

Active Capping Demonstration in the Anacostia River, Washington, D.C.

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An active capping demonstration project in Washington, D.C., is testing the ability to place sequestering agents on contaminated sediments using conventional equipment and evaluating their subsequent effectiveness relative to conventional passive sand sediment caps. Selected active capping materials include: (1) AquaBlok™, a clay material for permeability control; (2) apatite, a phosphate mineral for metals control; (3) coke, an organic sequestration agent; and (4) sand material for a control cap. All of the materials, except coke, were placed in 8,000-ft² test plots by a conventional clamshell method during March and April 2004. Coke was placed as a 1.25-cm layer in a laminated mat due to concerns related to settling of the material. Postcap sampling and analysis were conducted during the first, sixth, and eighteenth months after placement. Although postcap sampling is expected to continue for at least an additional 24 months, this article summarizes the results of the demonstration project and postcap sampling efforts up to 18 months. Conventional clamshell placement was found to be effective for placing relatively thin (six-inch) layers of active material. The viability of placing high-value or difficult-to-place material in a controlled manner was successfully demonstrated with the laminated mat. Postcap monitoring indicates that all cap materials effectively isolated contaminants, but it is not yet possible to differentiate between conventional sand and active cap layer performance. Monitoring of the permeability control layer indicated effective reductions in groundwater seepage rates through the cap, but also showed the potential for gas accumulation and irregular release. All of the cap materials show deposition of new contaminated sediment onto the surface of the caps, illustrating the importance of source control in maintaining sediment quality. © 2006 Wiley Periodicals, Inc.

INTRODUCTION

In situ containment of contaminated sediments is often achieved through capping, typically with a passive sand layer to physically separate contaminants from benthic receptors and to reduce the flux of contaminants to the overlying water. Sand provides excellent protection when contaminants are strongly sorbed to the solid phase and in the absence of rapid contaminant migration processes. Under some situations, however, such as high rates of groundwater seepage, achievement of the desired reductions in flux may require the use of a layer that can sequester or degrade contaminants. These types of caps are often termed active caps to differentiate from passive sand layers. A variety of active cap materials have been proposed that can provide advantages over sand for specific contaminants. Active cap materials that have been proposed include phosphate minerals for metals control, organoclays and sorbents such as activated carbon or coke for organic contaminant control, and clays for permeability control. The selection of an

appropriate active capping material for a site depends upon the contaminant of concern, the physical and chemical conditions and processes operative at a site, and feasible approaches that might provide additional control over exposure or risk. Laboratory testing has shown the potential for many materials to effectively control contaminants that might migrate through a conventional cap, primarily by retarding contaminant migration by sorption. In some cases, degradation can also be enhanced, but the opportunities for incorporating degradative layers into cap materials are not as well developed.

Active cap layers that sorb or sequester contaminants more effectively than conventional sand caps increase the capacity of a cap to control finite contaminant sources and the period of effectiveness for continuous sources. This results in more effective containment for a given cap thickness or allows a certain degree of containment to be achieved with a thinner cap, thereby reducing the impact of a cap on water depth or strength and consolidation concerns in the underlying sediment.

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Although effective, the introduction of active capping materials into the environment has been limited as a result of the lack of precedent and potentially increased cost. In order to encourage the consideration of active capping materials as potential cap components, a field demonstration of selected active capping technologies was conducted for the Anacostia River in Washington, D.C. The Anacostia River is a freshwater tidal system that drains an urban watershed encompassing 176 square miles in Maryland and the D.C. area. The river suffers from overall poor water quality caused by numerous pollutants, including suspended solids, excess nutrients, toxics, trash, and debris. This pollution results in chronically low dissolved-oxygen levels and high bacterial levels. The low dissolved oxygen threatens aquatic life, while the bacterial levels make recreational water activities, such as swimming, unsafe. The sediments contain a large inventory of contaminants of concern including metals, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs). Additional contaminants are introduced, particularly after rainfall events, from combined sewer overflows (CSOs). The combination of continuing sources and past sources is reflected by the poor sediment quality.

A range of potential sediment remediation approaches is being considered for the river, including capping. Conventional sand capping may be effective for many of the areas of concern in the river, but it was felt that alternative approaches to increase the effectiveness of capping (i.e., active capping) might also be applicable. This article presents the results from a demonstration project designed to better assess the applicability of active capping to provide enhanced control of exposure and risk to the sediment contaminants. The site for the demonstration project is an area with elevated contaminant concentrations as indicated by the site investigation data (Horne Engineering Services, 2003; Syracuse Research Corporation/National Oceanic and Atmospheric Administration, 2000). In addition, the site is downstream of an active CSO site. The contaminants of concern (i.e., PCBs, PAHs, and metals), near to and downstream of the CSO, are well documented. The area selected for the demonstration is also identified for potential remedial action by the Anacostia Watershed Toxics Alliance (AWTA; 2002).

The demonstration project was implemented by a team led by Danny Reible, then at Louisiana State University but currently at the University of Texas, in cooperation with the prime on-site contractor, Horne Engineering Services, with the active support and contributions from AWTA and its members, including the D.C. Department of Health. The U.S. Environmental Protection Agency Superfund Innovative Technology Evaluation (SITE) program also provided extensive field support as part of a supplemen-

tal and complementary analysis of the AquaBlok™ cap. The lead project team was from the US EPA–supported Hazardous Substance Research Center/South and Southwest, a multiuniversity research consortium of Louisiana State University, Rice University, Georgia Tech University, Texas A&M University, and the University of Texas. A variety of other groups also contributed to the overall project, and their contributions are acknowledged at the end of this article and at <http://www.hsrb-ssw.org/ana-index.html>.

