United States Environmental Protection Agency

Sediment Issue

Measuring Contaminant Resuspension Resulting from Sediment Capping

Monitoring the Water Column During Capping Activities at Boston Harbor

Purpose

The National Risk Management Research Laboratory (NRMRL) of the U.S. Environmental Protection Agency (U.S. EPA) is developing effective, inexpensive remediation strategies for contaminated sediments. This program theme includes the evaluation of capping to contain/stabilize contaminated sediments. Studies were conducted by NRMRL to evaluate the resuspension of surface materials contaminated with polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). This information, along with U.S. EPA's sediment guidance document (1), is intended to: a) be used as a reference for site managers and U.S. EPA decision makers who are considering the environmental impacts of capping contaminated sediments, and b) provide a better understanding of the techniques and mechanisms that can be applied to minimize the resuspension of contaminated material during capping.

The results of two NRMRL studies undertaken to evaluate solids resuspension before, during, and after capping of contaminated sediments are summarized below. These two studies were both conducted at marine sites. One study was carried out at the Boston Harbor/Mystic River Site in cooperation with U.S. EPA Region 1 and the U.S. Army Corps of Engineers (USACE). The other study took place at the Wyckoff/Eagle Harbor Superfund Site off Bainbridge Island, WA, in cooperation with U.S. EPA Region 10 and USACE.

Introduction

During sediment capping activities, clean material is commonly released from a barge at the water surface and falls through the water column to the sediment surface, providing an uncontaminated surface sediment layer (2). Information on the potential release of *in-situ* contaminated sediment during and after capping operations is sparse; therefore, NRMRL conducted studies as reported in Lyons *et al.* (2) in order to develop a better understanding of the amount of contaminants released into the surrounding water column before, during, and after capping. These studies evaluated whether the placement of conventional sand caps results in the disturbance of contaminated surface sediments and thus the release of contaminants into the surrounding water column through resuspension.

Two sites were examined where different capping methods (see Table 1 below) were employed for dissimilar sediment types (2). Data associated with the sites indicated that:

- The resuspension of contaminated sediments was measurable, remaining in the ng/L range (for contaminants in the water column), when capping was conducted over uncapped sediments.

- The magnitude of contaminant resuspension decreased with successive capping layers, suggesting the greatest potential for resuspension occurred when capping native uncapped contaminated material.

- After capping operations ceased, turbidity plumes dissipated rapidly (generally within hours) due to deposition and off-site transport.

Site Descriptions

Table 1 summarizes characteristics of the study sites, including capping techniques, source of capping materials, and contaminants-of-concern (COCs) at the study sites. For the Boston Harbor Site, confined aquatic disposal (CAD) cell M8, measuring 213 m by 61 m, was excavated to a depth of 27 m and had an estimated capacity of 118,500 m^3 of dredged material. CAD cell M19, the larger of the two cells measuring 244 m by 91 m, was excavated to a depth of 24 m and had an estimated capacity of 136,900 m^3. The Eagle Harbor study site covered an area of approximately 150 m by 275 m.

Methods

An aquatic monitoring tool was towed behind a boat to collect and integrate *in-situ* measurements with continuous water collection to monitor the effects of sediment suspension during capping operations. Aquatic monitoring of the capping events was conducted using the Battelle Ocean Sampling System (BOSS) deployed from a survey vessel. The BOSS is an integrated profiling system comprised of an underwater sensor unit, an electromechanical profiling cable for delivery of real-time data and continuous water samples to the shipboard laboratory, and a customized profiling winch and handling system, as shown in Figure 1. The BOSS *in-situ* sensor package (housed inside a towfish) includes a conductivity, temperature, and depth (CTD) sensor; a turbidity sensor; an Acoustic Doppler Current Profiler for vertical profiles of horizontal currents; and a Teflon™/titanium pumping system for sample collection that delivered water samples to the onboard laboratory at 12 L/min through a Teflon™ line. The survey vessel towed the BOSS at a depth of approximately 1 to 2 m above the sediment surface to optimize detection of resuspended sediments.

Table 1. Description of Study Sites.

