Navy Environmental Sustainability Development to Integration Program

Diver-less Deployment System for In-Situ Sediment Samplers

NESDI Project #529

Air and Port Operations (EEC-4) Project

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Dr. Jessica Carilli
Mr. Joel Guerrero
Dr. Lewis Hsu
Dr. Jim Leather
SPAWAR Systems Center, Pacific

Dr. Bart Chadwick
Coastal Monitoring Associates

Kimberly Markillie
Naval Facilities and Engineering Command, Pacific

Dr. Rachel Adams
Loyola Marymount University

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Acronyms and Abbreviations

COPC	Contaminant of Potential Concern
COTS	Commercial off the Shelf
DGT	Diffusive Gradient in Thin Film
DOD	Department of Defense
DON	Department of the Navy
DU	Decision Unit
EPA	Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
GPS	Global Positioning System
JBPHH	Joint Base Pearl Harbor Hickam
LED	Light Emitting Diode
LTM	Long-Term Monitoring
MCPP	2-(2-Methyl-4-chlorophenoxy) propionic acid
MEC	Munitions and Explosives of Concern
MIT	Massachusetts Institute of Technology
MS/MSD	Matrix Spike and Matrix Spike Duplicates
NAR	No Active Remediation
NIST	National Institute of Standards
ORP	Oxidation Reduction Potential
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PED	Polyethylene Sampling Device
PHNC	Pearl Harbor Naval Complex
PRC	Performance Reference Compound
PVC	Polyvinylchloride
RI/FS	Remedial Investigation/Feasibility Study
SCCWRP	Southern California Coastal Water Research Project
SD	Secure Digital
SERDP	Strategic Environmental Research and Development Program
SOP	Standard Operating Procedure
SPME	Solid Phase Micro Extraction
SSC-Pacific	Space and Naval Warfare Systems Center Pacific
TNT	2,4,6-Trinitrotoluene
TUR	Time Until Release
UCSD	University of California San Diego

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1. EXECUTIVE SUMMARY

The Passive Push diverless deployment system was designed to deploy and retrieve passive samplers at contaminated sediment sites without putting divers in the water to place or retrieve the devices. Passive samplers are a relatively new class of monitoring tool that are gaining in popularity and regulatory acceptance; samplers are comprised of different materials that sorb pollutants such as metals and organic compounds from the environment. One benefit of using passive samplers to monitor contaminated sediment sites is that they target the bioavailable compounds dissolved in marine and pore waters. Thus, results produced from monitoring contaminated sites using passive samplers may more accurately reflect contaminants in tissues of organisms that live at that site, as compared with bulk sediment or water concentrations, which might not be well correlated with food web contaminant levels. Another benefit of passive samplers is that the contaminant concentrations sorbed to passive sampling materials tend to exceed detection levels; in contrast, sediment samples and water samples in particular can fall below instrument detection limits, limiting the ability of cleanup managers to understand contaminant dynamics and treatment efficacy (eg. via fingerprinting techniques).

Before the design of the Passive Push system, passive samplers used to assess sediment contamination were typically deployed and retrieved by divers. This method limits the number of samplers that can be deployed or recovered each day to ~5 samplers, and typically up to 50% of the samplers would not be relocated and recovered. In addition, diving in suspected or known contaminated sites could pose health hazards to the divers. This poor recovery rate, safety concerns, and the slow and therefore expensive method of deploying and retrieving samplers called for the design of a system capable of deploying and recovering samples faster, without the use of divers, and with better recovery rates.

The Passive Push system was refined and tested in San Diego Bay and Pearl Harbor. Five performance criteria were evaluated: (1) whether the sampler could deploy multiple types of passive samplers, (2) the rate of sampler deployment and retrieval, (3) the percentage of samples successfully retrieved, (4) the ability to use the system under a range of environmental conditions, and (5) that the system was qualitatively easy to use.

During these tests and demonstrations, the system was able to (1) accommodate multiple types of passive sampling materials, (2) install and recover samplers from approximately 20 stations per day, (3) successfully recover 80-90% of samplers, (4) deploy and recover samplers in a range of water depths, currents, and bottom types, and (5) be used easily by a small field team. The increased rate of sampler deployment and recovery, and increased number of recovered samples both lead to the use of this system being much more cost effective than traditional diver-deployed methods.

2. INTRODUCTION

This final report provides the background, objectives, technology description, performance objectives, and field evaluation results of a diver-less deployment system for in-situ sediment passive samplers called the Passive Push. This section provides a general overview of the project including background, objectives and regulatory drivers.

2.1. BACKGROUND

Contaminated sediment in the Navy's harbors is anticipated to become a $2billion problem over time, more if potential natural resource damages are factored in. Dredging contaminated sediment is exorbitantly expensive and results in collateral impacts to aquatic biota. Resuspension and resettling of bedded sediment during dredging often leads to inability to meet target cleanup goals, even after multiple passes with a dredge. Capping contaminated sediment is relatively less costly, but is not always possible in harbors that entertain ship traffic. Monitored natural recovery is not always acceptable to regulators and public stakeholders. Driven by a lack of suitable options and the increasingly apparent limitations of existing technologies over time, there is a need to develop more nuanced technologies and risk assessment methods in all these categories – natural recovery, capping, and dredging. In addition, munitions and explosives of concern (MEC) are sometimes found in sediments and better methods to identify and manage (in place)/separate/dispose of them are required.

Improved risk assessment and more nuanced remedy strategies will require cost effective monitoring that accounts for not just the bulk sediment concentrations, but the bioavailable fraction of the contamination. For example, in-place treatment of contaminated sediments by activated carbon amendments has been shown to be effective in protecting ecological receptors from contaminants; however traditional bulk sediment sampling approaches, the typical method by which sediment cleanup goals are determined to be achieved, do not adequately account for the efficacy of activated carbon. In addition, traditional methods for assessing bioavailability in sediment risk assessments and remedy performance monitoring generally involve complex and expensive characterization of biota uptake either in the field or in the lab. Field methods are logistically very challenging and expensive and are often plagued by uncertainty associated with site fidelity of the target organisms. Lab studies are generally limited to lower trophic level organisms and have high levels of uncertainty associated with the handling and processing of sediments as well as the difficulty of reproducing field conditions in the lab.

Recently, the Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) have invested in the development of a new family of passive sampling devices for assessing sediments and monitoring contaminated sediment remedies (U.S. EPA/SERDP/ESTCP 2017). These devices generally rely on the partitioning of the bioavailable phase of the contaminant to the sorptive surface of the sampler. Detailed calibrations and performance assessments, along with incorporation of performance reference compounds has led to the ability to apply these devices both qualitatively and quantitatively in the field and the laboratory as evidenced by Environmental Protection Agency (EPA) endorsement and ESTCP guidance documents. As the technology transitions to application, one of the key limitations that has been identified is the ability to reliably deploy and retrieve the devices in the field in a cost-effective manner. Most of the demonstrations to date have focused on either shallow water deployments by wading, or deeper water deployments by divers. Experience has shown that the costs associated with these deeper water diver deployments may significantly reduce the cost effectiveness of the approach. This is especially relevant for Navy sites where many of the areas of interest are in water depths beyond the capability of wading. In addition, extensive boat, ship and other harbor activities in these areas preclude the use of surface floats which can significantly hamper retrieval. The ability to routinely deploy and retrieve these devices in Navy areas of interest without the costs associated with divers would thus significantly enhance their cost effectiveness.

2.2. REGULATORY DRIVERS

At the Federal level, contaminated sediments are regulated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund). Under CERCLA, suspected contaminated sites are assessed and if sites are determined to be contaminated, they are placed on the National Priorities list. Currently, this list contains 157 Federal sites, including 39 Navy sites (EPA, 2018). Cleaning up these contaminated sediments is anticipated to cost the Navy on the order of $2billion (SERDP/ESTCP 2016).

Division 7 of the California Water Code (Porter-Cologne Water Quality Control Act), CA State Water Board plans and policies, and the San Diego Region Basin Plan confer legal authority on the San Diego Water Board to regulate cleanup sites, including Navy sites, in San Diego Bay.

These cleanup regulations stipulate a number of steps that managers of contaminated sediment sites must complete, including initial assessment of the problem, solution design and implementation, and long-term monitoring to determine that cleanup was effective. At each of these stages, passive sampling can provide useful information on bioavailability of contaminants; the ultimate goal of cleanup efforts is to reduce bioavailability of contaminants below thresholds that are determined to be protective of ecosystems and human health.

2.3. OBJECTIVE OF THE PROJECT

The technical objective of this project was to adapt available technologies and demonstrate a rapid, cost-effective system and methodology for diver-less deployment of in-situ passive sediment samplers. Key technical requirements of the system were that it supports the current range of typically-used sediment passive samplers and that it can quickly and inexpensively deploy and retrieve the samplers without the use of divers under the expected conditions at Navy contaminated sediment sites. Types of samplers currently in use include polyethylene sampling devices (PEDs), solid phase micro extraction (SPME) devices, and diffusive gradient in thin film (DGT) devices. These samplers come in different forms and sizes that require some flexibility in terms of the design of the deployment system. Conditions at Navy sediment sites vary widely but are commonly expected to include (1) water depths in the range of 0-50 feet, (2) tidal currents and or river currents in the range of 0-2 m/s, (3) salinities ranging from fresh to seawater, (4) bottoms of soft silts to sands and gravels with potential for shell hash and debris, (5) ship and tug boat activities, (6) physical structures including piers, quay walls, jetties and bulkheads, and (7) low visibility. The system was tested with different sampler materials at the Spawar Systems Center Pacific (SSC-Pacific) pier. A full demonstration was completed using polyethylene samplers in Pearl Harbor, and slight modifications to the deployment and retrieval system were completed using lessons learned from that demonstration. These modifications were again tested at the SSC-Pacific pier, and further refined and tested during a second demonstration using polyethylene samplers in San Diego Bay in collaboration with the Southern California Coastal Water Research Project (SCCWRP).

3. TECHNOLOGY DESCRIPTION

3.1. TECHNOLOGY OVERVIEW

The Passive Push technology comprises a comprehensive, relatively inexpensive system to deploy and retrieve passive samplers for monitoring sediments and overlying waters for contaminants. A critical aspect of the deployment and retrieval technology refined and demonstrated here was that it be inexpensive so that large numbers of devices can be deployed without undue capital investment. The combination of a direct push deployment device and a controlled retrieval system provides an innovative and cost-effective solution to the deployment of passive samplers in Navy harbors.

3.2. TECHNOLOGY DEVELOPMENT

The technology demonstrated for this project was adapted from previous applications and from the oceanographic technology marketplace, proven for other applications.

Sample frame: The sampler frame is based on a design originally developed by Dr. Phil Gschwend at the Massachusetts Institute of Technology (MIT).

Deployment systems: The Passive Push deployment systems were developed under this NESDI project based off of two existing technologies. The push-pole system was developed based on the Trident Probe system (SPAWAR 2003), and the drive-frame system was developed based on multi-corer technology (e.g. Ocean Instruments MC-800; http://oceaninstruments.com/products/multi-corers/mc-800-multi-corer/).

Retrieval system: Potential retrieval approaches including galvanic links, timed releases, and acoustic releases were reviewed, and a timed release was selected as the primary technology for sampler retrieval. A prototype timed-release buoy device was developed by the Jacobs School of Engineering at the University of California San Diego (UCSD) as a senior design project under the mentorship of SSC-Pacific. This prototype provided proof of concept for the release system. A commercial system was then developed with Sub Sea Sonics during the course of the NESDI project that includes the release, line spool and surface float all integrated into a single unit.

Demonstration of this technology in Pearl Harbor was leveraged with ongoing contaminated sediment monitoring (e.g. DON 2015), and in San Diego Bay was leveraged with a baywide PCB study organized by SCCWRP.

3.3. ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The focus of this project was on development, demonstration, and transition of technology to significantly reduce the cost and complexity of deploying passive sediment samplers. Traditional deployment methods for sediment passive samplers involve a team of divers that deploy and retrieve the samplers by hand. Typical costs for traditional diver-based deployments including boat support, sampling crew and dive team are on the order of ~$8-10K per day. Typical sampling rates using the diver-based approach are on the order of 5-10 stations per day, primarily limited by dive safety and time requirements. In addition, retrieval rates for diver-based methods are poor – typically only about 50% of samplers are recovered because of the inherent challenges of re-finding small objects underwater in low-visibility conditions.

In contrast, the diver-less deployment and retrieval system demonstrated here is able to deploy and retrieve samplers at a rate of approximately 20 stations per day, at a cost of approximately $2-5K per day, with close to 90% sampler recovery rates. Thus, costs of the diver-less system are estimated to be on the order of ~5X lower depending on the comparative capital costs for the dive equipment versus the diver-less deployment technology, and how these costs are amortized over the life of the equipment. The technology is expected to be applicable across the full spectrum of Navy sediment sites because it is useful in both the risk assessment stage and the remediation and monitoring stages of the contaminated sediment cleanup process. The demonstrations achieved three critical goals including (1) documentation of the performance and costs, (2) standardization of the methods, and (3) assistance in transitioning the technology to industry.

The major limitation identified was less than 100% certainty in eventual sampler retrieval. As with any system deployed in and left unmonitored in the marine environment, there is potential for loss of samplers. If a particular site is critical to an investigation, deployment of more than one sampler would be recommended.

3.4. TECHNOLOGY DESCRIPTION

The Passive Push system consists of three modular components: (1) the passive sampler frame, (2) the deployment system, and (3) the retrieval system. The sampler frame is generic in the sense that it can accommodate different samplers, as well as providing a standardized interface for different deployment and retrieval systems. The frame was adapted from frames already in use for typical polyethylene sampling devices (PEDs) but incorporates a standardized interface that allows use of different types of samplers including SPMEs and DGTs. Two deployment systems were developed, one based on the Trident Probe release point (push-pole) technology, and one based on the multi-corer drive-frame technology. Both of these systems were designed to accommodate the standardized frame interface. The push-pole system is viewed as being more effective for shallow water deployments from small boats, particularly when a winch system is not available, while the frame system allows for deeper water deployments from larger vessels, and is generally faster to use than the push-pole, allowing for more sampler deployments over a given time period.

The retrieval system for the Passive Push system uses a retrieval buoy and line system controlled by a timed release. The retrieval system was adapted to allow it to accommodate the standardized sampler frame interface. The timed release is moderately priced and provides more certainty than other release mechanisms, and will work in both salt water and freshwater environments; however the time must be pre-programmed and thus lacks the ability to adapt to potential interferences. However, the retrieval system resulted in improved sampler recovery rates compared with diver-based methods, and faster and easier recovery compared with other grappling-hook based methods other groups have used to circumvent the need for divers. Overall, the system was demonstrated to be a successful addition to Navy technological needs for sediment monitoring programs.

3.4.1. Sampler Frame

The sampler frame is consistent with the original design developed by Dr. Phil Gschwend at MIT. The standard long frame was originally constructed from two identical sheets of thin anodized aluminum, with an overall length of about 64 cm and a width of about 20 cm (Figure 1). The sampler material is sandwiched between the metal sampler frame plates which are held together at regular intervals by stainless steel fasteners. The window for the sampler is about 47 cm high by 14 cm wide. The frame has a handle-shaped cut out at the top so it can be pushed in by hand in shallow sediment or by divers, and handled with ease by technicians deploying the frames from a boat using the deployment system. A hole above the handle cutout accommodates the release pin that is used with the push pole and the drive-frame systems. The standard short frame is identical to the long frame except the overall length is about 45 cm, and the window height is about 22.5 cm.

During the Pearl Harbor demonstration, samplers could not be deployed at one site, where sediment was coarser-grained – sampler frames simply bent sideways and could not penetrate the substrate. In addition, the aluminum sampler frames suffered significant corrosion, such that some frames could not be reused owing to failure at the fastener threading. For the San Diego Bay deployment, several stainless steel frames of the same dimensions, but slightly thicker, heavier, and stiffer metal were constructed for testing and demonstration. Each type of frame material had benefits and drawbacks, discussed below.

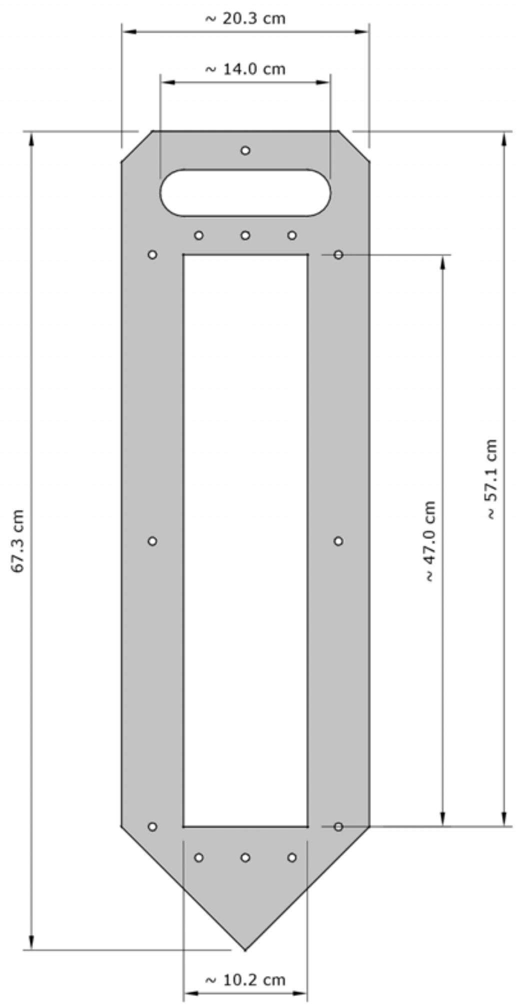


Figure 1: Passive sampler frame.

3.4.2. Push Pole Deployment System

The push pole system is designed for deployment of passive samplers in water depths to about 15 m depending on water current, wave, and wind conditions. Calmer conditions are required for successful deployment in deeper waters with this system. The push pole system includes the head unit and the push poles (Figure 2). The head unit has a socket into which the sampler frame inserts. A spring-loaded release pin secures the sampler frame inside the socket. The head unit also incorporates an adjustable stopper plate that sets the penetration depth of the sampler into the bottom. The stopper plate is adjusted by loosening the bolts that secure it to the head unit, adjusting to the desired level relative to the sampler frame, and then re-securing the bolts. The push poles are made up of 2 m long sections of 3.8 cm diameter aluminum tubing. Each section has a male and female socket on opposite ends to allow the poles to be secured together to the desired length that will accommodate the water depth at the deployment site. On the bottom of the first pole closest to the head unit, an underwater video camera is secured that allows the operator to observe the sampler installation. The video camera has a cable running to the surface that connects to a monitor and a recorder. The camera also has an adjustable Light Emitting Diode (LED) lighting system to accommodate low light conditions at greater water depths.

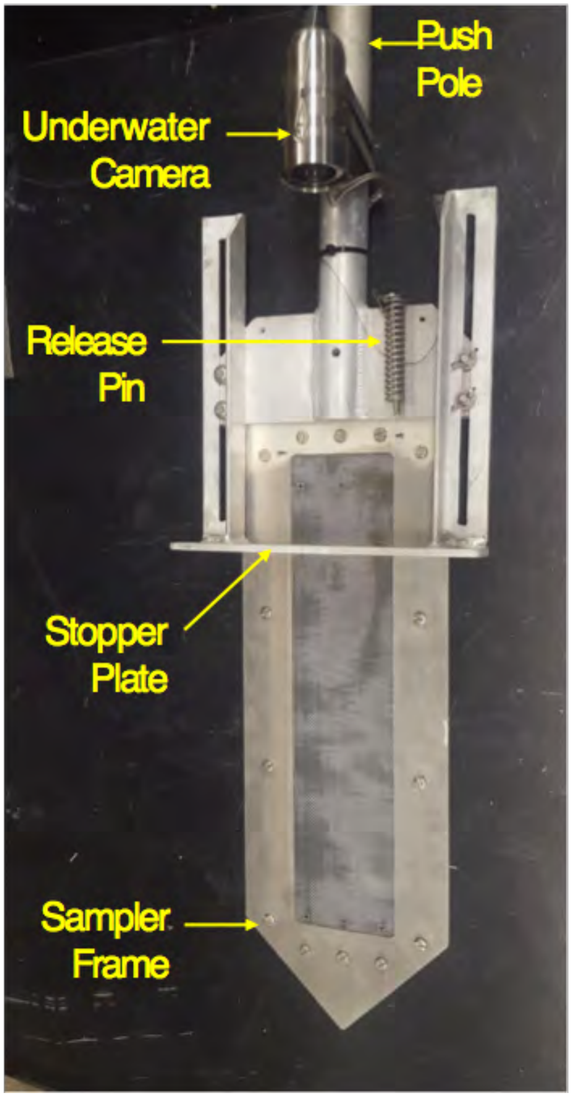


Figure 2: Push pole system.

3.4.3. Drive-Frame Deployment System

The drive-frame system is designed for deployment of passive samplers in all water depths up to about 100 ft. It is particularly useful when operations or physical conditions preclude station-keeping or where water depths exceed the range of the push pole system. The drive-frame system includes the deployment frame, the carriage, the drive weights, and the head unit (Figure 3). The drive-frame is an 8-leg frame that supports the drive system and provides stability for the system once it has landed on the seafloor. The carriage rides vertically along the central axis of the drive-frame and provides the vertical motion that allows for the installation of the sampler frame into the substrate. The drive weights are mounted on the carriage and provide sufficient force to push the sampler into the bottom under most conditions. The head unit is mounted on the bottom of the carriage and provides the interface to the sampler frame, similar to the push pole system. The drive-frame system also as an underwater video camera to provide visual reference for the operator to verify sampler placement.

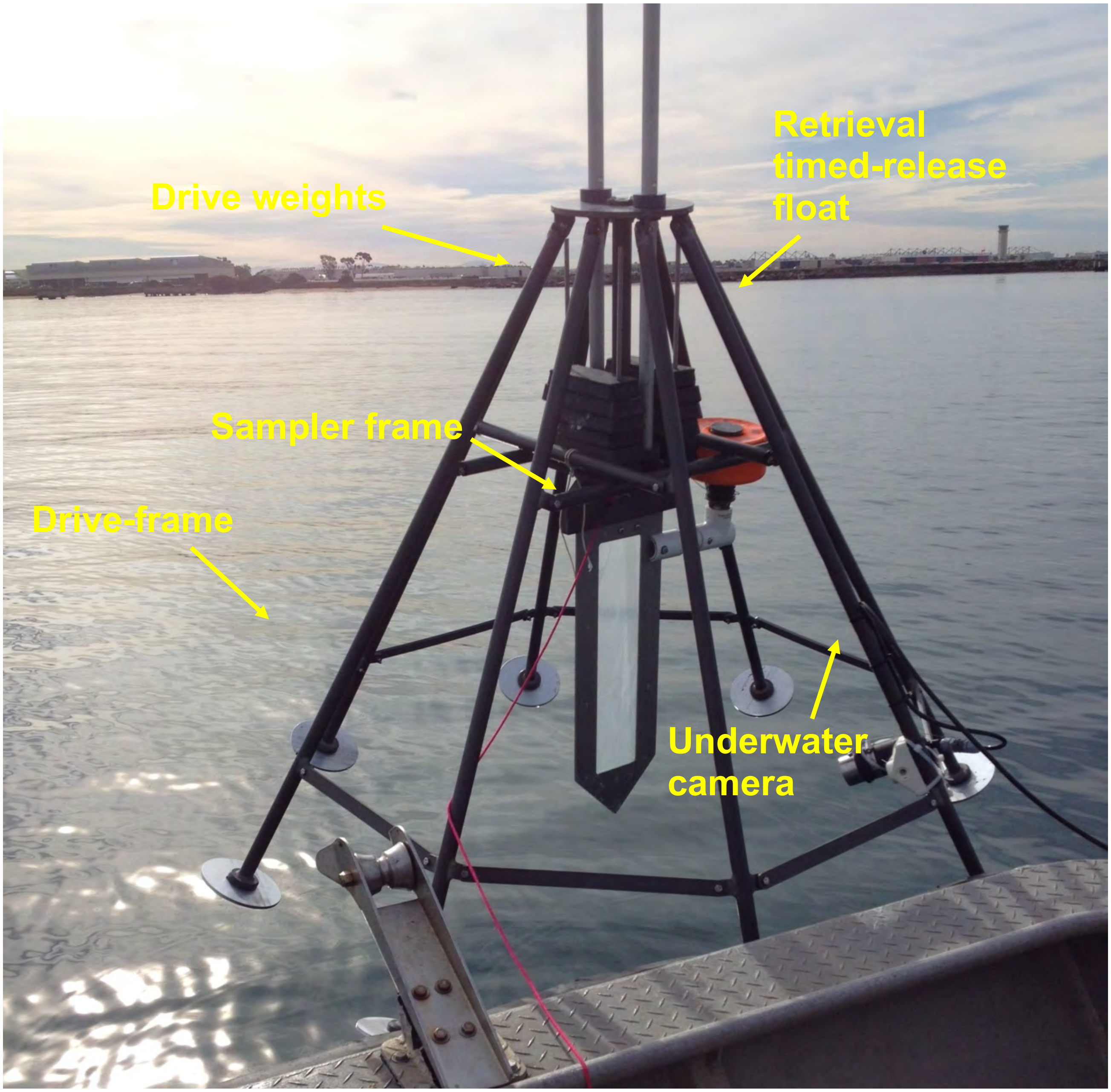


Figure 3: Drive-frame system.