As a result of the site characterization efforts, active capping materials appropriate for the site contaminants and conditions were selected for the demonstration. The materials included AquaBlok™, coke, and apatite. AquaBlok™ is a bentonite clay material formed around a granular core and manufactured by Hull and Associates in Toledo, Ohio. The granular core encourages settling of the clay through the water column. After settling to the bottom, the clay absorbs water and swells, thereby reducing the permeability of the surface layer. In this manner, the AquaBlok™ is expected to reduce tidal pumping of porewaters in the contaminated sediment and divert groundwater upwelling away from the contaminated sediments to other, presumably less contaminated, portions of the site. The US EPA SITE program participated in a separate characterization and evaluation of the use of AquaBlok™ as a result of their interest in this capping material.

Coke was included in the demonstration as an organic sequestration agent. Coke is a petroleum pyrolysis product that is widely available at low cost. The coke employed in this project was provided by U.S. Steel/Clairton Works of Clairton, Pennsylvania. The material exhibits particle sizes of 0.425 to 2 mm (10–40 mesh). Sorption measurements showed that the coke is similar in sorptive capacity to moderate organic carbon sediments while other sequestration agents (e.g., activated carbon) may exhibit 10–100 times greater adsorption capacity (Murphy et al., 2006). Coke contains residual PAH levels, but predemonstration leaching tests showed low levels of mobile PAHs due to the organic sequestration properties of the coke. Because cost was of paramount concern, the original plan was to place the coke in bulk and ignore more sorptive (but more expensive) cap materials, such as activated carbon. Initial investigations, however, showed that the coke contained a significant fraction (10–20 percent) of nonsettleable material, raising concerns about its bulk placement. An alternative placement approach was discussed with CETCO (Arlington, Illinois) and ultimately selected. This alternative involved placing coke within a mat (also referred to as a reactive core mat [RCM]) in a high void fraction polyester core with two filtering polyester laminate layers on each side. The mats were constructed in a roll approximately 10 feet wide and approximately 100 feet long. Although used in this study for coke placement, the inclusion of this technology in the demonstration also served to illustrate its use for the controlled, thin-layer placement of any high-cost or nonsettleable granular material.

The final capping material demonstrated was apatite, manufactured by PCS Phosphate Company, Inc., in Aurora, North Carolina. Apatite is a phosphate material with the ability to preferentially adsorb certain metals. The material has the consistency of coarse sand and was delivered and placed in bulk. To provide a comparison of the effectiveness of the active capping materials, a fourth 8,000-ft² capping plot was used to place sand. A fifth area slightly outside of the four capping areas was used as an uncapped control area. All cap materials were placed between March 8, 2004, and April 23, 2004. Sampling for the evaluation placement performance was conducted in May 2004, while additional sampling for postcap monitoring was conducted in fall 2004 and fall 2005.

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Additional sampling is planned for fall 2006 and fall 2007. This article summarizes the cap construction activities and results of postplacement monitoring through fall 2005.

SITE CHARACTERISTICS

Compressibility was enhanced by the presence of significant amounts of gas in the sediments due to denitrifying and methanogenic bacterial activity in the sediments.

The Anacostia River is a freshwater watershed located within the Potomac River Drainage Basin, which discharges to the Chesapeake Bay. The high volume-to-influx ratio in the Anacostia River results in a flow rate frequently described as sluggish. Under normal conditions, river currents are driven by tidal fluctuations. Tidal amplitudes are typically 1 to 2 feet. Median magnitudes for the average current velocity ranged from 0.13 ft/s for high slack to 0.21 ft/s for maximum flood. Maximum magnitudes ranged between 0.64 ft/s at high slack to 1.29 ft/s at maximum ebb, while all minimum magnitudes for all tide stages were 0.01 ft/s. The estimated cumulative flushing time, based solely on a tidal prism model (i.e., no river inflow), is 23 days (Katz et al., 2000). As a result of the relatively low flow in the river, the cap demonstration area is net depositional. Vertical profiles of cesium (^{137}Cs), lead (^{210}Pb), and beryllium (^7Be) were measured in three cores collected from the river (Bentley, 2004). Vertical profiles of ^{137}Cs were consistent with a uniform deposition rate over at least the past 50 years of 0.68 ± 0.21 cm/yr based upon three cores. ^{210}Pb in the same cores showed a similar deposition rate of 0.76 ± 0.21 cm/yr. Vertical profiles of ^7Be indicated that the surface 4 to 5 cm in these cores was mixed via biodiffusion or other processes at an effective diffusion coefficient of approximately 29 ± 5 cm²/yr. Taken together, this information suggests that the upper 4 to 5 cm of the sediment is expected to be relatively well mixed with deposited contaminants, but that sediments below this depth were placed at least five to ten years previously and were unlikely to be exposed or incorporated into the surface layer.

The cap demonstration area is generally featureless and exhibits a gentle slope with water depths ranging from approximately 5 to 20 feet below North American Vertical Datum 88 (NAVD 88) or 3.6 ft to 18.6 ft below Mean Lower Low Water (MLLW). The bathymetric data and geophysical survey tracklines are depicted in Exhibit 1. The topography in the eastern half of the area shows that the riverbed is steeper in the vicinity of a CSO. The cap demonstration was focused in the area of a gentler slope west of this region and east of a stormwater outfall to the west. The surficial sediment consisted of high-plasticity silty clay, classified as CH according to the Unified Soil Classification System (USCS). From the mud line to at least ten feet below this elevation, these soils were very soft, extremely weak, and highly compressible. Compressibility was enhanced by the presence of significant amounts of gas in the sediments due to denitrifying and methanogenic bacterial activity in the sediments.

Tidal fluctuations in the river give rise to hypopheric zone exchange between sediment porewaters and the overlying water. In addition, groundwater upwelling gives rise to transport from deeper sediments to the overlying waters. Net groundwater outflows from the river were measured in September 2003 prior to cap placement. The measurements averaged 4 cm/day at the east end of the demonstration area, but were effectively 0 cm/day at the west end (Horne Engineering Services, 2003; Matrix Environmental and Geotechnical Services, 2003). Tidally driven pore water pumping caused a cyclic fluctuation in this mean velocity, with amplitude in both locations of about 1 cm/day.

