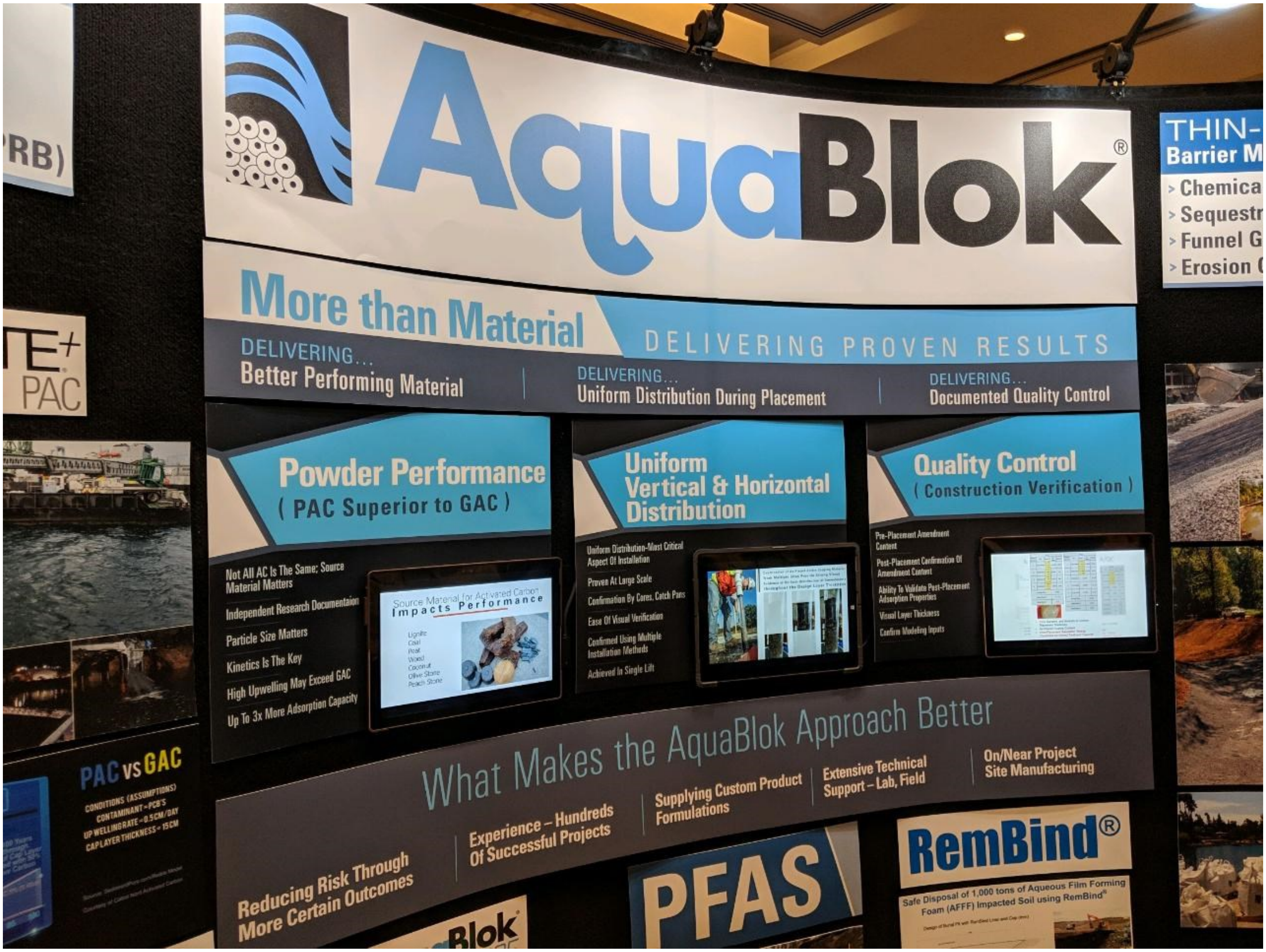

2019 Battelle Sediments Conference

Platform and Poster Presentations Authored and Coauthored by and Featuring AquaBlok, Ltd.

AquaBlok, Ltd. is thrilled to have participated in another successful Battelle Sediments Conference. This year, the 10th International Conference on Remediation and Management of Contaminated Sediments included 25 technical presentations, both platform and poster, that showcased materials provided by, testing performed by, and projects involving AquaBlok. Of these presentations, representatives from our company authored or coauthored six. The remaining 19 presentations represent not only a wide range of projects, pilot studies, and testing performed by well-respected firms in the sediment remediation industry, but a significant increase in the successful use of AquaBlok's technologies.

Below is a list of platform and poster presentations either authored or co-authored by or featuring AquaBlok. Detailed abstracts are also included. For easy access to them, click on the presentation title in blue.

I. AquaBlok Authored & Co-Authored Platform & Poster Presentations

Platform

In Situ Treatment for PCBs in Sediment: Treatability to Implementation

Keir Craigie, Gary Braun, and Senda Ozkan (Tetra Tech, Inc.), Ernest Ashley (CDM Smith), and John Collins (AquaBlok, Ltd.)

Detailed abstract on page 7

Sediment Cap Design, Modeling, and Construction

Dale Kolstad, Mike Ellis, and Tom Boom (Barr Engineering), John Collins (AquaBlok, Ltd.), Mike Welch (Sevenson Environmental Services), and Andrew Santini (Consumers Energy)

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Poster

Addressing Contaminated Groundwater to Surface Water Discharge: Application of Materials and Methods for Construction of In Situ Permeable Reactive Barriers (PRBs) to Limit Migration of PFAS

Richard Stewart (Ziltek, Pty Ld.) and John Collins and John Hull, PE, BCEE (AquaBlok, Ltd.)

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Biological Side Effects from Activated Carbon When Used in Contaminated Sediment Treatment: Trying to Put Things into Perspective

Joe Jersak (SAO Environmental), John Collins and John Hull (AquaBlok, Ltd.), and Tore Hjartland (AquaBlok Norge AS)

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Evaluation of Activated Carbon as a Reactive Sediment Cap Amendment for Feasibility Level Studies

David Flannery and Billy Barron (Cabot Corporation), Danny Reible and Tariq Hussain (Texas Tech University), John Collins and John Hull (AquaBlok, Ltd.)

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Join Expeditionary Base (JEB) Little Creek: Application of Active Materials as a Component of Contaminated Sediment Remediation

John Collins (AquaBlok, Ltd) and Stavros Patselas and Steve McGee (Tetra Tech)

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II. AquaBlok-Featured Platform & Poster Presentations

Platform

Application of a Technology Assignment Process at the Hunters Point Naval Shipyard Site

Eric Blischke, Melissa Harclerode, and Tamzen MacBeth (CDM Smith), Sharon Ohannessian and Danielle Janda (U.S. Navy), and Mitra Fattahipour (ECC-Insite)

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Balancing Remedial and Restoration Objectives for Sediment Capping on an Urban River

Tom MacDonald, David Hibbs, and Tom Boom (Barr Engineering) and Andrew Santini (Consumers Energy)

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Construction Management Challenges of Combined Sediment Remedy

Steve McGee, Gary Braun, and Senda Ozkan (Tetra Tech, Inc.) and Ernest Ashley and Katie Young (CDM Smith)

Detailed abstract on page 17

Development of a Custom Carbon Amendment Strategy Using Biochar for a Mercury-Contaminated River

Cameron Dixon, PE and Joshua Collins (AECOM) and Michael Liberati and Nancy Grosso (DuPont)

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Engineering Optimization/Validation of In Situ Reactive Cap for TPH-, PCB, and Hg-Impacted Sediment Site in Southern Coastal Europe

Claudio Sandrone and Andrea Campi (BAW s.r.l.) and Jim Mueller (Provectus Environmental Products, Inc.)

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Poster

AquaBlok Authored & Co-Authored Platform Presentations

In Situ Treatment for PCBs in Sediment: Treatability to Implementation

Keir Craigie (Keir.Craigie@Tetratech.com), Gary Braun, and Senda Ozkan (Tetra Tech, Inc.)
Ernest Ashley (CDM Smith)
John Collins (AquaBlok, Ltd.)

Background/Objectives: In one of the largest applications of in situ treatment for PCBs in sediment to date, the project went from treatability study to implementation. Treatability studies demonstrated that the effectiveness of the application of activated carbon at doses of 2.5% and 5% dry weight of the sediment resulted in 95% reduction in porewater concentrations and invertebrate bioaccumulation. The Feasibility Study for the site determined that the in situ application could be applied across approximately 13.7 acres where the concentrations of total PCBs in the surface sediments exceeded the remedial goals and were below 2.5 mg/kg. The Remedial Design incorporated the application of activated carbon at a target rate of 5% of the sediment dry weight across 13.7 acres. The remedial design selected two potential weighted approaches to apply powder activated carbon (PAC) to the surface sediment where the water depths ranged from 6 to 12 feet. For the full-scale implementation AquaGate+PAC® was selected as the delivery approach for the PAC application.