3.4.4. Timed-Release System

The timed-release system provides the ability to retrieve the sampler at a pre-programmed time. The timed-release uses a modified commercial off the shelf (COTS) oceanographic burn-wire release system manufactured by Subsea Sonics. This release unit is deployed underwater and contains a micro-computer and batteries and holds a replaceable release link with a screw-on retainer cap. It is programmed to the time-until-release (TUR) desired by electrical contact with the contacts on a programmer before deployment underwater. Release accuracy is +/-2 minute per month of deployment. After the programmed time has elapsed and release erosion initiates, it takes typically another 10 minutes for the link erosion to complete. To accommodate the retrieval of the passive sampler, a line spool, retrieval line, float and mounting bracket have been incorporated into the standard unit (Figure 4). The line spool can accommodate about 50 m of high-strength, small-diameter line (Dyneema or Spectra). A rigid polyurethane foam float encircles the top of the system to provide sufficient buoyancy to unfurl the retrieval line and come to the surface. The float is then retrieved and the sampler is pulled out of the bottom and recovered using the high-strength line. The entire release unit is attached to the sampler frame with a simple Polyvinylchloride (PVC) bracket.

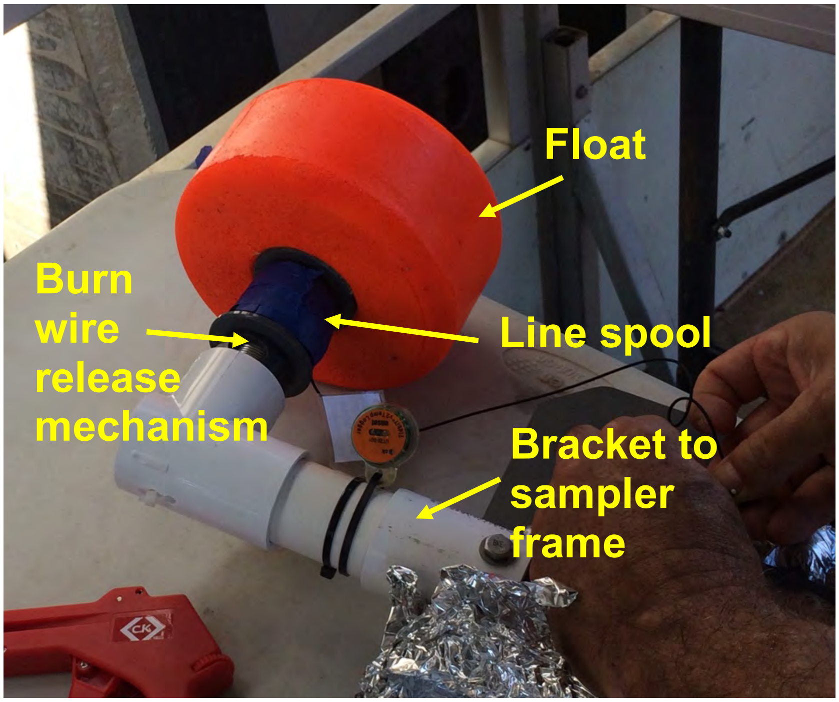


Figure 4: The timed-release retrieval float attached to a passive sampling frame.

4. PERFORMANCE OBJECTIVES

4.1. PERFORMANCE CRITERIA

The performance criteria for the project are aligned with the technical objectives. The key technical objective of this project was to develop and demonstrate a rapid, cost-effective system and methodology for diver-less deployment and retrieval of in-situ passive sediment samplers. Based on this overall objective, the following performance criteria were identified:

- The system should be adaptable to support the current range of sediment passive samplers, including polyethylene sampling devices (PEDs), solid phase micro extraction (SPME) devices, and diffusive gradient in thin film (DGT) devices.
- The system should be capable of rapid, inexpensive deployment and retrieval without the use of divers. While deployment rates are expected to vary somewhat with field conditions,

deployment and retrieval rates in the range of 10-20 stations per day represent a marked improvement over traditional diver-based methods.

- The system should be capable of operating under a range of environmental conditions typically experienced in Navy harbors, including: (1) water depths in the range of 0-50 feet, (2) tidal currents and/or river currents in the range of 0-2 m/s, (3) salinities ranging from fresh to seawater, (4) bottoms of soft silts to sands with potential for some gravels, shell hash and debris, (5) ship and tug boat activities, (6) physical structures including piers, quay walls, jetties and bulkheads, and (7) low visibility.

4.2. PERFORMANCE OBJECTIVES

Performance objectives related to the criteria above are summarized in the table below. Next, the success of the demonstration relative to each performance objective is described.

Table 1: Technology performance objectives, data requirements and success criteria.

Performance Objective	Data Requirements	Success Criteria
Quantitative		
Supports multiple passive sampler types	Engineering drawings, prototypes, and pre-commercial systems demonstrating adaptability to multiple passive sampler types	Successfully adapt to at least 3 of 4 common passive samplers (SPME, PED, POM and DGT)
Deployment and retrieval rates	Document deployment and retrieval rates under different environmental conditions during the field demonstrations	Deployment and retrieval rates without the use of divers in the range of 10-20 stations per day
Successful full-cycle rate	Document the number of target stations, and the number of samplers successfully completing the entire deployment, sampling and retrieval sequence	Successful full cycle rate >90%
Range of environmental conditions	Document environmental conditions at the field demonstration sites including current speed, water depth, salinity, bottom type, physical structures and debris	Maintain expected deployment, retrieval, and cycle rates under the documented range of environmental conditions, or identify limitations
Qualitative		
Ease of use	Feedback from field team on usability of technology and time requirements	Equipment can be operated by typical field technicians familiar with other types of sediment and water sampling devices

4.2.1. Supports multiple passive sampler types

This performance objective was successfully achieved. The sampler frame can easily sandwich sheets of PED (polyethylene) and POM (polyoxymethylene), with or without protective metal screen material. Likewise, the sampler frame can sandwich solid-phase micro-extraction (SPME) glass rods, although these were not tested in a full deployment and might be subject to breakage under some conditions. PEDs have become the most commonly used and accepted passive sampling material for organic contaminants, and these samplers were successfully demonstrated in both Pearl Harbor and San Diego bay, with and without metal screening material, respectively. For these demonstrations, the larger sampler frames were used to provide more surface area for the PEDs to adsorb contaminants; samplers were targeted for installation approximately 2/3 buried, to assess contaminants in both the water above and porewater below the sediment-water interface.

The sampler frame can also be used to deploy DGTs. These are considerably thicker than PED, POM, or SPMEs (5mm for DGT vs. ~0.025-0.1mm for PED and SPME, respectively). Instead of sandwiching these samplers directly into the sampler frames, DGTs can be attached facing outwards to the side of the sampler frame using nylon screws. The design for this approach was developed during this NESDI project, and it was applied during a subsequent application of the Passive Push system at Tern Island, Hawaii during a 2018 EPA-led effort for which SSC-Pacific played a supportive role (Figure 5).

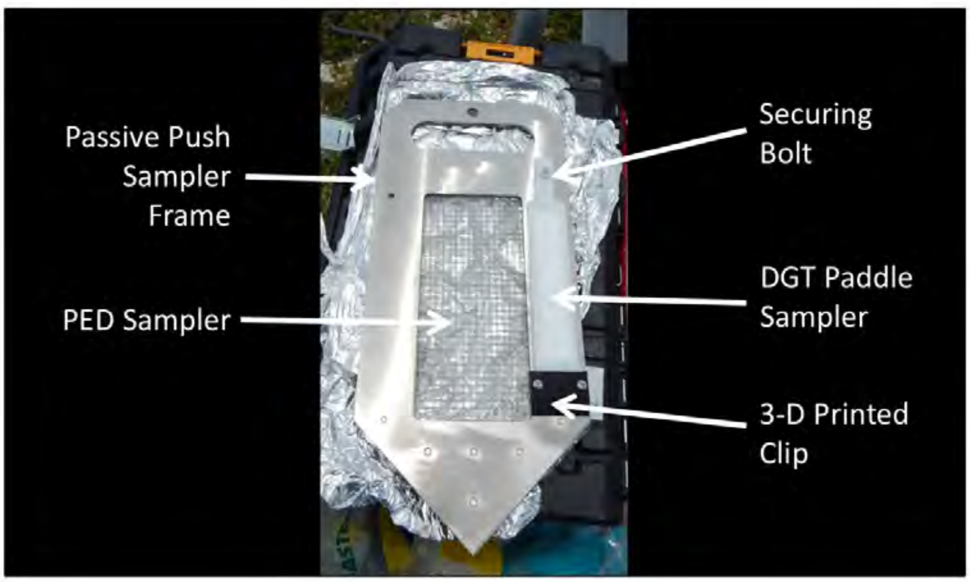


Figure 5: Sampler frame with both polyethylene device (PED) and diffusive gradient in thin film (DGT) samplers loaded for deployment at Tern Island.

4.2.2. Deployment and retrieval rates

This performance objective was successfully achieved. During the three deployment days conducted for the full-scale demonstrations for this project, between 10-14 samplers were deployed, over a timespan ranging from 3-6 hours. This results in an average sampler deployment interval of about 24 minutes. Much of this time was spent transiting between stations. In Pearl Harbor, time on station ranged between 6-21 minutes, and averaged about 11 minutes. In San Diego bay, time on station ranged from 7-29 minutes, and averaged about 17 minutes.

Once equipment was organized, deployment went relatively smoothly and quickly (

Figure 6).

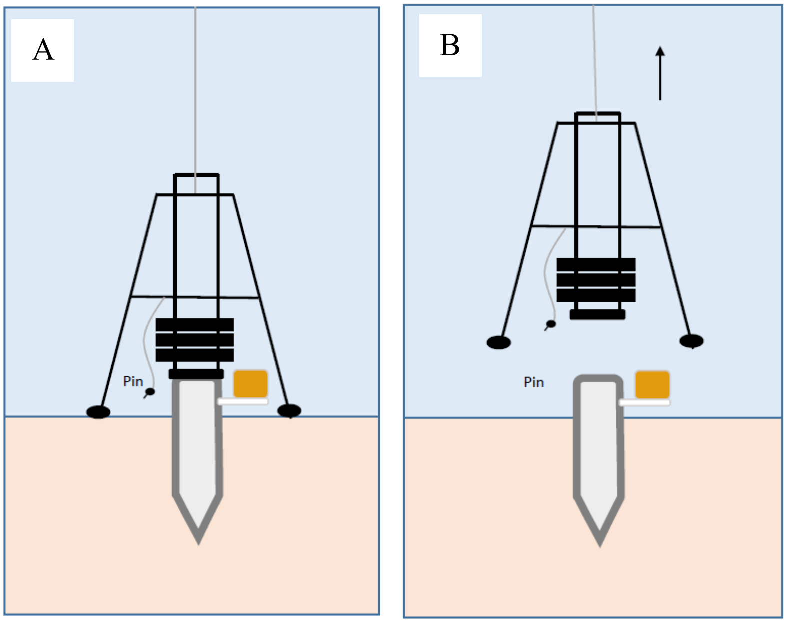
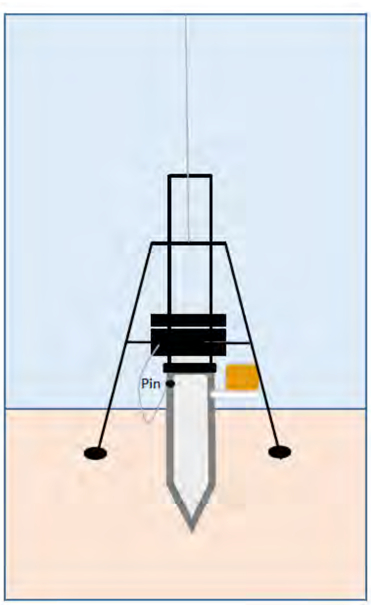


Figure 6 (left): Under ideal conditions, (A) the drive-frame would come to rest on the surface of the sediment, the carriage would then be driven downwards by the lead weights, and the sampler frame would be pushed into the sediment, releasing the cotter pin; then (B) the drive frame would be lifted cleanly off of the sampler, which would remain in the sediment as intended.

In Pearl Harbor, samplers were successfully installed at every station except one (at Bishop Point, near the entrance channel, where sediments were coarse and relatively consolidated). The following relatively minor problems were encountered during the Pearl Harbor deployment:

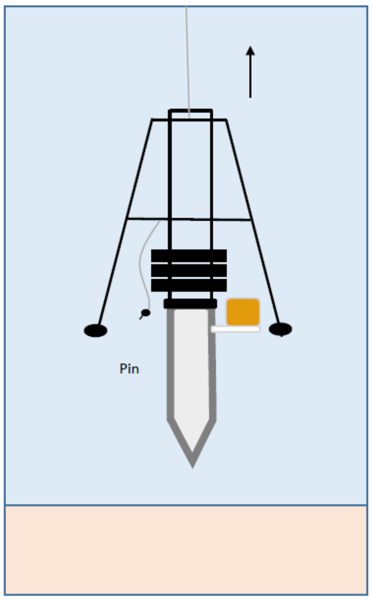
1. *Very soft sediments – sinking*: In very soft sediments, the drive-frame would sink into the bottom a fair distance, such that when the frame stopped sinking and the weights drove the carriage into the sediment, the differential displacement between the frame and the carriage was not large enough to pull and automatically release the cotter pin (Figure 7). In this case, the sampler would return to the surface in the sampler frame, with the pin still in place.



Solution undertaken for San Diego Bay demonstration: Added larger-surface area feet to sampler frame to reduce sinking. Solution was successful.

Figure 7 (left): If feet of frame sink in, cotter pin will not be released from sampler.

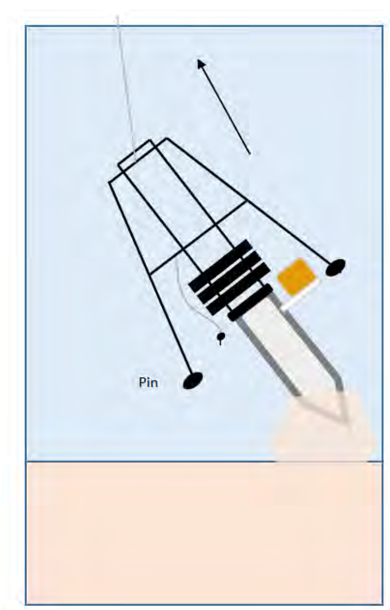
2. *Frame sticking in socket:* In some cases, the carriage would descend far enough to release the cotter pin, but the sampler would still remain in the frame socket, potentially because of sediment jamming (Figure 3).



Solution: In the field, the inside of the sampler socket was rinsed with water before emplacing a new sampler, which reduced jamming. For the San Diego Bay demonstration, the socket head for the sampler was routed out to allow a little more space around the sampler frame. Solution was successful.

Figure 8 (left): If sediment jams the frame socket, due to prior deployment or sediment resuspension, it may cause the sampler to remain in the drive frame, despite release of the cotter pin.

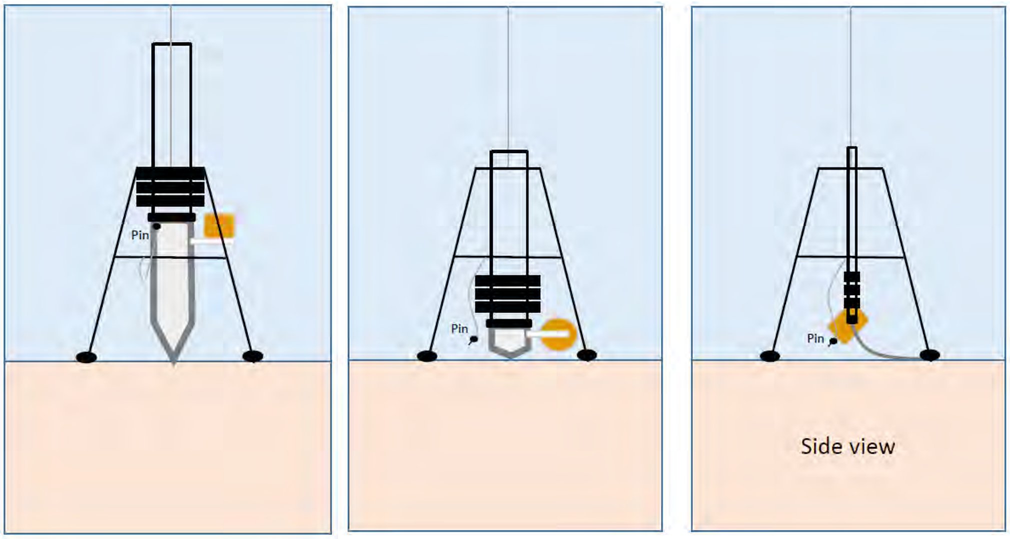
3. *Frame is recovered at an angle:* If boat is not held in position well, the drive frame will be pulled up by the A-frame winch at an angle, possibly precluding release of the sample frame, despite release of the cotter pin (Figure 9). This problem is exacerbated in shallower water.



Solution: Before pulling Passive Push frame back up, position A-frame directly over the frame, so that the winch line is vertical. Alternatively, in very shallow water, deploying samplers using the push-pole system may be preferred.

Figure 9 (left): If the boat cannot maintain position over the sampler deployment location, the frame may be pulled back up at an angle, preventing the release of the sampler despite release of the cotter pin.

4. *Hard sediment:* If sediment is not soft enough for easy sampler pushing, the sampler may simply be unable to puncture the sediment, thus remaining in the sampler frame, or the sampler may bend such that the carriage drops and the pin releases, but the sampler has not been driven into the sediment as desired (Figure 10).



Solution: Push pole system may work better for harder sediments. In deep water, use of the push-pole system may require 3-point vessel anchoring. Alternatively, more rigid stainless steel sampler frames could be used in hard sediments.

Figure 10 (above): If the sediment is too hard for the sampler to easily penetrate, it may (A) result in refusal or (B, C), result in the sampler bending up to 90 degrees along the bottom. In (A), the cotter pin does not release, while in (B/C) the pin releases; however the sampler is not deployed.

The following additional minor problem occurred during the San Diego Bay deployment:

5. *Obstruction:* Debris can prevent proper deployment of a sampler. In San Diego Bay, armor rocks placed on top of a thick clean-sand treatment cap at a prior contaminated sediment site had migrated and interfered with placement of a sampler adjacent to this cap. These rocks were sighted using the underwater live video feed, and the frame was pulled back up while the boat was repositioned. The underwater live video camera is critical for avoiding obstructions, and will be particularly useful in areas know to contain debris, as do many harbors.

Despite the possibility for issues such as those detailed above, average deployment rates of approximately 25 minutes were achieved. This suggests that in an 8-hour day on the water, up to approximately 20 samplers could be deployed under conditions similar to the Pearl Harbor and San Diego Bay deployments (i.e. relatively mild weather conditions, minor obstruction issues, and sampling sites within an approximately 15 minute range of one another). Note that loading the Passive Push equipment onto the boat took a team of 4-5 people approximately 1 hour on the initial day of each deployment.

4.2.3. Successful full-cycle rate

This performance objective was nearly achieved. In Pearl Harbor, 25 samplers were successfully deployed at 23 total stations (one station received triplicate samplers). Of these, 23 samplers were successfully recovered, for a successful full-cycle rate of 88.5% (23 samplers recovered of 26 samplers originally targeted for deployment). In San Diego Bay, all 10 samplers were successfully deployed at 10 total stations, and 9 of these were recovered, for a successful full-cycle rate of 90%. The goal for this performance objective was to achieve an >90% full-cycle rate, so this objective was very nearly achieved.

Some problems were experienced during recovery.

1. *Buoys releasing too early:* In both Pearl Harbor and San Diego Bay, one buoy released too early. In Pearl Harbor, this occurred at a site in Middle Loch, at a site between two decommissioned aircraft carriers. That buoy simply floated at the surface, acquiring a thick algal coating on the lower portion of the buoy, until recovery. The sampler itself was not affected, likely because this location was not visited by members of the public. In contrast, in San Diego Bay, one buoy apparently released early at a site inside a marina. This buoy and sampler were recovered and placed onto a nearby dock by a member of the public. We were alerted to this occurrence and were able to obtain the sampler, but not before the material dried in the sun for an unknown amount of time, possibly compromising the data from that sampler.

   It is not known what caused these buoys to release early. Clear labelling with contact information, *and* instructions not to remove the sampler from the sediment, are advised for deployment in locations where the public may interact with buoys that accidentally release before their scheduled time. Note that during the San Diego Bay deployment, 10 additional buoys were attached (without the PVC elbow-frame) to water-column passive samplers; all of these buoys released at the time expected.

2. *Recovery obstruction:* In San Diego Bay, recovery of one sampler at the buoy release time was compromised because a barge was parked over the top of the sampler location between the time of deployment and recovery. The owner was able to move the barge out of the way a few days after the scheduled buoy release; once the barge was moved, the buoy was sighted at the surface as expected and the sampler was recovered.

   This problem could have been avoided with better communication between the research team and the lease-holders of this Port-owned but leased area.

3. *Unknown problems – possibly sediment jamming or fouling:* Six buoys total in Pearl Harbor did not come to the surface at the expected time, but were still recovered. We believe the burn wires were released from all of these buoys, but that the buoyancy of the buoys was not great enough to overcome either fouling on the line spool or on the PVC socket that housed the base of the buoy timer, or that sediment jammed the buoy release in the socket. Three of these buoys were encouraged to come to the surface through mechanical "jostling" by dragging an anchor and chain over the sampler location. This method was unsuccessful for the other three of these buoys, but the buoys were located at the surface the following day and recovered as normal.

   Several modifications to the buoy system were designed and tested at the SSC-Pacific pier to alleviate these potential problems. First, a cover system was designed and tested to reduce the potential for biofouling on the line spool. This system did not work well, and caused more problems associated with hang-ups of the line than any reductions in biofouling that may have occurred, and thus was abandoned. Next, various sizes and styles of attachment of springs were included to assist in releasing the buoys from the PVC sockets. Some of these were problematic (Figure 11), but some worked well. For the San Diego Bay demonstration, a relatively large-diameter spring was attached with zip-ties to the inside of the PVC socket to assist in buoy release. No buoys were observed to experience the same "sticking" behavior as in Pearl Harbor, so this modification was considered successful.

Figure 11 (left): A spring attachment design that interfered with the line spool release and was abandoned.