A complete description of the site characterization delineating the sediment contamination is presented in the site characterization report (Horne Engineering Services,

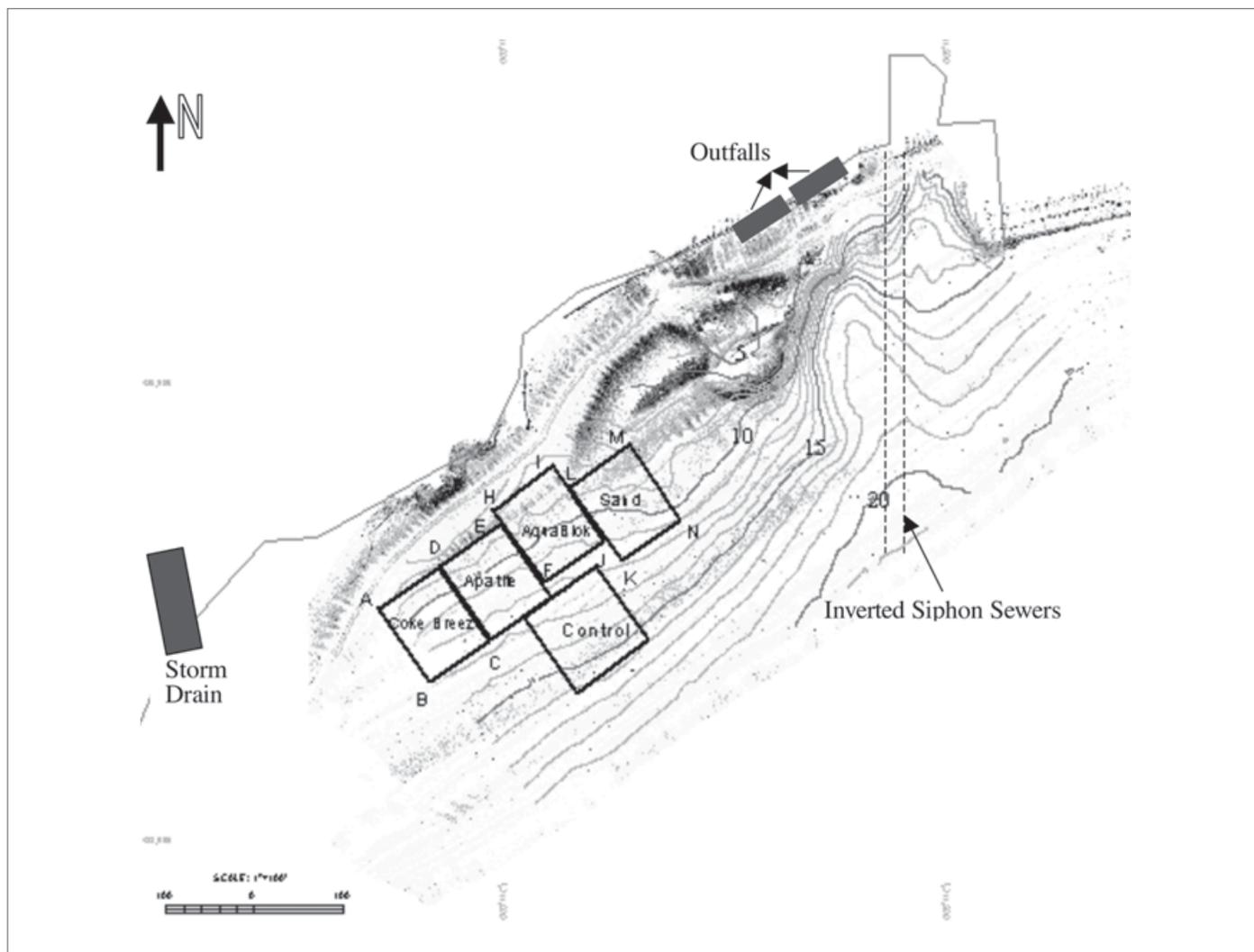


Exhibit 1. Map of study area showing bathymetry, sediment surface relief, cap locations, and potential local sources of continuing contamination

2003). The chemical concentrations were characterized across the site from a CSO outfall to the east to a stormwater drainage area to the west. Although the concentrations were highly variable across this area, as noted below, the variations within the cap demonstration area, which is a subset of the overall characterization area and not immediately adjacent to either CSO or stormwater drainage outfall, were more homogeneous. The surficial sediment characterization results over the entire site are as follows:

- *Polychlorinated biphenyls.* Sediment samples were analyzed for Aroclors. The total PCB in the surficial sediment ranged from 25 µg/kg to 2,400 µg/kg. Within the demonstration area, most of the concentrations were in the range of 500 to 2,000 µg/kg. The dominant Aroclors in the sediment were Aroclor 1248, 1254, and 1400. None of the Aroclors 1016, 1221, or 1232 were detected.
- *Polynuclear aromatic hydrocarbons.* Surficial sediment PAHs were characterized according to US EPA–regulated 16 PAH compounds expressed as “total PAH”

(tPAH). The 16 regulated PAHs are acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorine, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. The tPAH concentrations detected in the surficial sediment samples from across the entire site ranged from 470 $\mu\text{g}/\text{kg}$ to 82,360 $\mu\text{g}/\text{kg}$ dry weight. The highest tPAH concentration was detected near the CSO. The tPAH concentrations within the demonstration area were typically 10,000 to 30,000 $\mu\text{g}/\text{kg}$.

- *Metals.* Sediment samples from across the site were analyzed for the US EPA 13 priority pollutant metals, including antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. The detected metal concentration ranges in the surficial sediment samples were as follows, in mg/kg dry weight: antimony, 0.33 to 5.0; arsenic, 1.6 to 10.8; beryllium, 0.31 to 1.5; cadmium, 0.32 to 3.8; chromium, 11.3 to 94.8; copper, 18 to 437; lead, 29.3 to 726; mercury, 0.033 to 10.7; nickel, 15.3 to 69.8; selenium, nondetect to 1.9; silver, 0.29 to 22.5; thallium, nondetect to 2.0; and zinc, 109 to 892.