Study Site	Location	Sediment Type	Capping Technique	Capping Material	COCs	Contaminant Concentrations in Sediment Prior to Capping
Boston Harbor/ Mystic River Site	Boston, MA	CAD cells (M8 and M19) filled with dredged sediments, typically 85-100% silt/clay with *in-situ* solids ranging from 30-55% (3)	Pushing an open hopper dredge with a tugboat over the area to be capped	Sand dredged from the Cape Cod Canal having modal grain size of 0.25 mm diameter with an average of less than 1% fines (3)	PCBs PAHs	Average total PCBs and total PAHs were 220 µg/kg and 64,478 µg/kg, respectively (4)
Wyckoff/Eagle Harbor Superfund Site	Bainbridge Island, WA	Bedded (specifics about sediment unknown)	High-pressure washing of sediments off the surface of a barge over the area to be capped	Clean quarry sand with the following properties: 81.1% passed through a #10 mesh but retained on a #40 mesh (0.43- to 2.0-mm-diameter medium sand); 9.5% passed through a #40 mesh but was retained on a #200 mesh (0.075- to 0.43-mm-diameter fine sand); and 0.6% passed through a #200 mesh (less than 0.075-mm-diameter silt or clay) (2)	PAHs	Total PAH concentrations reported as 1,273 ± 2,116 mg/kg in the upper 10 cm of three sediment cores collected within 91 m of the site; farther from the site, total PAH concentrations decreased to 18.3 ± 6.6 mg/kg in the upper 10 cm of three sediment cores collected 305 m from the site (5)