4.2.4. Range of environmental conditions

This performance objective was largely achieved. In Pearl Harbor, samplers were successfully deployed and retrieved at sites with salinities ranging from 28.1-31.3 ppt. One sampler was deployed near a rivermouth, with salinity of 9.6 ppt; this sampler was not recovered. The burn wire mechanism for the floats should work in all salinities, so this is unlikely to be related to why the sampler was not successfully recovered. This sampler was deployed in approximately 6.6 feet water depth. However, it is unlikely that the shallow depth intrinsically affected the recovery; samplers were successfully deployed and recovered from depths ranging between approximately 3-42 feet in Pearl Harbor. Instead, we suspect that the sampler may have been snagged by an illegal fishing net (a small boat of people fishing with nets was observed in this area during the recovery effort).

The sampler that was not recovered in San Diego Bay was emplaced near the middle of the shipping channel. The substrate here was sandy, and tidal currents can approach approximately 2.5 knots in the San Diego Bay entrance channel (1.3m/sec; http://tidesandcurrents.noaa.gov). The sampler placed at this location was aluminum, and these sampler frame + buoy combinations were overall slightly positively buoyant (the stainless steel frames + buoys were negatively buoyant). We suspect that the high current speeds, positive buoyancy, and low overall sediment adhesion of the sandy material in this area may have allowed this sampler to come out of the sediment and float away (possibly out to sea).

4.2.5. Ease of use

This performance objective was achieved. The system is simple, easy to use, adaptable to different environmental conditions, and quick. Our partners on the demonstration projects agreed that the system worked very well and simply, and have requested further use for future assessments (for example, an additional round of monitoring in San Diego Bay in fall 2018). The push-pole system was commercialized and has been purchased by the environmental contractor group Geosyntec, who have used the system for passive sampling projects at a number of sites already.

5. FACILITY/SITE DESCRIPTION

The demonstration sites are briefly described below. The project was structured around a demonstration to leverage long-term monitoring for sediment remediation at Pearl Harbor Naval Complex (PHNC). A follow-on, smaller demonstration in San Diego Bay was selected to demonstrate slight modifications to the Passive Push system designed to address lessons learned from the Pearl Harbor demonstration, and to provide valuable data to contribute to an effort lead by SCCWRP to understand PCB contamination in the bay.

5.1. PEARL HARBOR NAVAL COMPLEX

Pearl Harbor is a delta-shaped natural estuary located on the south-central coast of the island of Oahu, Hawaii (Figure 12). The harbor's 36 miles of linear shoreline encompass approximately 5,000 acres of surface water within four major lochs (West, Middle, East, and Southeast) and a dredged navigation channel that opens to the Pacific Ocean to the south. Pearl Harbor is a natural trap, or sink, for sediments and chemicals present in approximately 110 square miles of watershed, or 20 percent of Oahu's land surface. Pearl Harbor is a major fleet homeport for nearly 40 warships, service force vessels and submarines, and associated support, training, and repair facilities. In October 2010, Naval Station Pearl Harbor merged with adjacent Hickam Air Force Base into Joint Base Pearl Harbor Hickam (JBPHH). JBPHH occupies the majority of the land area immediately surrounding Pearl Harbor, and approximately 75 percent of the harbor shoreline lies within its boundaries. The base incorporates the following major activities: Naval Station Pearl Harbor, Naval Submarine Base, Hickam Air Force Base, Naval Supply Systems Command Fleet Logistics Center, Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility, Naval Facilities Engineering Command Hawaii, JBPHH West Loch Annex, and the Naval Sea Systems Command Detachment/Naval Inactive Ship Maintenance Facility.

Long term monitoring associated with the sediment remediation of Pearl Harbor calls for the assessment of trends in the concentrations of PCBs in sediment and biota at locations throughout the harbor. Locations that were sampled in 2017 are shown in Figure 13 and include a total of 24 stations. The Passive Push system was demonstrated at these same 24 stations in Spring 2017, in coordination with the long-term monitoring program. The demonstration provided the opportunity to evaluate the performance of the Passive Push system while also providing valuable data to the Pearl Harbor sediment remediation program.

Figure 12: Pearl Harbor site map (from DON, 2013).

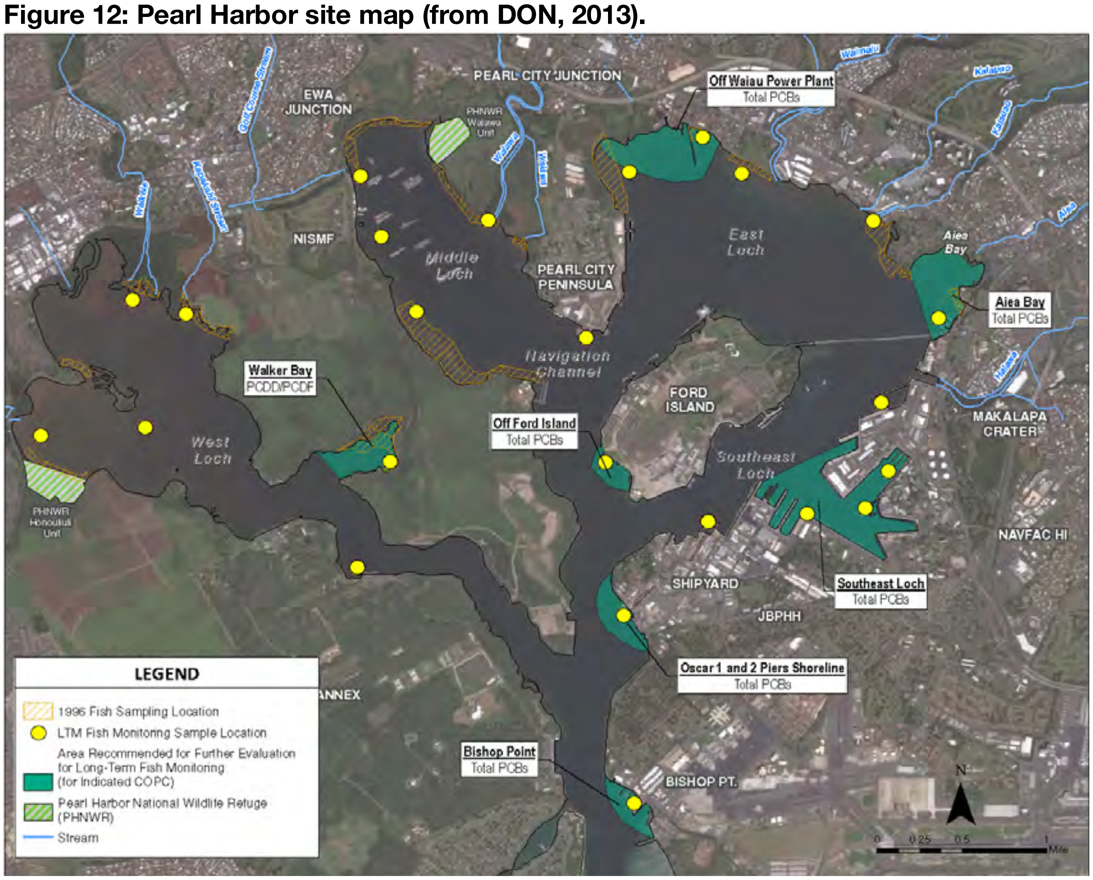


Figure 13: Long term monitoring stations in Pearl Harbor (from DON, 2017).

5.2. SAN DIEGO BAY

San Diego Bay is a hook-shaped bay, approximately 14 miles long from mouth to end, located at the southwest corner of the 48 contiguous United States. It is separated from the Pacific Ocean by a sand tombolo known as Silver Strand State Beach in the south, the large sandy Coronado Island inside of the hook (which is connected to the mainland via the tombolo), and Point Loma to the northwest, a raised rock promontory (Figure 14). The southern portion of the bay is very shallow, and bounded by an extensive wetland protected as the San Diego Bay National Wildlife Refuge. Tidal exchange and associated currents are swift near the mouth of the bay, but quite low in the southern reaches. San Diego Bay is a major homeport for the Pacific Fleet, with the following major activities in the vicinity: Naval Base Point Loma Complex including Point Loma Submarine Base, Marine Corps Recruiting Depot, Naval Base San Diego, and the Naval Base Coronado Complex including North Island Naval Air Station. Naval Base San Diego homeports 55 Naval vessels. San Diego Bay is also home to numerous industrial facilities, including shipbuilding and repair, shipping, and manufacturing facilities. The entirety of San Diego Bay is considered an impaired water body, and is listed on the Clean Water Act Section 303(d) List of Water Quality Limited Segments (or simply, the 303(d) list) for PCB contamination. Cleaning up San Diego Bay requires understanding and targeting sources of PCBs (presumed to be entering overlying waters and/or the food web from contaminated sediments). The second demonstration of the Passive Push system was conducted in coordination with SCCWRP, who lead a bay-wide PCB study to assess PCBS in sediments and overlying waters around the bay. Ten sites were selected for this effort (Figure 15).

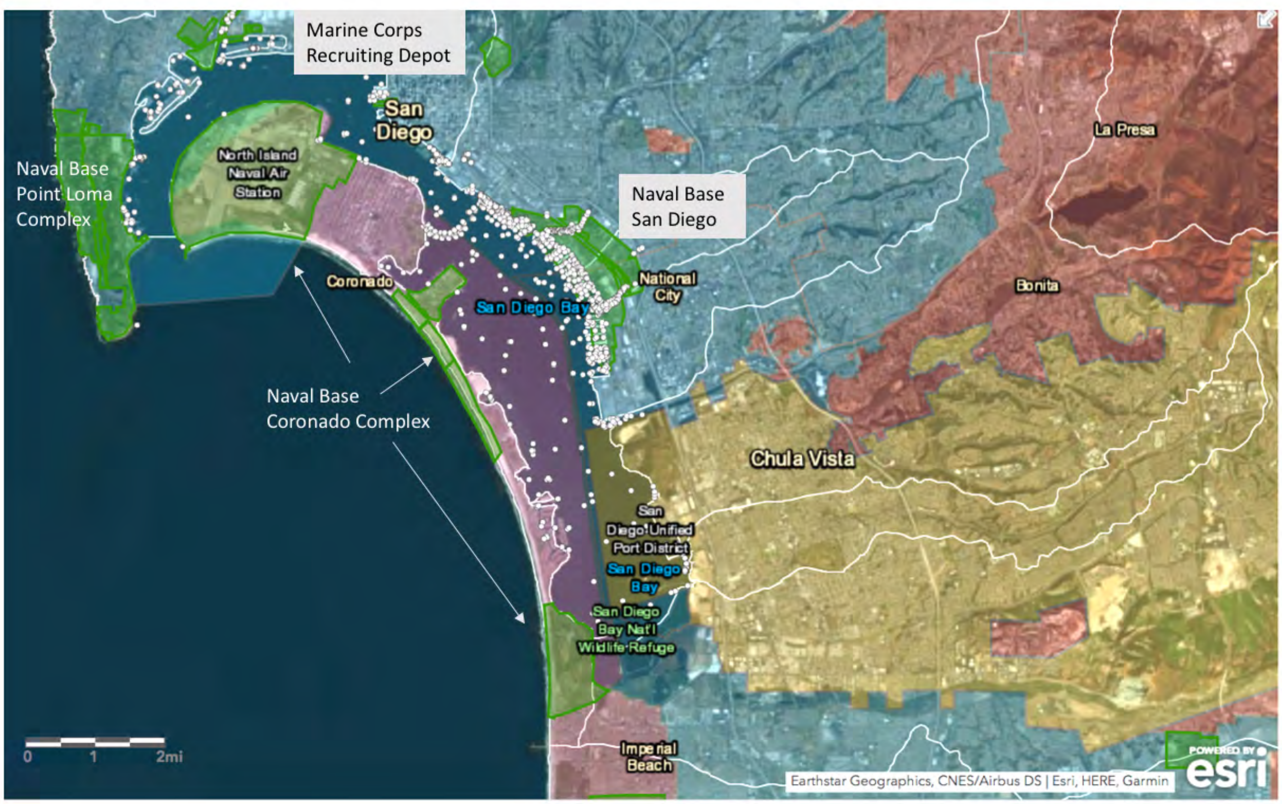


Figure 14: Map of San Diego Bay showing major cities and municipalities (colors), military bases (green), and historical sediment sampling locations (white circles). Map created from the San Diego Waterboard ArcGIS Online sediment chemistry project.

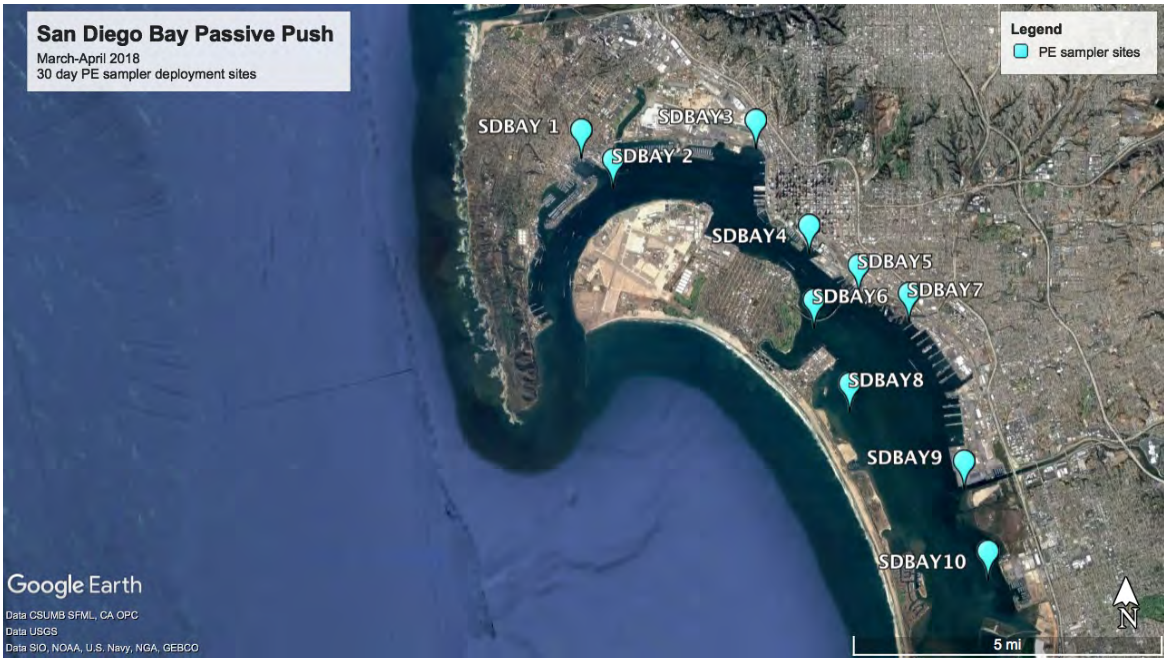


Figure 15: Map of sites in San Diego Bay where PE passive samplers were deployed and retrieved using the Passive Push technology in spring 2018.

6. TEST DESIGN

6.1. CONCEPTUAL EXPERIMENTAL DESIGN

The conceptual experimental design for the field demonstration focused on testing the performance of the Passive Push system under realistic field conditions. We tested the deployment and retrieval of passive samplers using the Passive Push system at stations co-located with the long term monitoring (LTM) program for the Pearl Harbor sediment cleanup program. The LTM program includes 24 stations that are dispersed across the entire harbor area. This provides a means of evaluating the Passive Push system under a wide variety of conditions including different water depths, bottom types, current speeds, debris fields and physical obstructions. To bring further value to the demonstration, actual samplers were used and analyzed so that the data from the samplers will be available to the LTM program. Analysis of the samples will also help to identify any unanticipated issues that might be associated with the deployment and retrieval systems. Thus, the conceptual design for the demonstration encompassed the preparation, deployment, retrieval, processing, chemical analysis and data analysis associated with passive samplers using the Passive Push system.

The project originally followed an approach that consisted of seven primary tasks. Task 1 focused on system design for the system components and variants. Task 2 was an integration step to integrate the components developed under Task 1. Task 3 focused on system testing and refinement. Task 4 included the selection of the demonstration site and development of the demonstration plan. Task 5 entailed the execution of the field demonstrations, and Task 6 the performance and cost analysis based on the demonstration. An additional task, here termed Task 6.5, consisted of modifications, testing, and a second smaller field demonstration of the Passive Push System in San Diego Bay, based on lessons learned from Task 6. Finally, Task 7 focused on technology transition. The primary tasks are summarized below.

6.2. PROJECT TASKS

6.2.1. Task 1: Final System Design

This task built on preliminary testing carried out at SSC-Pacific, as well as by Marine Sampling Systems and MIT along with the proof-of-concept prototype system development carried out at UCSD. Based on this experience, and the experience of the team with similar systems, the integrated system design was finalized.

6.2.2. Task 2: System Integration

This task focused on the engineering aspects of integrating the three primary system components. The goal of this task was to complete fabrication of a modular, integrated diver-less deployment system at the commercial prototype level. This task resulted in the final design and construction of the Passive Push system variants including the push-pole and drive-frame systems.

6.2.3. Task 3. System Testing and Refinement

In this task, the commercial prototype was tested against a set of defined performance criteria to make sure that the system was ready for field demonstration. These tests were carried out in the laboratory and pier-side test facilities at SSC-Pacific. Deficiencies identified during the testing were addressed through refinements to the systems.

6.2.4. Task 4. Site Selection and Demonstration Plan

In this task, final site selection for the demonstration was made, and the demonstration plan for Pearl Harbor was developed. The key aspect of site selection was to select a site that sufficiently challenged the breadth of capabilities of the system, and was representative of a site where samplers would traditionally be deployed by divers. The key aspect of the demonstration plan was the development of rigorous performance criteria. As documented above, these criteria focus on quantitative measures such as success rates for deployment and retrieval, as well as qualitative measures such as ease of use. Cost metrics were also captured for comparison to diver deployed methods.

6.2.5. Task 5. Field Demonstration

This task executed the field demonstration in Pearl Harbor based on the plan developed in Task 4. The field demonstration exercised the technology to the extent that performance could be fully assessed, cost data could be gathered, and potential for future implementation could be evaluated.

6.2.6. Task 6. Cost and Performance Assessment

In this task, results from the field demonstration were assessed relative to success and performance criteria developed in the demonstration plan. Potential cost savings and return on investment were evaluated by scaling cost data compiled during the demonstration and applying it to hypothetical full-scale implementation.

6.2.7. Task 6.5. Modifications and Second Field Demonstration

Here, modifications to the system were developed and tested at a pier-side test facility at SSC-Pacific, to address limitations identified during Task 5 and 6. Subsequently, a second full, but smaller-scale field demonstration at 10 sites was completed in San Diego Bay in coordination with SCCWRP.

6.2.8. Task 7. Technology Transition

During the course of the project, several steps were taken to ensure technology transition. These included producing standard operating procedures (SOPs), disseminating information about the technology to potential users through platform presentations (Ocean Sciences conference 2018, Sediment Working Group Meeting 2018) and professional networks, and connecting with other Navy sponsors who might make use of this technology.

The technology has already begin being transitioned to industry. For example, Geosyntec purchased a system and has used it for at least two field studies. Coastal Monitoring Associates is the point of contact for commercializing the technology, and has been contacted by other interested consulting groups as well.

In addition, the technology has begun to be successfully transferred to other Navy users. Navy Region Southwest has provided funding for a follow-on effort to assess PCBs in San Diego bay during the dry season, to compare and contrast with the wet-season effort conducted during task 6.5.

6.3. DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

See section 3.4.

6.4. OPERATIONAL TESTING

Field testing and refining these technologies and operational procedures was the primary focus of the demonstration projects. Testing the systems in the field under realistic operational conditions provides the best opportunity to understand their utility and gauge their performance. The field testing approach for each of the demonstrations is described in detail below.

The field testing approach for the Passive Push demonstration at both Pearl Harbor and San Diego Bay included mobilization, pre-deployment preparation, deployments, retrieval, post processing, and demobilization. The field testing approach used for these phases is described below in general terminology to allow application of this methodology to future requirements.

6.4.1. Mobilization

Mobilization includes making arrangements for access to the site, travel for the personnel, and organization and shipment of the required Passive Push equipment. Site access includes coordination of personnel clearances, schedule, access to the required areas of the harbor, and access to the deployment vessel. Mobilization should also include the development and use of checklists to minimize potential for loss or missing equipment at the field site.

6.4.2. Pre-Deployment Preparation

Pre-deployment preparation of the Passive Push system includes a number of steps that are detailed in the Standard Operating Procedure (SOP) (Appendix B-2). These steps consist of setting up the *boat*, preparing the *sampler frames*, preparing the *retrieval system*, setting up the *deployment system* (push-pole or drive-frame), and preparing the *camera system*. Each of these steps is discussed below in further detail.

The size, configuration, and capabilities of the *deployment boat* generally depend on site conditions and which deployment system is being used: the drive-frame or the push-pole. The first consideration for selection and preparation of the boat should always be for expected on-water conditions and safety of the operation. For the push-pole system, the boat should provide sufficient space and capability to accommodate the samplers, the push-poles and head unit, the camera system, and the crew. The push-pole system should generally not be employed in water depths greater than 50 ft and consideration must be given to the speed of the currents and associated drag on the poles. To successfully use the push-pole system, the boat must be able to hold station for sufficient time to push the sampler into the bottom, verify with the camera the required insertion depth, and release and remove the pole system. This generally requires 1-5 minutes. Thus, the boat should be equipped with the ability to hold station either by anchoring, spudding, or dynamic station keeping. The boat should be equipped with GPS navigation generally capable of placing the sampler at the desired location to within about 1-3 m. The boat should also be equipped with a depth sounder to determine water depth prior to deployment. For the drive-frame system, boat requirements are similar, but there are added requirements for lift capabilities, and less restrictive requirements for station keeping. The drive system generally requires a lift system capable of accommodating a working load of about 500 lb with a vertical clearance of about 8 ft and an over-the-side clearance of about 3 ft. Because the drive-frame is lowered on a flexible cable, it is not essential that the boat maintain station directly above the frame, and thus anchoring and spudding are generally not required.

Preparing the sampler frames generally includes pre-cleaning to make sure there are not residual sediments on the frames, and installing the samplers into the frames. Installation of the samplers will vary by sampler type. For standard PE samplers, the two halves of the frame are separated, the sampler is placed between them, and the halves are then re-secured together using the stainless steel fasteners. For DGT samplers, the DGT paddle is fastened to the face of the frame border using nylon screws with the exposure side facing out. For SPME samplers, the fibers may be placed in perforated stainless steel tubes that are then clamped within the frame, or they can be placed in mesh envelopes and fastened to a coarser mesh that is clamped within the frame. For this project, SP3 PE samplers were prepared by Geosyntec with the polyethylene sampler inside a copper mesh envelope, and the entire enveloped was clamped within the frame. See Appendix B-1 for the SP3 handling procedures used. In general, the samplers should not be installed in the frames until as close to the deployment time as possible. If the samplers are pre-installed in the frames ahead of time, they should be held under proper conditions (clean, cold and dark) prior to deployment.

Preparation of the retrieval system includes preparing the release unit and installing it onto the sampler frame. The release unit is prepared in accordance with the manufacturer's instructions (Appendix B-3) and the Passive Push SOP (Appendix B-2). Clock batteries for each float should be replaced and tested, and a new burn-wire should be installed prior to each deployment. The retrieval line should be carefully coiled onto the spool so that it will pay out cleanly on the retrieval. The unit should then be programed for the pre-determined release time using the deck unit. The float release unit is then installed into the PVC adapter and secured with a zip tie. The adapter is then secured to the sampler frame by sliding the notch in the PVC adapter over the metal edge of the frame, and securing with the stainless steel bolt and nut (this can be done during the prior step, if desired).