The nominal cap thicknesses were selected to demonstrate the ability to place caps in relatively thin layers using conventional equipment and to demonstrate that even thin layers could provide enhanced containment and control of sediment contaminants.

CAP PLACEMENT

Material was provided to the site in various forms. AquaBlok™ was packaged into approximately two-ton capacity SuperSacks (bags) for a total of 55 bags shipped to the site. Each bag was placed on a pallet at the manufacturing site and delivered to the site via flatbed trailer. Upon arriving at the site, the bags were unloaded with a forklift onto a 20-mil polyethylene sheet and covered with a 6-mil polyethylene sheet to prevent contact with precipitation because of the highly water-sensitive nature of this product. Apatite was delivered to the site by trucks. Approximately 235 tons of apatite were delivered to the site in 11 truckloads, each load being about 21 tons. Once arriving at the site, the dump truck unloaded the apatite onto a 20-mil polyethylene sheet with a size of 20 feet by 100 feet. Sand was delivered to the site by trucks. Approximately 1,355 tons of sand were delivered to the site in about 64 truckloads (each truckload had about a 21-ton capacity). Apatite and sand were also covered with a 6-mil polyethylene sheet, primarily to maintain ease of handling. Bulk materials were conveyed to a barge, which was then towed to the cap demonstration area for placement by conventional clamshell. Placement was achieved by filling a 2-yd³ bucket with the material and gradually opening the bucket, while swinging the crane arm through an arc of approximately three yards. The bucket placement was controlled from the crane through a Windows Offshore Positioning Software (WinOPS) system that tracked each bucket placed. Each cap was placed with a nominal cap thickness of approximately six inches and covered with a sand layer of six inches. The sand cap control area was covered with two layers, each of a nominal thickness of six inches. The nominal cap thicknesses were selected to demonstrate the ability to place caps in relatively thin layers using conventional equipment and to demonstrate that even thin layers could provide enhanced containment and control of sediment contaminants. For strongly sorbed sediment contaminants, the effectiveness of capping is largely independent of cap-layer thickness as long as benthic colonization and bioturbation do not extend through the cap. The biological active zone of freshwater sediments is typically less than 4–6 inches; thus, any recolonization by the benthic would be expected to be limited to the overlying sand layer and not the active capping layer.

As indicated previously, coke was incorporated within the laminated mat due to its near-neutral buoyancy relative to water and to the presence of fines that might not be adequately contained by near-surface placement. Coke was packaged into an approximately 10-foot-by-100-foot porous mat (less than one inch in thickness) and provided as a roll. The delivered coke-filled roll was approximately five feet in diameter, ten feet in length, and covered with a plastic sheet. Once at the site, the coke-filled rolls were unloaded to a 20-mil polyethylene sheet, then covered with a 6-mil polyethylene sheet. A total of 12 rolls were delivered to the site although only 11 were used to cover an area of approximately 80 feet \times 100 feet. Rolls were placed with use of the crane. Placement was achieved by tacking one end of a roll at the desired location on the bottom with sand and then unrolling by swinging the crane over the placement area. Each roll was overlapped with a previous roll by approximately 1 to 2 feet. In other applications that would entail capping all the way to shore, the rolls could be tacked from shore without the use of divers and unrolled by swinging the crane. After placement of the coke-filled rolls, a sand layer with a nominal six-inch thickness was placed as described previously.

The locations of the placed cap materials are shown in Exhibit 1 as an overlay on a side-scan sonar image of the site (geophysical support from Ocean Survey, Inc., Old Saybrook, Connecticut). Note that the AquaBlok™ was not placed over the entire design cap area due to placement at greater than design thickness. AquaBlok™ was the first active cap placed, and the crane operator had not yet developed an optimal placement procedure. In addition, the target AquaBlok™ thickness was less than the other cap materials, to allow for swelling of the clay layer after placement.

MONITORING IMMEDIATELY AFTER CAP PLACEMENT

Monitoring immediately after the cap placement (one to four months after placement) was designed to characterize cap-placement effectiveness and define initial conditions with which to compare subsequent cap monitoring. Sediment cores were collected to confirm and characterize the cap-layer thicknesses. Geophysical measurements, including bathymetry and side-scan sonar, were used to characterize the bottom conditions, including each cap's placement. Survey methods were also employed to estimate the thickness of each cap. Seepage measurements were conducted to evaluate the influence of cap placement on groundwater movement.

Bathymetry measurements were not sufficiently precise to adequately evaluate cap thicknesses. A large number of hand-driven cores (greater than 50), however, were collected and believed to provide the best indication of the thickness of each cap and thickness variations across the site. Exhibit 2 summarizes the cap thicknesses and standard deviations measured by hand-driven cores. As stated previously, the AquaBlok™ cap was greater than its design thickness, and, therefore, there was incomplete coverage of the design area. AquaBlok™ swells in water, however, and thus accurate comparison of the measured and placed thickness of AquaBlok™ is not possible. The average and standard deviations in cap-layer thicknesses show that the vast majority of the cap layers were near to design despite the effort to place relatively thin layers and the use of conventional clamshell bucket placement. Presumably, greater uniformity in cap-layer thickness could be achieved through placement by methods such as hydraulic broadcasting of the material (at least for sand and apatite that could be effectively placed as a slurry). Although the vast majority of the observed cap thicknesses were near to design, occa-

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Exhibit 2. Targeted and observed cap-layer thicknesses

| Cap | Target Thickness –in | Observed in $\pm \sigma$ |
|---------------|----------------------|--------------------------|
| Sand | 12 | 8.9 \pm 3.2 |
| Aquablok Sand | 4 | 4.5 \pm 2.0 |
| | 6 | 5.3 \pm 1.8 |
| Apatite Sand | 6 | 4.9 \pm 1.2 |
| | 6 | 4.5 \pm 1.2 |
| Coke Sand | 1 | 1 (mat) |
| | 6 | — |

sional cores showed little or no cap material or a layer of cap material that was excessively thick. The areal average effectiveness of a cap, however, is proportional to the area covered, and thus small areas left exposed would not significantly compromise the overall effectiveness of the cap. This fact should be considered when setting performance standards for field capping efforts, for example, by evaluating placement performance on the basis of 95 percent confidence limits in observed cap thickness rather than by requiring all measurements of cap thickness to exceed a specified value.