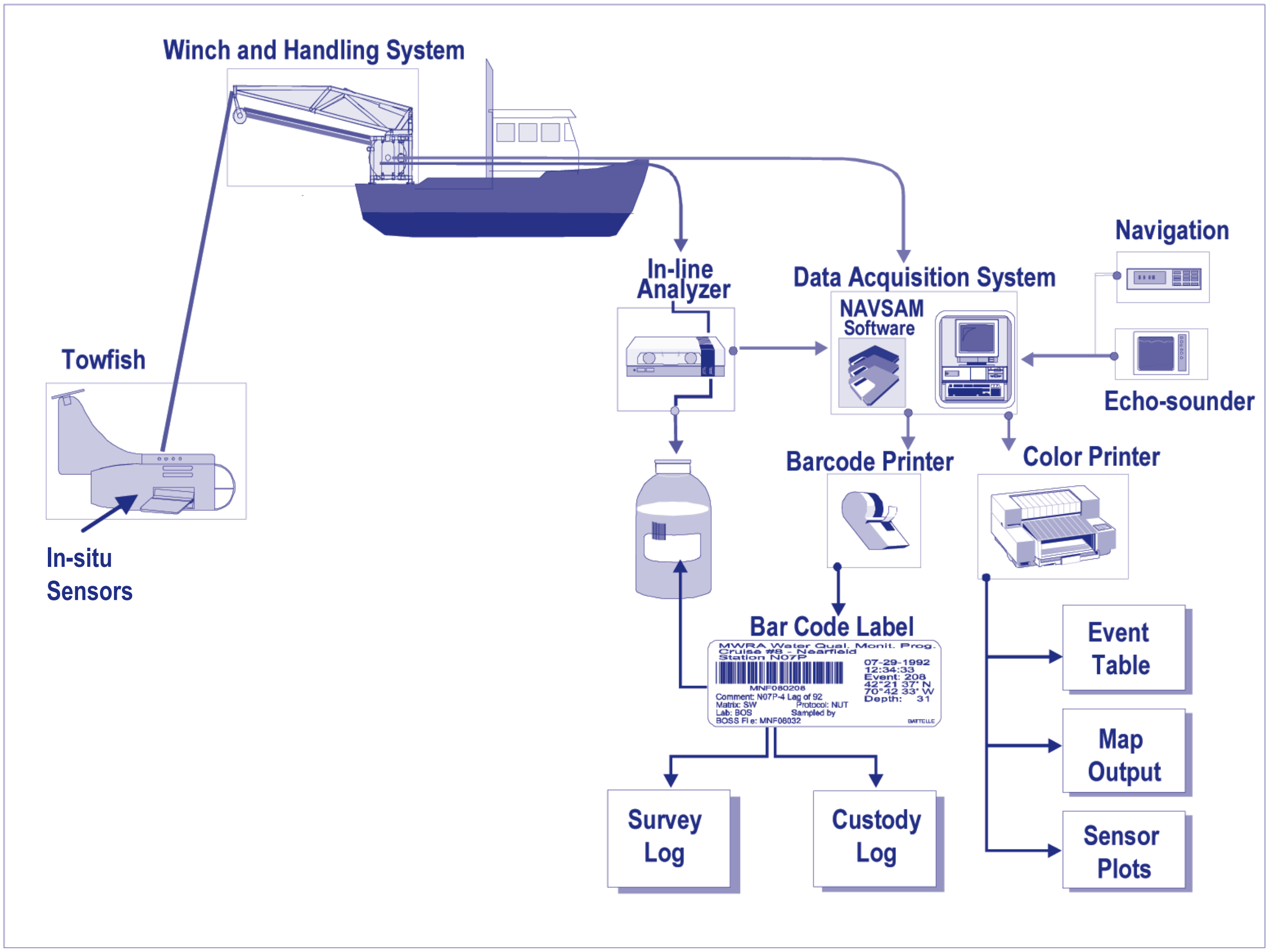

Figure 1. BOSS and On-Board Components.

A differential Global Positioning System (developed by Northstar) was interfaced with the BOSS computer to provide vessel positioning information during sampling operations.

In order to evaluate the amount of contaminants released into the surrounding water column before, during, and after capping, water samples collected by the BOSS were analyzed for total PCBs (i.e., sum of 18 PCB congeners [t-PCBs]), total PAHs (i.e., sum of 16 priority PAH analytes [t-PAHs]), and total suspended solids (TSS). If suspended sediment was visibly present in the water sample, a quartz glass fiber filter (1.0 µm) was used to remove larger sediment particles because they were considered to represent cap material, and because sediments greater than 1.0 µm in diameter would settle relatively quickly in the immediat e vicinity of the capping area. Smaller particles that passed through the filters were more likely to undergo long-range transport from the site.

Samples were collected before, during, and after capping activities and were generally defined as:

- Pre-Capping Survey: samples taken several days or 1 week before capping was initiated
- Pre-Capping Event: samples taken approximately 1 hour before each capping event
- Capping Event: samples taken during capping (i.e., each time a lift of capping material was applied)
- Post-Capping Event: samples taken approximately 1 hour after each capping event
- Post-Capping Survey: samples taken days to months after capping was completed

The sampling events and sample schedule for each of the studies are summarized in Table 2.

Figures 2 and 3 show the target BOSS transects and target sampling locations used for background surveys and active monitoring events (i.e., during capping) at Boston Harbor and Eagle Harbor, respectively. The top transect represents the daily Pre-Capping and Post-Capping background monitoring events. The bottom transect represents a typical monitoring event during capping. Actual transects differed significantly based on the barge location, capping operations, and turbidity plume migration.

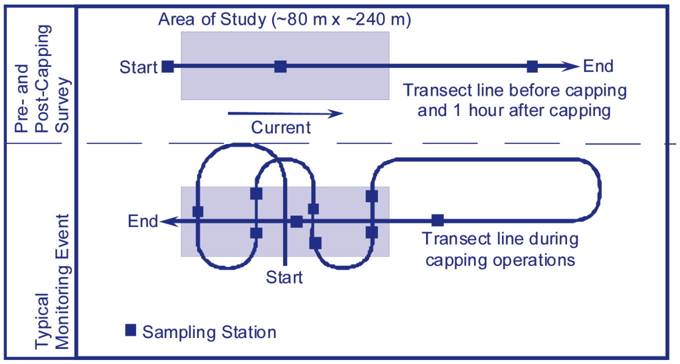

Figure 2. Transect Line and Sampling Station Locations for BOSS Surveys and Monitoring at Boston Harbor.

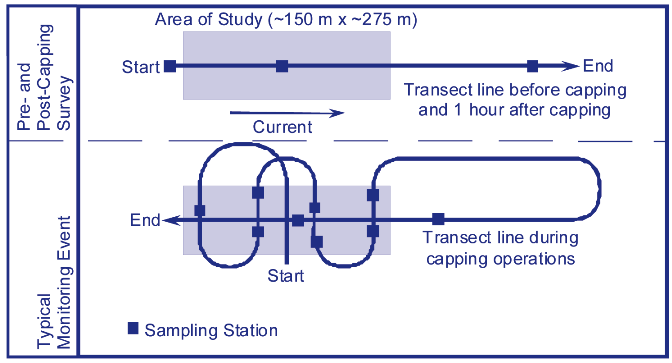

Figure 3. Transect Line and Sampling Station Locations for BOSS Surveys and Monitoring at Eagle Harbor.

