projects that have used these amendment materials so any lessons learned can be incorporated into this project (Menzie and Davis, 2010; Ghosh et al., 2011).

2.2 Amendment Selection and Placement

Given the above discussions of technologies and site characteristics, it is expected that the study will compare AquaGate and SediMite products that are placed by barge. Due to the shallow water depths of the site, placement will need to be done at high tides to allow barge access. Currents at the site are generally low, so AC materials should sink from the surface where they are placed. For example, an articulated conveyor could be moved over each half-acre site to place a uniform layer of either AquaGate or SediMite materials. As mentioned earlier in this section, final decisions on placement method will be made in consultation with the amendment providers and construction contractors.

3.0 Monitoring Test Design

This section provides the detailed description of the conceptual design, sampling, and analytical methods to be used to evaluate the effectiveness of reactive AC amendment addition to the proposed 1-acre site. Approaches presented below focus on the physical, chemical, and biological characterizations of the Site, both pre- and post-implementation of the AC amendment, to address the performance metrics described in this section.

3.1 Selection of Technology Components

Sampling and analysis includes physical characterization, chemical characterization, and biological characterization. Technology components include the following:

- Standard cores for sediment physical and chemical properties;
- Specialized cores for in situ bioaccumulation experiments (Figure 3-1);
- Petite Ponar grab sampler to collect benthic invertebrate census samples (Figure 3-2);
- In situ passive sampler (Figure 3-3 shows solid-phase microextraction [SPME] as an example) to measure concentrations of PCBs in sediment porewater; and
- Sediment profile imagery (SPI) camera to provide a qualitative examination of the benthic community and to assess the depth of sediment and AC amendment mixing by bioturbation placement (Figure 3-4).

Standard Operating Procedures (SOPs) are described in the SAP (KCH, 2014).

3.2 Study Design

The study design will be used to evaluate the performance objectives, including examination of physical, chemical, and biological parameters of the site, prior to and following placement of the reactive amendment.

Physical parameters assessed in this project include the following:

- The distribution, uniformity, and thickness of the amendment immediately after placement as well as after selected monitoring periods. This will be evaluated with before and after amendment placement measurements using SPI and core analyses of physical properties.
- The stability of the amendment and changes in amendment stability over time resulting from natural sedimentation, benthic mixing, wave and current disturbances, and any other physical disturbances over time. This will be measured by hydrodynamic (wave and current) monitoring and core measurements.

Chemical parameters include:

- Surface sediment chemical concentrations prior to and following amendment delivery to evaluate changes in bulk concentrations that may affect contaminant fate. This will be measured by PCB and AC contents measured in grab and core samples.
- Monitoring of the extent to which the reactive amendment reduces contaminant bioavailability (magnitude of the bioavailability reduction and sustainability of bioavailability reduction). This will be measured by tissue and passive sampler PCB concentrations before and after placement of AC.

Biological parameters include:

- Assessment of baseline benthic community and recovery following amendment delivery, as well as characterization of the extent to which the amendment may affect the health and composition of the benthic community. This will be measured both by SPI (semi-quantitatively) and traditional benthic community analysis (BCA).

3.3 Baseline Characterization and Monitoring Activities

3.3.1 Characterization and Monitoring Schedule

Five sampling events will be conducted:

- **Baseline Characterization (one event):** Baseline measurements will be established during the pre-amendment sampling event. A pre-amendment sampling event representing current conditions will take place to establish pre-remedial baseline physical, chemical, and biological conditions for the site.
- **Initial Placement Monitoring (one event):** Immediately following amendment placement (within 1 month) measurements will be made to confirm that the amendment materials have been placed as expected in the study area, as described in Section 3.4.1.
- **Post-Placement Monitoring (three events)**: Post-placement characterization is important to document the extent to which the amendment material mixes with underlying sediment and assess changes in contaminant bioavailability and ecological health. Post-placement monitoring will be conducted at 6, 12, and 18 months after placement of the reactive amendment. The 6-, 12-, and 18- month events will include the full suite of physical, biological, and chemical measurements, as described in Section 3.4.4.

3.3.2 Monitoring Design

The experimental design for baseline characterization and post-placement monitoring efforts are patterned after a similar study at the Puget Sound Naval Shipyard (Chadwick et al., 2014) and will consist of the following:

- **Twenty sample stations** (ten per amendment type) that will be placed on the target amendment placement area. These sampling stations will be multimetric stations because multiple parameters will be analyzed at these locations. Figure 3-5 illustrates the conceptual layout of the sampling stations within each amendment area. As noted in

Section 1.1, the precise location and geometry of the test plot and sampling location distribution will be determined based the site-specific conditions (i.e., access, obstructions, and water depths) observed at the pre-pilot site walk. The sampling locations will be evenly distributed throughout each amendment area using the distribution pattern depicted in Figure 3-5. Ten samples within each amendment area will provide a data set large enough to be used for statistical comparisons and will allow for reasonable spatial coverage (i.e., 10 samples within one-half acre). Figure 3-6 presents the proposed sampling layout within the anticipated pilot area. The following measurements will be conducted at each of the 20 stations:

1. The in situ bioaccumulation tests to evaluate bioavailability and potential adverse effects;
2. Core sampling to provide visual confirmation of amendment thickness and mixing and sectioning of cores for total organic carbon (TOC) and BC analysis to confirm stability and mixing of AC over time.
3. Surface sediment sampling (samples collected by cores or grabs (from 0 to 0.5 feet) of chemical (PCB sediment concentrations) and physical parameters (grain size and TOC).
4. The in situ passive sampler measurement of PCBs in sediment porewater.
5. Benthic sediment grab for benthic invertebrate census (5 per amendment instead of 10). A smaller number of benthic community samples will be collected because the benthic census data is not expected to vary markedly across the area and the SPI will provide qualitative information regarding benthic community at 42 locations within the amendment area.

- **Five benthic community census reference stations** will be located just outside of the target amendment area. Exact location will be determined in the field but anticipated to be located as near to the pilot study plot(s) as practicable. The location will cover a transect that includes the same range of intertidal to subtidal elevations. The purpose of reference area benthic community assessment is strictly intended to assess the response of the benthos to the amendment. In order to minimize confounding factors in that evaluation, a reference area with similar benthos, hydrodynamics, and physical and chemical sediment characteristics to the pilot area will be used. It is expected that the reference area will be immediately adjacent to the pilot area and will encompass the same range of intertidal to subtidal elevations. Chemistry analyses are not proposed for the reference areas.
- **Fifty (50) SPI stations (21 per amendment type and 8 reference locations)**. A SPI survey will be conducted during each monitoring event to determine the initial AC placement, distribution, and stability of the AC amendments. The sampling locations will be evenly distributed throughout each amendment area using the distribution pattern depicted in Figures 3-5 and 3-6. The eight reference locations will be distributed as near to the pilot study plot(s) as practicable and will cover a transect (s) that includes the same range of intertidal to subtidal elevations. Potential areas that will be used for the reference locations are illustrated in Figure 3-6.

The Initial Placement Monitoring event within one month of original amendment placement will include physical measurements to determine amendment placement. These measurements will include the cores at the 20 sampling stations to provide visual confirmation of amendment thickness and mixing and sectioning of cores for TOC and BC analysis. The 50 SPI stations will also be done to infer the results out over the entire amendment area. Since 20 SPI stations will coincide with the multimetric stations, it will be possible to extrapolate qualitatively amendment thickness and expected percent carbon content in the surface sediments. Additional discussion about the physical measurements is provided in Section 3.4.1.

Final sample locations are subject to change based on site-specific conditions and observations. The locations will be determined during the baseline characterization event. Final locations will be surveyed using a GPS unit to record permanently the coordinates of each station. Exact locations are guided by the following criteria:

- The multimetric sampling stations will be spatially distributed across the amendment area to maximize the spatial distance between the stations, and will be located in areas that encompass a range of elevated PCB concentrations;
- All stations will span a range of workable water depths (from approximately +1 meter mean lower low water [MLLW] to -1 meter MLLW) to suit the tools used for this study;
- Benthic invertebrate census reference stations will be located in similar habitats adjacent to the placement area; and
- SPI stations spatially distributed across the amendment area and reference areas.

3.4 Field Testing

The physical, chemical, and biological field testing components are generally described in the following sections. The associated SAP provides additional sample collection details and standard operating procedures.

3.4.1 Physical Characterization

Physical characterization will focus on evaluating the placement, mixing, and stability of the reactive amendment and the sediment. Relevant tools and methods for physical characterization include:

- **Sediment Coring**. Sediment and sediment-amendment samples will be collected via short cores. The cores will be sectioned into three parts for profiling. Cores will be visually analyzed for presence of the amendment mixed with the natural sediment. Each section will be analyzed for TOC and BC as an additional quantitative measure of amendment mixing depth.
- **SPI Survey**. SPI will be used to visualize physical processes at the amendment-water and sediment-amendment interfaces and provide additional monitoring of amendment thickness. Twenty-one stations will be spatially distributed across the two AC amendment areas (AquaGate™ and SediMite™) and eight stations will distributed across a reference area for a total of 50 stations per survey. The imagery obtained from

the SPI survey will provide information about sediment physical characteristics; amendment presence, depth, and mixing; and qualitative information about the ecological health of the benthic invertebrate community.

- **Hydrodynamic Monitoring**. The primary physical transport mechanisms in South Basin are the tides and waves. A pressure sensor will be installed at the site to obtain water level measurements and burst-sample pressure measurements for wave amplitude calculations. Water level integration and wave burst sampling intervals and durations can be programmed at intervals appropriate for South Basin. A detailed sediment dynamics study was performed as part of the Final HPS Parcel F Validation Study (Battelle et al., 2005) which showed that the hydrodynamic conditions within the South Basin do not vary significantly within the area where the pilot study will be performed. A single mooring is sufficient to collect representative hydrodynamic data.

3.4.2 Chemical Characterization

Chemical characterization will focus on evaluating the effectiveness of the reactive amendment in reducing contaminant bioavailability. In support of this characterization, relevant tools and methods for chemical characterization include:

- **Sediment In Situ Bioaccumulation Analysis**. Evaluation of the reduction of contaminant bioavailability will be addressed using in situ bioaccumulation experiments conducted with test organisms. Field-collected organisms (i.e., from Dillon Beach, California, approximately 66 miles north of HPNS or similar reference location); will be deployed within in situ exposure chambers for each monitoring event for 28 days. A total of 20 (10 per amendment type) exposure chambers will be deployed in the field with organisms for bioaccumulation analysis with bivalves (*Macoma nasuta*; bent-nosed clam). Bivalve tissue will be analyzed for PCBs (209 congeners), and lipids content. The in situ chamber will be removed in its entirety after the 28-day deployment period. The sediment from within the chamber will be collected in the field immediately after the test organisms are retrieved from the chamber.

- **Surface Sediment Chemistry Evaluation**. Sediment from the exposure chambers will be analyzed for PCBs (209 congeners), as well as factors affecting contaminant bioavailability (grain size and TOC content). Sediment from each of the 20 multimetric sites will be collected for analysis. Additional sediment will be collected adjacent to the in situ exposure chambers for analysis of bulk density (loss of ignition and moisture content).

- **Porewater Sampling Analysis**. Three passive samplers (for triplicate measurements) will be deployed at each of the 20 multimetric stations during each monitoring event to provide a measurement of dissolved PCBs (209 congeners) present in porewater of the surface sediment layer (top 15 cm). Passive samplers will be retrieved after 28 days, extracted with organic solvent, and the extract will be analyzed for PCBs. Analyses will include use of performance reference compounds to determine equilibration over a range of PCB chlorination levels.

Additional details related to sample collection and deployment are provided in Section 14.7 of the Field Sampling and Analysis Plan.