A review of the target and achieved cap thicknesses suggest that the goal of placing active capping materials in relatively thin lifts (six inches) using conventional clamshell bucket equipment was met. In addition, the ability to place high-value or difficult-to-place materials in a laminated mat was also demonstrated.

Settlement plates were used to assess consolidation of the underlying sediment. Total settlement of 0.75 to 2.25 inches was noted within 5 to 20 days of cap placement. Ultimate consolidation was much less than the total cap thickness placed (nominally 12 inches for the sand, AquaBlok™ and sand, and apatite and sand caps and 1–6 inches for the coke mat with sand). Some of the initial consolidation was associated with gas release due to the disturbance of cap placement. Gas generated by denitrification and methanogenesis in the sediments had accumulated in pockets of the sediments, and occasionally significant amounts of gas were released after the disturbance associated with a single-bucket placement of cap materials. In at least one instance, gas was released for 20 to 30 seconds after placement of a single bucket, as noted by vigorous bubbling at the surface.

Groundwater seepage measurements after the placement of the caps showed little or no change in the rate of pore water exchange in any of the cap areas except in and outboard of the AquaBlok™ cap. The presence of the AquaBlok™ cap showed effectively no groundwater outflow in an area that exhibited 2 to 4 cm/day net outflow prior to the cap placement. In addition, the control area immediately outboard of the AquaBlok™ cap area showed increases in groundwater seepage with effectively no specific discharge prior to cap placement to as much as 5 to 10 cm/day after cap placement. This is illustrated in Exhibit 3, which includes the sand cap (no change in specific discharge), AquaBlok™ (significant decrease in specific discharge), and the control area (significant increase in specific discharge).

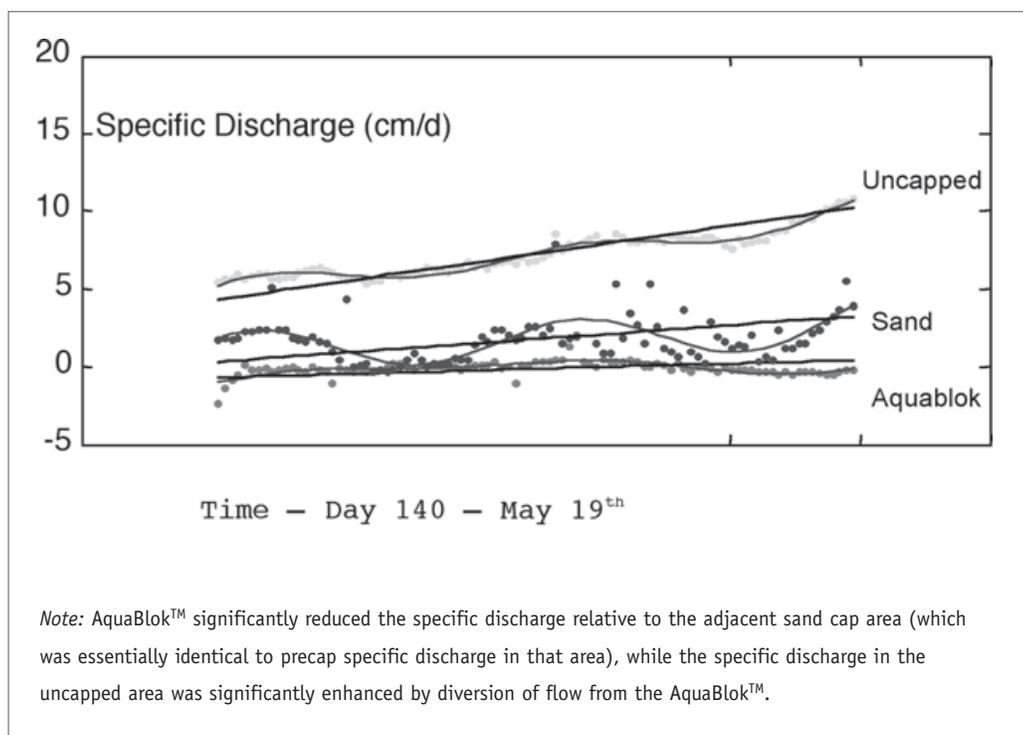


Exhibit 3. Specific discharge at three locations in the cap demonstration area

There were concerns that hydraulic forces, as a result of groundwater gradients, tidal forces, and gas accumulation, might cause vertical motions in the AquaBlok™ since its low permeability might limit relief from such forces. Immediately after placement of the AquaBlok™, an array of ten inclinometers (Slope Indicator, Inc., Mukiltea, Washington) were placed on top of the AquaBlok™ and covered by sand. The inclinometers embedded within the cap allowed for the measurement of vertical motions of the cap. As shown in Exhibit 4, tidal-level changes were observed to cause sub-mm heaving of the AquaBlok™ cap. Some sensors showed a continuous increase over time, although several showed significant decreases due to consolidation. A slow increase in elevation with time was especially significant in the outboard end of the inclinometer, and vertical uplift of approximately 20 mm was noted over a two-month period as shown in Exhibit 5. On May 25, 2004, however, somewhat less than two months after placement, the inclinometer showed a sudden deflection of 0.75 m. This was apparently due to the release of gas that had accumulated over time underneath the AquaBlok™. It was not known why the gas accumulated at the outboard end of the cap or what caused its rapid release, although the AquaBlok™ is thinnest near its outboard edge. The outboard end of the inclinometer was subject to similar rapid deflections every 30 to 45 days throughout the summer and then vertical motions effectively ceased, presumably due to the onset of cooler conditions and the resulting reduction in microbial gas generation. No similar deflections were noted during the subsequent summer, although some deterioration of the inclinometer sensors was expected by that time. In addition, the presence of the cap would eliminate the deposition of new organic matter, reducing and eliminating significant microbial activity over time.