Approach/Activities: A laboratory bench-scale study demonstrated the effectiveness of using activated carbon applied to the surface sediments to reduce the bioavailability of PCBs to benthic organisms and the concentrations in the porewater. Results from the treatability study were incorporated into the feasibility study and the design. The project was completed under an EPA-approved Risk Based Disposal Analysis. Field application of the in situ treatment material was completed over a period of 2 months using a cable assisted barge mounted roller drum to place the target loading of the AquaGate+PAC® to the surface sediments. A total of 2,504 tons of in situ material was placed over 13.7 acres of the site. Multiple quality control measurements and samples were collected to verify the AquaGate+PAC® material delivered and the application rate during placement. Monitoring of the in situ material and placement included verification of the delivered material, tracking of tonnage placed, area covered, material thickness, collection of samples for laboratory analysis, and the collection of material to collect, recover and measure the amount of activated carbon that reached the sediment surface.

Results/Lessons Learned: The collection of multiple measurements allowed for a full documentation of the in situ material placed over the 13.7 acres of the site. Verification of the PAC content in the material was completed over the several month period required for production and delivery to the site. Visual measurements of the in situ treatment layer via core samples a frequency of 15 locations per acre was able to confirm the activated carbon placement. The collection of samples from collected push cores for black carbon and total organic carbon were also used to verify the placement of the activated carbon. The collection of samples to measure the amount of activated carbon reaching the sediment surface confirmed that settlement occurred within the target placement areas as aggregate bound or unbound activated carbon. The results from the range measurement approached utilized provided multiple lines of evidence that the target amount of activated carbon was successfully placed within the target loading over the 13.7 acres. A long term monitoring program will measure the reduction in bioaccumulation of PCBs by benthic invertebrates and the reduction in sediment pore water concentrations. The just-finished first year of monitoring provides the first indications of progress to the remedial targets for the site. Subsequent monitoring in years 3 and 5 will verify the in situ treatment effectiveness and achievement of project goals.

Sediment Cap Design, Modeling, and Construction

Dale Kolstad (dkolstad@barr.com) (Barr Engineering, Minneapolis, MN)
Mike Ellis and Tom Boom (Barr Engineer, Ann Arbor, MI)
John Collins (jcollins@aquablok.com) (AquaBlok, Ltd., Swanton, OH)
Mike Welch (mwelch@sevenson.com) (Sevenson Environmental Services, Niagara Falls, NY)
Andrew Santini (Consumers Energy, Jackson, MI)

Background/Objectives: Sediment remediation at a former manufactured gas plant (MGP) site in Flint, Michigan was completed during the 2017 construction season that included dredging sediment and placing a multi-layer sediment cap within the Flint River. The cap layers consisted of a sand foundation, Blended Barrier™ (a patented mixture of AquaBlok® and gravel), cover sand, gravel, and gravel in-filled rip rap. The objectives of the cap were to: 1) create a barrier between remaining impacted sediments below the cap and the river, 2) provide stable riverbanks and riverbed, and 3) incorporate bedform diversity elements for improved aquatic habitat. Meeting these objectives required an evaluation of alternatives for the cap and included incorporation and analysis of materials, constructability, cap design, geotechnical modeling, performance-based construction quality standards and quality control (QC) requirements, and multi stakeholder engagement. Successful implementation of the selected remedy relied upon the placement of the cap materials within the construction QC requirements. An integrated project team was necessary to deliver the project to the stated objectives.

Approach/Activities: Options for establishing a barrier along 1,700 feet of the riverbed were evaluated during the feasibility phase and included Blended Barrier, geo-composite mats, and geosynthetic fabrics and membranes. Blended Barrier was selected as the preferred option for in-water cap applications and geomembrane was selected for above water capping. Early engagement between the manufacturer and engineer identified critical design parameters for Blended Barrier performance. Bench/lab scale testing (swell and strength) were performed on the material under simulated field conditions. The data was used to demonstrate capability to meet barrier objectives, provide inputs for geotechnical modeling, gather data for use in designing supplemental cap layers, and aid in establishing construction requirements. A filter layer evaluation was performed to develop material specifications needed to effectively grade from the bentonite coated particles to a final layer of coarse rip rap. The rip rap was evaluated by performing a hydrodynamic analysis. Global slope stability and veneer cover stability modeling were completed iteratively within the cap design process.

Effective implementation of the cap strategy required establishment of pragmatic construction specifications that included a wide range of core elements: on-site Blended Barrier preparation (mixing) and storage handling management, appropriate barge spudding, equipment setbacks from bank crests to maintain slope stability, and placement of cap materials to within the allowable tolerances and within suitable timeframes. Maintaining conformance to the specifications during construction required additional planning, adaptive management, modifications to construction methods as conditions changed, heightened coordination between the contractor and engineer, and expedited review of survey data.

Results/Lessons Learned: The project outcome is a physically stable and functional multilayer cap installed to meet the design intent. Results that will be discussed include requirements that were modified based on construction limitations, field observations, construction QC data collected and used during implementation, and other constructability and design lessons learned.

AquaBlok Authored & Co-Authored Poster Presentations

Addressing Contaminated Groundwater to Surface Water Discharge: Application of Materials and Methods for Construction of In Situ Permeable Reactive Barriers (PRBs) to Limit Migration of PFAS

Richard Stewart (Ziltek, Pty Ltd.)
John Collins and John Hull, PE, BCEE (AquaBlok, Ltd)

Background/Objectives: When contamination in soil or groundwater reaches surface water, the cost and level of complexity for remediation typically increases dramatically. At many sites, pump and treat systems have been used to hydraulically control/limit groundwater migration and attempt to reduce contaminant concentrations. However, these systems are expensive to operate/maintain, are often less responsive to fluctuating flow rates or levels of contamination, and many have been running for decades without meeting goals or regulatory requirements. As a result, a number of projects have looked at alternative passive designs to reduce costs, minimize or prevent the potential transfer of contamination to surface water bodies. Control of PFAS impacted groundwater, particularly in areas adjacent to canals, waterways or other bodies of water is an important capability that can reduce impacts on water sources and habitat. It has been demonstrated that a permeable reactive barrier (PRB) can intercept and limit the migration of a range of contaminants. In particular, examples include petroleum related facilities including pipelines, storage and distribution facilities and sites where PFAS contamination is present. Such an approach will also protect sensitive ecological areas (including wetlands and stream crossings) in a manner that minimizes the potential impact to the existing habitat.

Approach/Activities: Best available technology in materials and construction methods will be discussed with respect to the design of a PRB to address PFAS in groundwater. A description of the type of materials, the treatment approach and the use of a funnel and gate design will be provided. The presentation will provide data and case studies and an overview of materials that have been applied to both isolate (low permeability) and treat (via adsorptive amendments, e.g., RemBind®). Examples will highlight both petroleum- and PFAS-related sites and applications.

Results/Lessons Learned: Information available demonstrates that a PRB design can provide a cost effective, in situ, passive alternative to pump-and-treat that can minimize the potential movement and impact of petroleum and PFAS contamination from upland areas into surface water.

Biological Side Effects from Activated Carbon When Used in Contaminated Sediment Treatment: Trying to Put Things into Perspective

Joe Jersak (joe@saoec.se) (SAO Environmental Consulting AB, Ystad, Sweden)
John Collins and John Hull (AquaBlok, Ltd., Swanton, OH, USA)
Tore Hjartland (AquaBlok Norge AS, Sandefjord, Norway)

Background/Objectives: Abundant data published over the last 10+ years clearly shows activated carbon (AC) is a highly effective sorbent of many organic sediment contaminants. As a result, AC's international use in in situ isolation capping and treatment has grown dramatically. Earlier in situ treatment projects involved mechanically mixing AC-bearing material into surface sediments (mechanical mode) while later projects instead involve placing thin AC-bearing layers overtop sediment and rely on natural bioturbation for mixing (thin-layer mode). While AC's international reputation as a highly effective sediment management tool has grown substantially, so too has the number of studies reporting biological side effects from AC when used in in situ treatment (both modes). Such results have prompted Norway's Miljödirektoratet to note (2014) "It is difficult to conclude if [AC] can be used in large contaminated areas", and a 2017 study by Scandinavian researchers to state "The promising remediation potential of AC has been brought into question based on the adverse effects of AC to certain benthic organisms". There also appears to be a common belief powdered AC (PAC) causes greater harm to benthic organisms than granular AC (GAC). While credible evidence of AC's biological side effects cannot be discounted, conclusions being drawn from available results need to be carefully scrutinized.