3.4.3 Biological Characterization

Biological characterization will focus on evaluating ecological health following placement of the amendment. Relevant tools and methods for biological characterization include:

- **Benthic Community Census.** Benthic invertebrate community census data for evaluation of ecological conditions will be obtained from surface sediment grab samples at each of the sampling stations. Grab samples for the benthic community census will be conducted at these stations to provide reference benthic census data during each sampling event. Benthic community can be variable due to changes in season, current, and other reasons unrelated to the amendment. Reference data will provide information with which to interpret possible changes in the benthic community within the amendment placement area (e.g., discern possible changes that have occurred for the broader benthic community in the basin due to season or climatic effects unrelated to the amendment). The data will be collected using a petite Ponar grab sampler. A petite Ponar grab sampler samples an area of 0.023 square meter to a depth of 10 cm. Following collection, the content of each grab sample will be sieved through a stacked 1,000 to 500 micrometer mesh opening sieve. Samples will be rinsed with site water and invertebrates and other materials (e.g., sediment and debris) retained on the sieves will be collected and immediately preserved. Invertebrates will be identified to the lowest possible taxonomic level and enumerated, with results used to compute comparative ecological parameters such as organism density, species richness, and evenness. These comparative parameters will allow for evaluation of the ecological response of the benthic invertebrate community to the reactive amendment.
- **SPI Survey**. Information from SPI surveys will also be interpreted to provide a qualitative examination of the benthic community and to assess the depth of sediment mixing through bioturbation. The depth of bioturbation relative to the thickness of the amendment determines whether benthic organisms are still exposed to chemicals in buried sediment and, potentially, whether their actions mix buried sediment and chemicals toward the sediment-water interface. Additional qualitative information obtained from SPI survey will focus on habitat quality, and may include the depth of the redox boundary and variation in sediment grain size.

3.5 Sampling Plan

As stated in Section 1.0, the SAP was developed under a separate effort so this section provides a summary that is more fully described in that document. Figure 3-5 provides a conceptual layout of the sampling locations that will be used for the twenty multimetric sample stations where most measurements will be taken. Figure 3-6 illustrates the proposed sampling locations and potential reference areas. As noted in Section 1.1, the precise location and geometry of the test plot and sampling location distribution will be determined based on site-specific conditions (i.e., access, obstructions, water depths) observed at the pre-pilot site walk. The one-half-acre plot from Figure 1-3 is depicted here to conceptually represent the sample locations for each amendment (AquaGate and SediMite). Each half-acre plot has 10 multimetric sampling stations located in a transect that runs from intertidal to subtidal water depths. The reference area for the benthic community analysis will be located as near as possible to the pilot test area and the reference sampling locations will

also be distributed along a transect from intertidal to subtidal water depths. A table of the samples to be collected including number, quality control (QC) samples and locations, is provided in Table 3-1. A summary of the analytical methods is also presented in Table 3-2.

3.5.1 Calibration of Analytical Equipment

All analytical equipment will be calibrated according to manufacturer instructions and described in the SAP (KCH, 2014).

3.5.2 Quality Assurance Sampling

All samples collected for quality assurance (QA) purposes are listed in Table 3-1. Field duplicates will be collected for each set of chemical analyses (core samples, tissue, and SPMEs), and field blank will be collected following laboratory protocols. Additional laboratory QC samples required by the referenced method, including laboratory control sample/laboratory control sample duplicate analyses, matrix spike/matrix spike duplicate analyses, surrogate recoveries, and other method specific QC samples will be followed.

3.5.3 Decontamination Procedures

To the extent possible, disposable sampling equipment will be used for samples involving chemical measurements to minimize decontamination requirements. At this time, the project does not anticipate the need to re-use chemical sampling materials and equipment, so decontamination will not be required. In the event that materials or equipment involving chemical measurements requires re-use in the field, the materials will undergo the following decontamination process. If sediment adheres to the sampling equipment, it will be returned to the sampling location by rinsing with site water, unless otherwise directed by the Navy. Equipment will then be rinsed copiously with site water to remove any remaining sediment.

Equipment scheduled for re-use but not associated with chemical measurements will be rinsed copiously with site water before leaving the site.

3.5.4 Sample Documentation

For each field event, a field team leader will be identified and will ultimately be responsible for all data reporting and uploading to the Naval Installation Restoration Information System (NIRIS). All field data will enter a project-dedicated logbook. Samples will be accompanied by chain of custody forms, a copy of each retained by the field team leader before sending samples off-site. Chain of custody forms will be reconciled with samples received by the respective laboratory to ensure that all samples arrive safely.

Field and laboratory staff will record experimental activities and measurements and will compile analytical data from the laboratories as electronic data deliverables (EDDs). EDDs will facilitate data transfer to spreadsheets and to a project database. The analytical data received from each analytical laboratory will be checked by each task leader and will be retained with the project records. Data will be stored in a database or spreadsheet file for further evaluation and calculations. Field observations also will be recorded in the database or spreadsheet file.

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4.0 Field Activities and Data Collection

4.1 Site Preparation

Preparation activities described herein will be coordinated by KCH team in conjunction with the Navy and other regulatory agencies as required. The work described in the following subsections will be conducted prior to the start of activities.

4.1.1 Site Access

The KCH team will coordinate with the Navy to obtain site access for all required site personnel (including subcontractors) and vehicles. Every effort to limit the number of personnel and vehicles that need to enter the site will be made. The upland staging area will be secured in order to protect personnel and equipment throughout the duration of the project. Site security measures may include some combination of perimeter fencing and locking storage containers and temporary structures for equipment. If vessels or equipment are left in the marine work area, the contractors are required to procure guards to monitor the area during non-working hours. To the extent practicable, any deployed equipment will not be visible above the water surface to minimize potential for theft.

4.1.2 Permitting

In accordance with Section 121(e) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (42 United States Code, Section 9621[e]), as amended, no federal, state, or local permits shall be required for the portion of any removal or remedial action conducted entirely onsite. Although formal permits may not be required for all activities, substantive compliance with applicable permit requirements will be met. KCH team will be responsible for coordination with the Navy to obtain any permits that are determined to be necessary; however, currently no permits are anticipated but the need will be evaluated during pre-mobilization planning activities.

Prior to the field mobilization, the Navy Remedial Project Manager (RPM), Resident Officer in Charge of Construction, and the appropriate HPNS security and fire department personnel will be notified regarding the anticipated work.

4.1.3 Radiological Work Instructions

Parcel F is designated as radiologically impacted and is under control of the Navy's basewide radiological support contractor. Radiological control procedures will be required during application of the AC amendments, sediment sampling, and management processes for investigation-derived waste (IDW). The Navy's basewide radiological support contractor will implement radiological control procedures to properly identify and manage potential radioactive contamination that may be encountered during these activities at Parcel F. Radiological control procedures will be developed in detailed work instructions in concurrence with the Radiological Affairs Support Office (RASO) prior to mobilization. The work instructions will address radiological control procedures including, but not limited to,

managing the vessels, equipment, sample collection, and IDW disposal. The radiological activities will be done in accordance with the work instruction and with a RASO-approved work plan that is currently under development.

4.1.4 Training

Site workers, supervisors, and managers will have training appropriate to their assigned duties and as specified in the activity hazard analysis that is applicable to the work being performed. Safety and health requirements for this project are presented in the Accident Prevention Plan (APP)/ Site Safety and Health Plan (SSHP). KCH and all subcontractors will be radiologically trained by the HPNS basewide radiological contractor. Prior to the start of field activities, field personnel shall review and sign the APP/SSHP acknowledgement forms as provided by the basewide radiological contractor and conform to the requirements of the APP/SSHP throughout project activities.

4.1.5 Subsurface Utility Clearance

Protocols for utility clearance in marine sediments are not standardized. Before performing intrusive activities at the site, USA Dig-Alert (1-800-227-2600) will be contacted for subsurface utility location as required by California law. USA Dig-Alert will be notified of the proposed scope of work at least 2 working days before intrusive activities are planned. KCH will supplement the Underground Service Alert services by reviewing Navy as-built and utility maps. A geophysical survey is not scoped at this time; however, if deemed necessary then a survey will be performed prior to field activities.

4.1.6 Site Survey

A site survey (site walk) will be conducted from the shoreline prior to commencing sampling to identify staging and access areas, logistical issues, review site-specific data (e.g., bathymetry), and discuss coordination with other onsite contractors. The pilot study construction contractor responsible for placement of the carbon amendment may conduct a bathymetric survey as part of the carbon placement activities to ensure adequate coverage of material. Additional information will be provided in this section once the pilot study construction contractor is procured. Because sediment sampling is being conducted over water, the boat-mounted GPS will be used to record the longitude and latitude of all sample locations. The time of sampling and depth of water will also be recorded in the field notes.

4.1.7 Equipment Staging / Storage

Acceptable staging areas for field equipment will be coordinated with the Navy prior to subcontractor mobilization. Temporary facilities such as a storage shed (e.g., Conex box), portable toilet, storage container or other necessary equipment and material will be mobilized to the Site for use by the project personnel.

Work activities are anticipated to be completed during daylight hours. General work hours will be between 7:00 AM and 7:00 PM. Work on the weekends will be coordinated with HPNS personnel as needed.

4.2 Investigation-Derived Waste Management

IDW will consist of disposable sampling equipment (e.g., plastic scoops) and personal protection equipment (e.g., nitrile gloves) generated during sediment sampling activities. The IDW will be collected in heavy-duty plastic bags and disposed in an onsite waste container designated by the Navy RPM and/or Resident Officer in Charge of Construction prior to the sampling activities. If such a waste container does not exist, the project team will find a safe, temporary storage location until the waste can be disposed properly.

If sediment adheres to the sampling equipment, it will be returned to the sampling location by rinsing with site water, unless otherwise directed by the Navy. Equipment scheduled for reuse (that does not come in contact with the sample) will be rinsed copiously with site water before leaving the sampling location.

CERCLA waste is defined as solid waste generated at a CERCLA site that will be sent offsite and that contains a hazardous substance, pollutant, or contaminant. CERCLA wastes must be sent to at a facility approved by the USEPA under the Off-Site Rule, 40 *Code of Federal Regulations* §300.440. IDW generated under these proposed Pilot Study sampling activities is being generated before a decision document for Parcel F has been signed; as a result, IDW will be managed onsite in a manner consistent with USEPA guidance and base procedures.

4.3 Pre-Carbon Placement Monitoring Event

4.3.1 Mobilization

Prior to beginning fieldwork, the Navy RPM, and appropriate security and fire department personnel will be notified regarding the anticipated fieldwork and schedule. A field kickoff meeting will be conducted and will include (but may not be limited to) the Navy RPM, Task Order Manager, Field Manager, Construction Manager, field personnel, subcontractors, Project Quality Assurance Officer, and Program Safety and Health Manager. The primary discussion points for the kickoff meeting will include scope of work, schedule, logistics and field coordination issues, and safe access to South Basin in Parcel F.

Prior to conducting field activities, field personnel will review the applicable sections of this SAP, SOPs, schedule, SSHP, participate in radiological awareness training and sign the Project Personnel Sign-off Sheet (Worksheet #4 in the SAP). Safety considerations for proposed field tasks are discussed in the project-specific APP/SSHP.

Other mobilization activities include:

- Mobilize equipment, materials, and personnel.
- Mobilize temporary facilities (e.g., storage shed or portable toilet) as required.
- Assemble sampling vessel, passive samplers, bioaccumulation chambers and other field supplies, as necessary.
- Perform calibration of equipment (e.g. GPS unit) and QA/QC on all radiological survey meters (to be performed by the HPNS basewide radiological contractor).