CHEMICAL CONTAINMENT EFFECTIVENESS

In addition to demonstrating the ability to effectively place active cap materials in relatively thin lifts, a project objective was to measure the chemical containment effectiveness of the active caps relative to conventional caps or uncapped sediments. This effort is ongoing and will continue through 2007. A major impediment to demonstrating greater chemical containment effectiveness is the high degree of effectiveness of conventional sand caps. The differences between the caps with active sequestration agents and conventional sand caps are expected to be small initially but to slowly grow with time. The primary tool employed to assess containment of contaminants is the chemical concentration profile in cores. The ability to differentiate between the various cap treatments in

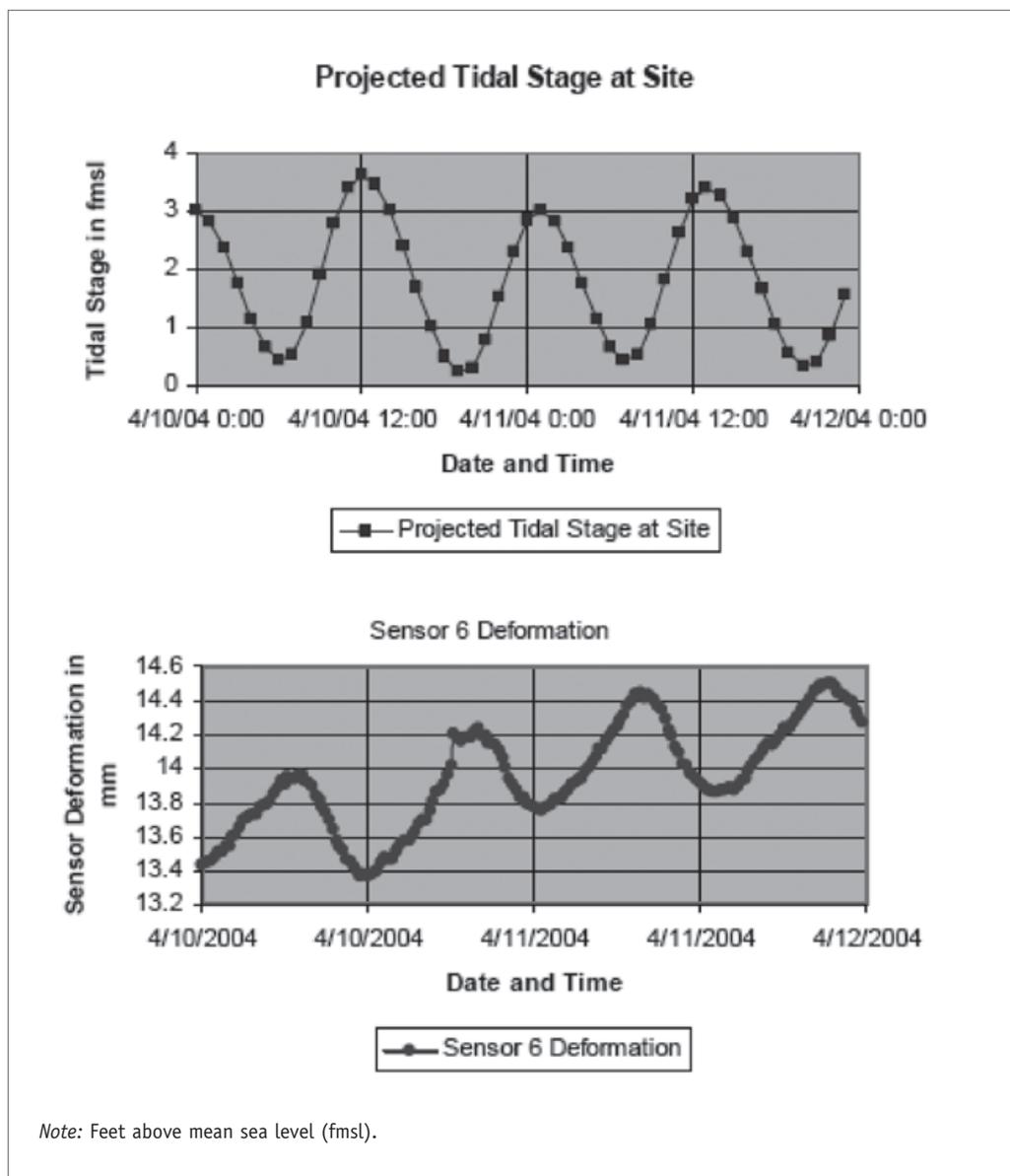


Exhibit 4. Tides and resulting deformation of the AquaBlok™ cap

such cores, however, is limited by the vertical resolution of the core samples, intermixing between cap layers and the underlying sediments, and the low sorption associated with the sand cap layers.

Conventional cores were collected with two-inch sample resolution. The large sample thickness was to ensure sufficient sample quantity for PAH and metal analyses and physical characterization by commercial laboratories. Such a large sample thickness can be relevant at the exposed sediment (or cap) water interface, where bioturbation may cause effective mixing over at least that depth. At the cap-sediment interface, however, there exists no bioturbation, and chemical migration processes are much slower. Exhibit 6 shows a typical vertical profile collected at this resolution. The concentration profile shows no measurable movement into the cap layer or the sand above the active capping layer, but the vertical resolution is insufficient to clearly identify any migration that might occur within 18 months of cap placement. Note that the concentration profile shows elevated concentrations at the top of the cap layer or at the cap-water interface. There appears to be no connection with the contamination beneath the cap. It is believed that the higher contaminant concentration at the surface is the result of deposition of new sediment and contaminants. Contaminant sources, including combined sewer overflows and stormwater drains, have not been controlled along the Anacostia; thus, additional contamination is to be expected. The recontamination of the surface of