Preparation of the deployment system depends on if the push-pole or drive-frame system will be employed (or both). For the push-pole system, preparation includes securing the head unit to the first pole using the rounded-retainer locking pin. The insertion depth is then set by adjusting the foot plate to the proper height relative to the sampler. The underwater camera is then installed onto the first push-pole, just above the head unit. The spring-activated release-pin should also be secured to the head unit using a short length of wire or line. The required number of push-poles and locking pins should be readied to accommodate the expected water depth.

For the drive-frame system, the insertion depth is set by inserting the stopper-pin into the appropriate hole on the drive rod so that the drive carriage will stop at the proper height above the sediment. The line that secures the clevis-pin portion of the release pin should also be adjusted so that the release pin is automatically pulled out by the vertical motion of the drive carriage at the proper level. Alternatively, the manual-release pin that is used with the push-pole system can be used with the drive-frame for further control on sampler release, if desired. The spring-activated portion of the release-pin should also be secured to the head unit using a short length of wire or line. Sufficient weight should be added to the weight racks on the drive carriage to assure that the sampler will be driven into the bottom given the expected bottom conditions. A small ball sampler could be used to assess bottom conditions at sites where expectations are unknown. The underwater camera should be installed onto the mounting bracket on the frame leg so that it provides a good view of the sampler frame at the inserted depth.

Preparation of the camera system should follow the manufacturer's instructions and the Passive Push SOP (Appendix B-2). For both the push-pole and drive-frame systems, once the camera is mounted on the system, sufficient cable should be paid-out off of the reel to accommodate expected water depths. The camera box should be set up in an appropriate area that is safe from exposure to weather and other moisture and shock exposure. The power and video connections can then be connected to the camera cable. The system should then be powered up and tested to assure that the camera is properly aligned. Make sure the camera batteries are fully charged, the micro secure digital (SD) card is installed in the recorder, and there is sufficient memory on the card to record the desired number of deployments. Note, that the camera deck system is prone to overheating and should be powered off between deployments.

6.4.3. Deployment

Deployment of samplers using the Passive Push system varies somewhat depending on the equipment in use. For the push-pole system, the sampler is installed into the head unit with the release pin (Figure 16). The boat then navigates to the station and holds position. Camera recording is turned on. The Passive Push operator then begins lowering the system toward the bottom while an assistant handles the release line and the camera cable. An assistant adds additional poles to the system as required by the station depth. When the sampler reaches the bottom, the operator forces the sampler into the sediment while an assistant monitors the camera read out. A GPS position and water depth is recorded. When the sampler is pushed completely to the insertion depth, an assistant pulls the release line, the sampler is released, and the operator begins retrieving the push poles to the surface. The time at full insertion is recorded. An assistant removes the push poles as they emerge and pulls in the cable slack from the camera. When the system is fully retrieved, the camera can be turned off and the equipment stowed and readied for the next station.

For the drive-frame system, the sampler is installed into the head unit with the release pin (Figure 17). The boat then navigates to the station and holds position. Camera recording is turned on. The drive-frame is lifted and lowered over the side toward the bottom while an assistant handles the release line and the camera cable. When the sampler reaches the bottom, the operator monitors the camera read out to verify full insertion of the sampler frame. A GPS position and water depth is recorded with the lift cable as vertical as possible. When the sampler is pushed completely to the insertion depth, the drive frame is lifted to the surface. The time at full insertion is recorded. During retrieval, an assistant pulls in the cable slack from the camera. When the system is fully retrieved, the camera can be turned off and the equipment stowed and readied for the next station.

6.4.4. Retrieval

The Passive Push retrieval system utilizes a timed-release float that is pre-programmed to surface at a user-specified time (Figure 18). This time is generally accurate to within about 5-10 minutes. The recovery boat should therefore arrive at the approximate location of the station about 10 minutes ahead of the expected surface time. Care should be taken not to locate the boat directly over the float, and vessel traffic in the area should be requested to stay clear until the sampler is retrieved. The crew should maintain a close watch for the float. At the retrieval time, the burn wire is activated, and the float is released to the surface. The boat then maneuvers to the float, and the float is retrieved using a hand-held net. Once the float is onboard, the boat should maneuver to be directly above the sampler, with the retrieval line as vertical as possible. The sampler can then be pulled from the bottom and onto the boat using the retrieval line. The time of retrieval is then recorded. The retrieval procedure is included in the Passive Push SOP in Appendix B-2.

6.4.5. Post Processing

Once the sampler is retrieved to the boat, the sampler should be processed in accordance with procedures for the specific samplers being used. For the SP3 samplers used for the Pearl Harbor demonstration, handling procedures are described in Appendix C-1. In general, the sediment-water interface is usually clearly evident from differences in coloring and fouling on the frame and the sampler. The sampler should be photographed with a scale in view for archival purposes. For the Pearl Harbor demonstration, the sampler was cut into appropriate intervals (surface water and both shallow and deep sediment sections) directly from the frame using a utility blade cleaned between uses with isopropyl alcohol. These sections were then placed in the pre-labeled sample bags for each sample/station in accordance with the SOP. Field blank samples were handled as directed by Geosyntec, also described in the SOP. For the San Diego Bay demonstration, entire sampler frames were wrapped in aluminum foil and placed in clean, labelled plastic bags. The samples should then be stored under appropriate conditions (for the PE samplers demonstrated here, samplers in bags were placed on ice in a cooler). Once all of the samplers were retrieved and the post-processing is complete, the samples were shipped overnight to the lab for analysis.

6.4.6. Demobilization

At the end of the field survey, demobilization includes breakdown, cleaning, and packing of the equipment and return travel. All of the Passive Push equipment should be cleaned and rinsed with fresh water and allowed to fully dry before packing. Sampler frames should be disassembled and cleaned. Batteries should be removed from the retrieval floats and disposed of properly.

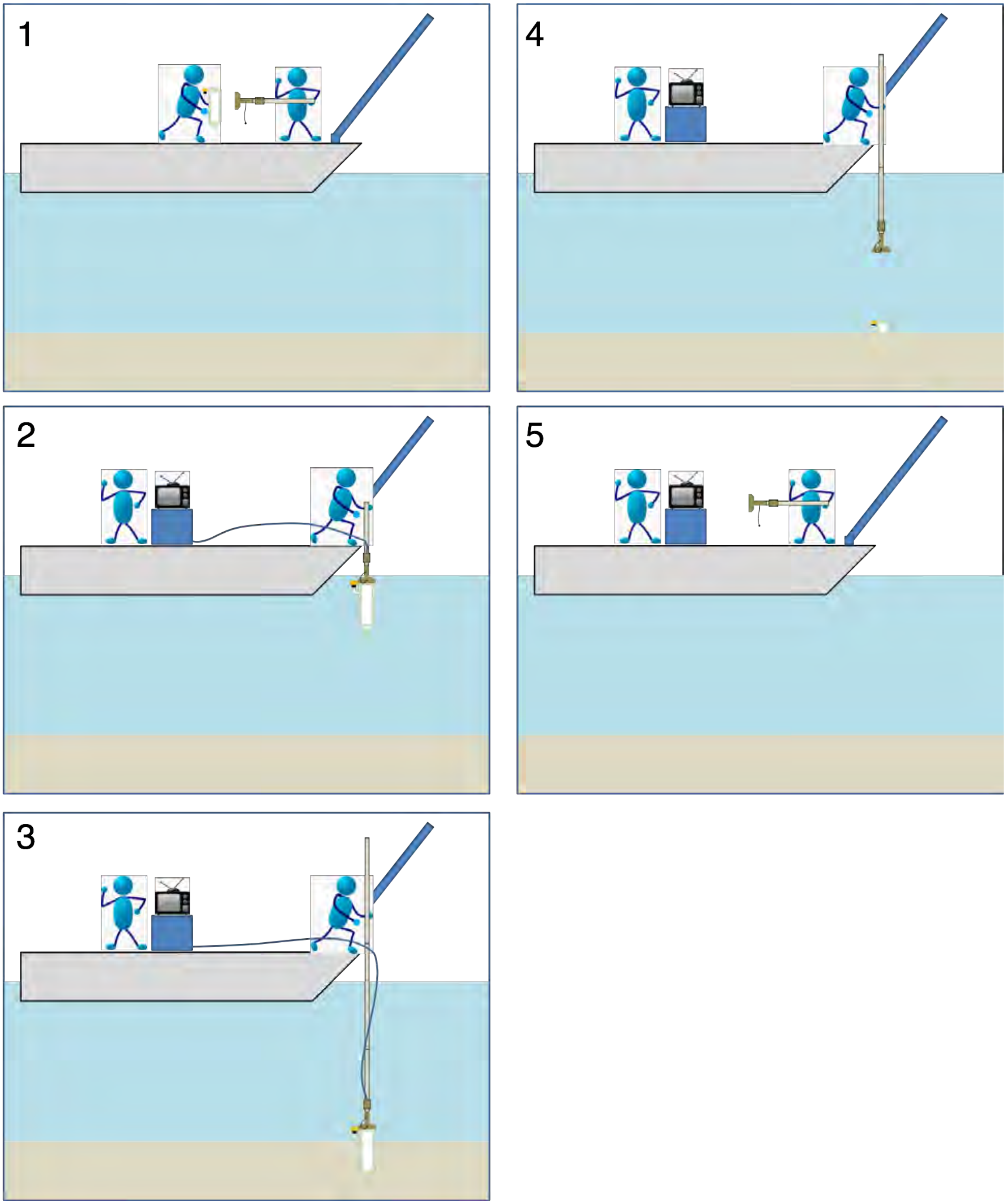


Figure 16: Deployment cartoon for the Passive Push push-pole deployment system.

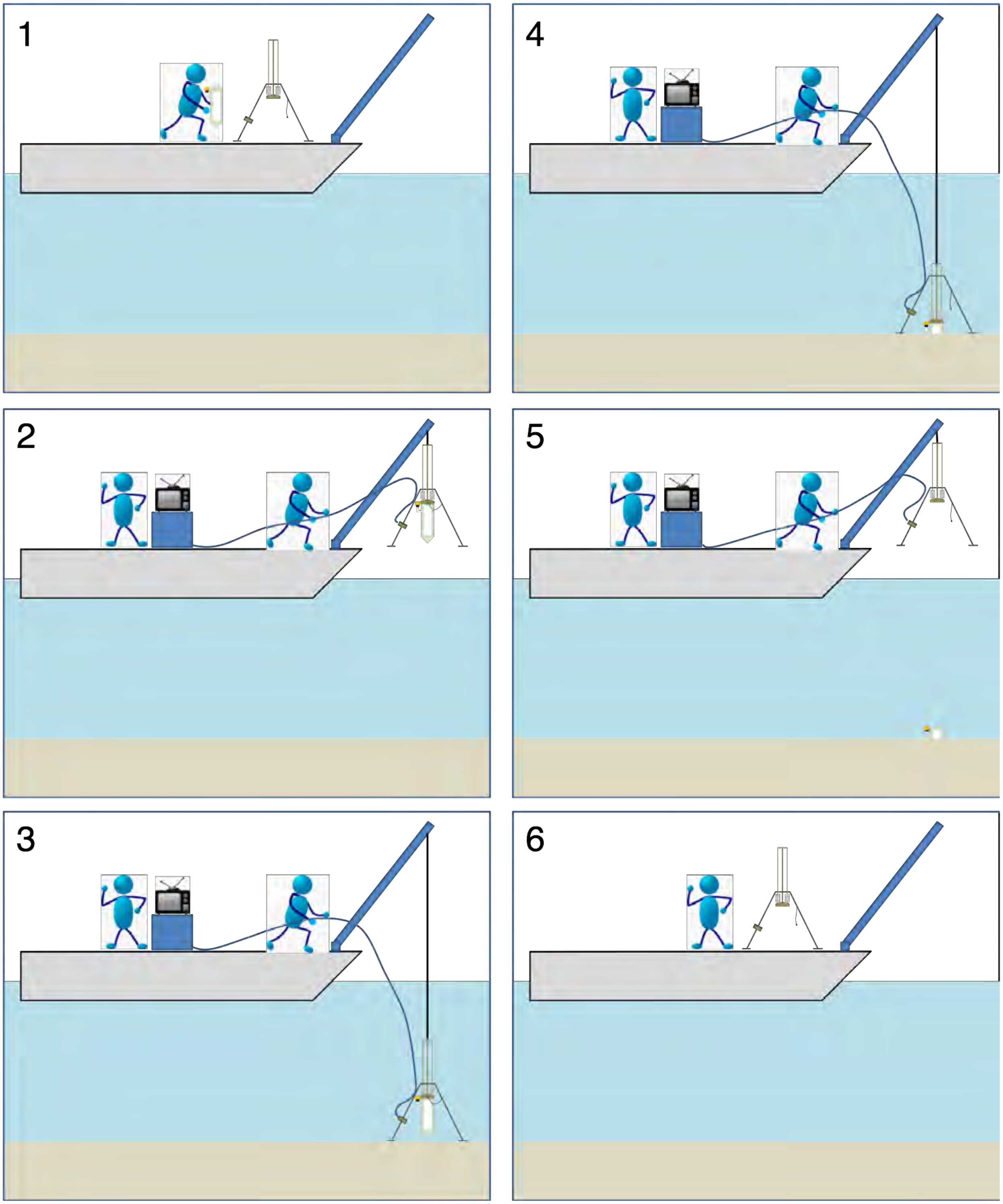


Figure 17: Deployment cartoon for the Passive Push drive-frame deployment system.

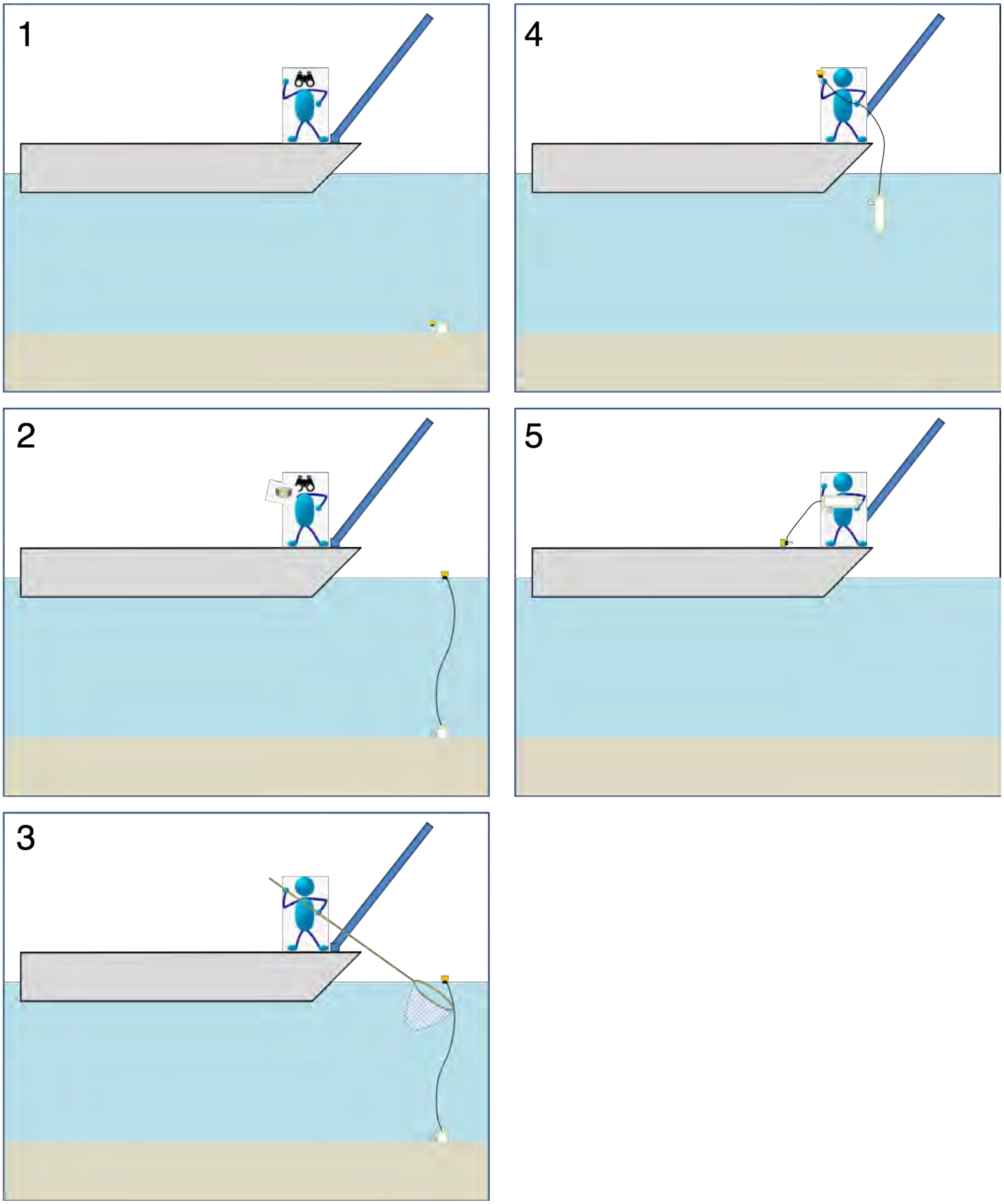


Figure 18: Retrieval cartoon for the Passive Push system.

6.5. SAMPLING PLAN

The sampling plan that was followed for each demonstration is detailed below.

6.5.1. Sampling Stations

There are 24 LTM sampling stations distributed throughout Pearl Harbor that were targeted for the Passive Push demonstration (Figure 13 and Table 2). These include 4 in the main navigation channel (Bishop Point, Oscar Pier, Ford Island and Pearl City Peninsula), 5 in Southeast Loch, 5 in East Loch, 4 in Middle Loch, and 6 in West Loch. All of the stations coincide with locations designated for long-term fish monitoring. In addition, several of the stations coincide with areas recommended for further remedial action. The stations span a range of water depths, bottom types, and hydrodynamic regimes.

Ten stations were targeted in San Diego Bay (Figure 15 and Table 3), selected through a combination of random selection from sites visited by SCCWRP previously, a desire for relatively even geographic coverage, and targeted selection from prior PCB assessments to ensure at least some of the samplers quantified contaminated sites (Figure 14).

6.5.2. Sampler Installation

At each station, the Passive Push system was used to install a PE passive sampler into the sediment bed. The target sampling depth for the passive samplers was specified to coincide with the surface sediment samples that will be collected during the LTM sampling which is for the interval from 0-15 cm below the sediment water interface. The samplers were targeted to be inserted such that at least 30±5 cm is below the sediment water interface, and the remaining 15±5 cm exposed to the overlying water. The retrieval floats were set for a 28-day exposure period in Pearl Harbor, and 30-day exposure period in San Diego Bay. A single sampler was placed at each station, with triplicates installed at one station in Pearl Harbor. At one station in each Pearl Harbor Loch area (Southeast, East, Middle, West and Channel), a temperature TidBit sensor was attached to the sampler to monitor temperature conditions at the site. Water quality measurements were made at each of these stations to document temperature, salinity, pH and Oxidation Reduction Potential (ORP) conditions in the surface water (Table 4).

6.5.3. Sampler Processing

Once the samplers were retrieved, the sampler was split between the sub-surface and surface sample in the field in Pearl Harbor. In San Diego Bay, samplers were split in the laboratory after being transferred wrapped in aluminum foil on ice. Deviations in the target sampler dimensions due to variations in sampler installations depths were noted. Trip blank samples were processed along with the field samples, placed in pre-labeled bags and shipped to the lab in coolers at <4 C. Samples were analyzed at the lab following standard EPA methods adapted for the use of passive samplers.

Calibration of Field Equipment. Temperature sensors used factory calibration settings. Water quality instruments were calibrated with NIST standards over the range of expected values for the field study.

Quality Assurance Sampling. Quality assurance sampling included field duplicates in Pearl Harbor, matrix spike and matrix spike duplicates (MS/MSD), and trip blanks. Field duplicates, MS/MSDs, and equipment blanks were collected at approximately a rate of one per twenty field samples.

Decontamination Procedures. Decontamination procedures focused on proper preparation of sampling equipment prior to the sampling events. These procedures will generally be in accordance with the standard operating procedures for the sampling and analysis methods defined for the project, and included use of clean aluminum foil to cover surfaces, clean gloves, and kimwipes with alcohol used to clean materials such as utility knives that could present cross-contamination.

Sample Documentation. Sampling documentation included electronic records, sample labels, custody seals, field logbooks, log sheets, photographs, chain-of-custody forms, and laboratory logbooks.

6.5.4. Performance Verification

In order to verify the performance of the Passive Push system, a range of additional data will be gathered during the field demonstration (Table 4). The rate of deployment will be determined by recording the number of samplers successfully deployed during each sampling day (or fraction of a day). Similarly, the rate of retrieval will be determined by recording the number of samplers successfully retrieved during each sampling day (or fraction of a day). The full-cycle rate will be determined by recording the number of samplers that successfully complete the entire sampling cycle as a fraction of the total number of samplers that were targeted in the sampling design. Finally, at the end of each phase of the survey, the field crew were interviewed to provide a qualitative assessment of the ease of use of the Passive Push system, along with any recommendations for improvement of the system.

Table 2: Station locations for the Passive Push demonstration in Pearl Harbor.

Station	Location	Area	Latitude (°N)	Longitude (°W)
BF1-1	Off Dry Dock 3	Southeast Loch	21.35240035	-157.9605532
BF1-2	Sierra 8 / 9 Pier	Southeast Loch	21.35497783	-157.9371143
BF1-3	Magazine Loch	Southeast Loch	21.35497783	-157.9437114
BF1-4	Hotel Pier	Southeast Loch	21.36344011	-157.9427905
BF1-5	B22 Wharf	Southeast Loch	21.35420264	-157.9504801
BF2-1	Bishop Point	Main Channel	21.32882927	-157.9658816
BF2-2	Off Dry Dock 4	Main Channel	21.34371929	-157.9657559
BF2-3	Off Ford Island Landfill	Main Channel	21.35783074	-157.9679704
BF2-4	Tip of Pearl City Peninsula	Main Channel	21.36951271	-157.9701528
BF3-1	Whiskey Wharves	West Loch	21.34880559	-157.99132
BF3-2	West Loch	West Loch	21.36304552	-158.01104
BF3-3	West Shore of West Loch	West Loch	21.36069472	-158.0204775
BF3-4	Waikele Stream mouth	West Loch	21.3702312	-158.0108213
BF3-5	Walker Bay	West Loch	21.35933573	-157.9885305
BF3-6	Kapakahi Stream mouth	West Loch	21.37123453	-158.0070562
BF4-1	West Shore of Middle Loch	Middle Loch	21.37194758	-157.9861305
BF4-2	Waipahu Drainage Ditch mouth	Middle Loch	21.38397204	-157.991635
BF4-3	Waiawa Stream mouth	Middle Loch	21.3793474	-157.97914
BF4-4	West Shore of Middle Loch	Middle Loch	21.37825303	-157.9892212

BF5-1	Off Waiau Power Plant	East Loch	21.38633188	-157.9594292
BF5-2	Off Blaisdell Park	East Loch	21.3835424	-157.9563792
BF5-3	Kalauao Stream mouth	East Loch	21.37857198	-157.944418
BF5-4	Rainbow Marina	East Loch	21.37102903	-157.9378558
BF5-4	Rainbow Marina	East Loch	21.3710426	-157.9379404
BF5-4	Rainbow Marina	East Loch	21.37103817	-157.9379055
BF5-5	West Shore of East Loch	East Loch	21.38179726	-157.9669182

Table 3: Station locations for Passive Push demonstration in San Diego Bay.

Station Name	Station location	Latitude (°N)	Longitude (°W)
SDBay-1	Shelter Island	32.7244	-117.225
SDBay-2	Channel off Shelter Island	32.71745119	-117.2159143
SDBay-3	Hawthorne Embayment/Embarcadero	32.726447	-117.175607
SDBay-4	Switzer Creek	32.7024	-117.16178
SDBay-5	KelCo just S of Coronado Bridge	32.6929	-117.148
SDBay-6	West Side of Coronado Bridge	32.68479375	-117.1600035
SDBay-7	Chollas Creek	32.686272	-117.13381
SDBay-8	S. of Amphib Base/E of Silver Strand	32.665184	-117.149804
SDBay-9	Sweetwater Creek	32.646936	-117.118238
SDBay-10	South Bay Chula Vista Channel	32.62580234	-117.1115252

Table 4: Performance verification sampling for the Passive Push demonstration.