Approach/Activities: From 2005 to 2017, a total of 23 studies were published in international journals in which AC effects on benthic organisms were evaluated. Typically, the studies: were by American and/or Scandinavian researchers, were laboratory or field-based, involved either (but not both) AC treatment modes, used PAC or GAC at different dosages (often < 5%), evaluated responses of selected benthic species or communities, and focused on specific ecological endpoints or community level responses. A critical review of this published body of AC-effects research was performed and key findings will be presented.

Results/Lessons Learned: Given currently available published data, the goal was to determine what conclusions can defensibly be drawn – or not – on biological side effects from AC when used in in situ treatment of contaminated sediments. Questions to be addressed include:

- In general, are there enough results to conclude that biological side-effects from AC outweigh its clearly demonstrated treatment benefits – especially when endpoint-specific and community responses are nearly always mixed?
- For the thin-layer mode, are the relatively few (and mixed) results enough to question AC's use in the context of this popular treatment mode?
- Can results for the mechanical mode be used to adequately predict biological effects from AC when used in the thin-layer mode? Don't these two treatment modes represent entirely different levels of AC exposure, including over time?
- Are there enough results to conclude PAC is more damaging to organisms and/or communities than GAC?
- The issue of biological side-effects from AC appears to receive more attention and focus in Scandinavia than in the USA, perhaps to the point that AC's use in sediment treatment is being limited in Scandinavia. If so, why is that?
- Are there ways possible biological side effects from AC use in sediment treatment can be minimized while still benefiting from its positive treatment effects, e.g. intermittent applications of lower doses over time?

Evaluation of Activated Carbon as a Reactive Sediment Cap Amendment for Feasibility Level Studies

David Flannery (david.flannery@cabotcorp.com) and Billy Barron (Cabot Corporation, Boston, MA, USA)
Danny Reible and Tariq Hussain (Texas Tech University, Lubock, TX, USA)
John Collins and John Hull (AquaBlok, Ltd., Swanton, OH, USA)

Background/Objectives: It has been demonstrated that the application of amendments (reactive materials) in the capping of contaminated sediment can enhance sequestration and remediation of a range of contaminants at costs well below conventional dredging approaches. However, during the early planning stages when reactive capping is being considered as a remedy, it is often difficult to estimate both the potential effectiveness and cost of this approach. At the Feasibility Study (FS) level, simple tools are needed to assist engineers and consultants to determine reliable reactive capping estimates.

Approach/Activities: To address this need, Cabot Corporation and Professor Danny Reible undertook a two-stage program. First, Cabot developed partition coefficients for specific activated carbon material for a range of common hydrophobic contaminants. Second, Professor Reible worked with Cabot to apply the CAPSIM model over a large number of scenarios to develop a matrix of results for various contaminant concentrations and cap/material application assumptions. AquaBlok provided input to Cabot regarding potential amendment applications for target contaminants, as well as treat-in-place considerations for determining thicknesses and approaches to delivering the reactive material. The matrix of results along with Aquablok's expertise were used to develop an online modeling tool engineers and consultants can use to quickly evaluate cap and in-situ treatment performance in sediment remediation projects.

Results/Lessons Learned: This presentation will provide an overview of the modeling tool's development, including support data and a tool demonstration. Issues relating to application of activated carbon will be discussed and evaluated. Examples of how the tool may be used to evaluate generalized designs and costs related to caps will be shown and discussed.

Joint Expeditionary Base (JEB) Little Creek: Application of Active Materials as a Component of Contaminated Sediment Remediation

John A. Collins (jcollins@aquablok.com) (AquaBlok, Ltd., Swanton, Ohio)
Stavros Patselas and Steve McGee (Tetra Tech)

Background/Objectives: The Joint Expeditionary Base (JEB) Little Creek (Norfolk, VA), now known as JEB Fort Story, is the major east coast operating base supporting Overseas Contingency Operations for maximum military readiness. The command provides front-line support for Sea, Air, Land (SEAL) Teams, Explosive Ordnance Disposal (EOD), and Riverine Squadrons. The facility is home to 155 shore-based resident commands and 18 home-ported ships. It is located in the Atlantic Coastal Plain within the Tidewater Region of Southeast Virginia occupying approximately 3,915 acres within the Chesapeake Bay watershed. On May 10, 1999, JEB Little Creek was placed on the National Priorities List (NPL) with the United States Environmental Protection Agency (USEPA) designated as the lead regulatory agency; a Federal Facility Agreement (FFA) was finalized in October 2003.

Approach/Activities: The remediation of sediment at SWMU 3 came with various challenges that made removal of all impacted media difficult and expensive to implement. Significant disruption to JEB Little Creek's mission would take place with respect to the adjacent marina. Although the implementation of a dredge removal action was possible across most of the site, various areas of the site were inaccessible, due to proximity to bulkheads and piers, without the use of engineering controls, such as sheet piling or complete demolition and rebuilding. A site closeout strategy was developed for SWMU 3 that utilized a treatment technology to address contamination in these areas. Through the placement of powdered activated carbon (PAC) to the sediment surface as part of a dense, granular aggregate (AquaGate+PAC), the bioavailability of sediment contaminants were addressed in the upper biologically active zone, which was the primary source of exposure to benthic organisms and the water column. The addition of the amendment was intended to sequester contaminants in the sediment that would otherwise enter pore water through dissolution. Unlike a capping technology, it was determined that the use of an In-situ amendment would not require post-placement maintenance. Following completion of the TCRA, no further action for sediment was required.

Results/Lessons Learned: This presentation will focus on the materials used and describe both the conceptual approach and best available technology in materials and methods that have been proven to minimize the potential movement and impact of contamination from the sediments or difficult to dredge areas. These methods can also address adverse environmental impacts that come from the formation of preferential pathways. Project examples will also be presented.

AquaBlok-Featured Platform Presentations

Application of a Technology Assignment Process at the Hunters Point Naval Shipyard Site

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Background/Objectives: The Hunters Point Naval Shipyard Site (HPNS Site) is located in San Francisco, California. Historical activities at the Shipyard have resulted in contamination of offshore sediments with polychlorinated biphenyls (PCBs), copper, lead and mercury. In 2008, a feasibility study was prepared for sediment remedial unit (Parcel F) of the HPNS Site. Since the 2008 FS was completed, new information regarding the effectiveness of in situ treatment using carbon-based amendments has become available (Patmont et al., 2014) and two pilot studies that evaluate in situ sediment treatment using activated carbon were completed at the site between 2005 and 2018. In addition, advances in our understanding of sediment remediation success factors allows for application of a formalized process for optimizing remedial alternatives consistent with the recent sediment guidance developed by the Interstate Technology and Regulatory Committee (ITRC, 2014).

Approach/Activities: Five site-specific factors were evaluated to aid in the development of an optimized remedial alternative and to refine the active remedial footprint based on information presented in the 2008 FS. The site-specific factors are: contaminant of concern (COC) sediment concentration, water depth, hydrodynamics, natural recovery rate, and constructability. COC sediment concentrations were evaluated against both not-to-exceed threshold concentrations protective of wildlife that consume fish and shellfish, and long-term background based preliminary remedial goals (PRGs) protective of humans that consume fish and shellfish. Water depth, hydrodynamic characteristics, natural recovery rate and constructability were used to assess the implementability and long-term effectiveness of applicable remedial technologies comprising a multi-component remedy. The remedial footprint of each technology component was developed based on the technology assignment framework and a global information system (GIS) model that assigned post construction estimates of sediment concentration on a Thiessen polygon basis.

Results/Lessons Learned: The optimized remedial alternative incorporates in situ treatment of contaminated sediments to a larger degree in conjunction with other remedial technologies. The optimized alternative removes intertidal sediments above not-to exceed PRGs where in situ treatment may not be effective due to the presence of metals and the potential for wave induced erosion. Intertidal sediments will be removed to a depth of one foot and covered with backfill designed to both resist erosion and improve nearshore habitat. Subtidal sediments with PCB contamination too high for in situ treatment to be effective (12,400 μg/kg) will be also be removed. Subtidal sediments above 1,240 μg/kg but below the 12,400 μg/kg removal threshold will be remediated through in situ treatment. Sediments with PCBs below the not-to exceed PRG of 1,240 μg/kg will be remediated through MNR. The optimized alternative was evaluated against the NCP evaluation criteria and identified as the preferred remedial alternative in the Proposed Plan for Parcel F sediments at the HPNS Site. This alternative is expected to effectively reduce site risks by removing significant amounts of COCs and safely contain or treat the remaining contaminants.