Table 2. Survey Event and Sample Schedule. *Reprinted with permission from (2). Copyright 2006, American Society of Civil Engineers.*

Type of Event	Number of Events			Total Samples
		Boston Harbor Sample Schedule		
		CAD Cell M19	**CAD Cell M8**	
Pre-Capping Survey	1	5	5	10
Pre-Capping Events 1 – 4	4	3	--	12
Capping Events 1 – 4	4	9	--	36
Post-Capping Events 1 – 4	4	3[a]	--	10
Pre-Capping Events 5 – 8	4	--	3	12
Capping Events 5 – 8	4	--	9	36
Post-Capping Events 5 – 8	4	--	3	12
Post-Capping Survey	1	5	5	10
Total				**138**
		Eagle Harbor Sample Schedule		
		Capped Area		
Pre-Capping Survey[b]	1	3		3
Day 1, Capping Events 1-3	3	6 to 9[c]		24
Day 2, Capping Events 1-3	3	6 to 9[c]		24
Day 3, Capping Events 1-3	3	6 to 9[c]		24
Days 1-3, Post-Capping Events	3	3		9
Post-Capping Survey	1	15		15
Total				**108**

a - Sampler struck bottom immediately following sample collection for the first Post-Capping Event 3 sample, and system components fouled with mud. As a result, the second and third samples for Post-Capping Event 3 could not be collected.
b - Pre-capping samples were collected by divers during a separate site investigation, and the AMT was not used for the pre-capping survey.
c - Nine samples were collected daily during Transects 1 and 2, and six samples were collected daily during Transect 3.

Results and Discussion

Boston Harbor

Two-dimensional turbidity maps using levels detected by the BOSS were generated to depict turbidity levels in the area where capping took place, as shown in Figure 4. Turbidity data generated by the BOSS *in-situ* sensors were calibrated using TSS concentrations measured in the water samples. Cells M8 and M19 produced similar turbidity and TSS data; however, only results for CAD Cell M19 are depicted in Figure 4. The highest turbidity and corresponding TSS concentrations were noted during the first capping event, followed by progressively decreasing turbidity and TSS during subsequent events. This observation clearly indicates that the amount of bed sediment resuspended decreased with each successive capping event.