- Establish exclusion zones (to be performed by the HPNS basewide radiological contractor)
- Secure radiation check sources (to be performed by HPNS basewide radiological contractor, as applicable)
- Provide site-specific training to field personnel (to be performed by HPNS basewide radiological contractor)

4.3.2 Sampling Procedures

- **SPI Camera –** After the sampling vessel is positioned over the sampling station, the SPI system will be lifted off the deck (using a wench, crane, or similar equipment). The SPI system will be slowly lowered over the side of the vessel to the sediment surface ensuring the SPI system comes into contact with the sediment surface in a controlled and gentle manner. On contact with the sediment surface, the operator will leave the wire slack for about 20 seconds to allow time for the prism to fully penetrate the sediment and collect the image. The SPI system will then be hoisted back near the sampling vessel where it will be rinsed with site water prior to moving to the next station.
- **Sediment Shallow Core Sampling –** Sediment and sediment-amendment samples will be collected via short cores (approximately 20 cm) at the 10 multimetric sampling locations within each activated carbon amendment plot. Duplicate samples will be collected immediately adjacent to the original sample. It is anticipated that hand-push cores will be collected from the side of the sampling vessel. Cores collocated with the other chemical samples (sediment and tissue samples). Cores will be visually analyzed for presence of the amendment mixed with the natural sediment. The cores will be subsampled at three intervals (0 to 0.2, 0.2 to 0.4, and 0.4 to 0.6 feet below sediment surface [bss]; or 0 to 6 cm; 6 to 12 cm, and 12 to 18 cm bss). Subsamples will be transferred to a glass jar for shipping to the laboratory. Each section will be analyzed for TOC by Lloyd Kahn and BC by CHM-Black Carbon and CHM-CHN-MAC as an additional quantitative measure of amendment mixing depth.
- **Sediment Grab Sampling –** Upon retrieval of the bioaccumulation chambers, a sediment grab sample will be collected from the sediment in the chamber and analyzed for PCB congeners by USEPA Method 1668C (including percent solids), as well as factors affecting contaminant bioavailability (TOC by Lloyd Kahn, moisture content by ASTM D7582, and grain size by ASTM D422-63). A second grab sample will be collected adjacent to the bioaccumulation chamber for a total of 20 grab samples at the 10 sampling stations in each of the carbon amendment test plots. Grab samples (0 to 0.5 feet bss) will be collected using a petite Ponar grab sampler (or similar sampling device) deployed from the sampling vessel at locations adjacent to the in situ bioaccumulation chambers. The sediment sample will be collected from within the center of the grab samplers to avoid contact with the sampling equipment and more disturbed sediment. The sediment will be placed directly into the sample jars using a disposable scoop. These grab sediment samples will only be analyzed for loss on ignition (LOI) by ASTM D7348 and moisture content by ASTM D7582 to evaluate bulk density of the sediments.

- **Tissue Sampling –** Evaluation of the reduction of contaminant bioavailability will be addressed using in situ bioaccumulation experiments conducted with the bivalve test organism, bent-nosed clams (*Macoma nasuta*). Field-collected organisms will be deployed within in situ bioaccumulation chambers for 28 days for each monitoring event (it is anticipated that approximately five clams will be added to each chamber). The bioaccumulation chambers will be deployed directly from the side of the sampling vessel and will be pressed approximately 0.5 feet (15 cm) into the sediment. A total of 20 bioaccumulation chambers (1 at each of the 10 monitoring stations in each carbon amendment plot) will be deployed in the field with organisms for bioaccumulation analysis. After retrieval, live clams will be depurated for 24 hours in an appropriate laboratory tank to exclude gut contents of the clams from analyses and focus on contaminants bioaccumulated in soft tissues. After retrieval from the tank, whole clams will be immediately wrapped in foil, placed in resealable plastic bags, and frozen prior to shipment to the laboratory. Unexposed tissue samples (source blank) from clams maintained at the laboratory during the field deployment will also be sent for laboratory analysis after each monitoring event as a tissue blank. Whole soft tissues will be resected from the clams received by the analytical lab. Bivalve tissue will be analyzed for PCB congeners, percent solids, and lipid content by USEPA Method 1668C.

- **Passive Sampling –** Three passive samplers (for triplicate measurements) will be deployed at each of the 10 multimetric sampling stations within each of the carbon amendment plots for each monitoring event to provide a measurement of dissolved PCBs present in porewater of the surface sediment layer (top 15 cm). The passive samplers, approximately 1 foot (30 cm) in length, will be placed into the sediments adjacent to the bioaccumulation chambers with a primary focus of evaluating the 0 to 0.5 feet (15 cm) bss depth interval. The passive samplers will be deployed in triplicate with approximately 1 foot between each sampler. Passive samplers will be retrieved after 28 days (along with the bioaccumulation chambers), extracted with organic solvent at Texas Tech University, and then the extract will be analyzed for PCB congeners. Analyses will include use of performance reference compounds (PRCs) to determine equilibration over a range of PCB chlorination levels. The PRCs are compounds not present in significant quantities within the sediment and these compounds can be loaded onto the passive samplers to assess the degree of equilibration with the surrounding sediment. Between 5 and 10 PCB compounds labeled with carbon-13 (13C) will be used as PRCs for this study. Only sub-nanogram levels, much less than the part per million concentrations currently present, will be released into the sediments through use of the PRCs. This secondary line of evidence will be analyzed by Texas Tech University and will not be used to make remedial decisions for Parcel F.

- **Benthic Community Analysis –** Benthic invertebrate community census data for evaluation of ecological conditions will be obtained from surface sediment grab samples at five of the sampling stations within each carbon amendment plot. The data will be collected using a petite Ponar grab sampler deployed from the side of the sampling vessel. A petite Ponar grab sampler samples an area of 0.023 square meters to a depth of 10 cm. Following collection, the content of each grab sample will be sieved through a stacked 1,000- to 500-micrometer mesh opening sieve. Samples will be rinsed with site water and invertebrates and other materials (e.g., sediment and debris) retained on the sieves will be collected in a jar and immediately preserved with formaldehyde.

Preserved samples will be sent to a subcontracted benthic taxonomist for identification. Invertebrates will be identified to the lowest possible taxonomic level and enumerated, with results used to compute comparative ecological parameters such as organism density, species richness, and evenness. These comparative parameters will allow for evaluation of the ecological response of the benthic invertebrate community to the activated carbon amendment.

- **Hydrodynamic Monitoring –** Hydrodynamic monitoring equipment will be deployed at the 1-acre Pilot Study site in Parcel F for the duration of the study to measure the water levels and wave activity. A pressure sensor will be installed to obtain water level measurements and burst-sample pressure measurements for wave amplitude calculations. Water level integration and wave burst sampling intervals and durations can be programmed at intervals appropriate for South Basin.

4.3.3 Demobilization

Following the completion of sediment sampling, the appropriate site personnel will be notified and all equipment and materials will be moved offsite. Screening of vessels, equipment, and materials for radiation will be performed by the basewide radiological contractor.

4.4 Carbon Amendment Placement

4.4.1 Equipment

It is anticipated that a barge with a hopper and conveyer belt equipment (e.g., telebelt system) will be used during activated carbon placement activities. Further specific information will be available after the construction contractor is procured.

Specs for Aquagate and SediMite are as follows.

AquaGate+PAC

- Activated carbon by weight: 10 percent
- Dry Bulk Density: 60 to 70 pounds per cubic foot
- Settling velocity of standard AquaGate+PAC™ is 15 cm per second
- Placement of AquaGate+PAC™ will include a 10 percent contingency amount (for anticipated losses); approximately 10.3 pounds per square foot, or 1.9 inches thick.

SediMite

- Activated carbon by weight: 40 percent
- Dry Bulk Density: 45 to 55 pounds per cubic foot
- Settling velocity of standard SediMite™ is 10 cm per second
- Placement of SediMite will include a 25 percent contingency amount (for anticipated losses); approximately 3 pounds per square foot, or 0.8 inches thick

4.4.2 Procedures

Each carbon amendment shall be placed as a uniform layer over the designated demonstration plot area using a broadcast application with relatively uniform placement. A second barge used to supply material to the delivery system may be required, although the final placement design is subject to change as conditions warrant. Final decisions on placement method will be made in consultation with the carbon amendment and construction contractors.

GPS and other methods can be used to monitor equipment location at the time the material is discharged, but currents can cause material to drift once released creating uncertainty in actual placement location. GPS receivers and other positioning equipment can be mounted on the end of an articulated conveyor.

Cover thickness during placement will be verified using the "pan" method. Pans will be 2 feet by 2 feet by 1 foot in dimension, and will be placed on the bottom of the area to receive carbon amendments (pans will be weighted so they sink through the water column). After placement of the material, the pans will be retrieved using a cable to verify the thickness of material placed. A minimum of two pan checks per 5,000 square feet will be used. If a pan is retrieved and fails to meet the minimum thickness requirement, it will be emptied and lowered back down. The entire area assigned to that pan is assumed deficient by the shortage, and the quantity by which the area is deficient will be deployed. The pan verification method will be used again to verify thickness and the process repeated, as required.

4.4.3 Quality Control Procedures

The activated carbon amendments will be placed in strict accordance with the type, manufacturer, sequence, pounds per square foot, and placement calculations. The activated carbon amendment manufacturer will provide the active material specifications and product literature including certification that furnished products have specified property values prior to the delivery to the site. Monitoring of the carbon amendment properties and placement will be performed in accordance with the Construction Quality Control Plan (CQCP). During carbon amendment placement, pans will be utilized as described above. The placement of the carbon amendments will be coordinated with the placement of sampling and monitoring devices required according to the CQCP, SAP, and/or QA Plan.

4.5 Post-Placement Monitoring Events

Post-construction monitoring will be performed to verify the carbon amendment placement. The placement will be monitored and verified by SPI camera surveys after the carbon amendment is placed. The SPI surveys will be conducted to determine the placement, distribution, and stability of the carbon amendments.

Twenty one stations will be spatially distributed across the two activated carbon amendment areas (AquaGate™ and SediMite) and eight stations will distributed across a reference area for a total of 50 stations per survey. The imagery obtained from the SPI survey will provide information about sediment physical characteristics; amendment

presence, depth, and mixing; and qualitative information about the ecological health of the benthic invertebrate community.

After the sampling vessel is positioned over the sampling station, the SPI system will be lifted off the deck (using a wench, crane, or similar equipment). The SPI system will be slowly lowered over the side of the vessel to the sediment surface ensuring the SPI system comes into contact with the sediment surface in a controlled and gentle manner. On contact with the sediment surface, the operator will leave the wire slack for about 20 seconds to allow time for the prism to fully penetrate the sediment and collect the image. The SPI system will then be hoisted back near the sampling vessel where it will be rinsed with site water prior to moving to the next station.

Sediment cores will also be collected, segmented, and analyzed as noted in Section 4.3.2. The data from these cores will provide information about the carbon content with depth immediately after the amendment placement. Data collected during subsequent monitoring events will be compared with this, and the baseline data, to assess the depth of carbon mixing over time.

5.0 Data Analyses and Reporting

5.1 Data Validation

Data validation will be conducted by independent third-party data validation subcontractor consistent with Naval Facilities Engineering Command (NAVFAC) Southwest Environmental Work Instruction (EWI) No. 1, *Data Validation Guidelines for Chemical Analysis of Environmental Samples* (Navy, 2001), *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Superfund Data Review* (USEPA, 2010), and *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (USEPA, 2008). One hundred percent of the analytical data will be validated by a third-party data validation subcontractor, with 20 percent full (Level IV) validation and 80 percent standard (Level III) validation.

Full (Level IV) data validation will follow the USEPA Contract Laboratory Program (CLP) criteria set forth in the functional guidelines for organic and inorganic data review (USEPA, 2008 and 2010, respectively). These CLP functional guidelines apply to analytical data packages that include the raw data (e.g., spectra and chromatograms), backup documentation for calibration standards, analysis run logs, laboratory QC, dilution factors, and other types of information. This additional information is used in the full (Level IV) data validation process for checking calculations of quantified analytical data. Calculations are checked for field and laboratory QC samples (e.g., matrix strike/matrix strike duplicate [MS/MSD] and laboratory control sample [LCS] results) and routine field samples (including field duplicates, source blanks, equipment rinsate blanks, and trip blanks). To be sure that detection limit and data values are appropriate, an evaluation is made of instrument performance, method of calibration, and the original data for calibration standards.

Under the standard (Level III) data validation effort, the data values for routine samples and field and laboratory QC samples are generally assumed to be correctly reported by the laboratory. Data quality is assessed by comparing the QC parameters listed above to the appropriate criteria (or limits) as specified in this SAP, by CLP requirements, or by method-specific requirements (e.g., CLP, SW-846). If calculations for quantitation are verified, it is done on a limited basis and may require raw data in addition to the standard data forms that are normally in a data package.