Balancing Remedial and Restoration Objectives for Sediment Capping on an Urban River

Tom MacDonald (tmacdonald@barr.com), David Hibbs, and Tom Boom (Barr Engineering Co.)
Andrew Santini (Consumers Energy)

Background/Objectives: Barr Engineering Co. provided river restoration design services as part of a sediment dredging and capping project conducted at a former manufactured gas plant (MGP) site in Flint, Michigan during the 2017 construction season. The project was completed on a 1,700-foot reach of river flowing through an urban area. Hamilton Dam, classified as a high hazard dam by the Michigan Department of Environmental Quality, defined the downstream end of the work zone. The main objectives of the remediation were to remove MGP-related impacts in the riverbed and riverbanks, install an impermeable cap along the riverbed to prevent groundwater from venting into the river, restore the riverbed and riverbanks to meet flood stage requirements, and minimize secondary impacts to the public.

The project reach is within a college campus on an urban stretch of the Flint River, with an incised channel that lacked bedform diversity and bound laterally by adjacent urban development. The banks were fairly steep with roads on either side of the river. Plans to modify Hamilton Dam were in the works by others, but the design was conceptual at the time of the remediation design. The river restoration design needed to work within these constraints to meet the remedial objectives while still improving the function of the channel corridor.

Approach/Activities: The project constraints created challenges for river restoration that were met through an iterative design process, hydraulic modeling, and stakeholder collaboration. The restored channel bed was designed to prevent potential downcutting into deeper sediments and habitat features were incorporated to improve floodplain connectivity, sediment transport, and habitat. The design of the restored channel was tailored to address a range of proposed modifications to Hamilton Dam. Consumers Energy collaborated with state and local regulators and dam designers so that the two projects could be sequenced in a manner that protected human health and the environment while improving the river corridor.

Newberry riffles composed of cobble-sized rock and a bankfull bench with an elevation tailored for the post dam removal condition were incorporated. An existing pedestrian bridge was removed and replaced with a single span pedestrian bridge, which resulted in the removal of bridge piers within the channel. To protect the sediment cap, the restored channel and lower river banks were armored with riprap. Native vegetation was planted in the upper river banks and, following dam removal, along the floodplain bench. Native trees and shrubs will be established to reintroduce native landscape to the area.

Results/Lessons Learned: Dredging and construction were substantially completed in late 2017, with final site restoration occurring in 2018. Throughout the design and construction process, regular stakeholder collaboration resulted in multiple iterations of design, supported by hydraulic modeling and analysis in order to address input. Although modification of the Hamilton Dam was imminent, the design and hydraulic characteristics were not finalized at the time the remediation project was completed. Therefore, channel geometry and floodplain bench were designed to provide flexibility for the likely range of scenarios resulting from the Hamilton Dam removal. The final restoration improved the geomorphic function of the channel, maintained appropriate sediment transport, improved floodplain connectivity, created bedform diversity, and maintained adjacent riparian wetlands.

Construction Management Challenges of Combined Sediment Remedy

Steve McGee, Gary Braun, and Senda Ozkan (Tetra Tech, Inc.)
Ernest Ashley and Katie Young (CDM Smith)

Background/Objectives: Combining remedies are becoming more common for addressing multiple environments within contiguous areas of contamination effectively and efficiently. While combined remediation elements can successfully be designed and permitted, the coordination of multiple design and construction elements can be challenging. Comprehensive coordination and continual communication is essential to obtaining informed consent from all stakeholders. This presentation will highlight lessons learned from a construction project involving two seasons of sediment removal, residuals management, habitat restoration and one of the largest applications of in situ treatment to date.

Approach/Activities: The site is located in the mid-Atlantic region and includes an upland stream, tidal and non-tidal wetlands, a large cove and a tidal creek. Sediment is impacted with PCBs, PAHs and metals. Remediation elements included sediment removal by dredging and excavation, residuals management, in situ treatment, source controls through bulkhead rehabilitation, storm drains and outfalls reconstruction, and habitat restoration and enhancement. Design, permitting and construction of the right balance of remediation elements proved to be challenging at every stage of the project.

Results/Lessons Learned: A multi-component remedy requires extensive communication and coordination. Design elements for the varied environments and construction sequence must be well planned. Permitting requirements of different remedy elements extends to multiple regulated environments. Procurement requires selection of contractors with many different areas of expertise. This presentation will document the technical approach to combine remedy elements, the coordinated communication effort during the permitting and construction stages of the project, and construction sequences and challenges to successfully complete a complicated combined remediation project.

Development of a Custom Carbon Amendment Strategy Using Biochar for a Mercury-Contaminated River

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Background/Objectives: Operations at the former DuPont Waynesboro facility from 1929 to 1950 included a mercuric sulfate catalyst that resulted in the release of inorganic mercury into the South River. Loading from historically contaminated bank soils is the primary, on-going pathway allowing mercury to enter the aquatic system. The approach to remediate mercury (Hg) impacts from erosion of bank soils along the South River in Waynesboro, Virginia includes a unique, layered cap which incorporates biochar (BC).

Extensive research has shown that BC is effective at removal of mercury in water. The cap includes a reactive layer of BC to remove Hg from bank storage water that drains through the cap back to the South River after precipitation and storm events. During the initial remedial design phase, BC was selected as the reactive layer instead of activated carbon due to its sustainable sources, availability and lower price per pound compared to activated carbon; BC also has a lower greenhouse gas footprint compared to activated carbon.

Approach/Activities: BC has been incorporated into the cap using two designs. The initial cap design for the first two BMAs included a 6-inch layer of BC mixed with a planting substrate (PS) in a 50:50 ratio by volume (PS+BC). This mixture was then placed into 12-inch geocells, and covered with an additional 6 inches of PS. The BC was purchased directly from a vendor in chip format, and mixed on site with the PS material using an excavator. A thinner cap profile had to be considered for the third BMA due to space constraints. Based on that evaluation, the bank cap included the use of an activated carbon reactive core mat (RCM) for a small section of the cap profile which had to be placed in the wet, and the PS+BC mixture above the water table. During the evaluation of the thinner cap profile, use of a manufactured biochar coated aggregate (AG) was also explored. The AG will be implemented for the next (fourth) BMA to be constructed. The manufactured material consists of a gravel aggregate coated with 10% BC by mass (AG+BC).

Results/Lessons Learned: There were several important findings based on the evaluation of the PS+BS to create a thinner cap. While the PS+BC had the lowest raw material cost of all options evaluated, it had the highest overall in-place cost, due to the labor required to mix and place the material, and increased geocell costs. The lowest overall in-place cost is for the AG+BC, which also has the advantages of being able to be placed in the wet, and providing a proven consistency of BC in the cap layer. The increased carbon density compared to the PS+BS also allowed for placement of a much thinner cap, reducing the material costs for geocell and lowering the impact of the cap on the river flow geometry. The assessment and outcome of several phases of remediation demonstrate the importance of revisiting assumptions and approaches in an adaptive management framework during a long-term, multi-phased remediation, to ensure the remedy is optimal.

Engineering Optimization/Validation of In Situ Reactive Cap for TPH-, PCB-, and Hg-Impacted Sediment Site in Southern Coastal Europe

Claudio Sandrone and Andrea Campi (BAW s.r.l., Italy)
Jim Mueller (Provectus Environmental Products, Inc.)

Background/Objectives: In situ sediment capping remediation systems mitigate the environmental impact of resident contaminants. Two general approaches are possible: i) passive capping, which is the deployment of a barrier of material that is relatively impermeable to both the water above and the contaminants below, and ii) active/reactive capping, which exposes contaminants to one or more additives or amendments to address source and impacted porewater as it migrates through the treatment area. The choice of approach depends on a wide variety of site-specific issues. One resulting complication of any sediment capping or the addition of reactive reagent is that the implementation/construction processes themselves typically create an initial spike of methanogenic activities because the sediment becomes disturbed and available carbon sources are more rapidly consumed. A second methane spike can occur later as oxygen is depleted from the remediation site, thus shifting the balance between aerobic biodegradation and anaerobic degradation in favor of the methanogenic anaerobes. These can have significant, negative consequences such as: i) methylation of heavy metals increasing their toxicity and mobility, and ii) induced contaminant migration via ebullition.

Approach/Activities: Provect-CH4® is a proprietary amendment for environmental remediation applications that effectively inhibit methanogens while permitting other biodegradation processes to occur. These antimethanogenic reagents (AMRs) have been combined with AquaBlok®/AquaGate® technologies to yield composite particles containing an aggregate core that is layered with reactive amendment materials and deployed through a water column over a contaminated site. When applied in situ the resulting permeable reactive cap simultaneously treats contaminants while controlling methane production, which addresses both ebullition of gasses and methylation of heavy metals.

Results/Lessons Learned: Marine sediment at an industrial site in southern coastal Europe is impacted by elevated concentrations of petroleum hydrocarbons, PCB, and mercury (along with other heavy metals). Conceptual remedial designs entail a combination of dredging, capping and natural attenuation based on contaminant type and concentration. Laboratory tests were conducted to evaluate the effectiveness AquaGate as an in situ capping technology and delivery vehicle for various amendments to yield effective treatment. Columns were prepared with marine sediments and sea water collected from an area of interest. Above the marine sediments a sequence of different layers were positioned to simulate the installation of a horizontal permeable, reactive cap with different combinations of AquaGate, AquaGate+CH4 (with methanogen inhibitors), AquaGate+ZVI (with zero valent iron), and AquaGate+PAC (with fine-grained activated carbon). Monitoring of concentrations in column effluents and sediments highlighted the reduction of the contamination, with a clear correlation associated between the composition of the layer placed in the columns and effectiveness. Design and installation options for field -scale (pilot) application will be presented.