Performance Objective	Supporting Data
Deployment rate	Number of samplers deployed per hour (over total hours on boat)
Retrieval rate	Number of samplers retrieved as expected
Full-cycle rate	Number of samplers successfully completing full sampling cycle compared to planned number
Range of conditions	Physical variables such as water depth, bottom type, current speed, vessel traffic, obstructions, debris, salinity, temperature, pH, etc.
Ease of use	Survey of field crew

6.6. DATA ANALYSES

Data analyses for the demonstrations included analysis of data from the SP3 samplers, ancillary field data, and verification data.

7. PERFORMANCE ASSESSMENT

Data analyses and performance assessment for the demonstrations included analysis of data from the PE samplers and assessment of verification data. The following details methods associated with these analyses, and presents results from the Pearl Harbor demonstration.

7.1.1. Passive Sampler Data Analyses

For each Pearl Harbor sample, the mass of the polyethylene and concentration of organic analytes in polyethylene on a dry weight basis (i.e., ng analyte per g PE [dry weight basis]) was reported from the lab. These results were then converted to bioavailable porewater or surface water concentrations (C_{free}) based on performance reference compound corrections by SiREM. The standard operating procedure for the SP3 samplers, which details this data conversion procedure, is included in Appendix B-1.

Passive sampling results from Pearl Harbor indicated that regions nearest the most Navy activity (SE Loch and the Main Channel) had the highest concentrations of freely-dissolved total PCBs (Figure 19). Freely-dissolved PCBs were highest in deep sediments and lowest in overlying waters across Pearl Harbor, consistent with expected results suggesting legacy contamination of the Harbor with PCBs, deposition of cleaner sediments above the most contaminated sediments, and flux of PCBs out of the sediments into overlying waters (Figure 20, Figure 21).

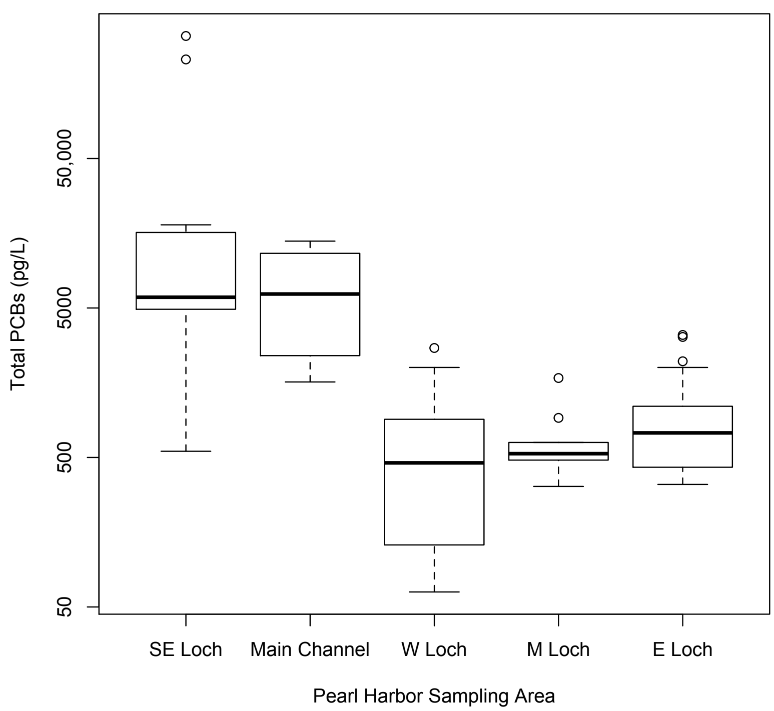


Figure 19: Boxplots showing total freely-dissolved PCBs in both porewaters and overlying waters from each of the major regions in Pearl Harbor. Note that the y-axis is on a log scale.

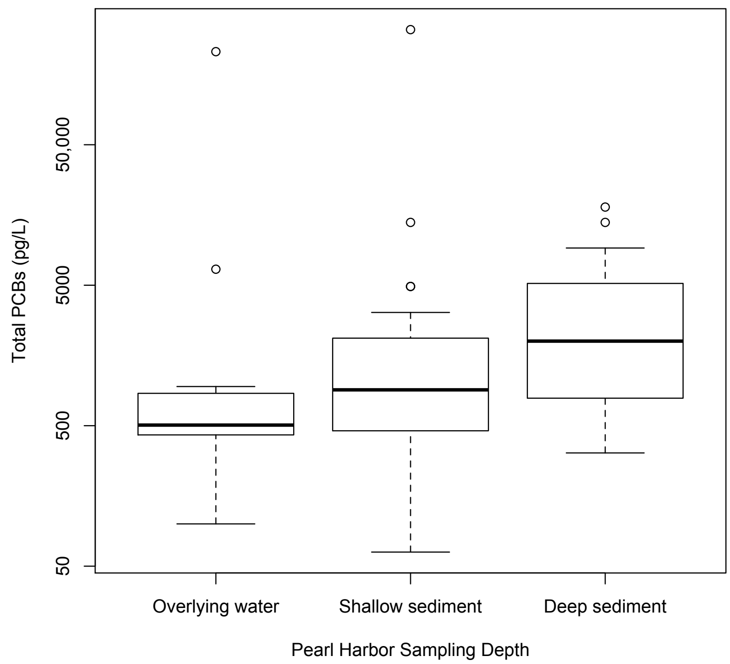


Figure 20: Boxplots showing total freely-dissolved PCBs in both deep and shallow porewaters and overlying waters from all samplers deployed in Pearl Harbor. Note that the y-axis is on a log scale.

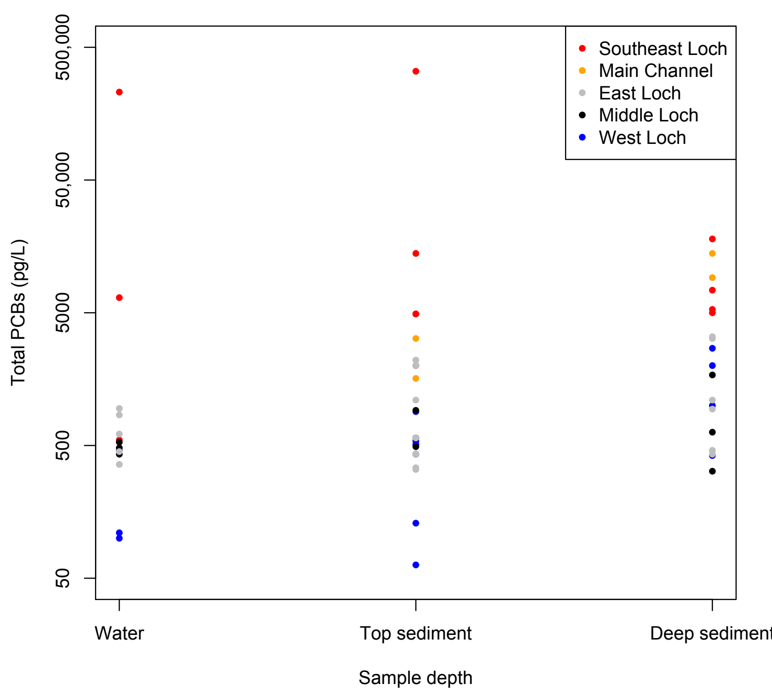


Figure 21: Individual color-coded datapoints showing total freely-dissolved PCBs in both deep and shallow porewaters and overlying waters from all samplers deployed in Pearl Harbor. Note that the y-axis is on a log scale.

7.1.2. Verification Data Analyses

Performance verification data was evaluated based on the performance objectives described in Table 1:

1. Supports Multiple Passive Sampler Types

Four common passive sampler materials were tested with the Passive Push sampler frames. All four of these materials could be loaded into the frames for deployment.

2. Deployment and Retrieval Rates

The time spent on the water each day of each deployment and retrieval was divided by the number of samplers deployed or retrieved to calculate the average time spent on each of these activities (Table 5, Table 6). This was scaled to a full 8-hour day on the water (each of the deployments and retrievals for the demonstrations undertaken for this effort were performed in less than a full day) to estimate the total number of samplers that could be deployed in a full day.

In addition, the time spent on station for these activities was also calculated in the same way. This is an important metric, because time spent transiting between stations can be larger or smaller to that undertaken here, and is unrelated to the Passive Push technology.

Table 5: Summary of deployment data

Site	*Pearl Harbor Day 1*	*Pearl Harbor Day 2*	*San Diego Bay*	***Site Average***
Number of samplers installed	14	11	10	**11.7**
Approximate time on boat (hours)	6	3	4.75	**4.6**
Average time transiting between stations (minutes)	8.4	11.3	14.8	**11.5**
Average time on station (minutes)	10.9	10.6	16.6	**12.7**
Approximate total time per sampler installation (minutes)	25.7	16.4	28.5	**23.5**

Table 6: Summary of retrieval data

Site	*Pearl Harbor Day 1*	*Pearl Harbor Day 2*	*San Diego Bay*	***Site Average***
Samplers retrieved as designed	8	8	7	**7.7**
Samplers retrieved with additional effort	5	1	1	**2.3**
Samplers retrieved/surfaced earlier than designed	0	1	1	**0.7**
Samplers lost	1	1	1	**1**
Total number of samplers retrieved	13	10	9	**10.7**

3. Successful Full-Cycle Rate

The number of samplers that were successfully recovered (23 in Pearl Harbor, 9 in San Diego Bay) was divided by the number of samplers that were meant to be deployed (25 in Pearl Harbor, 10 in San Diego Bay). This takes into account failure of either deployment and/or recovery to calculate the successful full-cycle rate.

4. Range of Environmental Conditions

Water depth, temperature, salinity, weather, and currents were assessed quantitatively or qualitatively for each deployment. A yes/no was assigned to determine whether any of these metrics was likely related to unsuccessful full-cycles in each case where a failure point was encountered. The following environmental conditions were identified:

Deployment failure:

A. Bishop Point, Pearl Harbor – bottom too hard for aluminum frames to penetrate. Possibly, stainless steel frames could be successfully deployed here.

Retrieval failure:

A. Off Ford Island landfill, Pearl Harbor – no unusual environmental conditions.
B. Waiawa stream mouth, Pearl Harbor – lowest salinity site. Believe this sampler was snagged by fishers (not related directly to environment conditions other than being relatively shallow site with increased chance for interference by public).
C. Shipping Channel, San Diego Bay – highest current site, largest grain size (qualitatively). Believe sampler released from sediment and floated away. Possibly, a heavier stainless steel frame could be successfully retrieved from this site.

5. Ease of Use

This is a subjective, qualitative metric, assessed by speaking with the field team.

8. COST ASSESSMENT

The focus of the cost assessment was to develop an understanding of the expected operational costs of the Passive Push technology. Considerations for the cost assessment including cost drivers, cost modeling, and the cost based are summarized below.

8.1. COST MODEL

The cost model uses a per-event cost approach for the Passive Push technology. The cost model incorporates the cost drivers described below and was applied using assumptions regarding the scale of the application.

Data to support the cost assessment were derived from vendor supplied information on the equipment costs. Typical industry labor and overhead rates were used to estimate the field work and analysis elements associated with this technology. Logistics costs were estimated assuming travel to typical DoD sites within the U.S. and data from the Pearl Harbor demonstration. Analytical costs were estimated from analyses conducted during the Pearl Harbor demonstration, and cost estimates provided from other laboratories.

The NESDI Technology Integration and Cost Analysis (TICA) report is included below. This indicates that the Passive Push technology significantly improves efficiency related to passive sampling, and this was demonstrated in both Pearl Harbor and San Diego Bay. Along with this efficiency follows significant cost savings, which increase as the size of a given field effort increases.

TICA Report (Project 529)

Title	Status	Type	PI	TI
Diver-less Deployment System for In-Situ Sediment Samplers	Active Project	New Technology	Jessica Carilli SSC San Diego 619-553-2768	Not Assigned

Transition Description:

We plan to address the key aspects of technology transition including:
(1) Documented demonstration and validation
- Final technical, cost and performance report
- Technical publications describing the technology and protocols
(2) Access to equipment
- Collaboration with industry partner as part of project
- Take forward successful products to commercialization
(3) Access to expertise
- Partnering with Marine Sampling Systems and SEE - potential service providers
- Partnering with Massachusetts Institute of Technology - a leader in passive sampling development
- Also partner with on-site consultants at demonstration sites
(4) Documented methodologies
- Development of standard operating procedures
- Requirement for incorporation of the technology in Navy workplans

It is expected that the first Navy users are likely to be RPMs at active Navy sediment sites such as Pearl Harbor, Apra Harbor, Bremerton, Quantico, Anacostia, etc. There are no known barriers to implementation.

Intangible Benefits:

Benefit	Description
Increased Efficiency	Adoption of this system would result in increased efficiency due to higher sampling rates and the elimination of diver requirements.

Integration Sites, ROI, and Payback:

No Integration Sites Entered

Cost Details by Site/Scenario:

No Sites/Senerios Have Been Entered

8.2. COST DRIVERS

Cost drivers for the application of the Passive Push are largely driven by capital equipment and maintenance costs, labor and overhead costs associated with the field work, logistics costs, consumables, analytical costs associated with the sampling elements, and labor and overhead costs associated with the data analysis and reporting. However, some of these costs (analytical costs and labor and overhead costs associated with data analysis and reporting) are part of any passive sampling effort, and are not specific to use of the Passive Push technology.

The majority of the cost that is not specific to the Passive Push (or diver-deployed) technology is for laboratory analysis of passive samplers ($900 per sample for EPA1668 method analysis). This cost could decrease with advances in laboratory techniques over time, or could be reduced if a different analytical method were used (for example a simpler method such as NOAA18 [approximately $250 per sample] that may be appropriate for a given field effort). This assessment shows that passive sampling, regardless of the sampler installation and retrieval method, can be a relatively expensive method compared, for example, to bulk sediment PCB analyses (~$150 per sample). However, as discussed, passive sampling can provide more relevant data to cleanup managers, and with regulatory acceptance, could potentially replace even more costly efforts such as fish tissue analyses, which require substantial field effort to capture the correct species and number of fish at a given site.

Assuming these baseline costs to use passive sampling at a given site, the cost drivers for using the Passive Push technology to install and retrieve the samplers vs. using divers to install the samplers comes down primarily to time saved on vessel rental costs and reduced labor costs, because the Passive Push technology is more time-efficient. These cost savings also do not take into account the inherent benefit of the higher full-cycle success rate of the Passive Push technology (approaching 90%) vs. diver methods (approximately 50%).

When a local field effort is conducted (such as the San Diego Bay demonstration), overall costs are lower for both the Passive Push and diver-deployed methods. The cost difference between local and remote field efforts is greater for the Passive Push technology than for diver methods, primarily driven by the relatively high costs of shipping the Passive Push equipment to and from the remote site. The cost difference between using the Passive Push technology and divers to install and retrieve samplers is reduced for very small numbers of sites, and increases for larger efforts with more sites. Thus, the Passive Push technology is increasingly efficient for larger field efforts.

8.3. COST ANALYSIS AND COMPARISON

The focus of the Passive Push technology is to minimize or eliminate the need for costly, time-consuming dive operations for passive sampler deployment and retrieval. Cost comparisons were thus made to comparable scale field events using dive teams as opposed to the Passive Push system.

First, a general cost analysis was performed to examine the baseline costs for a given passive sampling effort, regardless of the method of sampler installation and retrieval (Table 7). This resulted in an estimated baseline cost of approximately $47,476 to deploy and analyze 20 passive samplers to assess both porewater and overlying water PCB contaminants.

Table 7: Cost analysis for example field deployment of 20 PE samplers; shared costs for any deployment/retrieval method

Costs for a given example passive sampler project shared between deployment methods		
Item	**Cost estimate basis**	**Total cost**
Shipping ice chest with samplers to be deployed	San Diego - Pearl City; 3ftx1.5ftx1ft; 35 lbs, Fedex 2 day	$146
Shipping ice chest with deployed samplers	Pearl City - Maxxam (NY); 12”x12”x8”; 8 lbs, Fedex Priority overnight	$128
Ice chests for samplers	2x 150 qt, marine ice chest, Rubbermaid, white	$200
Ice packs	20x blue ice packs	$59
Utility knives	3x knives	$30
Aluminum foil	1x large roll	$10
Gloves	2x boxes	$20

Ethyl alcohol	1x bottle	$15
Kimwipes	2x boxes	$24
Ziplock bags for samplers	UV-resistant, 6" x 8" (3 packs; $6.25 each)	$19
Ziplock bags for samplers	UV-resistant, 8" x 10" (3 packs; $8.22 each)	$25
Pre-loaded PE samplers	"SP3" samplers, $300 each, plus blanks	$7200
Analysis of PE samplers	2x analyses per sampler at $900 per analysis	$39,600
Total cost for deployment and analysis of 20 PE samplers, regardless of method	Includes analysis of 4x field blanks/duplicates	**$47,476**

Next, capital investment costs associated with the Passive Push technology were calculated (Table 8). These estimates were then fed into a calculation that amortizes these costs (Table 9).

Table 8: Assessment of capital investment costs associated with the Passive Push technology

Component	Unit Cost	Notes
Push Pole Component		
Sampler-attachment header	$750	Required
Extension poles	$100	Required - each
Field Kit/Tools	$200	Required
Video camera and attachment	$2,090	Optional
Typical Unit Cost Per Demo Configuration	**$3,640**	
Landing Frame Component		
Landing frame	$3,000	Required
Weights	$200	Required
Field Kit/Tools	$200	Required
Larger surface area foot plates for frame	$160	Optional
Video camera and attachment	$2,090	Optional
Typical Unit Cost Per Demo Configuration	**$5,650**	
Sampler Frame Component		
Aluminum sampler frames - each	$260	Required
Stainless steel frame screws	$10	Required
PVC float attachment device	$10	Required
Timed float	$300	Required
Passive sampling material (varies; SP3 shown here)	$300	Required
Stainless Steel sampler frame (additional; each)	$130	Optional - upgrade
Hobo Temperature/Conductivity Sensor	$750	Optional

Plastic line attachment point	$2	Optional
Typical Unit Cost Per Demo Configuration	**$882**	

Table 9: Long-term costs of Passive Push equipment

Estimate of Initial Cost for Capital and Ancillary Equipment			
Item			Initial
Passive Push Pole System			$ 3,620
Ancillary - Field Kit			$ 200
Ancillary - Float Release Timer			$ 595
Ancillary - Field Video Camera Viewer			$ 1,000
Total Push Pole System			$ 5,415
Equipment Replacement Cost Estimate			
Inflation Rate	*4%*		
	Years of Use		
	0	5	10
Passive Push Pole & Ancillary Replacement	$ 5,415	$ 6,498	$ 7,581
Estimated Rental Rate Including Inflation and Maintenance			
Maintenance Rate	*10%*		
		Years of use	
	Uses/year	5	10
Passive Push Pole & Ancillary	3	$ 477	$ 278
	6	$ 238	$ 139
	9	$ 159	$ 93
	12	$ 119	$ 69
	15	$ 95	$ 56
Rental Rate for Cost Analysis			
Passive Push Pole System			$ 139

Estimate of Initial Cost for Capital and Ancillary Equipment			
Item			Initial
Passive Push Lander System			$ 5,450
Ancillary - Field Kit			$ 200
Ancillary - Float Release Timer			$ 595
Ancillary - Field Video Camera Viewer			$ 1,000
Total Push Pole System			$ 7,245
Equipment Replacement Cost Estimate			
Inflation Rate	*4%*		
	Years of Use		
	0	5	10
Passive Push Lander & Ancillary Replacement	$ 7,245	$ 8,694	$ 10,143
Estimated Rental Rate Including Inflation and Maintenance			
Maintenance Rate	*10%*		
		Years of use	
	Uses/year	5	10
Passive Push Lander & Ancillary	3	$ 638	$ 372
	6	$ 319	$ 186
	9	$ 213	$ 124
	12	$ 159	$ 93
	15	$ 128	$ 74
Rental Rate for Cost Analysis			
Passive Push Lander System			$ 186

Finally, field costs were assessed for a typical field deployment, assuming 20 sites. This was computed for both a remote and a local field site, for both the Passive Push technology (Table 10) and the typical method of using divers to deploy and retrieve passive samplers (Table 11). For a field effort at a non-local location with 20 sites, using the Passive Push technology represents a cost savings of approximately $22,449. For a local field effort with 20 sites, using the Passive Push technology represents a cost savings of approximately $24,980. Clearly, the capital investment costs (maximum of ~$7,245; Table 8) of the Passive Push technology are recouperated after only one mid-size passive sampling field effort.

Table 10: Cost analysis for example field deployment of 20 PE samplers using Passive Push

Costs unique to Passive Push		
Item	**Details**	**Total cost**
Shipping Passive Push equipment to site	San Diego - Pearl City; (2) 5ftx5ftx3ft, 400-lb pallet boxes; (2) 8ftx0.5ftx0.5ft, 40-lb sampler poles, Fedex Air freight	$2280

Shipping Passive Push equipment from site	Pearl City - San Diego; (2) 5ftx5ftx3ft, 400-lb pallet boxes; (2) 8ftx0.5ftx0.5ft, 40-lb sampler poles, Fedex air freight	$2450
Vessel rental	1x day each to install and retrieve 20 samplers at $2500 per day; assumes safety equipment supplied	$5,000
Truck rental	3x days at $120 per day to move equipment	$360
Labor	1x day each, deployment and retrieval, plus 1x day each mobilization/demobilization 5-person field team	$16,500
Travel	Flights ($800), hotel ($180) and per diem ($1400) for 5-person field team, 3 day effort	$8,800
Total cost to use Passive Push to install/retrieve samplers	Installation at remote site	**$35,391**
Total cost to use Passive Push to install/retrieve samplers	Installation at local site (no shipping or travel costs)	**$21,500**

Table 11: Cost analysis for example field deployment of 20 PE samplers using divers

Costs unique to diver-deployment		
Item	**Details**	**Total cost**
Vessel rental	4x days each to install and retrieve 20 samplers at $2500 per day	$20,000
Labor	4x days each to install and retrieve, 4-person field team, plus one day each mobilization and demobilization	$26,400
Travel	Flights ($800), hotel ($180) and per diem ($140) for 4-person field team, 6 day effort	$10,880
Rental car	6x days to move field team between hotel and site, $40 per day	$240
Air tank fills	$5/tank, 4 tanks/day	$80
Shipping dive gear	$120 each way	$240
Total cost to use divers to install/retrieve samplers	Installation at remote site, assumes dive gear owned	**$57,840**
Total cost to use divers to install/retrieve samplers	Installation at local site (no shipping or travel costs)	**$46,480**

9. CONCLUSIONS, RECOMMENDATIONS, AND IMPLEMENTATION ISSUES

The Passive Push technology developed and demonstrated under this NESDI project performed successfully, particularly after small improvements to the system were made between the Pearl Harbor and San Diego Bay demonstrations. The system has been transitioned to vendors, and all components are now commercially available. Coastal Monitoring Associates is the contact-point for users interested in purchasing a system, and will bundle components to fit user needs from vendors.

Follow-on work in this area has already begun, as evidenced by Geosyntec's development of a new sample-frame adapter design to deploy their custom-built "peeper" samplers using the Passive Push push-pole system (Figure 22). As Navy monitoring needs evolve, further work to develop additional sampler adapters like this example could be warranted.

Figure 22: Prototype sampler frame to deploy cylindrical samplers to assess metal contamination in sediments, designed by Geosyntec (photo courtesy of Geosyntec).