5.2 Data Management

Data management will begin upon collection of field measurements, which will be recorded in the investigation-specific field logbook or field forms and retained in the project files, to the final submittal of the analytical data that are checked for accuracy through the data validation process. Throughout the data life cycle, the project team and project subcontractors (i.e., laboratory and data validation) will be responsible for performing data

verification so that the data are complete, correct, and compliant with project objectives and contractual requirements.

Analytical data will be provided by the analytical laboratory in hard copy and electronic KCH-required formats. If the electronic data have successfully passed the data checker, the laboratory will provide the analytical data in the contractually required EDD format, which will then be loaded to the KCH data management system for further data verification and validation. The data will not be released to the project team or Navy until the data are final with data validation qualifiers applied. Once the data are deemed final and complete, the data will be prepared in the required Naval EDD format and uploaded to NIRIS, consistent with NAVFAC Southwest's EWI No. 6, *Environmental Data Management and Required Electronic Delivery Standards* (Navy, 2005).

5.3 Data Evaluation

The following general statistical approaches will be used to guide the interpretation of data:

- **Sediment and porewater chemical data** will be evaluated for heteroscedasticity and normality ($\alpha = 0.05$) using standard tests (e.g., Shapiro-Wilk or Levene) to evaluate the appropriateness of parametric or non-parametric mean comparison methods. Data may be transformed to meet tests for parametric tests, and may be normalized by the average concentration at each station if stations are significantly different. Parametric mean comparisons will include paired t-tests (before amendment, after amendment) and analysis of variance (ANOVA) (analysis of multiple post-amendment datasets) followed by Tukey's Honestly Significant Difference (HSD) *a posteriori* comparisons. Nonparametric mean comparisons will include Wilcoxon test followed by Tukey's HSD *a posteriori* comparisons of the mean ranks. Data may also be explored using linear regression, correlation, or Spearman rank correlation, using TOC, grain size, or other variables as dependent variables. Chemical data will also be compared among the sampling events to evaluate changes over time using a two-way ANOVA.
- **In situ bioaccumulation data** will be compared among the sampling events to evaluate the effects of time, as well as before and after the amendment. Data may be transformed to meet tests for parametric tests, and may be normalized by the average organism concentration at each station if stations are significantly different. Calculation of Biota-Sediment Accumulation Factors (BSAFs), obtained by dividing concentrations of chemicals in biota by concentrations of chemicals in sediment, may also be used to evaluate differences in bioavailability. Parametric mean comparisons will include paired t-tests and ANOVA followed by Tukey's HSD *a posteriori* comparisons. Nonparametric mean comparisons will include Wilcoxon test followed by Tukey's HSD *a posteriori* comparisons of the mean ranks. Data may also be explored using linear regression, correlation, or Spearman rank correlation, using TOC, grain size, or other variables as dependent variables.
- **Benthic Community Census data** will be evaluated pre- and post-amendment. Abundance, species richness, and diversity indices will be estimated for evaluation statistically using paired t-tests, ANOVA, and Wilcoxon tests.

- **Qualitative SPI data** will be used to determine benthic health qualitatively**.** Physical measurements made with the SPI system from profile images provide information about gradients in physical disturbance (caused by dredging, trawling, or storm resuspension and transport) in the form of maps of sediment grain size, boundary roughness, sediment textural fabrics, and structures. The apparent redox potential discontinuity depth, distribution of biological successional stages, presence, or absence of sedimentary deposits are assessed and measured visually for each SPI photograph. Measurements are evaluated statistically to identify spatial and temporal trends.

Worksheet #11 (specifically Step 5) in the SAP contains a description of how the data will further evaluated to assess the results of the pilot test.

5.4 Reporting

Final, validated, sediment, and tissue analytical data collected during this Pilot Study will be presented in a technical memorandum upon completion of the Pilot Study. The technical memorandum will include data reduction, tabulation and analysis, report preparation, and QC checks. The report will include a description of field activities, field logs and data sheets, analytical results and associated laboratory reports, qualitative results, a description of any deviations from the work plan, and a discussion of the data evaluation conducted to meet the objectives of the Pilot Study. In addition to test files and QC data, the data report will include the identification of outliers, as appropriate, details regarding the corrective actions taken in the laboratory, if any, and discussion of any necessary deviation from the protocols established in the referenced methods.

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Tables

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TABLE 2-1
Methods for Placement of Granular Materials
Hunters Point Naval Shipyard, San Francisco, California

Placement Method	Description of Method	Site Access	Water Depth	Current Velocities	Placement Accuracy and Precision	Compatibility with AquaGate and SediMite
Crane with Clamshell Bucket	Conventional crane with wire supported clamshell bucket.	Can be land based (reach limited) or barge mounted, can have significant reach depending upon size. Can place material around pilings if no overhead obstructions.	Can be used in wide range of depths, deploy material by opening bucket at water surface or any depth below water surface.	High current velocities can cause drift of material or bucket.	Moderate accuracy and precision, depending upon water depth, current velocity, and operator capability.	Good
Excavator with Clamshell Bucket	Excavator with clamshell bucket.	Can be land based (reach limited) or barge mounted, limited reach compared with crane. May be able to place material around pilings if no overhead obstructions, depending upon reach.	Can be used in a limited range of depths, deploy material by opening bucket at water surface or any depth below water surface. Bucket cannot be placed as deep as with crane.	High current velocities can cause drift of material. Opening bucket near bed can reduce effects.	Improved accuracy and precision, depending upon water depth, current velocity, and operator capability.	Good
Pneumatic Methods (such as express blower truck)	Material is blown thru a delivery pipe and hose system, material is discharges above water surface.	Application point typically water based floating equipment. Use of flexible pipeline allows blowing into access limited areas. Blower operations can be land or water based.	Material is discharged at water surface. Drift thru water column depends upon current velocities.	High current velocities can cause drift of material. Material is discharged at water surface.	Limited accuracy and precision. Material is blown over water surface and allowed to sink.	Limited due to potential for degradation of particle coating, dust generation, and loss of AC to water column.

TABLE 2-1
Methods for Placement of Granular Materials
Hunters Point Naval Shipyard, San Francisco, California

Placement Method	Description of Method	Site Access	Water Depth	Current Velocities	Placement Accuracy and Precision	Compatibility with AquaGate and SediMite
Hydraulic Methods	Material is mixed with water to create a slurry and then pumped to placement location. Typically discharged at water surface but can be discharged at depth.	Application point typically water based floating equipment. Use of flexible pipeline allows blowing into access limited areas. Slurry operations can be land or water based.	Material is typically discharged at water surface, but submerged placement can be performed with modified equipment.	High current velocities can cause drift of material. Submerged discharge can be used to lessen effect, but need to compensate for discharge velocity.	Moderate to improved, depending upon current velocity and water depth and use of surface or submerged discharge.	Limited due to potential for degradation of particle coating, turbidity generation, and loss of AC to water column.
Salt Spreader (Spinning Disk) Placement	Dry material is discharged onto a spinning disk with vanes which throws the materially radially out from the disk.	Typically used from water based floating equipment. Hopper and disk placed near side of barge and barge moved during application.	Material is discharged at water surface. Drift thru water column depends upon current velocities.	High current velocities can cause drift of material. Material is discharged at water surface.	Limited accuracy and precision. Material is thrown over water surface in random pattern and allowed to sink.	Moderate, some potential for particle degradation and dust generation due to impact forces.
Articulated Conveyor	Dry material is loaded into a hopper that discharges onto a conveyor belt. Belt can telescope to some distance and has ability to sweep horizontally.	Can be used from land or water, reach limited.	Material is discharged at water surface. Drift thru water column depends upon current velocities.	High current velocities can cause drift of material. Material is discharged at water surface.	Moderate accuracy and precision, depending upon water depth, current velocity, and operator capability.	Good. Material can be kept dry and rehandling limited until placement. Use of scatter plate at end of conveyor may cause loss of particle coating.
Stone Slinger	A short, often high-speed conveyor belt mounted on back of dump trucks that can “sling” materials discharged from truck bed.	Can be used from land or water, throwing distance limited.	Material is discharged at water surface. Drift thru water column depends upon current velocities	High current velocities can cause drift of material. Material is discharged at water surface.	Limited accuracy and precision. Material is thrown over water surface in random pattern and allowed to sink.	Moderate, some potential for particle degradation and dust generation due to impact forces.

TABLE 3-1
Sample Analyses Summary
Hunters Point Naval Shipyard, San Francisco, California

Analysis		Samples per Station	Number of Stations	QA/QC Samples	Total Number of Samples Per Event
Grab Sample	Benthic Community Census	1	10 + 5 Ref	0	15
	Bulk Density	1	20	2	22
In Situ Core Samples	In situ bioaccumulation analysis of bivalve tissue for: PCBs, lipids content, percent moisture	1	20	1 (unexposed) 2 (field duplicates)	23
	Sediment analysis for: PCBs, TOC, water content, grain size	1	20	2	22
Passive Sampler	PCBs in sediment porewater	1	20	2	22
Core Sample	TOC and BC in sediment sections / visual confirmation of amendment mixing	1 core split into 3 sections	60	6	66

TABLE 3-2
Analytical Methods Summary
Hunters Point Naval Shipyard, San Francisco, California

Matrix	Analytical Group	Analytical and Preparation Method/ SOP Reference
Sediment	PCB Congeners	USEPA Method 1668C/ SOP #31
Sediment	TOC	Lloyd Kahn/ CHM-CS500
Sediment	Grain Size	ASTM D422-63/ GEN-PSATM
Sediment	BC	CHM-Black Carbon/ CHM-CHN MAC
Sediment	LOI	ASTM D7348/ CHM-TGA
Sediment	Moisture Content	ASTM D7582/ CHM-TGA
Tissue	PCB Congeners	USEPA Method 1668C
Tissue	Percent Solids	USEPA Method 1668C
Tissue	Lipid Content	USEPA Method 1668C

Notes:

USEPA methods = *USEPA Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* (SW-846), Third Edition, Fourth Update (USEPA, 1989).

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Figures

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FIGURE 1-1
Site Location Map

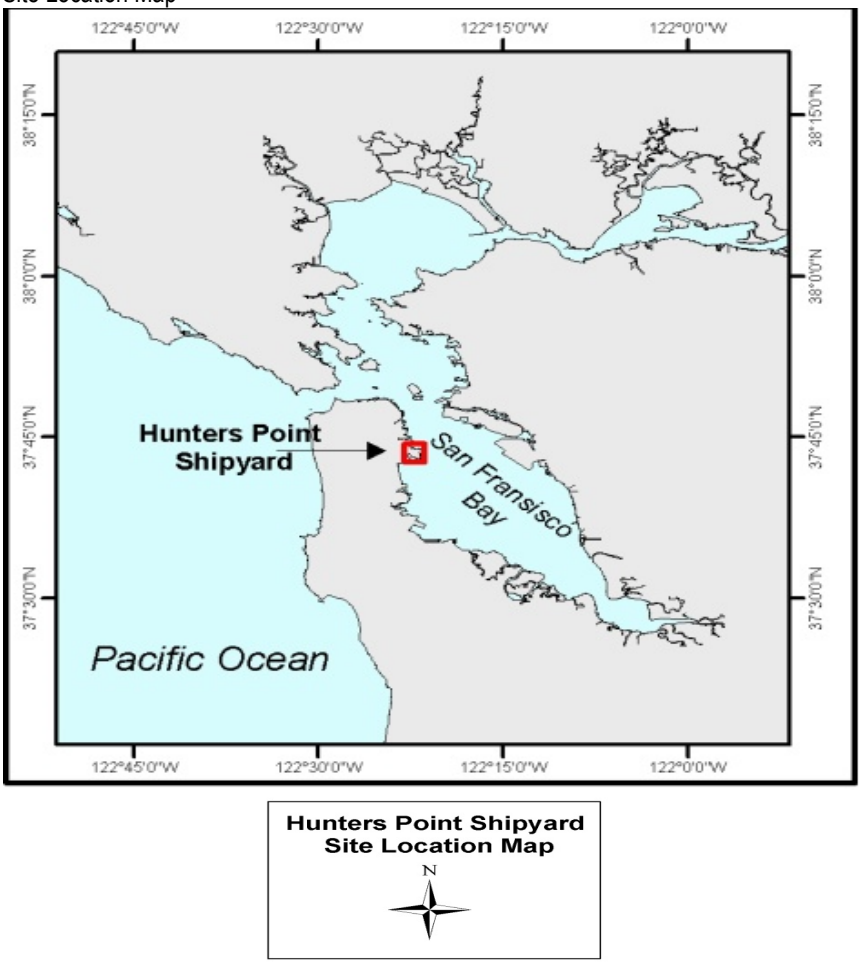

FIGURE 1-2
Map of HPNS with Parcel Boundaries, Including Parcel F with Offshore Sediments