In Situ Capping of Sweden's Fiberbanks: Will Remedies Established for Minerogenic Sediments Also ”Work” on These Organic-Rich Sediments?

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Background/Objectives: Since the early 1800s, Sweden's paper and pulp industry has made significant contributions to regional and national economies, but a legacy of their past activities threatens the environment. Prior to regulatory requirements, factories discharged untreated wood-fiber waste along with processing chemicals (including PCBs, PAHs, dioxins, metals and metalloids) into surface waters. The material plus bound contaminants settled and accumulated to create ”fiberbank deposits”. These organic rich deposits, which also occur in other countries, are found in many Swedish counties, and efforts to characterize their extent and other in situ properties are ongoing. Risk assessments are still being conducted and results will likely indicate unacceptable risks occur at many fiberbank sites, risks that will need to be managed. Fiberbank remediation is in its infancy worldwide, and it is unknown if already internationally-established in situ sediment remedies can also be effectively applied to manage risks associated with fiberbank sediments. Certain inherent characteristics of these anthropogenic deposits (including relatively high gas production, low bearing strength, and low geotechnical stability) may differ substantially from ”typical” mineral-based (minerogenic) contaminate sediments, perhaps to the point that in situ capping remedies developed and used for decades on minerogenic sediments may not be directly applicable for also managing fiberbank sediments. To that end, a three-year research project called FIBREM (funded by VINNOVA) is underway to evaluate, first at laboratory scale, the applicability of established in situ capping remedies for managing risks associated with fiberbank sediments.

Approach/Activities: Tests using transparent columns and tanks of different dimensions have been (and are being) conducted to evaluate the effectiveness of selected in situ capping remedies in meeting typical cap-performance objectives, including physical and chemical contaminant isolation. As a critical precursor for meeting such objectives, the geotechnical stability of capped fiberbank sediment, including on slopes, is also investigated.

Results/Lessons Learned: Testing to date has involved constructing conventional granular caps at different thicknesses (5, 15, 30 cm) overtop two different types of fiberbank sediment (finer versus coarser [chippy] particle-sized wood fibers). Early on, it became clear high sediment-gas production at room temperature required all testing to be conducted at significantly colder temperatures (at or near 4 °C) more representative of in situ field conditions. Testing continues, but some noteworthy observations (visual, physical) from testing in 10 cm diameter columns include: (a) gas production is highly temperature dependent, as noted above, (b) both sediment types produce significant amounts of gas (CH4, CO2, H2S) at the colder temperatures, both before and after capping, (c) consolidation-induced porewater advection seems to be enhanced or accelerated by sediment gas formation and ebullition; gases replace porewaters in sediment pore spaces then essentially ”push” the waters upward along with and/or ahead of the migrating gas front, (d) this mechanism for gas-facilitated porewater transport seems especially pronounced when capping the finer sediment, and (e) gas migration eventually results in porewater transfer into and through caps. Overall, results to-date collectively imply gas-facilitated contaminant transport in capped fiberbank sediments may be at least as important as diffusive and advective transport mechanisms. In an effort to confirm such implications, follow-up testing in much larger (40 cm diameter) columns will include chemical testing to estimate contaminant fluxes before, during, and after capping.

Investigation and Design Considerations for Active Harbors with Contaminated Sediments

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Background/Objectives: The presence of contaminated sediments creates a management challenge for active harbors and marinas. Several sites in San Francisco Bay, including a recreational marina and a ferry landing, are currently in various stages of investigation, design, environmental review and project permitting. The challenges are technical in terms of site investigation, project design, and regulatory approvals, but also create long-term operational controls and management, monitoring and maintenance.

Approach/Activities: Four topic areas will be discussed: site characterization, engineering evaluations and design, environmental review and agency permitting, and long-term management and maintenance considerations. The site characterization approach at an active harbor needs to include the typical data quality objectives to define the area of remediation (dredging capping, or other) but also included the collection of data to assess the feasibility of dredging to remove all contaminated sediment vs placement of a cap and additional data needed to evaluate and design the cap (e.g., post-cap z layer for breakthrough analysis and other important parameters such as upwelling velocity and geotechnical data). Additional data and evaluations are necessary to assess factors that include long-term stability, wave and vessel scour potential, recontamination potential, and dredge residuals among others. As part of the remedial alternatives evaluation, there may be a need to consider reconfiguration of the harbor or berths (e.g., berth depth, location, etc.) and/or changes in uses and usage patterns to minimize operational impacts to the cap and facilitate future maintenance and long-term effectiveness of the remedy. Special considerations during environmental review and permitting include impacts of the quantity and types of fill, habitat alterations, and related mitigation requirements. Long-term performance monitoring and maintenance needs to ensure stability and integrity of the remedy (e.g., protection of a cap) as well as the ability to cost-effectively operate within the harbor. An important post operational challenge is how to effectively conduct future maintenance dredging of the harbor without impacting the sediment cap.

Results/Lessons Learned: The presentation will review the approach and results of evaluations described above for two harbors: (1) a recreational marina where the configuration and usage of the marina were redesigned along with a plan for dredging and capping, and (2) a newly planned ferry landing where scour analysis, chemical breakthrough, sediment transport and recontamination potential were assessed to address long term stability and performance of a cap over a portion of the project dredge footprint.

Pacific Meat Sediment Remedy Leads to Evaluation of Columbia Slough Cleanup by a Presumptive Remedy

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Background/Objectives: The Columbia Slough (Slough) is an approximately 31-mile urbanized waterway located in Portland, Oregon. Sediment in the Columbia Slough waterway has been contaminated with a variety of hazardous substances such as PCBs, pesticides and metals over the past 100 years by industrial, commercial, and agricultural facilities. Pacific Meats is a former industrial facility located along the Slough where PCB transformer recycling occurred. Site soils containing PCBs historically discharged through several private stormwater outfalls to the Slough. In 2015, baseline testing was conducted at Pacific Meats, followed by a PCB sediment cleanup pilot study. The pilot study consisted of placing two different types of activated carbon (AC) amendment caps across two 20,000 square foot sections of PCB-impacted sediment. Baseline and follow-up pore water and sediment data were collected to evaluate the performance of the AC caps and to assess the bioavailability of the PCBs. DEQ contracted with state contractors and with Texas Tech University to execute the pilot study at the Pacific Meats site. The data collected, including baseline and post-construction porewater and bulk sediment sampling, showed an overall 90 percent reduction of porewater concentrations, 1-year after the implementation of the AC caps. The immediate success of the pilot study is being considered for the permanent cleanup action for the Site. DEQ's goal is to use AC as a presumptive remedial technology for addressing PCB hot spots throughout the Slough as a way to streamline the remedial action implementation, and reduce the implementation costs and timeline.

Approach/Activities: Other key data factors will be evaluated as the next step towards streamlining to approach to cleaning up the Columbia Slough. Key data factors, including the Site-specific partitioning rates and resulting pore-water concentration ranges for the PCBs, the expected absorption capacity and longevity of AC capped areas, how the remedial action addressed other co-mingled constituents, such as metals and polycyclic aromatic hydrocarbons will be evaluated. The key factors at the Pacific Meats site will be compared to three other high priority PCB-impacted sediment sites within the Columbia Slough. The data comparisons provide a basis to evaluate whether AC capping can be implemented immediately as a presumptive remedy, without conducting extensive investigations, and only using a few key pieces of information to determine which Sites might qualify for an equivalent cleanup action within the Slough. Unknowns and challenges to implementing a streamlined remedy at each of the three additional project sites will also be explored.

Results/Lessons Learned: The results at Pacific Meat provide the basis to develop a decision framework for a larger-scale application of the remedial approach at other, similar Slough sites. The application of a presumptive remedy within the Slough reduces the need for extensive data studies and achieving an immediate reduction of risk to receptors, thereby reducing the overall time and cost of the larger scale Columbia Slough cleanup.

Remediation of a Former Oil Well, Leaking into a Freshwater Lake

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Background/Objectives: A light non-aqueous phase liquid (LNAPL), consisting of weathered crude-oil, had been seeping through the sediment, causing extensive sheening on a tributary to Bear Lake known as the Fenner's Ditch canal ("the Site:"). The sheening had been documented on Fenner's Ditch as early as 1978. The presence of this LNAPL sheen was impacting the local ecosystem and preventing local home owners from enjoying the benefits of the natural resources adjacent to their properties. On a broader watershed perspective, Fenner's Ditch is listed as a beneficial use impairment (BUI) for degraded aesthetics in the Muskegon Lake Area of Concern (AOC), and that the remedy will support the removal of this BUI.