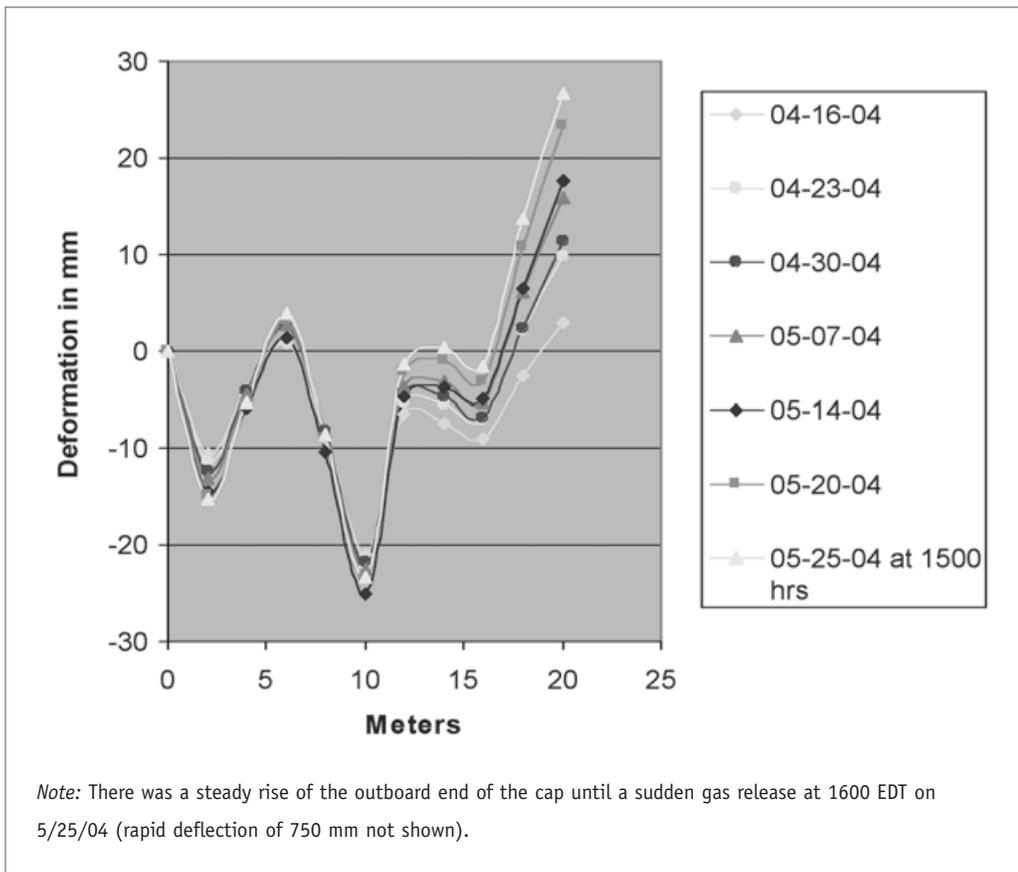


Exhibit 5. Deformation of the AquaBlok™ as a function of distance into the river at various times after placement

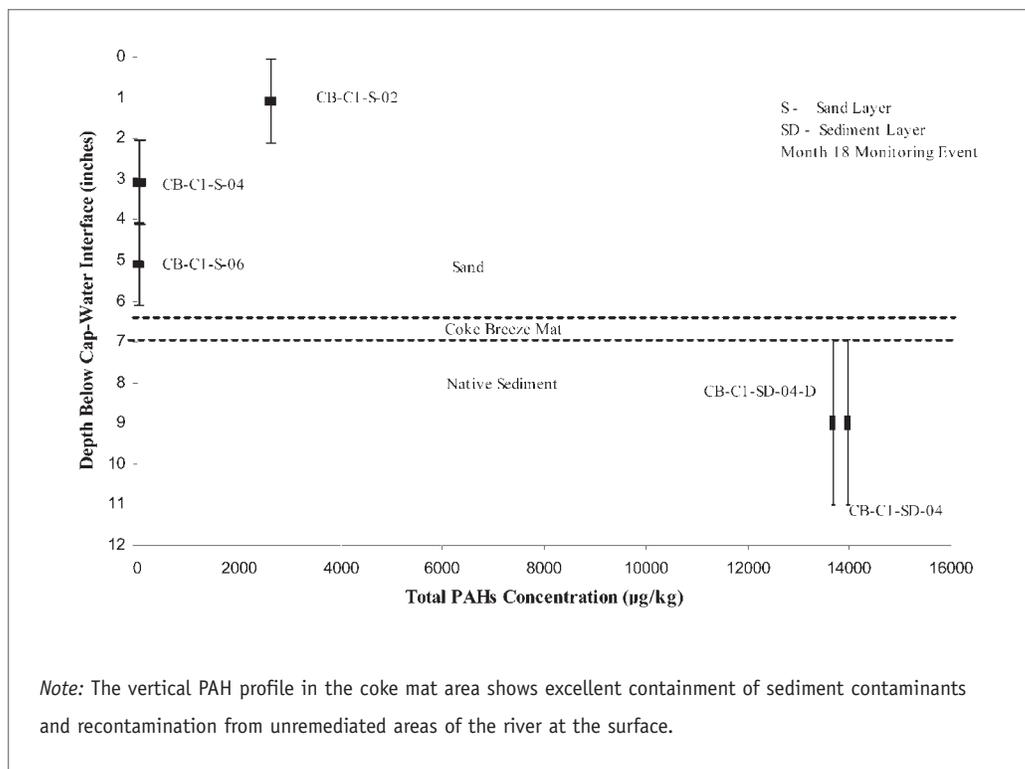


Exhibit 6. Coke core 1 total PAHs versus depth—October 2005

the capping materials appears to be widely variable across the site presumably due to the presence of specific sources outside of the cap area, such as a CSO on the east end of the site and a storm drain at the west end. Although the storm drain should exhibit minimal contaminant loading, sheens are regularly observed from this drain, and, in addition, the latest monitoring shows significant new sediment deposition in this area. Up to two to four inches of new deposition has occurred on the coke cap, while less than one inch was observed elsewhere.