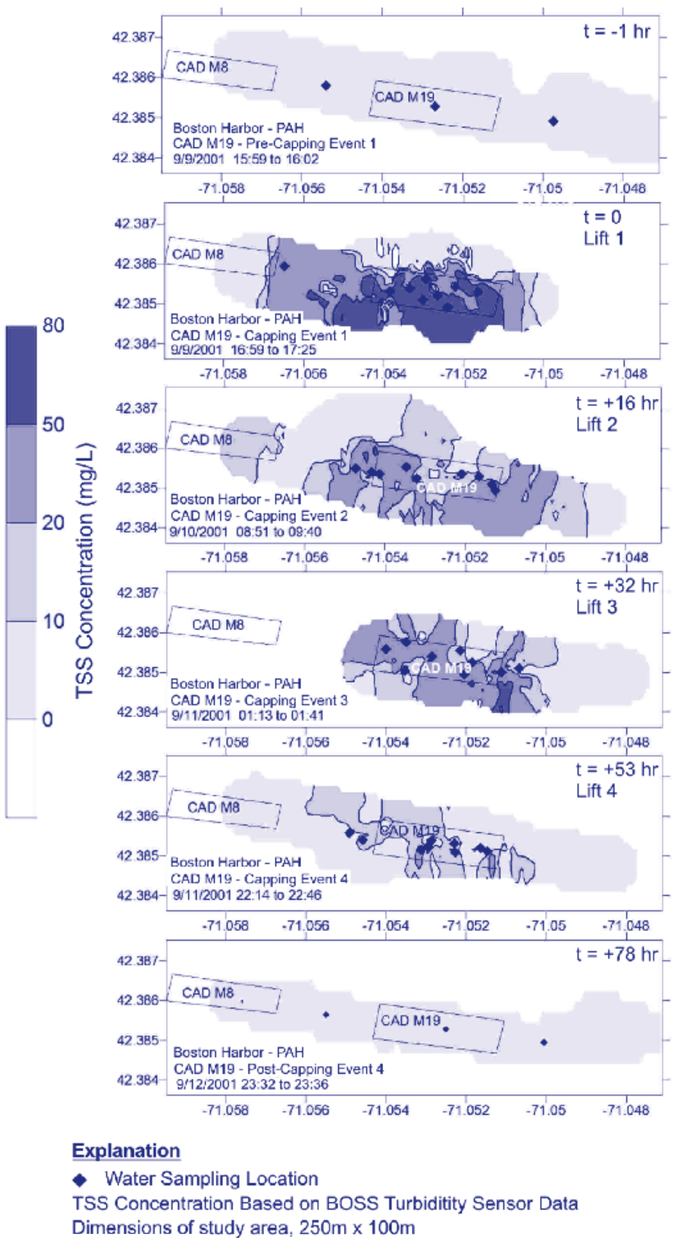

Figure 4. Boston Harbor Turbidity and TSS Maps for Cell M19. TSS values were based on turbidity readings and correlations derived from measured turbidity and TSS samples. *Reprinted with permission from (2). Copyright 2006, American Society of Civil Engineers.*

In order to quantify changes in contaminant concentrations in the water column caused by capping activities, analytical results of water samples collected before, during, and after capping activities were compared. As indicated previously, results obtained for both CAD Cells M8 and M19 were similar; therefore, only results from Cell M19 are presented here. Figures 5 and 6 indicate that the t-PAH and t-PCB concentrations collected during Capping Event 1 were much greater than for any of the successive capping events, suggesting that the greatest release of contaminants

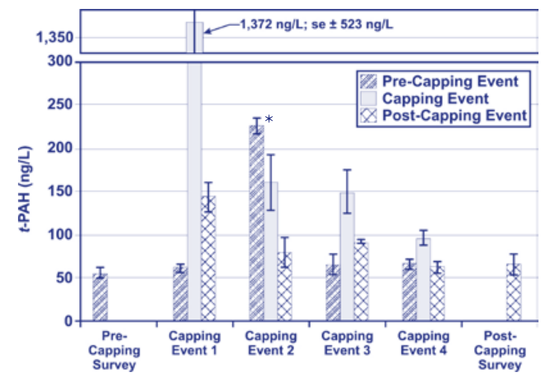

Figure 5. Average t-PAH Concentrations at Boston Harbor Cell M19. Error bars represent the standard error. *Elevated concentration for Pre-Capping Event 2 is attributed to the engine turbulence of a large container ship that docked near Cell M19 during sampling. *Reprinted with permission from (2). Copyright 2006, American Society of Civil Engineers.*

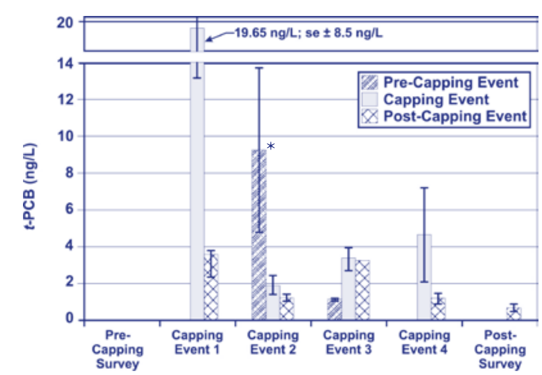

Figure 6. Average t-PCB Concentrations at Boston Harbor Cell M19. Error bars represent the standard error. *Elevated concentration for Pre-Capping Event 2 is attributed to the engine turbulence of a large container ship that docked near Cell M19 during sampling. *Reprinted with permission from (2). Copyright 2006, American Society of Civil Engineers.*

occurred when cap material was placed on previously uncapped sediment. Statistical comparisons among the four capping events were conducted by omitting the data from the Pre-Capping and Post-Capping Events and using Tukey multiple comparisons at a fixed significance level of 0.10. For t-PAHs, Capping Event 1 concentrations were significantly greater than those for Capping Events 2, 3, and 4, and there were no significant differences between Capping Events 2, 3, and 4. For t-PCBs, Capping Event 1 concentrations were significantly greater than those for Capping Events 2 and 3. Capping Event 4 concentrations could not be distinguished from those for Capping Events 1, 2, and 3, and resided somewhere between these three capping events.