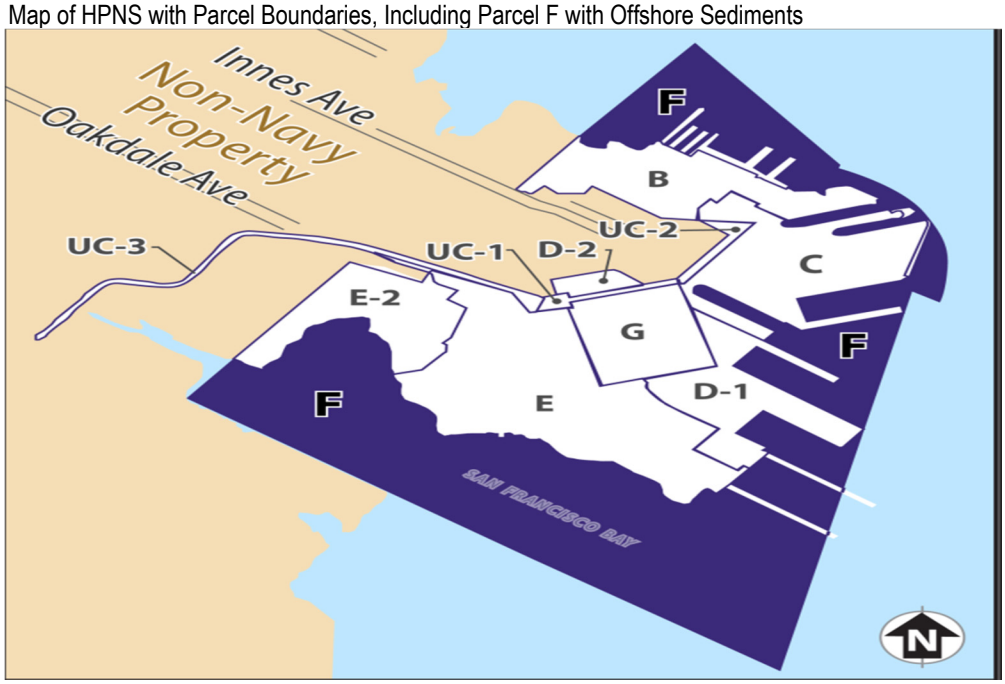

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FIGURE 1-3A

Proposed Location of 1-acre Amendment Study Site along the MLLW Contour in South Basin, HPNS

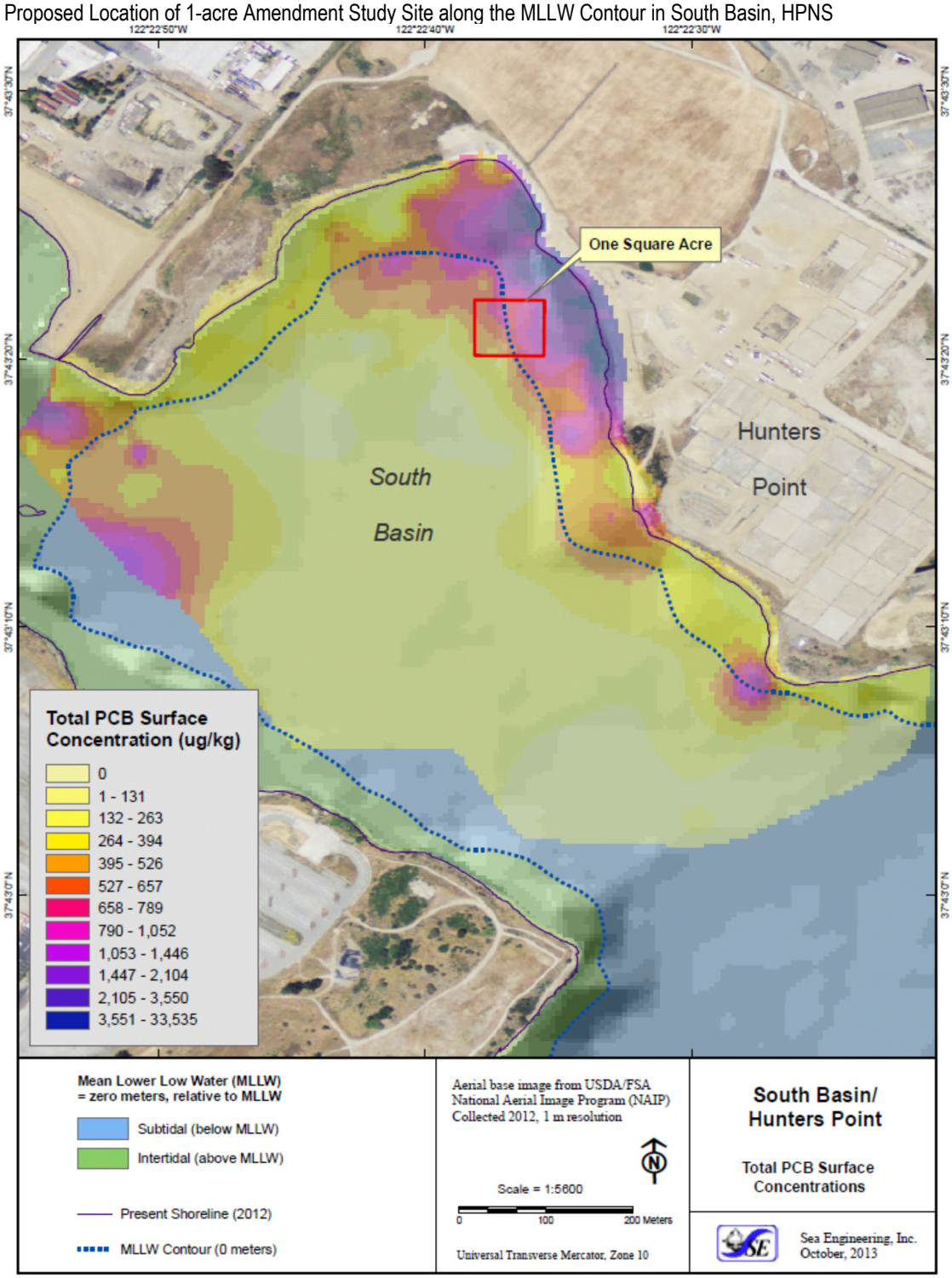

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FIGURE 1-3B

Proposed Location of 1-acre Amendment Study Site along Selected Bathymetry Contours in South Basin, HPNS