Approach/Activities: While the actual source of the venting LNAPL was unknown, previous investigators had surmised that the source is a historic oil well formerly known as the Doll Damm #4, which had been reported as abandoned in 1931. Venting may be occurring related to repressurization of the inactive Muskegon Oil field, and later modifications/dredging in Fenner's Ditch might have further exacerbated a preferential pathway for vertical migration of oil to the surface water. An investigation performed in 2010 indicated that the oil was migrating upward from depth and "daylighting" at a near-shore venting location. Later, in November 2016, TRC conducted a focused Remedial Investigation (RI) of the historical oil well, which included the investigation of the subsurface using both high resolution site characterization ("HRSC", i.e., optical imaging profiler) coupled with traditional soil and groundwater sampling methods. Work was performed both in the canal (via barge) and on the adjacent upland. The focused RI provided the necessary additional information on extents and provided analytical data to support final remedy selection. Based on the results of the RI, in January 2016 TRC, EPA and Michigan Department of Environmental Quality (MDEQ) completed a Focused Feasibility Study and selected the preferred remedy, an innovative capping system to contain and capture the NAPL. In 2017 the remedy was designed, and during the summer of 2018 the remedy was constructed.

Results/Lessons Learned: To address the continuing release of LNAPL to surface water, TRC designed and oversaw the installation of an innovative capping system with passive recovery captures LNAPL moving upward due to buoyant forces, as well as ebullition-facilitated transport. The basis of this design incorporated the results of investigations and bench-scale tests completed in 2017 using a Site-surrogate LNAPL, which were designed to evaluate LNAPL mobility, geometries, and collection within the capping system. The project was completed within five weeks in summer of 2018, and after a monitoring period, the cap and trap system has been shown to be effective. Field monitoring parameters (e.g., LNAPL thickness, methane and CO_2 measurements) indicate that the LNAPL is being contained and natural degradation of the oil is occurring within the system, as designed. The canal and shoreline at Fenner's Ditch has been restored and the community is able to enjoy this natural resource.

Use of Dredged Materials for Contaminated Sediment Source Control

David W. Moore, Damarys Acevedo, Dave Perkey, Dan Farrar, Jim Biedenbach, Steve Larson, Paul Schroeder, Joe Gailani, and Gunther Rosen

Background/Objectives: Navigation channels, turning basins, and other US Army Corps of Engineers (USACE) managed navigation infrastructure often become repositories for contaminated sediment originating from offsite sources. It has been estimated that about 10% of the material that the USACE dredges annually is contaminated to the extent that it requires additional and more costly management (e.g., re-handling and placement in engineered confined disposal facilities). Presence of contaminated sediments constrains dredged material (DM) management options resulting in additional management costs as well as opportunity loss resulting from the inability to beneficially use the material. One potential solution is thin layer placement of clean or perhaps marginally suitable DM to stabilize and isolate contaminated sediment sources preventing further transport and introduction to USACE managed navigation infrastructure. Sediment removed during maintenance dredging programs often has organic carbon content in the 1-2% range (supporting contaminant sequestration) and may be more representative of local substrate occurring at off channel contaminant source areas (facilitating improved recovery of the benthic community). Consequently, DM may represent a better, more cost effective alternative when compared with other traditional source control measures (clean sand, activated carbon, etc.). However, as materials from maintenance dredging are often finer grained it is important to understand the nature and necessity of engineering controls for handling and placement to ensure viability of the approach under a variety of field conditions.

Approach/Activities: The USACE Engineer Research and Development Center (ERDC) conducted a series of laboratory bench-scale studies to better understand behavior and stability of fine grained dredged materials placed as thin layer caps. Five representative capping materials placed as 5-inch layers (based on final estimated consolidation) were evaluated for post-placement stability (measured as critical shear stress) using a sediment erosion flume (SedFlume) coupled with x-ray density scans. Cap treatments assessed included a fine grained (96% fines) DM from Pascagoula, MS, Pascagoula DM with 10% sand added (86% fines), Pascagoula DM with a biopolymer addition (1% by dry weight, sodium alginate), a dried DM from the Waipio upland confined disposal facility in Pearl Harbor, HI (64% fines) and a DM from West Loch Pearl Harbor, HI (72% fines). All caps were placed over a base layer that had consolidated 40 days with representative benthic organisms added (an amphipod and a polychaete). Cap treatments utilizing Pascagoula DM were placed as 200 g/L slurries using a diffuser tube just beneath the water surface. The Waipio material was sprinkled as a dry mixture on top of the water column while the West Loch Pearl Harbor Sediment was placed as a 445 g/L slurry to better represent practical handling/placement strategies under consideration for those materials. Both the Waipio and West Loch materials were also evaluated in a separate parallel US Navy SPAWAR-led field effort evaluating efficacy of these materials in reducing contaminant bioavailability. Stability of cap treatments were assessed at 48 hours, 7 days, and 30 days post -placement.

Results/Lessons Learned: Good survival of representative benthic organisms' post-cap placement suggests organisms are able to tolerate thin layer placement of fine grained materials (>60%) either in the dry or as a wet slurry. Addition of biopolymer substantially reduced TSS during placement in comparison to unamended materials but resulted in elevated BOD and anoxic conditions in the amended treatment. Results of SedFlume analysis are presented and the consequent implications for handling and placement strategies discussed.

Use of Natural Sediments towards Enhanced Monitored Natural Recovery

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Background/Objectives: Conventional isolation capping involves the placement of 1 to 3 m of clean, sandy sediment to securely bury and isolate sediment contaminants. More recently, thin layer (10 to 30 cm) sand treatments have been increasingly employed to accelerate, or rapidly enhance, ongoing natural recovery processes and minimize potential impacts to the aquatic environment that can occur during placement of thicker caps. Thin layer treatments to facilitate natural recovery processes, termed enhanced monitored natural recovery (EMNR), typically involves clean sand, which can still act as an effective isolation barrier in some cases, but has little or no propensity (i.e., carbon, clay, or other materials) to bind contaminants. In cases where physical disturbance and/or bioturbation mix the sand with the underlying sediment, these sand layers only serve to dilute the bulk concentrations, but have limited influence on exposure and bioavailability. In contrast to conventional thin-layer sand capping approaches, thin-layer treatments comprised of natural sediment that contains fines and organic carbon have the potential for increased contaminant binding capacity, and thus could result in improved longterm outcomes compared with conventional EMNR, while also providing a potential re-use opportunity for clean dredge material. The use of these natural sediments that contain fine grained material and/or organic carbon has been termed “true EMNR” (tEMNR) because of the use of material that is more closely matched to what would truly deposit at the site. tEMNR is currently being evaluated at a mesocosm scale by the Navy at Pearl Harbor Naval Shipyard, and in benchtop evaluations by the US Army Corps of Engineers and Geosyntec.

Approach/Activities: This presentation will summarize recent US Navy and Army investments towards the practical application of tEMNR using clean dredge materials (DM) as a potentially cost-effective and beneficial use alternative to sand for meeting site-specific remedial goals. The approach focuses on both development of a literature-based comparative between EMNR and tEMNR methods and two mesocosm scale assessments, one at a creek mouth site at Naval Base San Diego, and one adjacent to Pearl Harbor Naval Shipyard in Pearl Harbor, Hawaii. The approach integrates results from these recently completed and current efforts including:

1) Comparative analysis between EMNR and tEMNR including benefits with respect to confined disposal facility storage space, costs, and reuse potential;
2) The in situ mesocosm-scale evaluations conducted in San Diego and Pearl Harbor;
3) Laboratory assessments examining handling and placement strategies to ensure stability of placed sediments and reduce benthic community impacts;
4) Challenges and considerations towards regulatory acceptance

Results/Lessons Learned: This presentation will focus on addressing the results associated with the multiple lines of evidence presented above. Overview of a draft-Navy technical document comparing EMNR with tEMNR will be followed by empirical results associated with field studies conducted in San Diego and Pearl Harbor, which currently point to enhancement of the benthic community and reduced PCB availability, respectively. Laboratory evaluations suggest that use of natural sediments result in reduced impacts to the benthic community in comparison to sand. Challenges associated with the use of potentially finer-grained natural sediments with detectable concentrations of contaminants of concern will be discussed.

AquaBlok-Featured Poster Presentations

Activated Carbon Placement on the Lower Columbia Slough

Carmen Owens and Adam Reese (Apex Companies, LLC)
Jennifer Sutter (Oregon DEQ)

Background/Objectives: The Columbia Slough, located in Portland, Oregon, comprises a 19-mile main channel that parallels the Columbia River, with approximately 12 additional miles of secondary waterways which drain over 32,700 acres of land. Much of the land use immediately adjacent to the Slough is industrial. Stormwater runoff and historical discharges have contaminated sediment and fish tissue throughout the waterway. PCBs have been found at elevated concentrations in sediments and fish tissue, and represent the primary risk driver in the Slough.