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11. APPENDICES

Appendix A: Points of Contact

Name	Organization	Phone	E-mail	Role in Project
Jessica Carilli	SSC-Pacific 53560 Hull St. San Diego, CA 92152	619-553-2781	Jessica.carilli@navy.mil	Replacement Principle Investigator
Bart Chadwick	Current: Coastal Monitoring Associates Formerly: SSC-Pacific 53560 Hull St. San Diego, CA 92152	619-218-5882	Bart.chadwick@coastalmonitoring.net	Original Principle Investigator
Joel Guerrero	SSC-Pacific 53560 Hull St. San Diego, CA 92152	619-553-4169	joel.guerrero@navy.mil	Field work lead
Jim Leather	SSC-Pacific 53560 Hull St. San Diego, CA 92152	619-553-6240	jim.leather@navy.mil	San Diego Bay effort and data interpretation support
Kim Markillie	NAVFAC Pacific, Pearl Harbor, HI	808-472-1465	Kimberly.Markillie@navy.mil	Site contact for JBPHH demonstration
Melissa Grover	Geosyntec 16644 West Bernardo Drive, Suite 301 San Diego, CA 92127	858.716.2928	MGrover@Geosyntec.com	SP3 support
Brian Thomas	Thomas Marine, Inc. 2835 Cañon Street San Diego, CA 92106	(619) 224-5220	brian@thomasmarinewelding.com	Push pole support
Tim Marrs	Ocean Instruments, Inc. 5312 Banks Street San Diego, CA 92110	619-291-2557	tmarrs@oceaninstruments.com	Drive frame support
Roger Hubbard	Sub Sea Sonics, LLC 1513 Vista De Montemar El Cajon CA 92021	619-590-2800	roger@subseasonics.com	Release float support
Ashley Parks	Southern California Coastal Water Research Project 3535 Harbor Blvd, Suite 110 Costa Mesa, CA 92626	714-755-3216	ashleyp@sccwrp.org	Site contact for San Diego Bay demonstration

Appendix B: Equipment Manuals and SOPs

APPENDIX B-1

SP3 Passive Sampler SOPs

Overview:

Polyethylene (PE) "SP3^{TM}" passive samplers will be shipped to site in cooler(s) on ice and maintained cool (4 degrees Celsius [°C] ± 2 °C) until deployed in the surface sediments and overlying water via diver-less deployment methods (See Deployment SOP for passive sampler handling details). The samplers will be retrieved, sectioned (one sampler will be sectioned into two samples for analysis), handled, and shipped to the analytical laboratory after four to eight weeks of in situ exposure (see Retrieval SOP for passive sampler handling details).

Passive sampling will be performed in general accordance with *Laboratory, Field, and Analytical Procedures for Using Passive Sampling in the Evaluation of Contaminated Sediments: User's Manual* (U.S. EPA/SERDP/ESTCP 2017).

The SP3 PE material is spiked with Performance Reference Compounds (PRCs) consisting of rare PCBs congeners assumed to: 1) not be present in the media in which the samplers were deployed, or 2) present at concentrations so low as to be inconsequential, not affect calculations involving PRCs, and insignificant compared to the concentration of other freely-dissolved PCBs in the media sampled. The PRCs used for this project were: PCB-14, PCB-36, PCB-78, PCB-104, PCB-121, PCB-142, PCB-155, PCB-184, PCB-192, and PCB-204[1].

Sampler processing:

All primary samplers will be sectioned into two primary samples (one surface water exposed sample and one surface sediment exposed sample per sampler) at the time of retrieval by field support. Additionally, one field duplicate sampler will be sectioned into two samples per sampler during retrieval by field support. Also at the time of retrieval, two samplers (field blanks) will be shipped to field support on ice and maintained cool, these field blanks will be sectioned, handled, and shipped to the analytical laboratory with the primary samples (two field blank samplers sectioned into four field blank samples; see Retrieval SOP for additional detail).

Laboratory analysis:

Laboratory provided sample results of the concentration of PCB congeners (US EPA Method 1668A) in PE will be used to calculate freely-dissolved concentrations (C_{free}) of PCB congeners in surface sediment porewater and overlying surface water.

Data processing:

The concentration of PCBs in PE obtained from the information provided in the analytical laboratory report will be used in a multi-step data process to calculate C_{free} PCBs. These steps are described here:

<u>Step 1:</u>
The concentration of the PRCs in PE [PE_t] will be used to calculate the elimination rate (k_e) values for the PRCs in each sample using the following equation (Lohmann 2012):

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[1] PCB shorthand nomenclature used in this report follows the Chemical Abstract Service (CAS) nomenclature used by USEPA (2003): United States Environmental Protection Agency (USEPA). 2003. Table of PCB Species by Congener Number.

$$PRC\ k_e = \ln\left(\frac{[PE_{t=0}]}{[PE_{t=final}]}\right) \div t_{final}$$

where:

$PE_{t=0}$ = the average concentration of the PRC in the PE at the beginning of the deployment (obtained from an average measurement of the Field Blanks);

$PE_{t=final}$ = the concentration of the PRC in the PE after the deployment (obtained from each deployed PE sampler); and

t_{final} = the deployment time (in days).

k_e = the elimination rate (in days^{-1})

PRC k_e values and percentage of steady state (concentration at equilibrium) for the PRCs will be provided for each sample. If $PE_{t=final}$ values are equal to or greater than $PE_{t=0}$ values, PRC k_e values may be treated as outliers.

<u>Step 2:</u>
The second step will be to estimate k_e values for the non-PRC PCBs (primary analyte PCBs) in each of sample. This will be accomplished by developing a linear regression model using PRC k_e values (dependent variable) and PE-water partition coefficients (K_{PE}) for each PCB (independent variable, from Smedes et al. 2009). Note that regression models will be specific to each sample (i.e. not global to the whole deployment) as local geologic and hydrodynamic conditions can vary greatly.

Values were $\log_{10}$-transformed per Tomaszewski and Luthy (2008). By entering the PCB-specific K_{PE} into the linear regression model developed for each sample, k_e values for each of the primary analyte PCBs for each sample will be calculated.

<u>Step 3:</u>
Concentrations of some primary analyte PCBs in PE may corrected for trace levels of primary analyte PCBs present in the Field Blank samples (due to trace levels present in the PRC spiking solutions). Using the sampler specific k_e values, the expected amount of these trace primary analyte PCBs present in the sampler at the end of deployment (*Trace PCB* $_{t=final}$) will be calculated via the following equation:

$$[Trace\ PCB_{t=final}] = \frac{[Trace\ PCB_{t=0}]}{e^{k_e \times t_{final}}}$$

where:

Trace $PCB_{t=final}$ = the expected concentration of trace PCBs assuming to be remaining in the sampler at the end of the deployment;

Trace $PCB_{t=0}$ = the average concentration of the trace PCB assumed to be present in the PE at the beginning of the deployment (obtained from an average measurement of the trace PCBs in the Field Blanks);

k_e = the elimination rate value predicted by the sampler-specific regression model (in days^{-1}); and

t_{final} = the deployment time (in days).

Concentrations of *Trace PCB* $_{t=final}$ values will then be subtracted from the measured concentrations of primary analyte PCBs in PE.

Step 4:
This step describes the calculation of sampling rate correction factors (*CF*s) for each primary analyte PCB in each sample. The following equation will be used, as adapted from Lohmann (2012):

$$CF = \frac{1}{1 - e^{-k_e \times t_{final}}}$$

where:
k_e = the elimination rate value predicted by the sampler-specific regression model (in days^{-1}); and
t_{final} = the deployment time (in days).

Step 5:
The concentration of PCBs in the PE of each sample will be multiplied by the *CF* values to calculate the steady-state concentration of PCBs.

Step 6:
In the final step, the steady-state concentrations will be divided by K_{PE} values (Smedes et al. 2009) to obtain the concentrations of C_{free} PCBs. In cases in which the percentage of steady state is indicated to be less than a certain threshold (e.g., 10% or 20%) for a primary analyte PCB, the results will be flagged with an "L" qualifier.

References Cited

Lohmann, R. 2012. Critical review of low-density polyethylene's partitioning and diffusion coefficients for trace organic contaminants and implications for its use as a passive sampler. Environ. Sci. Technol.: 46:606-618.

Smedes, P., Geerstma, R. W., van der Zande, T., and Booij, K. 2009. Polymer-water partition coefficients of hydrophobic compounds for passive sampling: Application of cosolvent models for validation. Environ. Sci. Technol. 43:7047-7054.

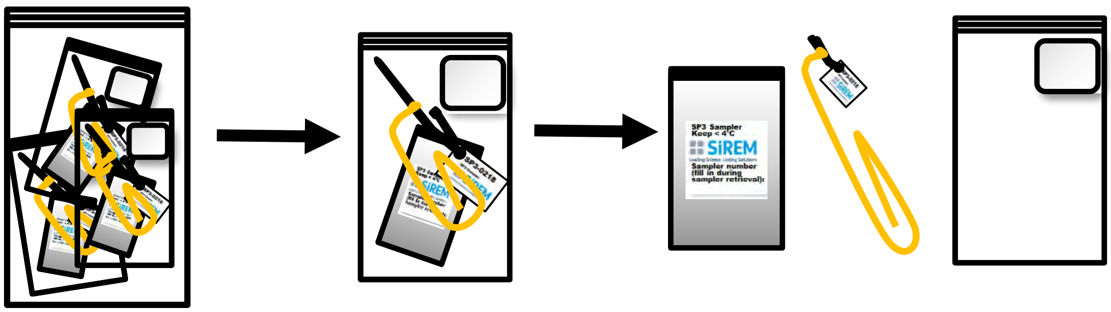
Tomaszewski, J.E., and Luthy, R.G. 2008. Field deployment of polyethylene devices to measure PCB concentrations in pore water of contaminated sediment. Environ. Sci. Technol. 42:6086-6091

U.S. EPA (United States Environmental Protection Agency). 2003. Table of PCB Species by Congener Number.

U.S. EPA/SERDP/ESTCP. 2017. Laboratory, Field, and Analytical Procedures for Using Passive Sampling in the Evaluation of Contaminated Sediments: User's Manual. EPA/600/R-16/357. Office of Research and Development, Washington, DC 20460.

STANDARD OPERATING PROCEDURE (SOP)
DEPLOYMENT OF *IN SITU* PE PASSIVE SAMPLERS [procedure followed for Pearl Harbor demonstration]

1. Keep the SP3™ samplers cool (4°C ± 2°C) and in the dark as much as possible.
2. Prior to deployment, with gloved hands, remove a single bagged SP3™ sampler from the large bag of samplers (also laminated tags and flagging), and remove the opaque resealable sampler bag from the clear plastic Ziploc bag (keep Ziploc bag).



3. Remove the sampler (PE in copper mesh envelope) from the opaque resealable sample bag (keep opaque resealable bag), affix mesh envelope by stretching the mesh envelope along the length and width of the window of the frame until taught, align the holes in the top/bottom of the mesh envelope with the screw holes in the top/bottom of frame, and secure with screws around the frame window.
4. Attempt to keep the sampler out of direct sunlight and heat as much as possible during the above preparation steps.
5. Wrap prepared sampler in clean aluminum foil and maintain cold until deployment.
6. Deploy frame with diver-less deployment system such that the desired overlying water and surface sediment intervals are measured.
7. Record the date, time, and location of deployment for each sampler in the field deployment notes.

STANDARD OPERATING PROCEDURE (SOP)
RETRIEVAL, HANDLING, AND SHIPPING OF *IN SITU* PE PASSIVE SAMPLERS
[procedure followed for Pearl Harbor demonstration]

Field Blanks

1. Two samplers will be shipped to field crew near the site at the time of retrieval for use as Field Blanks (FB). For each FB sampler, with gloved hands, remove it from the labeled, opaque resealable sampler bag. Expose the sampler to ambient air and light conditions at the site for 5 minutes. Section the sampler into two samples by cutting with a clean utility knife in half.
2. Place each sample (mesh envelope with PE) back into each labeled opaque resealable sampler bag, mark label with a unique sample ID (e.g., "FB1"), and place in a clear Ziploc bag.
3. Maintain in cooler on ice (4°C ± 2°C) until shipped to the analytical lab (ideally within 1 to 4 days of deployment or in accordance with project-specific quality control documents).

Deployed Samples

As soon as possible and ideally within 15 minutes of retrieval, with gloved hands, the passive sampler (mesh envelope with PE) will be observed (depth of penetration into surface sediment noted); sectioned into samples (two samples per sampler); removed from the frame; placed and sealed into labeled opaque bag then clear Ziploc bag; and placed in a cooler on ice.

1. Do not remove sediment if adhered.
2. Place frame with affixed passive sampler horizontally onto a stable surface covered with clean aluminum foil.
3. Place tape measure along the length of the frame and note and/or photograph presence of depth of passive sampler penetration into the sediment surface (i.e., biofouling or presence of sediment).
4. With gloved hands, using a clean utility knife, cut the envelope out the frame maintaining the width of the sampler (4 inches) and to the desired project-specific length (e.g., 8 inches). Surface covering (aluminum foil) and utensils (utility knife) will be decontaminated between sample locations and prior to sectioning of the first sampler.
5. Place each sample (mesh envelope with PE) into a separate opaque labeled resealable bag and mark label with unique sample ID for each sample. Place sealed opaque bag into a clear Ziploc bag.
6. Place samples into a cooler on ice and maintain cool (4°C ± 2°C) until shipping (ideally within 1 to 4 days of retrieval or in accordance with project-specific quality control documents).
7. For shipping, include:
    a. Ice (double Ziploc bagged) or bagged blue ice packs,
    b. Samplers,
    c. Extra packaging (bubble wrap) as needed.
    d. Chain of custody
    e. Ship overnight for next morning delivery.

APPENDIX B-2

Passive Push System SOP

Passive Push: A Diver-less Deployment System for Passive Samplers

Standard Operating Procedure

Revision 1.0
February 12, 2017

1 INTRODUCTION

This Standard Operating Procedure (SOP) describes the equipment and procedures associated with the Passive Push system, a new diver-less deployment system for in-situ sediment passive samplers. This section provides a general overview of the project including background, objectives and regulatory drivers.

1.1 BACKGROUND

Recently research has led to the development of a new family of passive sampling devices for sediment. These devices generally rely on the partitioning of the bioavailable phase of the contaminant to the sorptive surface of the sampler. Detailed calibrations and performance assessments, along with incorporation of performance reference compounds has led to the ability to apply these devices both qualitatively and quantitatively in the field and the laboratory. As the technology transitions to application, one of the key limitations that has been identified is the ability to reliably deploy and retrieve the devices in the field in a cost effective manner. Most applications to date have focused on either shallow water deployments by wading, or deeper water deployments by divers. Experience has shown that the costs associated with these deeper water diver deployments may significantly reduce the cost effectiveness of the approach. This is especially relevant for sites where many of the areas of interest are in water depths beyond the capability of wading. In addition, extensive boat, ship and other harbor activities in these areas preclude the use of surface floats which can significantly hamper retrieval. The ability to routinely deploy and retrieve these devices in areas of interest without the costs associated with divers would thus significantly enhance their cost effectiveness. These diver-less deployments and retrievals are the purpose of the Passive Push system.

2 TECHNOLOGY

This section provides an overview of the Passive Push technology to be demonstrated including a description of the origin of the systems, the commercialized configurations, and the potential advantages and limitations of the systems.

2.1 TECHNOLOGY DESCRIPTION

The Passive Push technology was adapted from previous applications and from the oceanographic technology marketplace. The Passive Push system consists of 3 modular components including (1) the passive sampler frame, (2) the deployment system, and (3) the retrieval system. The sampler frame is generic in the sense that it can accommodate different samplers, as well as providing a standardized interface for different deployment and retrieval systems. The frame was adapted from frames already in use for typical polyethylene sampling devices (PEDs) but incorporates standardized interface that allow use of different types of samplers including SPMEs and DGTs. Two deployment systems have been developed, one based on the Trident Probe release point (push-pole) technology, and one based on the multi-corer drive-frame technology. Both of these systems are designed to accommodate the standardized frame interface. The release point system is viewed as being more effective for shallow water deployments from small boats, while the frame system allows for deeper water deployments from larger vessels.

The retrieval system for the Passive Push system utilizes a retrieval buoy and line system controlled by a timed release. The retrieval system was adapted to allow it to accommodate the standardized sampler frame interface. The timed release is moderately priced and provides more certainty and will work in both salt water and freshwater environments, but the time must be pre-programmed and thus lacks the ability to adapt to potential interferences. By standardizing the interfaces to these systems, and allowing for a range of options, the system will provide the range of capabilities needed to accommodate a broad range of applications at sediment sites.

2.1.1 Sampler Frame

The sampler frame is consistent with the original design developed by Dr. Phil Gschwend at MIT. The standard long frame is constructed from two identical sheets of thin anodized aluminum with an overall length of about 64 cm and a width of about 20 cm (Figure 1). The sampler is sandwiched between the aluminum plates which are held together at regular intervals by stainless steel fasteners. The window for the sampler is about 47 cm high by 14 cm wide. The frame has a handle-shaped cut out at the top so it can be pushed in by hand in shallow sediment or by divers. There is a hole above the handle cut out that accommodates the release pin that is used with the push pole and the drive-frame systems. The standard short frame is identical to the long frame except the overall length is about 45 cm, and the window height is about 22.5 cm.

2.1.2 Push Pole Deployment System

The push pole system is designed for deployment of passive samplers in water depths to about 15 m depending on conditions. The push pole system includes the head unit and the push poles (Figure 2). The head unit has a socket that the sampler frame inserts into. A spring-loaded release pin secures the sampler frame inside the socket. The head unit also incorporates an adjustable stopper plate that sets the penetration depth of the sampler into the bottom. The stopper plate is adjusted by loosening the bolts that secure it to the head unit, adjusting to the desired level relative to the sampler frame, and then re-securing the bolts. The push poles are made up of 2 m long sections of 3.8 cm diameter aluminum tubing. Each section has a male and female socket on opposite ends to allow the poles to be secured together to the desired length that will accommodate the water depth at the deployment site. On the bottom of the first pole closest to the head unit, an underwater video camera is secured that allows the operator to observe during the installation. The video camera has a cable running to the surface that connects to a monitor and a recorder. The camera also has an adjustable LED lighting system to accommodate low light conditions at greater water depths.

2.1.3 Drive-Frame Deployment System

The drive-frame system is designed for deployment of passive samplers in all water depths up to about 100 ft. It is particularly useful when operations preclude station-keeping or where water depths exceed the range of the push pole system. The drive-frame system includes the deployment frame, the carriage, the drive weights, and the head unit (Figure 3). The drive-frame is an 8-leg frame that supports the drive system and provides stability for the system once it has landed on the seafloor. The carriage rides vertically along the central axis of the drive-frame and provides the vertical motion that allows for the installation of the sampler frame. The drive weights are mounted on the carriage and provide sufficient force to push the sampler into the bottom under most conditions. The head unit is mounted on the bottom of the carriage and provides the interface to the sampler frame similar to the push pole system. The drive-frame system also as an underwater video camera to provide visual reference for the operator.

2.1.4 Timed-Release System

The timed-release system provides the ability to retrieve the sampler at a pre-programmed time. The timed-release uses a modified COTS oceanographic burn-wire release system manufactured by Subsea Sonics. This release unit is deployed underwater and contains a micro-computer and batteries and holds a replaceable release link with a screw on retainer cap. It is programmed to the time-until-release (TUR) desired by electrical contact with the contacts on a programmer before deployment underwater. Release accuracy is +/-2 minute per month of deployment. After time is up and release erosion initiates it takes typically another 10 minutes for the link erosion to complete. To accommodate the retrieval of the passive sampler, a line spool, retrieval line, float and mounting bracket have been incorporated into the standard unit (Figure 4). The line spool can accommodate about 50 m of high-strength, small-diamter line (Dyneema or Spectra). A rigid polyurethane foam float encircles the top of the system to provide sufficient buoyancy to unfurl the retrieval line and come to the surface. The float is then retrieved and the sampler is pulled out of the bottom and recovered using the high-strength line. The entire release unit is attached to the sampler frame with a simple PVC bracket.

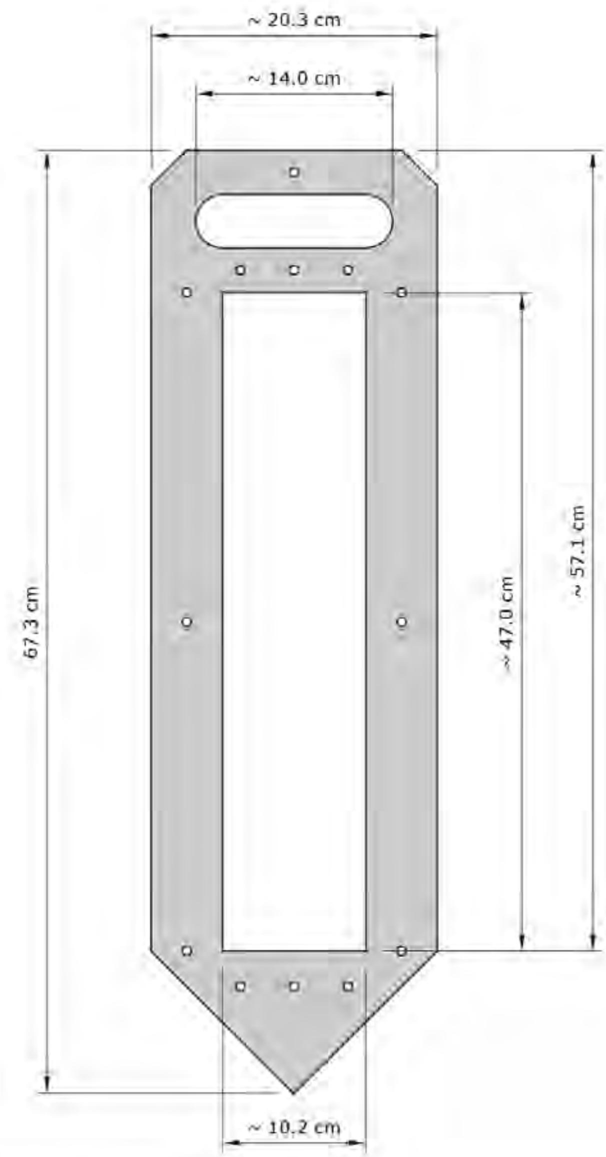


Figure 1. Passive sampler frame.

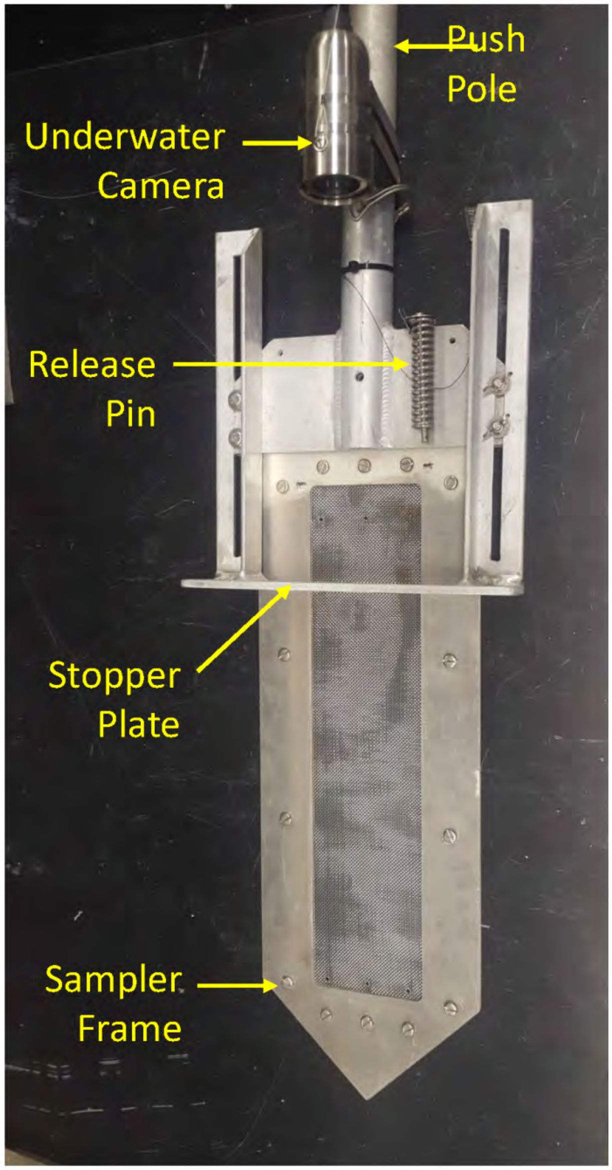


Figure 2. Push pole system.