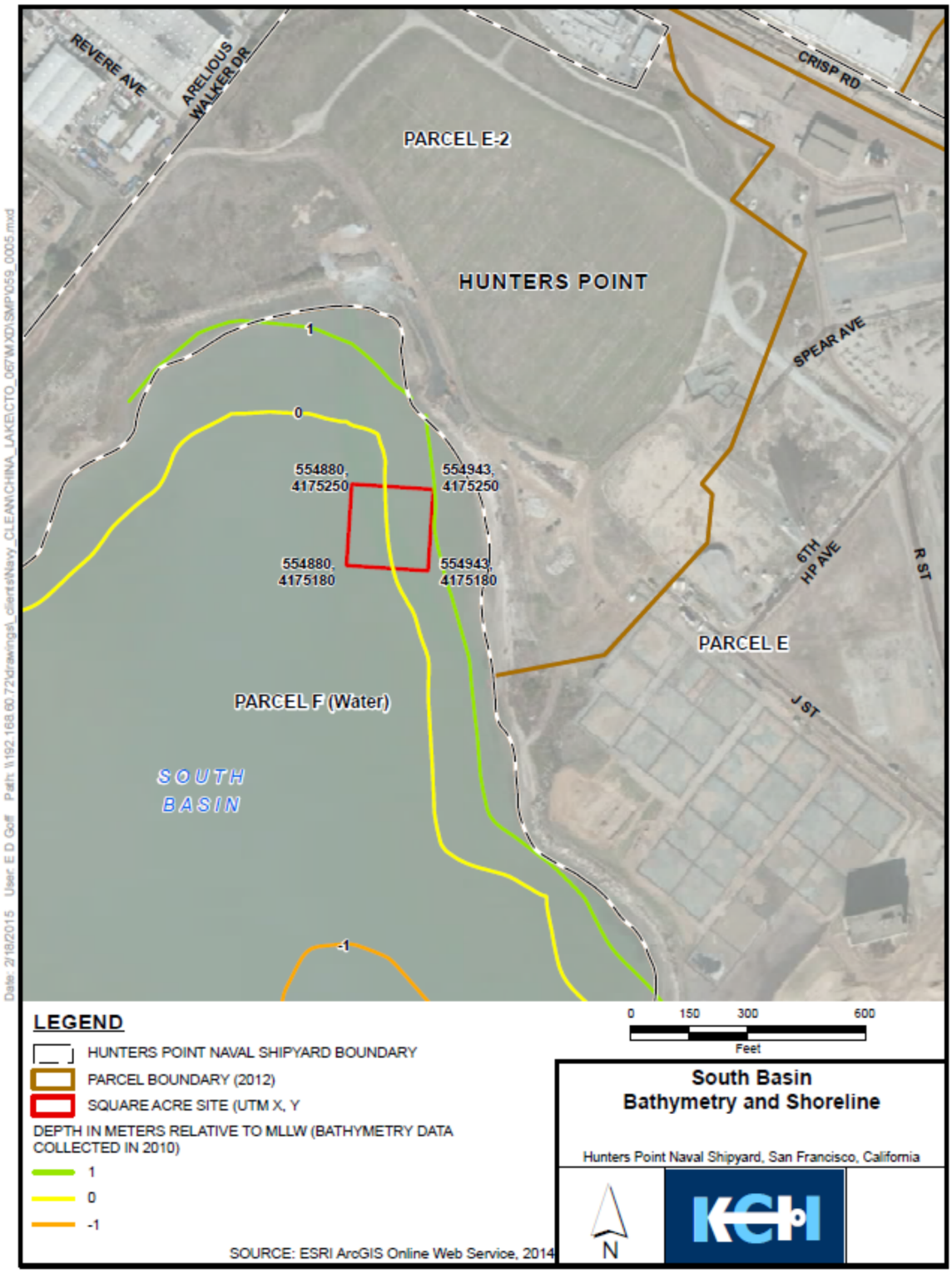

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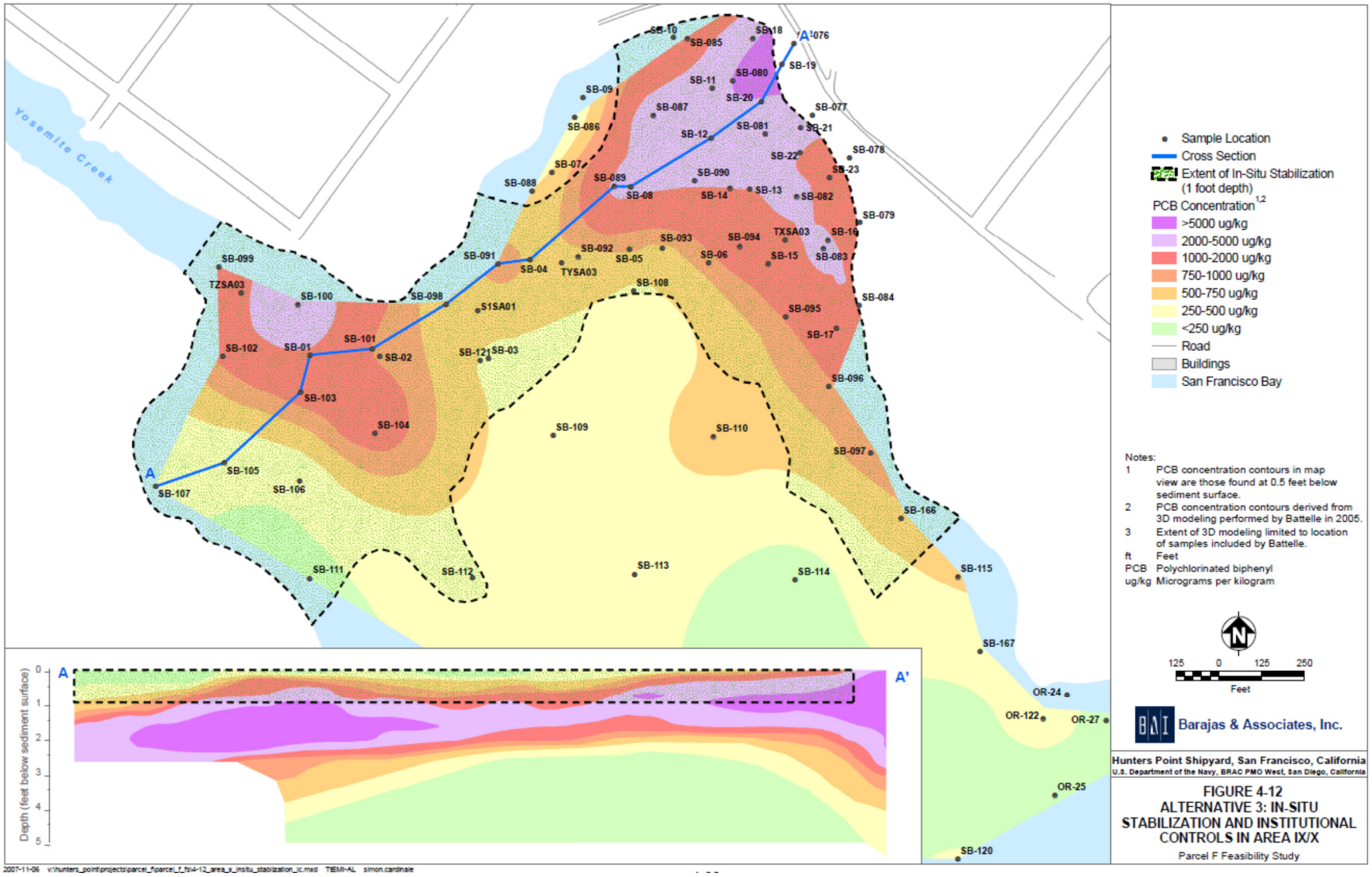
FIGURE 1-4
FS Alternative 3: In Situ Stabilization



Source: BAI, 2007

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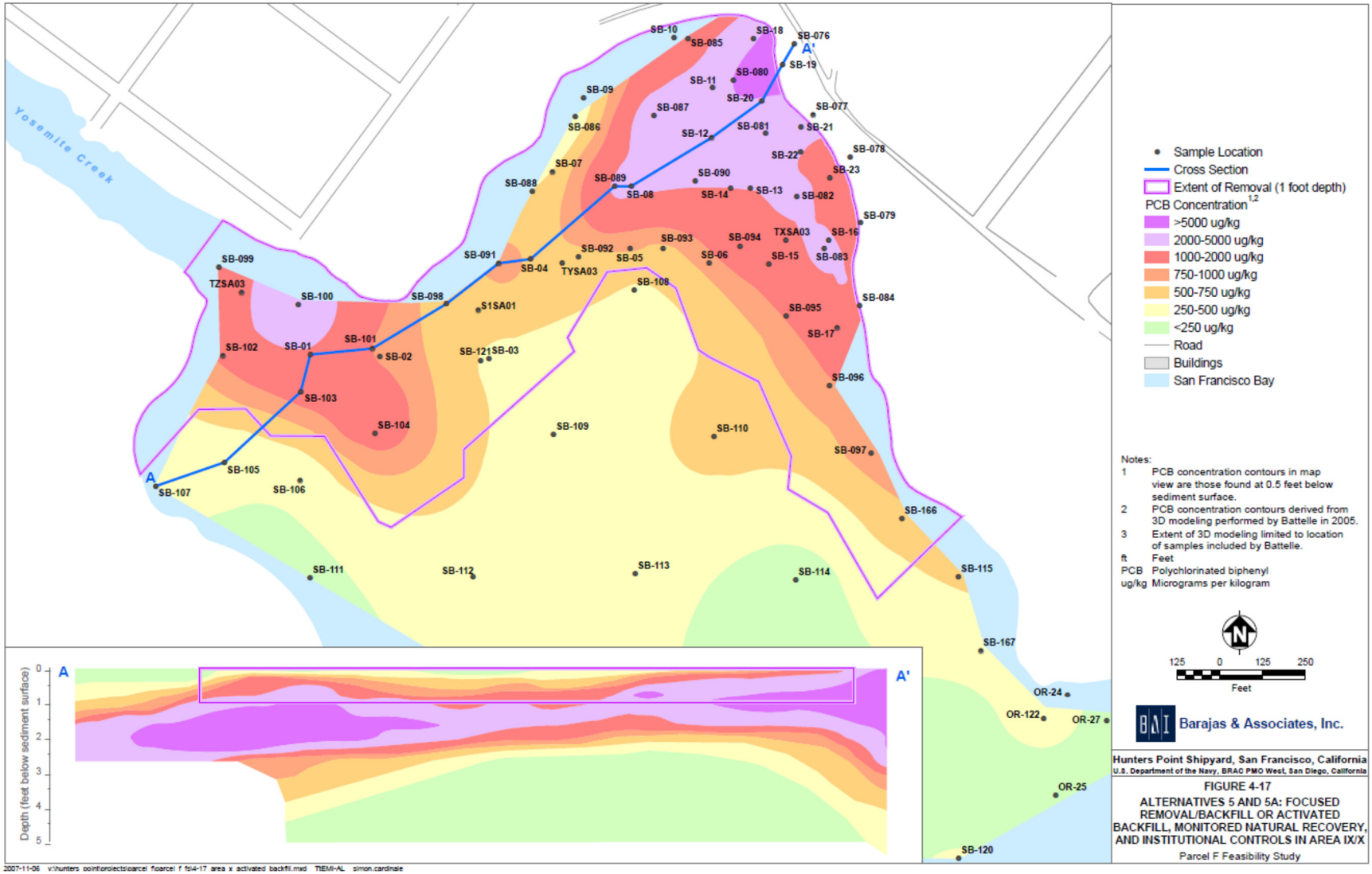
FIGURE 1-5

FS Alternative 5a: Focused Removal and Backfill with AC Material



Source: BAI, 2007

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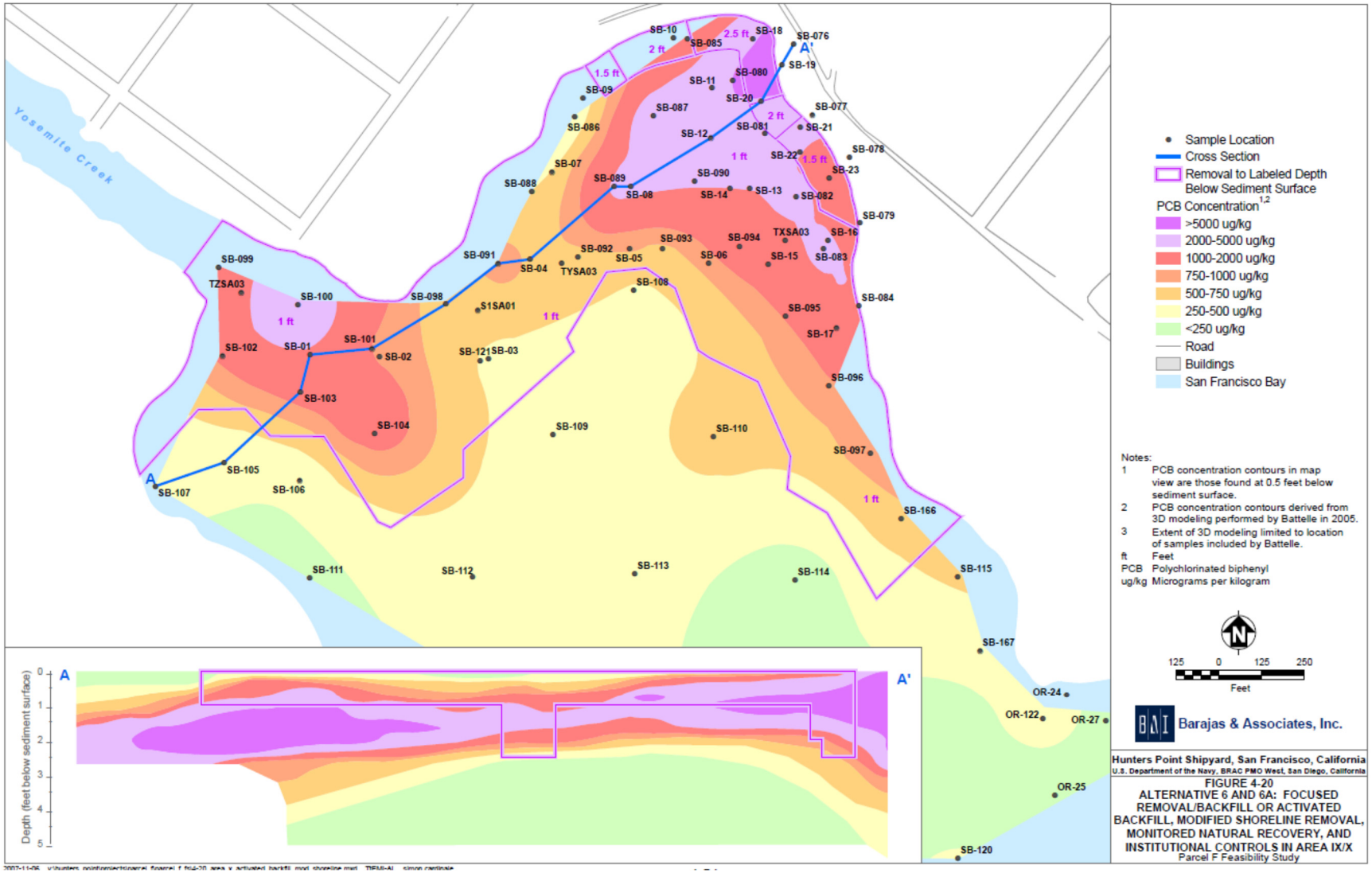
FIGURE 1-6

FS Alternative 6a: Focused Removal with Modified Shoreline and Backfill with AC Material