Sediment adjacent to the former Pacific Meats site is one of the polychlorinated biphenyl (PCB) hot spots targeted for remedial action in the Lower Columbia Slough. Significantly contaminated sediment extends over an approximately 60,000 square foot area adjacent to three stormwater outfalls. Because this hot spot area has relatively consistent PCB concentrations and sediment conditions over a large area, it provides a uniquely suitable location to compare approaches for reducing the bioavailability of PCBs to aquatic receptors. Apex implemented the pilot study/hot spot cleanup on behalf of the Oregon Department of Environmental Quality (DEQ). This pilot study/ consisted of placing two types of activated carbon (AC) products in separate cells within the study area. This presentation summarizes the unique challenges of the permitting required for this project, as well as strategies used to overcome design and implementation changes.

Approach/Activities: The two AC products were to be delivered to the Slough within the application area at the design-specified thickness, accounting for variable placement conditions and drift during delivery. Challenges associated with the AC placement were significant and included:

- Very thin design amendment layer thickness;
- Permit-limited in-water work window;
- Limited over-water access due to low water conditions during in-water work window;
- Daily tidal fluctuations;
- Limited upland access and bank use restrictions on both sides of the waterway; and
- Distributing two different AC products within the application area at the design-specified thickness, accounting for variable placement conditions and drift during delivery.

Results/Lessons Learned: Multiple project design iterations were necessary prior to successful implementation. Hurdles encountered included limited contractor interest due to unpredictable conditions and financial risk associated with project access uncertainties, as well as challenges in finding an application method that ensured accurate layer thickness.

Apex and DEQ overcame these implementation challenges by working with adjacent property owners to create temporary upland access areas; employing low water access techniques, including inflatables, kayaks, air boats, and floating docks; and applying innovative value-engineered design solutions, modifying AC application techniques to include the use of landscape-product blowers and telebelt trucks to achieve project quality assurance goals while avoiding disturbance of the Slough bank.

The result of this project was the successful application of activated carbon to the sediment surface at this PCB contaminated site. The unique implementation challenges of applying activated carbon in the Columbia Slough were overcome, and lessons were learned that can be applied to other similar sites.

Post-carbon sampling showed an 86% and 95% reduction of total PCBs in porewater in the Sedimite™ and AuqaGate+PAC® cells respectively. Visual mixing was evident in the AquaGate+PAC cell, but could not be seen in the Sedimite cell. However, both cells show significant reduction in PCB porewater concentrations.

Active Sediment Tracing Using Dual Signature Tracers: The Findings of an ESTCP Demonstration Program

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Background/Objectives: Contaminated sediments are found in numerous ports and harbor environments worldwide, where they comprise legacy deposits from historical industrial activities as well as more recent deposits from on-going contamination. In complex industrial settings, there persists a great interest in determining the source, and the spatiotemporal distribution of contaminated sediments to areas of the depositional environment to assist or inform mitigation/remediation strategies. As part of an ESTCP demonstration program, the performance of dual signature sediment tracers and the applied fluorescent, magnetic active sediment tracing (particle tracking) technique was evaluated via a series of performance objectives. The technique/technology was critically assessed in terms of hydraulic matching, the efficacy of innovative sampling technologies and analytical processes, data analysis and interpretation, ease of use and environmental considerations. Evidence to meet these performance objectives were garnered through laboratory testing and two field case studies. The first field study was designed to assess/monitor the near and far field impact of an unregulated point source of contamination on marine waters at San Diego Naval Base. The second field study assessed the stability against wave and tidal erosion of an activated carbon amendment cap deployed at Hunters Point Shipyard, San Francisco.

Approach/Activities: The determination of sediment transport pathways and the assessment of source – sink relationships, remains a complex challenge in nearshore coastal and estuarine environments, principally as it is difficult to distinguish between the sediment in transit and the native sediment load. An active sediment tracing technique provides a field methodology to monitor suspended and bed load transport. The technique is usefully applied to elucidate sediment/particulate transport pathways and investigate the sedimentation pattern of solids occurring variously across space, and through time. The technique uses geological analogues called tracers, which are natural or artificial materials ‘tagged’ or ‘marked’ with an identifiable signature. A robust sediment tracer must closely match the physical and hydraulic properties of the target sediments and/or particulates of interest, remain uniquely identifiable within the native sediment load following introduction to the environment and not impact upon natural sediment transport processes occurring within the system.

Results/Lessons Learned: The laboratory studies performed demonstrated dual signature tracer particles are an effective, tracer material. In addition, the two field studies demonstrated the utility of the fluorescent, magnetic tracing technique. The findings of the demonstration program resulted in the development of a standard operating procedure (or methodological framework) for the application of active sediment tracers at DoD sites. In addition, the program highlighted requirements for future research in the field of active sediment tracing, which included the development of biodegradable sediment tracer materials and methodologies to monitor the transport of fine silts and clays, which have been progressed since project completion.

Combining Remedies for Contaminated Sediment at Southeast Loch, Pearl Harbor, Hawaii

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Background/Objectives: Sediment contamination has been identified in six areas or decision units (DUs) at the Pearl Harbor Sediment site. The majority of the contamination is primarily located within the Southeast Loch portion of the harbor. The feasibility study (FS) developed and evaluated a total of 13 potential alternatives for Southeast Loch. Seven of the 13 alternatives were retained in the FS for detailed and comparative analysis based on the preliminary screening for effectiveness, implementability and cost. The FS identified a preferred remedy for Southeast Loch that included a combination of focused dredging, enhanced natural recovery (ENR), monitored natural recovery (MNR), and activated carbon (AC) amendment. Key features identified in the Southeast Loch DU are: chemicals of concern (COCs) that include polychlorinated biphenyls (PCBs) and metals (including mercury); high maximum COC concentrations (> 10× site-specific preliminary remediation goals); relatively deep contamination (> 8 feet), deep water (30–60 feet), co-location with a large maintenance dredging area, and potential for recontamination from maintenance dredging, stormwater runoff, and erosion of contaminated sediments from steep slopes under piers. The objective of combining multiple technologies into a remedial alternative is to incorporate ongoing natural recovery processes along with active remediation to develop a remedy that is green, resilient, and sustainable, while still maintaining acceptable risk protectiveness.

Approach/Activities: Remedial alternatives (i.e., dredging, capping, ENR, MNR, and AC) comprised of multiple technologies were developed, and designed to work as an integrated remedy to achieve the remedial goals within reasonable timeframes by assigning specific and appropriate technologies to the DUs based on the level of sediment contamination. With these multi-component remedial alternatives, there is no single component of the alternatives that is considered the “primary” approach. Each individual element of the multi-component remedial alternative is equally important and necessary to achieve the remedial goals.

Results/Lessons Learned: The selected remedial alternative for Southeast Loch at the Pearl Harbor Sediment site combines active remedial technology (focused dredging) with natural recovery based remedies (ENR, MNR, and in situ treatment with AC amendment). The combined multi-technology alternative achieves a similar level of protectiveness by achieving remediation goals in 20 years at a significantly lower cost than comprehensive dredging, and is well received by regulatory agencies (Environmental Protection Agency and State of Hawaii Department of Health).

Construction Quality Assurance during Environmental Dredging and Capping Projects

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Background/Objectives: Barr provided construction quality assurance (CQA) during an environmental dredging and capping project conducted at a former manufactured gas plant (MGP) site in Flint, Michigan during the 2017 construction season. The project was completed on a 1,700 foot reach of river flowing through an urban area. A high hazard dam defined the downstream end of the work zone. The main objectives of the remediation were to remove MGP-related impacts in the riverbed and riverbanks, install an impermeable cap along the riverbed to prevent groundwater from venting into the river, restore the riverbed and riverbanks to meet flood stage requirements, and minimize secondary impacts to the public.