Higher resolution cores were collected 18 months after placement in an attempt to gain a better understanding of the chemical migration to date. Exhibit 7 shows one such profile in which PAH concentrations are measured in the sand cap with a resolution of 5 mm. A grain-size analysis was also conducted for each sample in an attempt to identify the effect of intermixing between the sand and the sediment. The intermixing zone was defined as the zone between the samples that exhibited a sand fraction identical to that of the underlying sediment (approximately 30 percent sand) and effectively 100 percent sand, which meant that the sample was all cap material and contained no underlying sediment. The PAH concentrations in this interval are consistent with the sediment fraction in each sample, indicating that the PAH concentrations at each interval were the result of intermixing between the underlying sediment and the sand cap and not PAH migration. This does not necessarily exclude the potential for PAH migration in pore water, since the sand has little sorption capacity for PAHs relative to the sediment. In order to better understand dissolved PAH migration, pore water profiling using diffusion samplers is currently being tested. The results from these studies are not yet available.

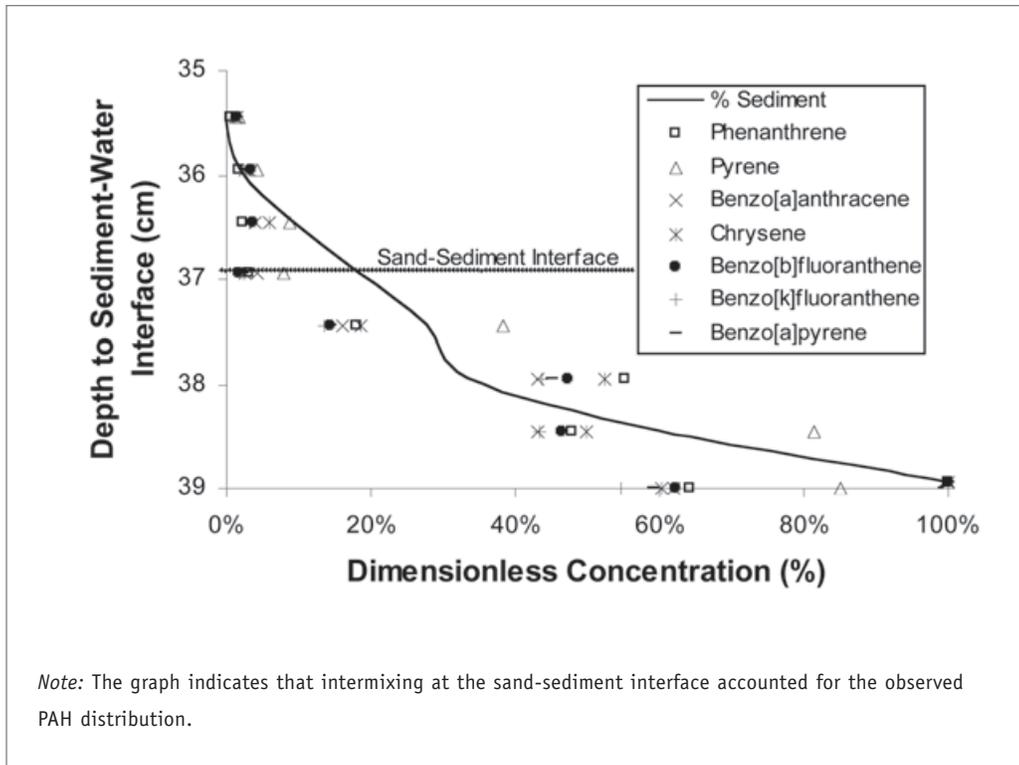


Exhibit 7. PAH concentrations versus depth in the sand cap 18 months after placement

SUMMARY AND PRELIMINARY CONCLUSIONS

The Anacostia active capping demonstration successfully demonstrated the ability to place selected capping materials including AquaBlok™ (for permeability control), apatite, (for enhanced metals sorption and control), and coke (for enhanced organic sorption and control). Apatite and AquaBlok™ were successfully placed using a conventional clamshell in layers of six inches or less. The coke was successfully placed in a laminated mat, demonstrating that high-value and/or difficult-to-place material can be placed in a controlled fashion. Sand was successfully placed by conventional clamshell in six-inch layers on top of the active cap materials to act both as an armoring layer and as a better bottom substrate. The placement efforts demonstrated that active capping materials could be effectively placed with conventional equipment in relatively thin layers. Subsequent monitoring has shown deposition of additional fine-grained material and no loss of cap material due to erosion or other processes.

The deposition of additional fine-grained material, at rates expected to be similar to historical depositional rates of approximately 0.75 cm/yr ± 0.2 cm/yr has led to the recontamination of the top of the capping layers since sources have not yet been completely controlled in the Anacostia. It is expected that this redeposited sediment contains contaminant levels similar to the surficial precap concentrations. Deposition of new sediments is especially significant near a stormwater outfall near the western edge of the cap.

Postcapping performance monitoring has shown no measurable contaminant migration in any of the caps, including the sand cap control. Observed concentration profiles are consistent with intermixing of the cap material in the soft sediment during the cap place-

ment. Monitoring will continue for at least another year and include pore water measurements in an effort to better differentiate the performance of the various cap layers.

The AquaBlok™ cap has been shown to effectively halt groundwater upwelling in the capped area, with subsequent increases in upwelling in surrounding uncapped areas. The low permeability of this layer, however, also led to a slow uplift due to the accumulation of gas beneath the cap and the rapid release of this accumulated gas several times during the first summer after placement. This release is expected to subside over time due to the elimination of organic matter deposition that drives gas ebullition in the sediments protected by a cap. When gas-ebullition processes are active, however, gas accumulation and release will occur and a cap design should consider its implications. In this case, no effect on contaminant release, or cap-layer integrity, has been noted.

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