Source: BAI, 2007

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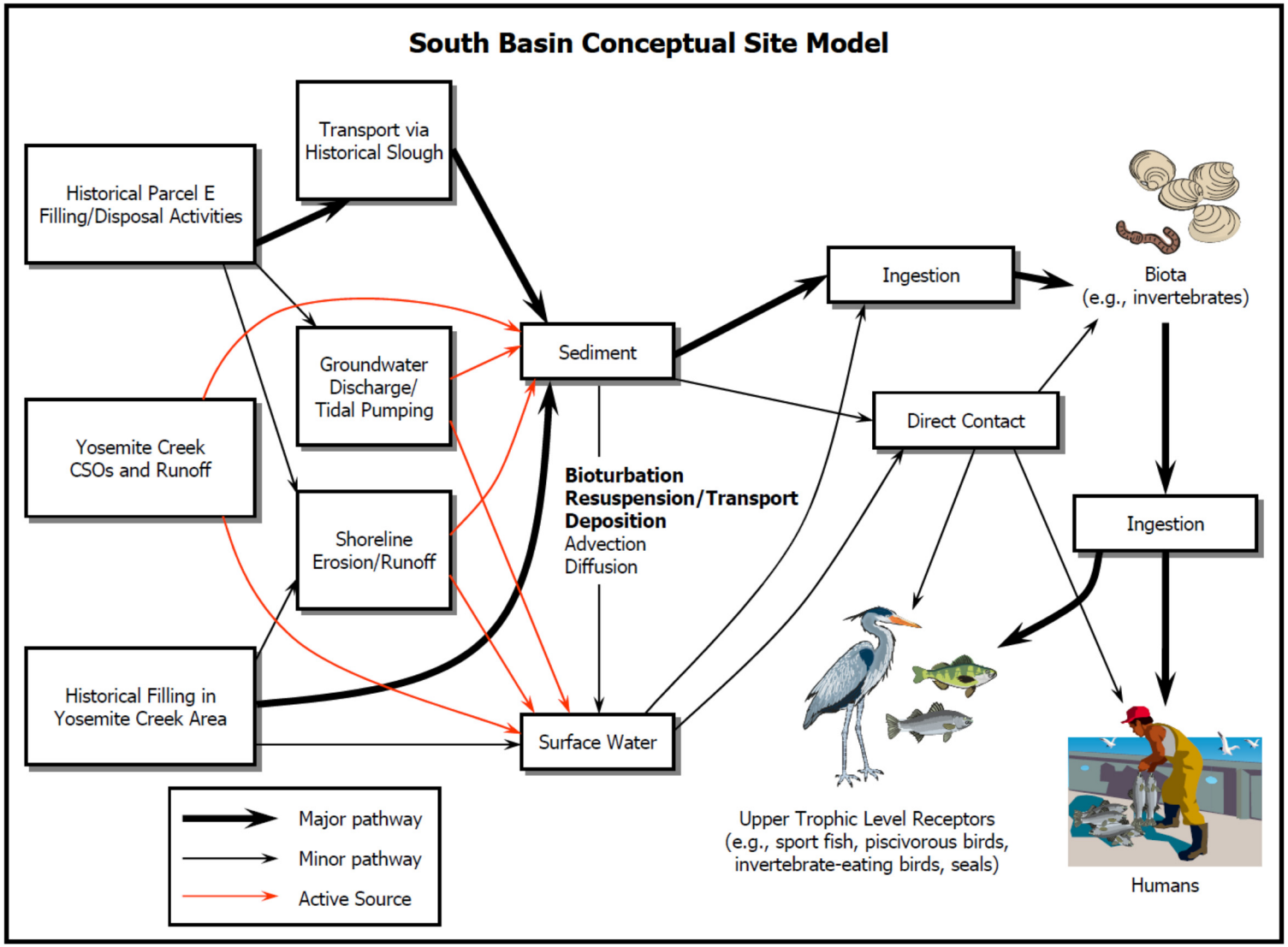
FIGURE 1-7
CSM for South Basin Sediments



Source: Battelle et al., 2006

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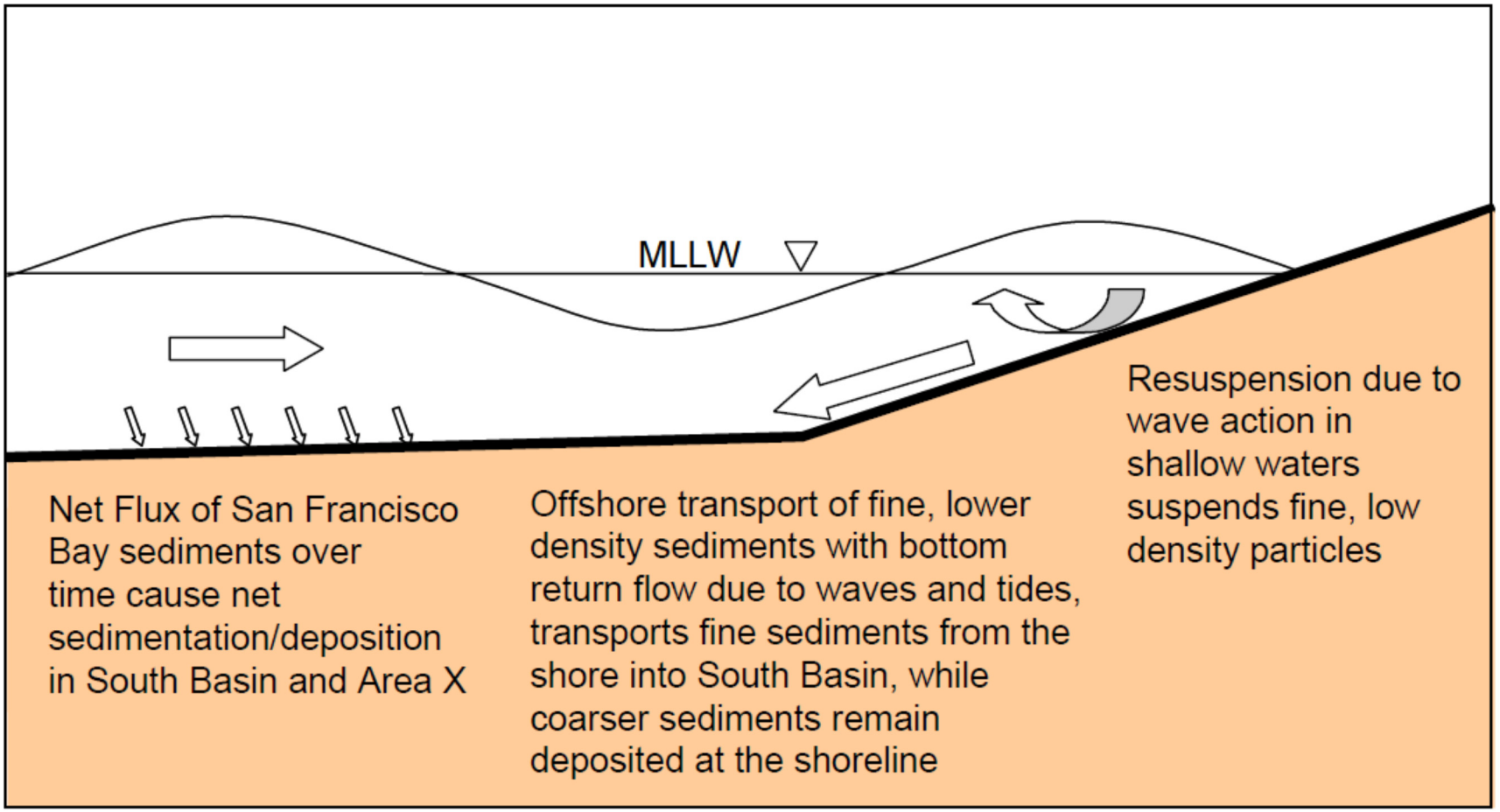
FIGURE 1-8
Sediment Transport Processes in South Basin



Source: Battelle et al., 2006

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FIGURE 2-1
Technology Demonstration – Reactive Amendment, Conventional Delivery System, and a Suite of Monitoring Tools

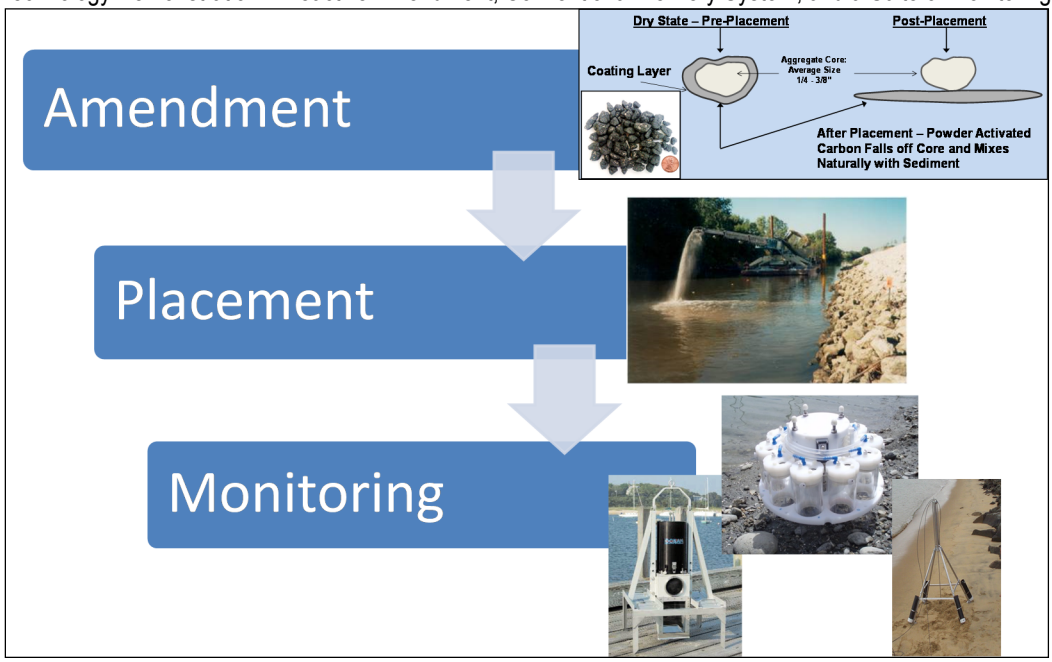

FIGURE 2-2
AquaGate Composite Particle Technology

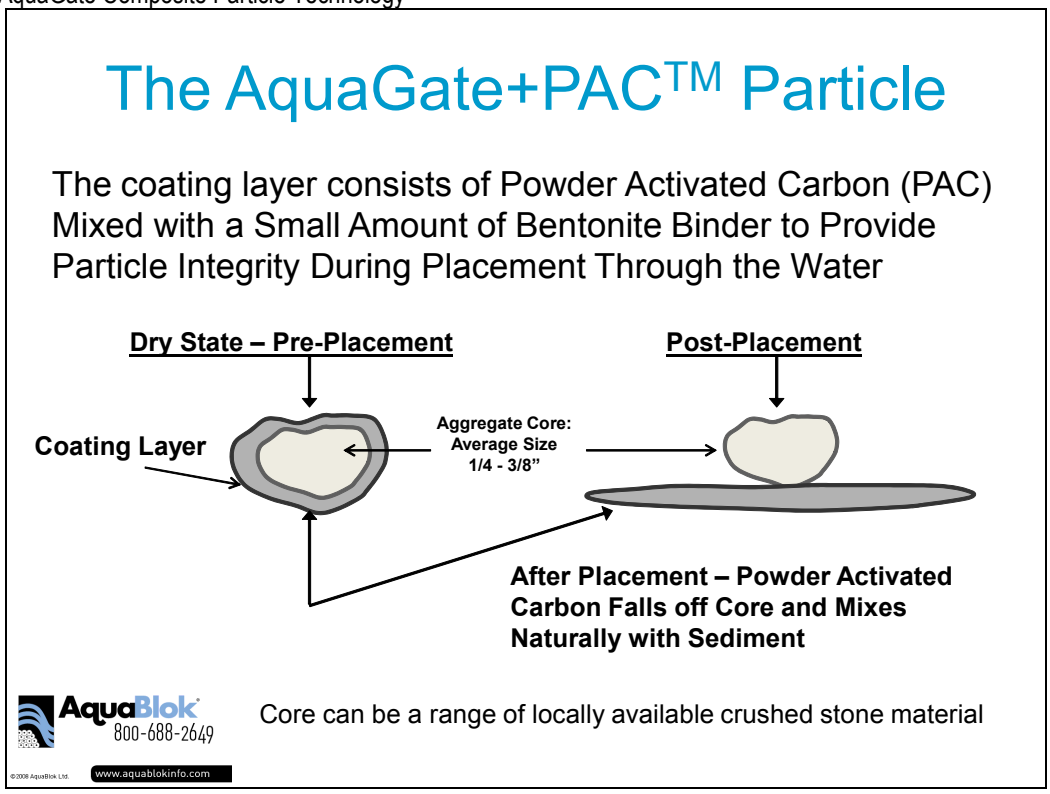

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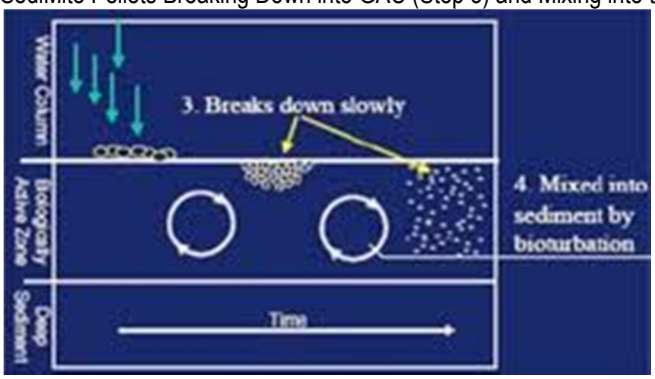
FIGURE 2-3
AquaGate: Crushed Stone Core Coated with a Combination of Bentonite-Based Clay and Powder-Activated Carbon Materials

FIGURE 2-4
Typical SediMite Pellets Used in Sediment Application

FIGURE 2-5
SediMite Pellets Breaking Down into GAC (Step 3) and Mixing into the Sediment (Step 4)



Note: Prior manufacture (Step 1) and delivery at top of water column (Step 2) not shown here.