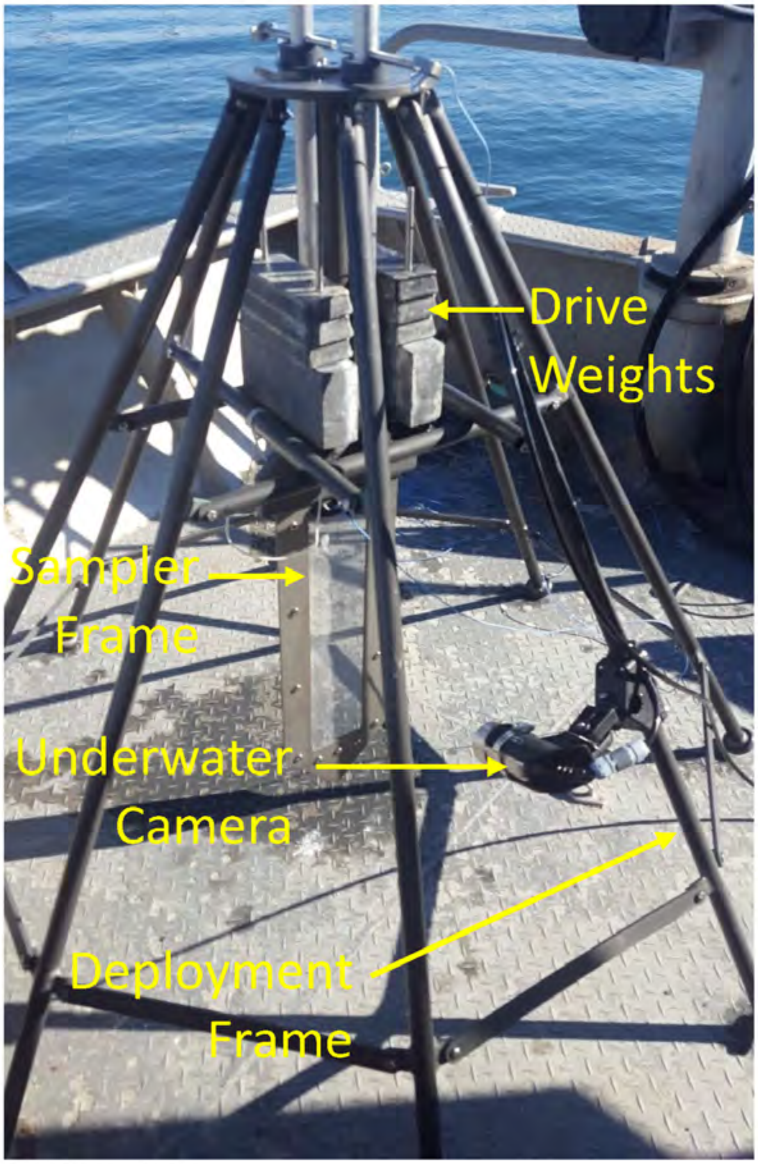


Figure 3. Drive-frame system.

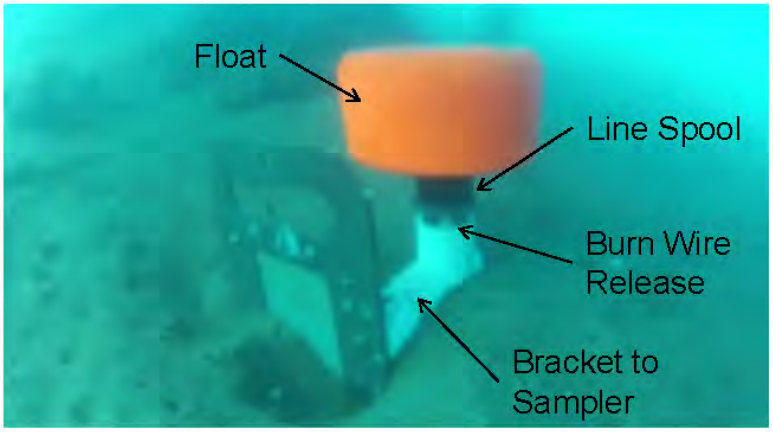


Figure 4. The timed-release retrieval float.

3 FIELD PROCEDURES

The field application for the Passive Push system generally includes mobilization, pre-deployment preparation, deployments, retrieval, post processing, and demobilization. The field application procedures for these phases are described below.

Mobilization: Mobilization includes making arrangements for access to the site, travel for the personnel, and organization and shipment of the required Passive Push equipment. This should include the development and application of checklists to minimize potential for loss or missing equipment at the field site.

Pre-Deployment Preparation: Pre-deployment preparation of the Passive Push system includes a number of steps. These steps consist of setting up the boat, preparing the sampler frame, preparing the retrieval system, setting up the deployment system (push-pole or drive-frame), and preparing the camera system.

The size, configuration, and capabilities of the deployment boat generally depend on site conditions and which deployment system is being used; the drive-frame or the push-pole. The first consideration for selection and preparation of the boat should always be for expected on-water conditions and safety of the operation. For the push-pole system, the boat should provide sufficient space and capability to accommodate the samplers, the push-poles and head unit, the camera system, and the crew. The push-pole system should generally not be employed in water depths greater than 50 ft and consideration must be given to the speed of the currents and associated drag on the poles. To successfully use the push-pole system, the boat must be able to hold station for sufficient time to push the sampler into the bottom, verify with the camera the required insertion depth, and release and remove the pole system. This generally requires 1-5 minutes. Thus the boat should be equipped with the ability to hold station either by anchoring, spudding, or dynamic station keeping. The boat should be equipped with GPS navigation generally capable of locating the sampler to within about 1 m. The boat should also be equipped with a depth sounder to determine water depth prior to deployment. For the drive-frame system, boat requirements are similar, but there are added requirements for lift capabilities, and less restrictive requirements for station keeping. The drive system generally requires a lift system capable of accommodating a working load of about 500 lb with a vertical clearance of about 8 ft and an over-the-side clearance of about 3 ft. Because the drive-frame is lowered on a flexible cable, it is not essential that the boat maintain station directly above the frame, and thus anchoring and spudding are generally not required.

Preparing the sampler frames generally includes pre-cleaning to make sure there are not residual sediments on the frames, and installing the samplers into the frames. Installation of the samplers will vary by sampler type. For standard PE samplers, the two halves of the frame are separated, the sampler is placed between them, and the halves are then re-secured together using the stainless steel fasteners. For DGT samplers, the DGT paddle is fastened to the face of the frame border using nylon screws with the exposure side facing out. For SPME samplers, the fibers may be placed in perforated stainless steel tubes that are then clamped within the frame, or they can be placed in mesh envelopes and fastened to a coarser mesh that is clamped within the frame. In general, the samplers should not be installed in the frames until as close to the deployment time as possible. If the samplers are pre-installed in the frames ahead of time, they should be held under proper conditions prior to deployment.

Preparation of the retrieval system includes preparing the release unit and installing it onto the sampler frame. The release unit is prepared in accordance with the manufacturer's instructions. A new burn-wire should be installed prior to each deployment. The retrieval line should be carefully coiled onto the spool so that it will pay out cleanly on the retrieval. The unit should then be programed for the pre-determine release time using the deck unit. The release unit is then installed into the PVC adapter and secured with a zip tie. The adapter is then secured to the sampler frame by sliding the notch in the PVC adapter over the metal edge of the frame, and securing with the stainless steel bolt and nut.

Preparation of the deployment system depends on if the push-pole or drive-frame system will be employed (or both). For the push-pole system, preparation includes securing the head unit to the first pole using the rounded-retainer locking pin. The insertion depth is then set by adjusting the foot plate to the proper height relative to the sampler. The underwater camera is then installed onto the first push-pole, just above the head unit. The spring-activated release-pin should also be secured to the head unit using a short length of wire. The required number of push-poles and locking pins should be readied to accommodate the expected water depth.

For the drive-frame system, the insertion depth is set by inserting the stopper-pin into the appropriate hole on the drive rod so that the drive carriage will stop at the proper height above the sediment. The line that secures the clevis-pin portion of the release pin should also be adjusted so that the release pin is pulled out by the vertical motion of the drive carriage at the proper level. The spring-activated portion of the release-pin should also be secured to the head unit using a short length of wire. Sufficient weight should be added to the weight racks on the drive carriage to assure that the sampler will be driven into the bottom given the expected bottom conditions. The underwater camera should be installed onto the mounting bracket on the frame leg so that it provides a good view of the sampler frame at the inserted depth.

Preparation of the camera system should follow the manufacturer's instructions. For both the push-pole and drive-frame systems, once the camera is mounted on the system, sufficient cable should be paid-out off of the reel to accommodate expected water depths. The camera box should be set up in an appropriate area that is safe from exposure to weather and other moisture and shock exposure. The power and video connections can then be connected to the camera cable. The system should then be powered up and tested to assure that the camera is properly aligned. Make sure the camera batteries are fully charged, the micro SD card is installed in the recorder, and there is sufficient memory on the card to record the desired number of deployments.

Deployment: Deployment of samplers using the Passive Push system vary somewhat depending on the equipment in use. For the push-pole system, the sampler is installed into the head unit with the release pin (Figure 5). The boat then navigates to the station and holds position. Camera recording is turned on. The Passive Push operator then begins lowering the system toward the bottom while an assistant handles the release line and the camera cable. An assistant adds additional poles to the system as required by the station depth. When the sampler reaches the bottom, the operator forces the sampler into the sediment while an assistant monitors the camera read out. A GPS position and water depth is recorded. When the sampler is pushed completely to the insertion depth, an assistant pulls the release line, the sampler is released, and the operator begins retrieving the push poles to the surface. The time at full insertion is recorded. An assistant removes the push poles as they emerge and pulls in the cable slack from the camera. When the system is fully retrieved, the camera can be turned off and the equipment stowed and readied for the next station.

For the drive-frame system, the sampler is installed into the head unit with the release pin (Figure 6). The boat then navigates to the station and holds position. Camera recording is turned on. The drive-frame is lifted and lowered over the side toward the bottom while an assistant handles the release line and the camera cable. When the sampler reaches the bottom, the operator monitors the camera read out to verify full insertion of the sampler frame. A GPS position and water depth is recorded with the lift cable as vertical as possible. When the sampler is pushed completely to the insertion depth, the drive frame is lifted to the surface. The time at full insertion is recorded. During retrieval, an assistant pulls in the cable slack from the camera. When the system is fully retrieved, the camera can be turned off and the equipment stowed and readied for the next station.

Retrieval: The Passive Push retrieval system utilizes a timed-release float that is pre-programmed to surface at a user-specified time (Figure 7). This time is generally accurate to within about 5-10 minutes. So the recovery boat should arrive at the approximate location of the station about 10 minutes ahead of the expected surface time. Care should be taken not to locate the boat directly over the float, and vessel traffic in the area should be requested to stay clear until the sampler is retrieved. The crew should maintain a close watch for the float. At the retrieval time, the burn wire is activated, and the float is released to the surface. The boat then maneuvers to the float, and the float is retrieved using a hand-held net. Once the float is onboard, the boat should maneuver to be directly above the sampler, with the retrieval line as vertical as possible. The sampler can then be pulled from the bottom and onto the boat using the retrieval line. The time of retrieval is then recorded.

Post Processing: Once the sampler is retrieved to the boat, the sampler should be processed in accordance with procedures for the specific samplers being used. In general, the samplers should be rinsed with DI water to remove excess sediment and marked to distinguish the interface between the surface water and the sediment. This interface is usually clearly evident from differences in coloring and fouling on the frame and the sampler. The interface can be marked using a clean, stainless steel punch to make a small hole in the sampler at both edges near the frame at the level of the interface. The sampler can then be removed from the frame and given a final rinse to remove any excess sediment material that was caught between the frame and the edge of the sampler. The sampler can then be cut into appropriate interval (surface water and surface sediment), and placed in the pre-labeled sample bags for that station. Field blank samples should be handled using the same process as the field samples. The samples should then be stored under appropriate conditions. Once all of the samplers are retrieved and the post-processing is complete, the samples can be shipped to the lab for analysis.

Demobilization: At the end of the field survey, demobilization will include breakdown and packing of the equipment and return travel. All of the Passive Push equipment should be cleaned and rinsed with fresh water and allowed to fully dry before packing. Sampler frames should be disassembled and cleaned. Batteries should be removed from the retrieval floats and disposed of properly.

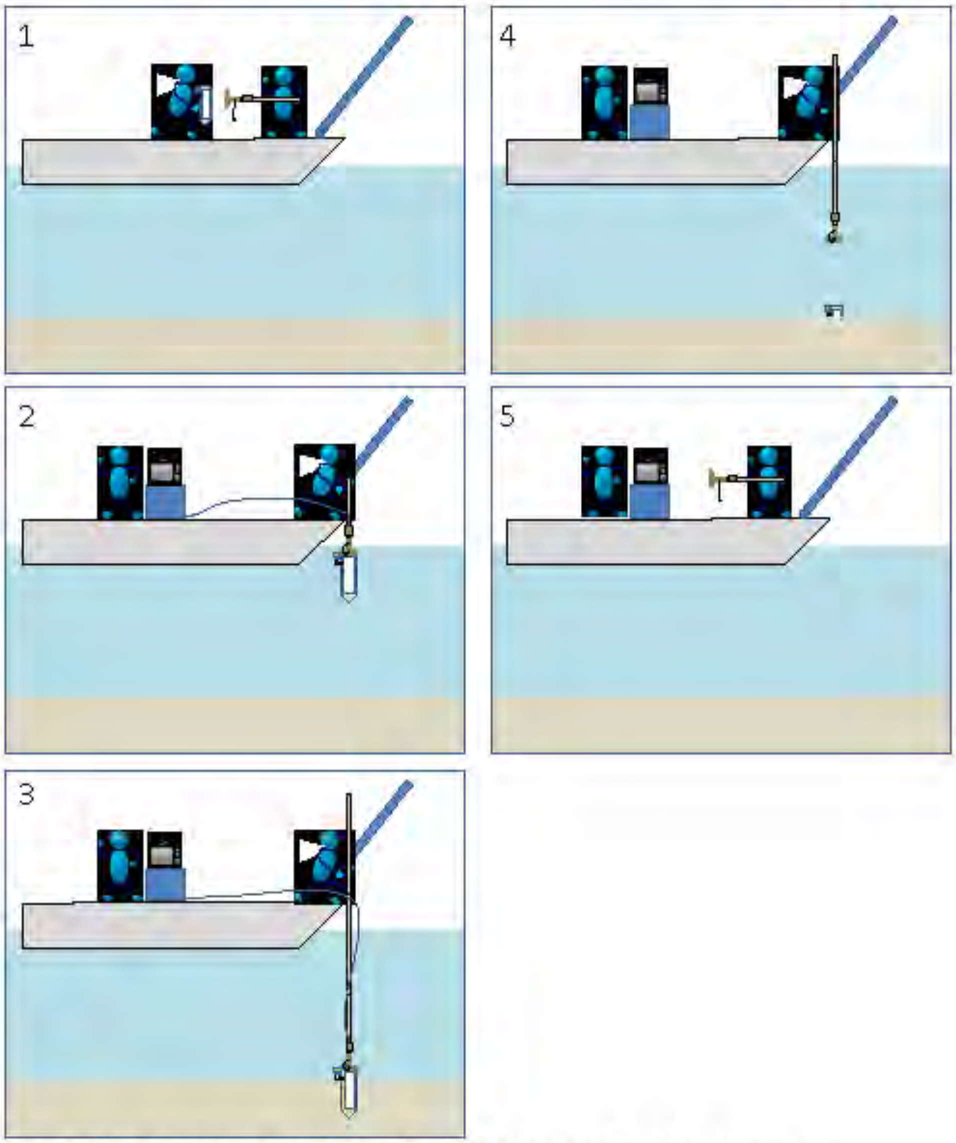


Figure 5. Deployment cartoon for the Passive Push psu-pole deployment system.

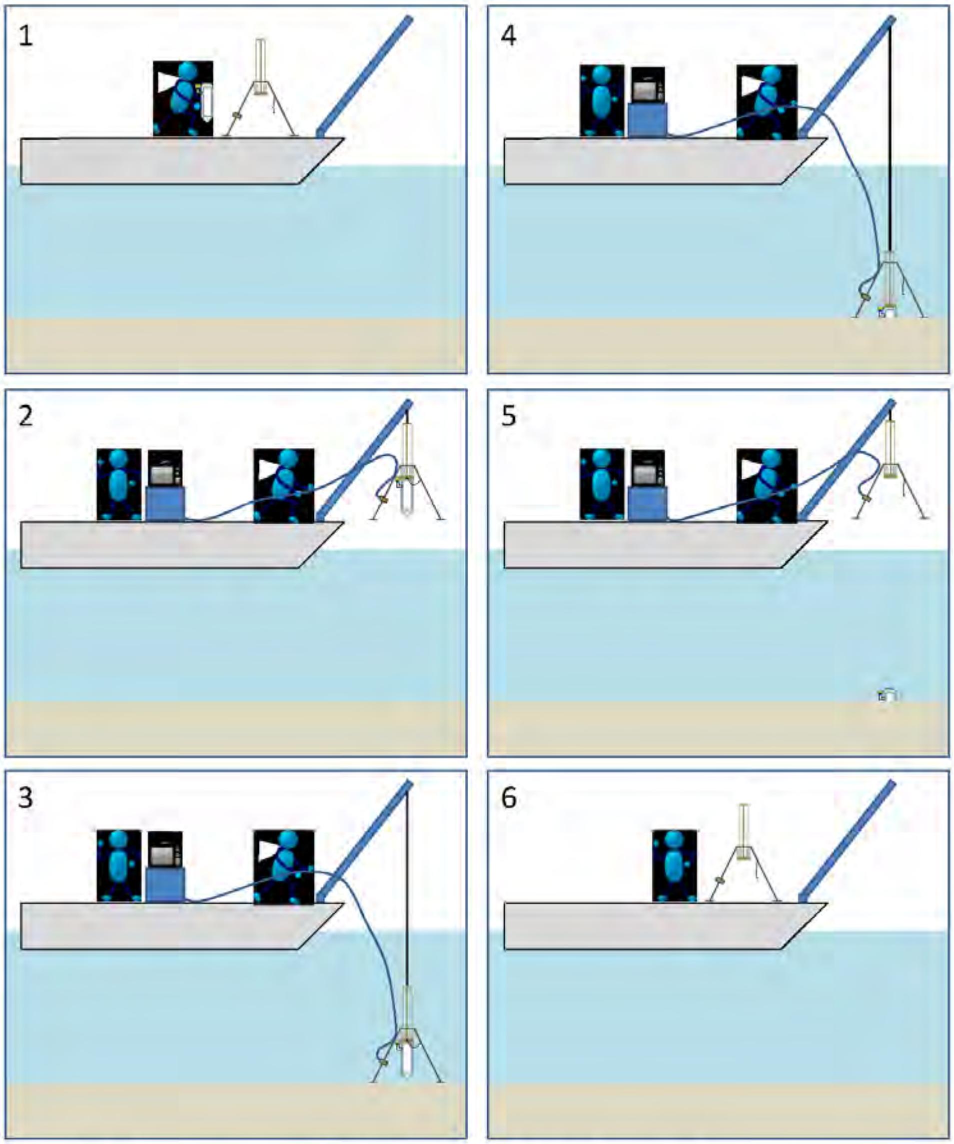


Figure 6. Deployment cartoon for the Passive Push drive-frame deployment system.

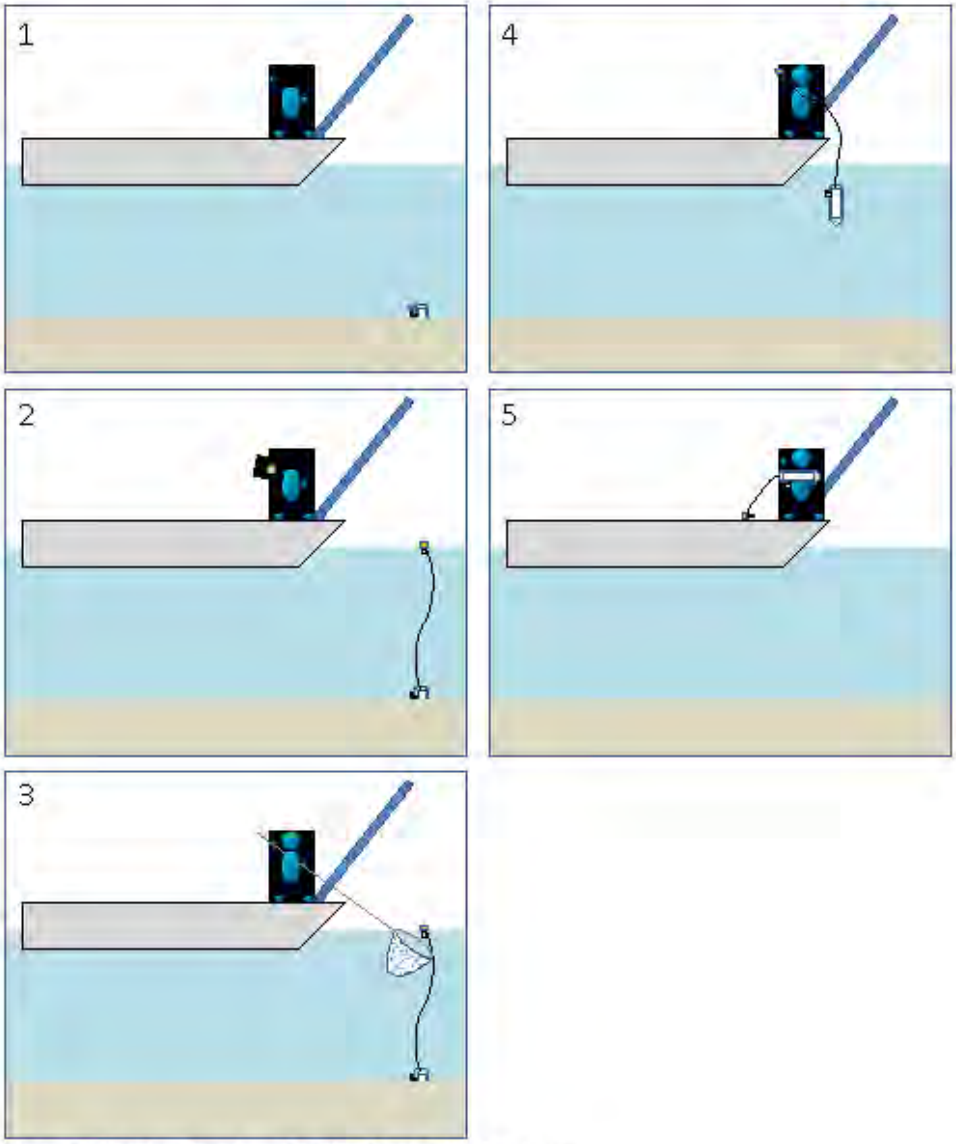


Figure 7. Retrieval cartoon for the Passive Push system.

APPENDIX B-3

TR45 Release Instructions

tr45c-ma8.doc, tr45c-ma8.pdf   Revised on 11-28-2012.

INSTRUCTIONS FOR UNDERWATER TIMER RELEASE SYSTEM.