Turbidity concentration plots for Capping Events 1 through 4, the Pre-Capping Survey, and the Post-Capping Survey for Cell M19 and water sample locations are plotted in Figure 4. The relationship between contaminant concentrations and turbidity was analyzed by plotting t-PAH and t-PCB against TSS concentrations for water samples collected during capping operations. The correlation coefficients (r^2 values) for the best-fit linear regression lines were calculated (2). Despite the visual observation that higher TSS/turbidity concentrations during Capping Event 1 coincided with higher t-PAH and t-PCB concentrations, as shown in Figures 5 and 6, a strong correlation between high TSS concentrations and high organic contaminant concentrations could not be determined statistically. It is likely that the contribution of bed sediments to TSS and turbidity was overshadowed by the TSS from the cap material.

Eagle Harbor

TSS concentrations measured in the water samples and turbidity data generated by the BOSS *in-situ* sensors were used to develop two-dimensional turbidity maps, shown in Figure 7, to display turbidity levels in the area where capping took place. Elevated turbidity levels were observed at varying distances and along different directions from the barge, extending beyond the boundaries of the study area based on analysis of samples collected outside the study area. The Post-Capping Event map in Figure 7 shows that turbidity levels quickly decreased to near Pre-Capping Event transect levels within 1 to 2 hours after capping. As with Boston Harbor, the contribution of TSS from the cap material itself may have partially overshadowed the contribution of bed sediments to elevated turbidity and TSS levels. Nonetheless, in the vicinity of the capping operations, turbidity and TSS levels were highest during Capping Events 1 and 2, indicating decreased turbidity with successive capping events. These data suggest that the measured turbidity includes a significant contribution from *in-situ* sediment and not only capping material during the initial capping events.

Average t-PAH concentrations measured for the successive sampling events conducted over the 3-day Eagle Harbor monitoring period are shown in Figure 8. Elevated contaminant concentrations were observed during capping operations, which appeared to decrease with each successive capping day and dissipated after capping was completed. Such rapid dissipation likely was the result of the combined effects of sedimentation and off-site plume

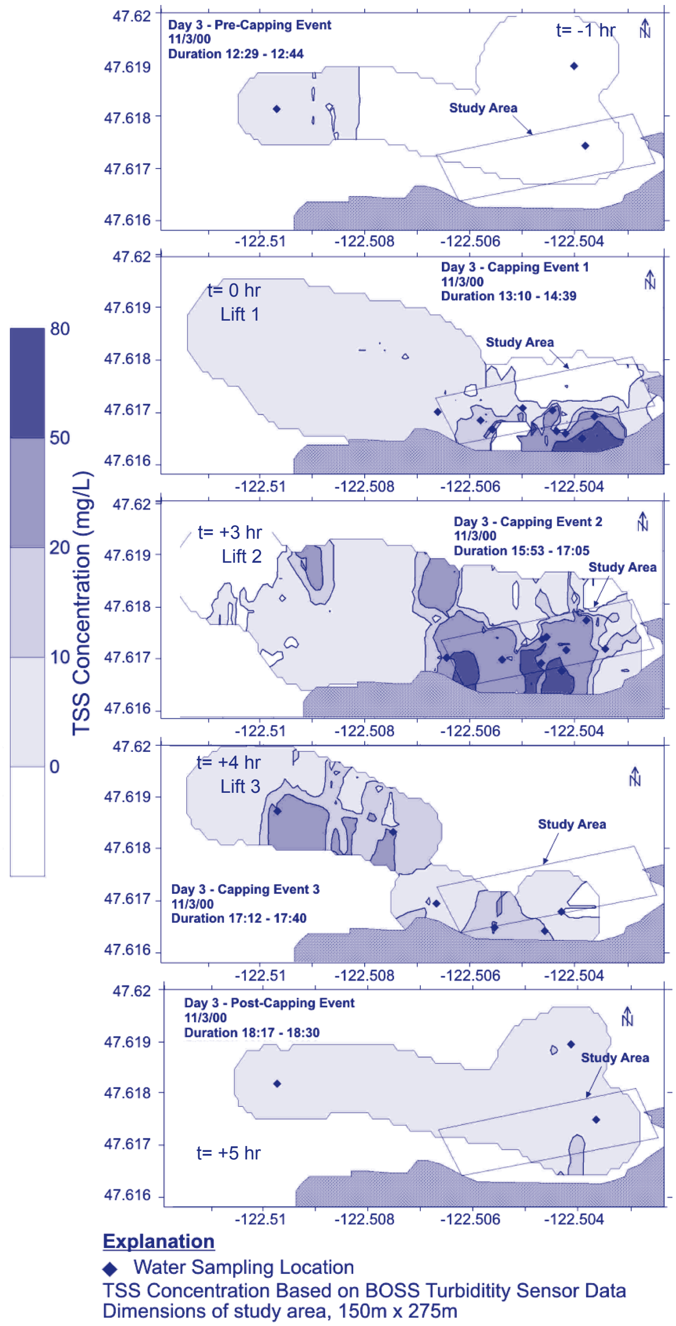

Figure 7. Turbidity and TSS Maps for Eagle Harbor Day 3. TSS values were based on turbidity readings and correlations derived from measured turbidity and TSS samples. *Reprinted with permission from (2). Copyright 2006, American Society of Civil Engineers.*