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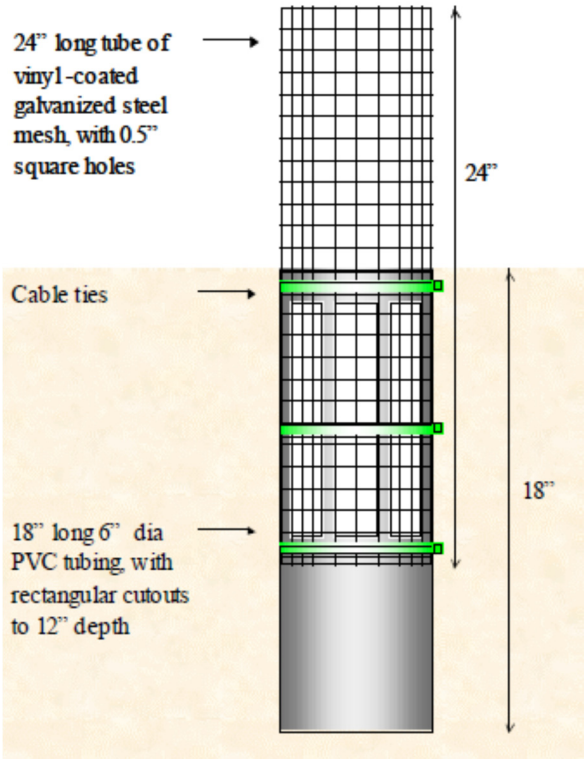
FIGURE 3-1
Example of Cores Used for in Situ Bioaccumulation Analyses



Source: Luthy et al., 2009

FIGURE 3-2
Petite Ponar Grab Used for the Benthic Invertebrate Surveys

Note: Photo courtesy of Wildco (www.wildco.com).

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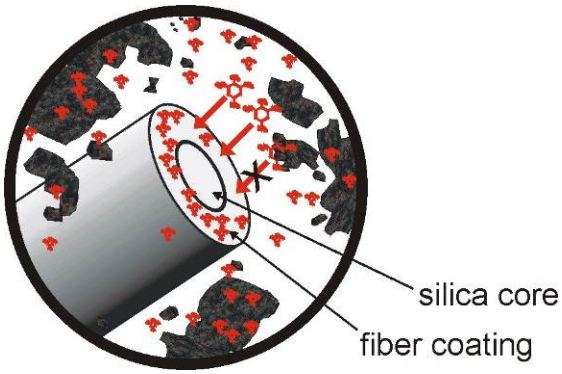
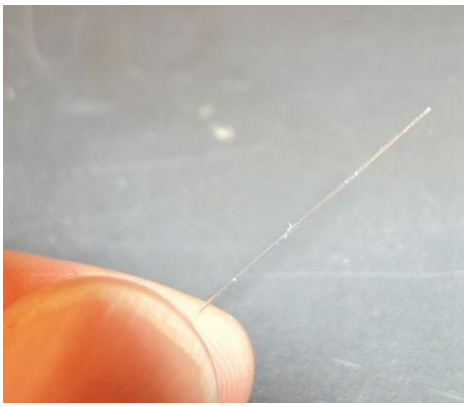
FIGURE 3-3
Passive Samplers Include (But Not Limited to) SPME Technique: Conceptual Model (Left); SPME Fiber and SPMEs in Steel Mesh Envelope Applicator (Right)





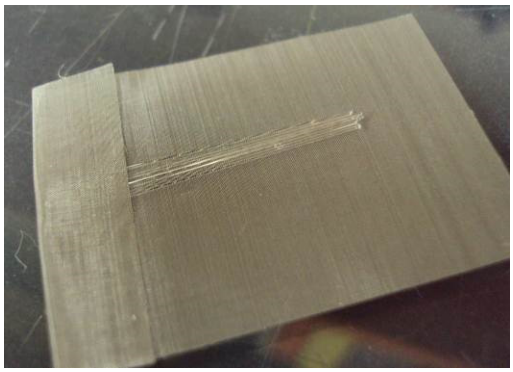


FIGURE 3-4
SPI Camera (Left) and SPI Image (Right)

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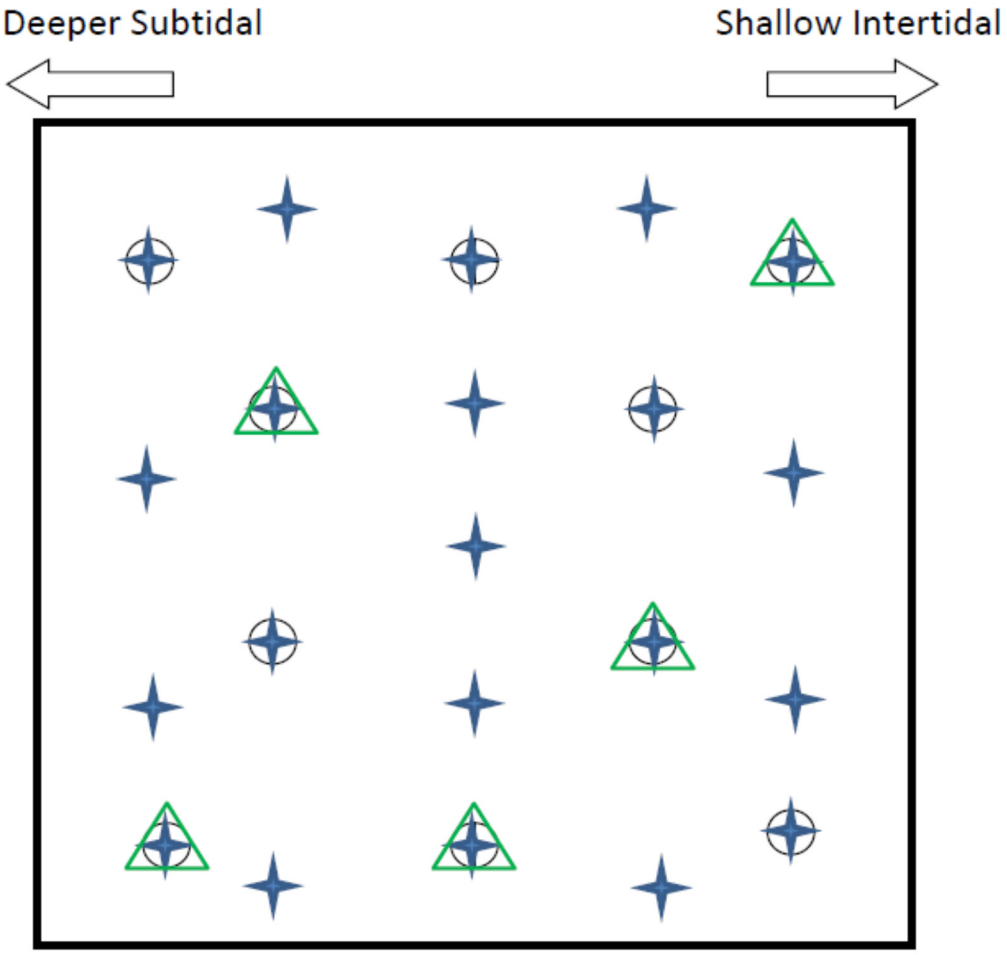
FIGURE 3-5
Conceptual Sampling Location Layout of the 10 Multimetric Sampling Stations within Each Amendment Plot Shown in Figure 1-3



Note:
Final locations will be dependent on field conditions and results of initial placement assessment.

Legend:

SPI location

Multimetric sampling location (Sediment core, sediment grab, bioaccumulation chamber, and passive sampler

Benthic community analysis location

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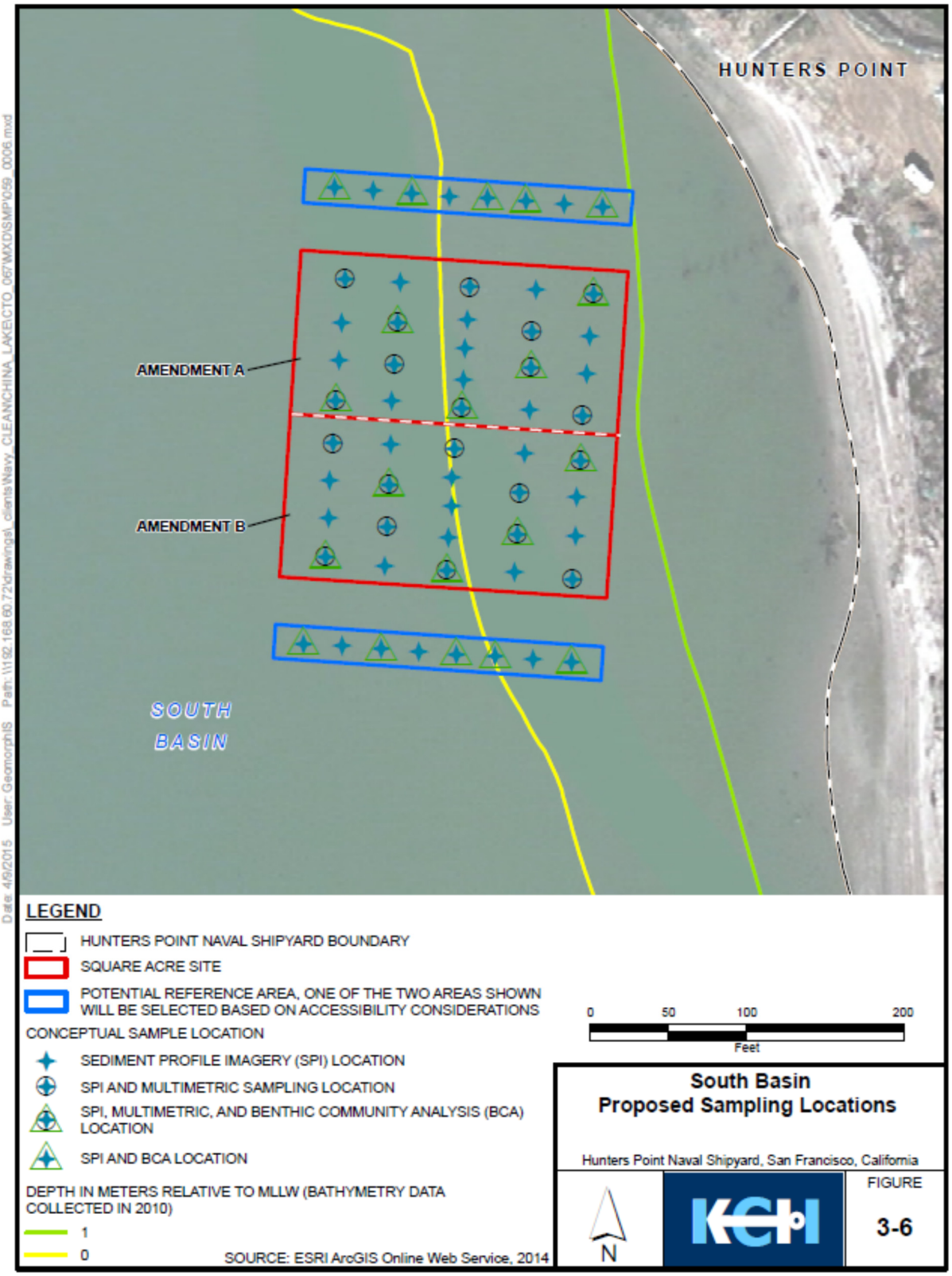
FIGURE 3-6
South Basin Proposed Sampling Locations



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