TR-45 release, TRP-45C programmer.

Sub Sea Sonics (www.subseasonics.com)

5485 55th Street, #21A

San Diego, CA 92115-1240

Phone: 619-286-7546

Overall description of system:

This underwater timer release system consists of two units. The unit that is deployed underwater has model number TR-45 and performs the release action by rapid erosion of a release link after a preset time period. This preset time period is referred to herein as the time-until-release (TUR). It is set by the user into a programming unit (TRP-45C) that is then used to transfer this time into the underwater unit (TR-45). This transfer is made by direct touch dual contact between the programmer (TRP-45C) and the underwater release unit (TR-45). The timing starts at this moment of transfer.

Features:

Much lower cost vs. acoustic release system

Smaller size vs. an acoustic release

No mechanical release mechanism to foul or fail

Releases by “solid state” accelerated electrolysis

No mechanical moving parts to be fouled or hang-up

Longest time: 170 days (7.5 minute steps)

Shortest time: 0 minutes (useful for checkout)

Reprogramming: Okay to reprogram at any time

Release link rapid change by unscrewing retainer cap

Battery voltages measured under load and displayed

Programmer preparation and use (TRP-45C):

BATTERY INSTALLATION FOR PROGRAMMER.

Remove the four corner screws that hold the box top and bottom halves together. Install two 9 volt batteries into the two 9 volt battery holders. Inspect the 9 volt battery contacts and positions in the holders to insure reliable contact. As an aid in this inspection the battery can be removed and each contact watched closely during reinsertion for the spreading of the leafs of the larger contact. Re-assemble the two halves of the box using the four corner screws.

TURNING ON AND OFF THE PROGRAMMER:

Press the 'ON' switch to turn-on the programmer. It automatically shuts itself off if not used. It can also be shut off with the fifth menu item. In typical use battery life will be nearly the same as battery shelf life. When first turned on a banner will show on the LCD display [Sub Sea Sonics – subseasonics.com – Timer Release – Model TRP-45C – Firmware Ver x.x – Press 'STOP'.]. To get to the main menu press 'STOP'. A test of the programmer battery will occur displaying its voltage under a heavy load and indicate GOOD, OK, or BAD. This battery test with display can be terminated by pressing 'STOP' again. The start of the main menu should appear [MENU FOLLOWS: - Press 'NEXT'.].

FINDING AND SELSECTING A MENU ITEM:

Successive pressing of 'NEXT' advances through each of the menu items. When the desired one is found press 'ACCEPT' to accept and act on it.

MENU ITEMS AS DISPLAYED ON LCD [Menu items in brackets]:

1. [Set the time until release.] Permits entering the desired time-until-release (TUR). This is the time from the moment of programming a release unit (third menu item) until that release unit initiates the release erosion process. The physical release occurs typically 10 to 15 minutes after erosion starts. The display shows days, hours, and minutes. To set the TUR press 'INCREASE' or 'DECREASE' as needed until unit displays the desired TUR.

2. [Check the time until release.] Permits checking the desired time-until-release (TUR). Again, this is the time from the moment of programming a release unit (menu item #3 next) until that release unit initiates the release erosion process. This check can be omitted. It is included as a way to double check the time-until-release (TUR).

3. [Transfer time to release unit.] This transfers the time-until-release (TUR) stored in the programmer to the release unit before deployment underwater. Once this menu item is selected by pressing the 'ACCEPT' switch, there is up to 40 seconds in which to make dual contact between the programmer probes and the underwater release unit. Make this dual contact by holding the top metal probe in contact with the small exposed metal wire sections at the base of the erosion hoop. Simultaneously, hold the lower contact in contact with the coil of metal wire wrapped around the body of the release. The instant this dual contact is made, maintain it without interruption for at least three seconds for the transfer of the time (TUR), battery checking, and verification. Watch the LCD display. Within 3 seconds the display should change from the slowly flashing [Make 2 contacts to release unit.] to displaying [Successfully programmed unit.]. This is followed by the display of the time-until-release (TUR); the display of the release battery voltage (loaded with a 47 ohm resistor); the voltage sag measured over 0.3 seconds; and last an advisory as to the battery state: HIGH, GOOD, LOW, or BAD. The [Successfully programmed unit.] display repeats several times. It can be interrupted by pressing 'STOP'. If LOW or BAD is displayed then repeat the programming to see if it still shows LOW or BAD. It could have been that the hand-held contacts made were not steady giving a LOW or BAD reading. In either case when the message displayed is [Successfully programmed unit.] followed by the time-until-release (TUR), it is certain that the release unit was programmed to the correct time. If a message appears [Failed. Interrupted contact.]

then do not proceed to deploy as the time-until-release (TUR) was not transferred correctly. Repeat the programming insuring good dual contact for the maximum of three seconds needed for programming.

4. [Measure programmer battery.] Displays the programmer battery voltage measured with a heavy load (520 ohm). Do not confuse these programmer batteries with the batteries in the underwater release unit. The underwater release unit batteries are tested only during the programming of the release unit in menu item #3 above.

5. [Shut unit off. (Time is saved.)] The programmer can be shut off without waiting for the automatic time-out shut off. The time-until-release (TUR) is saved inside the micro-controller in flash memory to save operator time from having to re-enter it upon power up.

The next and last main menu item (#6) is not needed. It is included as an extra for those who might be interested. Pressing 'ACCEPT' to select it puts the programmer into a submenu mode. Once in this submenu mode there are abbreviated directions, a diagnostic 1800 x release clock speeded up test mode, a way to recall past programmed time-until-release times (the 'successful' ones only), and a submenu item used to clear all past release data.

6. [Optional submenu items (ACCEPT)] Pressing 'ACCEPT' here enters a submenu of items including the following: [Directions: …] a brief directions check list. [Diagnostic test: 1800x speedup] speeds the clock in the release unit up by a factor of 1800 for accelerated checkout. This is normally used only by the factory; but is included for those interested. If this test is used the message [DIAGNOSTIC TEST DO NOT DEPLOY!] is displayed in place of the message [Successfully programmed unit.] to prevent the user from accidentally deploying a release running 1800 times faster than expected. The submenu also includes a way to look at past data. [Look at past release data.] This saved past data includes only the data on 'successful' transfers to an underwater release unit. Last the submenu item [Clear memory of past releases.] permits the clearing of memory of all past data. Again, these submenu items mentioned in this paragraph and called [Optional submenu items (ACCEPT)] need not be used.

BATTERY INFORMATION FOR RELEASE UNIT:

The TR-45 release They have a shelf life of 15 years and work well in cold water.unit batteries are three Lithium L91 Energizer AA batteries (in series). These Lithium batteries are installed by Sub Sea Sonics in the TR-45 underwater Timer Release. See LK-xx data sheet for battery life.

The battery voltage and voltage sag are measured during menu item #3 above [Transfer time to release unit.]. The battery voltage measured is the voltage put out by the release (through a FET switch dropping 0.2 volts) and to a 47 ohm resistor in the programmer. The measurement is made in the programmer across the resistor during communication between the two units. The 'sag' is the decrease in voltage which occurs over a 0.30 second period due to the 47 ohm load. A large 'sag' would indicate batteries that can not maintain output under a load.

Release battery states displayed:

HIGH - - - - - - - - - - - above 4.60 volts and sag < 0.10 volts

GOOD - - between 4.00 and 4.59 volts and sag < 0.40 volts

LOW - - - between 3.70 and 3.99 volts and sag < 1.50 volts

BAD - - - - - - - - - - - - below 3.70 volts or sag > 1.49 volts

A fresh set of three AA lithium L91 batteries made by Energizer typically measures 4.83 volts with sag of 0.01 volts. A 50% discharged set of three AA lithium batteries should measure > 4.40 volts with sag < 0.03 volts. If the release batteries become LOW as displayed during a programming then repeat the programming to insure it was not just poor hand-held contact during programming. If they still measure LOW then consider replacing them. If they measure BAD then the risk of failure of release is even higher. (For replacement see the special procedure explained here-in).

Since alkaline AA batteries are inferior to lithium AA batteries it is not recommended that they be used. If used then divide all of the life times by a factor of 3 for warm water and 6 for cold water. Note that four alkaline AA batteries are needed not the three needed for lithium AAs.

UNDERSTANDING THE THREE MODES OF A RELEASE UNIT:

The release unit has three modes. At any one time it is in one of these three modes. When not in use it in its SLEEP mode and draws no battery current. When it is programmed by contact with a programmer it goes into its TIMING mode and draws up to 100 uA. Here it stays until the time-until-release (TUR) is up. It then changes into its RELEASE mode. Here it switches the full battery voltage to the release link to start the erosion process. The battery current varies in RELEASE mode starting high and tapering to near 100 uA when the link has been eroded away. The unit stays in this mode for exactly four hours and then reverts back to the SLEEP mode. It remains in sleep mode until it is programmed again. Leave it in SLEEP mode when not in use to save battery.

UNDERWATER RELEASE UNIT PREPARATION AND USE (TR-45):

To prepare a release unit (TR-45) first remove the old erosion link by unscrewing the retainer cap and removing the expired erosion link. (Save the expired links for use during TR-45 storage). Second, inspect the stainless steel contact on the top end of the release unit by pressing on it with a metal tool such as a screwdriver. Verify that it has not been damaged by electrolysis. This will not happen if the O-ring is in place and does not leak excessively. The O-ring can leak a little without damage; but, if it leaks a lot and especially if it was missing during last use then after the water leaks in electric current can flow through the leaking area and this may damage this contact by electrolytic erosion, the same erosion upon which this release system is based. Third, reassemble with a new erosion link and an O-ring (#205, 11/16" OD x 1/8" cross-section, durometer 70). The O-ring gets positioned between the top end of the release body and the erosion link. In its correct position the O-ring will surround the contact. As the retainer cap is hand tightened it can be felt to bottom out when tight. It is best if it is very tight to insure electric contact, keep the O-ring squeezed, and hold the erosion link in place for handling its load. AGAIN NOTE: THE O-RING MUST BE CORRECT AND IN

THE RIGHT PLACE. IF IT IS NOT, ELECTROLYTIC DAMAGE TO THE TR-45 POSITIVE CONTACT MAY OCCUR DURING RELEASE.

DEPLOYMENT NOTES:

Do not obstruct the outside part of the release link from making contact with the salt water. Salt water must be able to reach the two small unpainted sections of the stainless steel painted hoop on the release link. Tests have shown that oil on the two small exposed metal points of the link is no problem. Oil rinses off immediately upon immersion in water. Fourth, program the release unit. FAILURE TO PROGRAM THE RELEASE UNIT WILL RESULT IN FAILURE OF RELEASE. The time to release starts when the release unit is programmed. Fifth, deploy the release unit. There are many possibilities for deployment. It is best to keep the pull on axis. (E.g. Do not permit side-to-side heavy pulling since it could bend the erosion link back and forth until it breaks off.) Consider releasing a work line pulled by a powerful rubber band or bungee. Use the work line to release a coil of line and a float or some other desired action. This gives a definite release force that is consistent in strength and direction compared to the variable and sometimes weak tug of just a float (especially that of a small float or one that has been compressed by depth).

Extra notes:

1. METAL TOUCHING EROSION LINK METAL HOOP. WARNING: DO NOT LET METAL TOUCH THE EROSION HOOP. If something metallic rubs through the epoxy paint on the erosion link and makes electrical contact it will cause the voltage to get to it as well as the erosion link metal wire. If the extra metal in question is small it will simply be eroded away with extra drain on the batteries possibly shortening their life. If it is large it may prevent the release and completely drain the batteries in the release unit. The piece itself will also be damaged. If it is desired to use a hook to clip onto the erosion link hoop then be sure it is nonmetallic or adequately insulated to prevent electrical contact.

2. BATTERY REPLACEMENT IN THE RELEASE UNIT (TR-45). The TR-45 release unit uses three Energizer L91 lithium size AA batteries wired in series. It is not recommended that the user replace the batteries. They are connected in series utilizing either welded tabs or a special battery-specific soldering technique. However, if field replacement is decided upon access is obtained by cutting off the bottom end just above the bottom ¾" slip cap, being careful to not cut the wires inside. A new ¾ slip PVC cap and some PVC cement is required. After repeated replacements a new coupling and some 3/4 inch schedule 40 PVC pipe may also be required. The three lithium L91 size AA batteries make up a 4.5 volt pack. The red wire goes to the positive end, the black wire goes to the negative end. (Do not connect the battery pack in reverse as this will likely damage the release electronics.) At this point stop and perform the POWER-ON-RESET described in the next paragraph. Then return to here. A nine inch long piece of ¾ inch shrink tubing works well to slip over the battery train to help hold the batteries together. If not available consider forming a splint out of folded writing paper or stiffer manila folder and use tape to hold the batteries to the splint. This gives them some integrity when pushed in or pulled out. Insert the positive end first and keep the bulk of the wires outside until the batteries are inserted all the way. Tuck in a small piece of wet suit rubber (1" x 1.5"x ¼"). Tuck in the wires. Tuck in another small piece of wet suit rubber. Check the tube end to insure that the new PVC slip cap will fit. Last, glue on the slip cap.

3. SPECIAL POWER-ON-RESET REQUIREMENT WHEN CONNECTING NEW BATTERIES. Immediately upon connection of the new batteries and before slipping them into place in the PVC tube perform a POWER-ON-RESET. The easiest way to do this is to short out the batteries briefly. The batteries have enough internal resistance that if the battery pack is shorted out for one second then only 0.20% of the energy is drained from the batteries. Shorting them with a quick touch lasting much less than one second is fully adequate to achieve a correct POWER-ON-RESET. After this and before gluing on the new slip cap test the unit with a programmer. Verify that the unit does accept a time-until-release (TUR) as indicated by the LCD displayed message [Successfully programmed unit.].

4. USE OF AN 'AM' RADIO TO AID IN CHECKING THE OPERATION OF A UNIT. (Note that this is just an option which is not necessary and generally not used.)

An AM radio set on about 550 kHz can be used as an aid to checking out the operation of a release unit. Hold it touching the body of the release unit near the battery end (the end away from the erosion link). Hold it there while programming it. During the one second of programming, pulses will be heard on the AM radio. If programmed for zero time (immediate release which puts the unit in release mode) then pulse sounds will be heard precisely once per second. This can be used with a stop watch to check the time base of the release unit. When programmed for any nonzero time (places unit in the main timing mode) it is usually possible to hear a steady sound from the release unit if the AM radio is held very close and all other AM signals are made low enough by careful positioning of the AM radio to minimize interference pick up. When finished, program the unit to zero time (puts it in release mode) and protect the contacts from accidental contact to something in the environment for at least the four hours that the unit is in release mode. In any case the installation of an expired link or a dummy link is recommended for protection when not in use.

5. IMMEDIATE STORAGE OF TR-45 RELEASE UNIT. Keep an old erosion link with O-ring installed on the end to protect the erosion link contact (located inside the O-ring) from accidental erosion. This also protects the batteries from accidental drain.

6. GENERAL STORAGE OF ALL COMPONENTS. Store out of direct sunlight in a moderate temperature environment. Keep a dummy or an old erosion link installed on the TR-45 release unit during storage. The batteries inside the release unit are not being drained when the unit has timed out and the release mode four hours have elapsed.

7. INFORMATION ON THE METAL 'COIL' SALT WATER CONTACT. This coil is the negative contact and is made from a high quality nickel metal alloy. When erosion is occurring tiny bubbles will form on it and rise off of it at the same time the release link is eroding away. Minerals may deposit on this coil at the same time. These may either be left alone or be occasionally rinsed off (if fresh) or scraped off (if hard). Accidental contact between this coil and other dissimilar metals (e.g. copper, tin, lead) should be avoided as ordinary electrolysis over extended periods of time might damage it.

8. DURATION OF RELEASE MODE: Preceding the release mode the release unit is deployed and is running in timing mode. When the time is up the release unit changes to release mode and stays in release mode for exactly four hours. It then goes to sleep. In this sleep mode no battery drain is occurring. This saves battery and stops the erosion from continuing through the plastic base of the erosion link and into the contact cavity, preventing damage to the link contact.

9. OUTPUT CIRCUIT DRIVE: This information is not needed for the intended use of the release where it drives a release link. If using the release to drive a relay or some other scheme then note the following. The release unit is short circuit proof for a zero ohm short. However, a partial short from a 1 ohm to 10 ohm load might burn out the internal power FET switch. Again, there is no concern if the unit is used as intended.

10. EROSION TIME INFORMATION: This is the additional time required for release after the unit switches to release mode (i.e. after the programmed time-until-release (TUR) completes). For the TR-45 these are typically between 10 and 20 minutes. For estimates of the release link (LK-xx) times see the data sheets on the release links located on the website or the last pages with the manual.

11. RE-PROGRAMMABILITY: At any time an underwater timer release unit (TR-45) when dry can be programmed or re-programmed. If the unit is already running (in a timing mode or in a release mode) then re-programming simply cancels the current operation and starts fresh with the new programmed time-until-release (TUR). The normal programming verification and battery tests are also performed upon re-programming. The timing countdown always starts at the moment of programming or reprogramming.

SPECIFICATIONS FOR TRP-45C TIMER RELEASE PROGRAMMER:

Description: The TRP-45C is a programmer for the TR-45 underwater timer release units. First the time-until-release is manually entered into the programmer. Second, the time-until-release is transferred from the programmer to theTR-45 underwater release unit by direct contact of two electrical contacts between the two units.

Example programmable times: Shortest = 0 days, 0 hours, 0 minutes (useful in checkout). Longest – 170 days, 15 hours, 52.5 minutes. Increment size – 7.5 minute.

Re-programmability: Can re-program at any time.

Start of timing: Timing starts at the moment of programming (or re-programming).

Data transfer time: 1 second. (After select 'Transfer time…' and make dual contact between programmer and release.)

Reliability of programming: Virtually certain when user checks the message displayed just after programming a unit. As part of the programming the time-until-release is returned to the programmer for verification. Further, batteries are checked under load and their voltage displayed.

Display: LCD display having two lines each with 16 characters.

User Input: Three SPDT momentary switches.

Contacts: Stainless steel protrusions designed for making temporary connection to the link and coil contacts on the TR-45 unit being programmed.

Programmer Battery Life: Approximately 50 hours of active use time (5 mA average). Unit automatically shuts off if not in use providing one year or more of battery life for typical use. (Suggest the removal of batteries for long term storage to protect against possible battery "acid" leak).

Batteries: Two common 9.0 volt alkaline batteries (access by removing four screws to open box).

Size: 7.0 inch x 4.8 inch x 2.3 inch (17.8 cm x 12.2 cm x 53.8 cm) without contact protrusions. Add 1.0 inch (2.5 cm) to the long dimension for contact protrusions.

Weight: 1.4 pound (650 gram) with batteries.

Water resistance: Splash resistant but not water tight. Do not submerge.

SPECIFICATIONS FOR TR-45 UNDERWATER TIMER RELEASE:

Description: Unit performs a release action underwater after being programmed before deployment for the desired amount of time-until-release (TUR).

Environment: Must be used in salt water (ocean or bay water). System will not work in fresh water (e. g. will not work in a fresh water river or lake).

Coil contact: Serves the dual function being a contact first used for programming and second being used as the negative water contact necessary to complete the circuit so that the accelerated erosion can occur. This contact does not erode.

Link contact: Serves the dual function being a contact first used for programming and second being used as the two points of erosion. After deployment when the release action starts this water contact is connected to the positive side of the internal battery and the accelerated erosion of it occurs.

Link retaining cap: A modified ½ inch threaded PVC cap holds the LK-xx erosion link in place.

Batteries: Three L91 lithium AA size batteries made by Energizer are wired in series for 4.5+ volts. These are sealed inside by gluing on a ¾ inch slip cap after inserting new batteries. Access to replace the batteries is only by cutting the cap off. (See 'Instructions' above for battery replacement suggestions).

Battery Life (LK-xx): Less than 100 micro Amps is the drain on the three AA lithium batteries while in timing mode. This is the equivalent to using 30% of the battery energy over one year in timing mode. (Note: No drain exists when unit is not in use.) About 100 micro Amps plus whatever the link draws is the drain when in release mode. In release mode an LK-xx link can draw 100 mA during the first high current part of the erosion phase.

Battery life vs. Link Paint: The yellow paint on the hoop of the release link focuses the erosion to two small points on the metal wire hoop. By having the paint in place the battery drain is reduced. If it is found that the paint is not getting scraped off then the above number of releases expected per set of batteries could be increases up to double.

Battery life in storage: Same as shelf life of batteries. (i.e. there is no battery drain when unit is not in use). At this time Energizer is marking these L91 lithium AA batteries with a "best if used by" date 14 years into the future. The possibility of a single cell going bad increases with time. For critical applications the batteries should be replaced a least every 5 years.

Time-until-release (TUR): Transferred from a programmer (TRP-45C) to a release unit (TR-45) by the two units being hand held in contact with each other. This time-until-release can be set to anytime between zero and 170 days in 7.5 minute steps. A setting of zero time-until-release is useful for testing. When programmed for zero time the release unit skips the timing mode and starts immediately in the release mode.

Start of timing: Timing starts at the moment of programming (or re-programming). Units can be reprogrammed over-and-over as many times as desired.

Duration of release mode (battery voltage applied to link): Exactly 4.00 hours or until reprogrammed, which ever occurs first.

Operating Depth: Zero to 600 feet (183 meters).

Size: 1.35 inch max diameter x 15.0 inches long.

Weight in air: 0.65 pound (295 gram). Includes internal lithium batteries.

Weight in sea water: 0.10 pound (45 gram). Includes internal lithium batteries.

APPENDIX

NOTES ON PROGRAMMER SWITCHES:

ON: Turns unit 'on'. Automatically shuts off after about a minute to save on battery. (For operator shut off an additional menu item exists [Shut unit off. …)])

STOP: Used to 'stop' any flashing or scrolling display. Can be used at any time to proceed without waiting. Does not affect any settings. Does not shut unit off (see ON above for shut off information).

NEXT: Used to advance to the 'next' menu item. (Advances without activating the currently displayed menu item).

ACCEPT: Used to 'accept' the menu item which is currently being displayed. (This is like an OK key or ENTER key on common electronic devices). When pressed it starts the programmer acting on the menu item in the current display.

INCREASE: Used to 'increase' the displayed time-until-release (TUR). Holding it causes acceleration of the 'increase'.

DECREASE: Used to 'decrease' the displayed time-until-release (TUR). Holding it causes acceleration of the 'decrease'.

EXAMPLE OF PROGRAMMING A RELEASE:

Step 1. Press ON. (observe banner [Sub Sea Sonics …])

Step 2. Press STOP. (observe programmer battery test)

Step 3. Press STOP. (observe [MENU FOLLOWS: …])

Step 4. Press NEXT. (observe [Set the time-until-release])

Step 5. Press ACCEPT. (observe [DAYS HOURS MIN …])

Step 6. Press INCREASE and/or DECREASE to obtain the

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time-until-release (TUR) which is desired.

Step 7. Press ACCEPT. (observe the just set time-until-release now flashing) (Verify that it is correct.)

Step 8. Have unit to be programmed available. It should have a new link properly installed with O-ring and securely hand tightened.

Step 9. Press NEXT, NEXT, NEXT, ACCEPT. (observe [Make 2 contacts to release unit]). This will be flashing. Between each flash the programmer is trying to communicate with the release. This flashing will continue for 40 seconds giving plenty of time for the following dual contact to be initiated.

Step 10. Hold the programmer box in your left hand and the release unit in your right hand. Quickly make secure dual electrical contact between the two units for three seconds. Watch for the display of [Successfully programmed unit.]. This will be followed by the time-until-release display, the battery voltage, the sag voltage, and the battery state; HIGH, GOOD, LOW, or BAD. If the message [Failed. …] is obtained then do not proceed to deploy. Try again. Probably good dual contact was not maintained for the one second needed to transfer and verify the time-until-release (TUR).