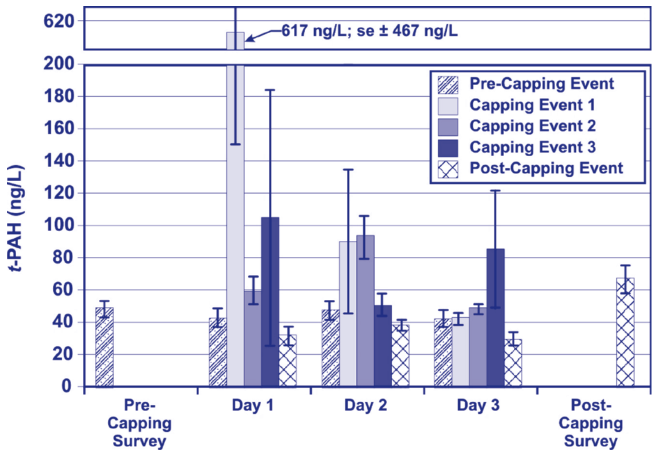

Figure 8. Average t-PAH Concentrations at Eagle Harbor. Error bars represent standard deviations. *Reprinted with permission from (2). Copyright 2006, American Society of Civil Engineers.*

migration. A two-way analysis of variance was conducted to determine whether there were statistically significant differences between different days or sampling events within a single day using the raw data, log-transformed data, and a significance level of 0.10. Because of high data variability, no statistically significant differences were found between the four sampling events (i.e., samples collected during Capping Events 1, 2, and 3, and the post-capping sample) within any single day for Days 1, 2, and 3, and no differences existed between Days 1, 2, and 3.

Scatter graphs plotting t-PAHs against TSS were generated to determine the relationship between contaminant concentration and turbidity. During the first survey day, r^2 values ranged from 0.72 through 0.95, indicating a correlation between turbidity and t-PAHs. However, r^2 values decreased during subsequent capping surveys and, by the third day, r^2 values were less than 0.54, indicating that a correlation between turbidity and t-PAHs was lacking. As with Boston Harbor, it is suspected that the suspended solids generated by the cap material overshadowed the solids resulting from suspension of contaminated bed sediments during subsequent capping events (i.e., after Capping Events 1 and 2).

Table 3. Concentrations of Suspended Contaminated Sediments Before, During, and After Capping.

	Boston Harbor		Eagle Harbor
Monitoring Event	PCB (ng/L)	PAH (ng/L)	PAH (ng/L)
Before Capping	BDL	46 – 59	46 – 73
During Capping	BDL – 84	65 – 5,242	20 – 3,872
After Capping	0.4 – 1.5	41 - 83	38 - 159

BDL - below detection limits

Conclusions

A comparison of sampling results at Boston Harbor and Eagle Harbor is provided in Table 3. COC levels were below detection limits or at very low levels at both sites before capping. The highest resuspension of contaminated material was seen during the first capping event at both sites. In general, contaminant resuspension, although substantially higher than observed during pre-capping sampling, was relatively low for all capping events during both surveys, where contaminant concentrations remained in the low ng/L range for most samples. Resuspension of TSS and COCs occurred continuously throughout capping operations but dissipated to background levels in a matter of hours following cessation of capping activities.

Data generated during these two studies have helped to achieve a better understanding of the amounts and patterns of contaminants released into the surrounding water column resulting from the capping events. Data from Boston Harbor and Eagle Harbor indicate that the resuspension of contaminated sediments was measurable, but relatively low, when capping was conducted over uncapped sediments.

Based on the results of the two studies summarized here, resuspension during capping may be reduced by placing cap material in lifts in which the first lift provides a uniform layer of clean material using techniques that minimize potential disturbance. The data presented here suggest that subsequent lifts could be placed more aggressively once the contaminated sediment is covered.

References

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