Approach/Activities: The project included removal of approximately 5 feet of sediment then placement of a multilayered cap. The cap layers, beginning with the lowest layer, consisted of a sand foundation, Blended Barrier™ (a mixture of AquaBlok® and gravel), cover sand, gravel, and rip rap. Site-specific modifications to the cap were designed around existing structures and other areas. Implementation of the dredging and capping required construction quality monitoring to document that the design objectives of the project were met. Specific construction quality monitoring activities included:

- Survey verification, including defining the requirements for collecting survey points at planned locations for each cap layer to verify the thickness of each layer, survey tolerances, and tabulations developed for rapid approval in the field
- Verification of Blended Barrier™ mixing, including documenting integrity of the material and correct mixture ratios prior to placing the material
- Management of the leading edge of the Blended Barrier™ layer, including field evaluation of cap material drift during placement and specific surveying and cover requirements for the Blended Barrier™ layer
- Structural monitoring of existing infrastructure in the work area, including using an automated total station programmed to regularly collect survey data from prisms installed on infrastructure throughout the work area
- Geotechnical monitoring, including assessment of dredged material and surveying of the subsurface along the riverbanks
- Implementation of post construction monitoring devices, including vibrating wire piezometers installed to assess groundwater pressures

Results/Lessons Learned: Field factors can affect construction quality if appropriate CQA is not conducted. For each construction quality monitoring activity, the monitoring data and the evaluation of data influenced construction and informed future decisions. Monitoring results were used to verify that specifications were being met and construction controls were performing effectively. Data were used to adjust specifications in the field as needed. The collected data also improved communication with project stakeholders.

Evaluation of Porewater Reductions Due to Carbon Placement via Sedimite™ and AquaGate+® at a Contaminated Sediment Site

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Background/Objectives: Contaminant flux and availability in impacted sediments can be significantly reduced with activated carbon (AC) amendment technology. AC is more often placed as a composite material to aid in settling and retention at the sediment surface. A demonstration of two such composite materials, Sedimite and AquaGate, was conducted in open water near Hunters Point Naval Shipyard (HPNS), California. The objective of this study was to evaluate changes in freely dissolved concentration (C_{free}) of polychlorinated biphenyls (PCBs) in the surface sediments and in deeper layers (i.e., 30 cm below the sediment surface) by in situ passive sampling using polydimethylsiloxane (PDMS) coated fibers. Bioaccumulation reductions in bivalves exposed to AC materials was also assessed and compared to co-deployed passive samplers.

Approach/Activities: In situ monitoring of C_{free} with passive samplers was conducted before sediment amendment and up to 26 months following AC placement. Passive samplers with 34.5 µm PDMS coating were preloaded with a wide array of $^{13}C_{12}$ PCB congeners as performance reference compounds (PRCs). PDMS samplers were inserted to unshielded holders, attached to a tripod frame and embedded vertically 30 cm into the sediment at 20 sampling locations. After 28 days the fibers were retrieved, sectioned into a 1-6, 6-11, 11-16 and 21-26 cm segments below the sediment surface and analyzed for PRCs and 111 PCB congeners. C_{free} was calculated from the accumulated PCBs in the passive sampler and the sampler-water partition coefficients.

Results/Lessons Learned: Baseline sampling showed uniform C_{free} across the site with lower concentrations in the near surface versus the deeper layers due to exchange with the overlying water from the shallower zone. Post-placement monitoring showed an 83% decrease of C_{free} after 8 months in the surficial layer with further reductions reaching 90% after 26 months. Smaller but significant reductions in C_{free} was also noted at the deeper depths, which continued to improve with time in line with AC mixing. Bioaccumulation of PCBs in clams (*Macoma Nasuta*) showed very good agreement (i.e., factor of 2-5) with predictions from measured C_{free} using equilibrium partition theory. The presentation provides information on the effectiveness of AC by means of C_{free} measurements and discusses the advancement of AC technology based on results from this demonstration as well as earlier AC studies conducted at HPNS site.

In Situ Passive Sampling for the Evaluation of Carbon Amendment Performance

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Background/Objectives: In 2006, the Portland District of the U.S. Army Corps of Engineers collected sediment samples from varying depths near a portion of the Lower Columbia Slough at the Pacific Meats cleanup site. Sediment samples presented polychlorinated biphenyl (PCB) concentrations up to 2,450 μg kg. The PCB concentrations were found to be higher in the Lower Slough than in other reaches and were detected more consistently within the more industrial and commercial development of this area.

Approach/Activities: In 2015, Texas Tech University performed a baseline study by evaluating in-situ and ex-situ porewater sample analyses at 20 locations at two depth intervals (0-13.5 cm and 13.5-29 cm). In- itu sampling was performed by solid-phase microextraction (SPME) passive sampling using polydimethylsiloxane (PDMS) coating on a glass fiber to act as a sorbent for PCBs. In 2017, a thin cap of activated carbon (AC) was placed across two separate plots (East and West). After the placement of AC in two forms, as amendments of Sedimite™ and Aquagate+PAC, the analysis and comparison of pore water concentrations within the 20 approximately identical cap locations across the two plots was determined. SPME samplers were deployed in triplicate in the sediment for 28 days to achieve equilibrium with the contaminants of concern for both the baseline analysis and the carbon amendment results.

Results/Lessons Learned: The reductions from the baseline porewater concentrations ranged from 68 98% in the surficial sediment layer, and a central tendency of 90% reduction in porewater concentrations was presented for both the surface and deeper layer across both AC plots. Environmental drivers are presented as an indicator for the sediment porewater exchange rates and reduction of PCBs throughout the site. When using SPME samplers with PDMS fibers a fractional approach to steady state (*fss*) of the contaminants is determined, using performance reference compounds (PRCs), to evaluate the transport processes within the site. The *fss* was determined from the 2015 study and is compared to the 2017 post carbon amendment sampling event. The carbon placement influences the apparent approach to steady state as indicated by performance reference compounds. Various means of correcting the apparent approach to steady state will be discussed.

Integration of Remediation, Restoration and Revitalization Objectives: A Case Study on the Mercury-Impacted South River, Virginia

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Background/Objectives: Historically released mercury (Hg) from a textile manufacturing facility (Site) has accumulated in depositional areas on the banks of the South River, Virginia. Introduction of legacy Hg impacted soils to the South River through bank erosion is the most significant source of Hg loading to the system. Phase 1 Interim Measures with the objective of reducing or eliminating this source of loading are being conducted stepwise. The strategy is to progress from upstream to downstream for higher loading locations in the first two river miles downstream of the Site. This phase of the program includes stabilization of approximately 6,000 linear feet of eroding riverbanks across several bank management areas (BMAs) with both public and private land ownership.

Approach/Activities: The South River is an important socioeconomic resource for the City of Waynesboro and is considered an integral part of the City's revitalization vision and redevelopment plan. In 2001, the City adopted a city-wide Greenway plan that follows the river course. To date, 1.2 miles of the South River Greenway has been constructed and is utilized for a variety of recreation and river access. Portions of the Greenway are collocated with bank areas targeted for remediation. Open communication with multiple stakeholder groups during the remedial design process identified a number of factors that were considered and accommodated in the design of each project. These design modifications were described in a presentation at the previous 2017 Battelle Conference. This update provides the status of the program and relationships that have matured over the past two years, as more complex and broad scale interests associated with the Greenway have been incorporated. The development of remedial designs that balance stakeholder values while accomplishing remedial action objectives is crucial to achieving successful project outcomes for all.

Results/Lessons Learned: As each project has been completed, relationships built upon mutual trust with local stakeholders, permitting authorities and the public have continued to grow and influence more efficient and positive outcomes of each successive stage. This presentation will highlight how the completed and on going South River remedial designs are a key aspect of the local revitalization vision, and incorporate stakeholder preferences associated with the City of Waynesboro Greenway in order to optimize project outcomes.

Willamette River Downtown Reach Remediation at Two Sites: Challenges and Lessons Learned for Future Actions

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Background/Objectives: The Downtown Reach of the Willamette River in Portland Oregon has been heavily developed and modified during the past 150 years. The Downtown Reach is the four-mile stretch of river directly upstream of the Portland Harbor Superfund Site. In 2008, the Oregon Department of Environmental Quality (DEQ) and other partners initiated a study of sediment quality in the Downtown Reach. Portland General Electric (PGE) worked with DEQ during this effort; culminating in the Record of Decision issued for two PGE sites in 2015 that specified the installation of two one-acre sediment isolation caps at River Miles 13.1 and 13.5. Design, permitting and construction were completed from 2015 to 2017. These projects demonstrate what is really needed to design, permit and construct sediment caps in an active urban waterway and highlight applicable challenges and lessons learned that will impact future remedial actions within Portland Harbor.

Approach/Activities: PGE investigated two areas in the Willamette River, each several acres. Through investigation and design, the footprints identified for capping were reduced to a little over one acre at each site. For implementation purposes, construction was performed over multiple years, rather than constructing multiple caps in the same year. Each cap had its own set of technical and regulatory challenges, with design and permitting performed separately. During design for one area, a 20-foot deep scour hole from a water line leak was found which exposed and undermined four high voltage submarine cables. One cap had to be redesigned due to cap material not meeting specification, resulting in one-third of the cap being supplemented with activated carbon. Overall, 230 tons of debris were removed from the river and roughly 24,000 cubic yards of sand and gravel were placed to cap 2.5 acres.

Results/Lessons Learned: Many lessons learned and challenges were encountered during implementation of these two smaller-scale projects. Challenges, similar in nature but of much greater size and complexity, can be expected during the significantly larger Portland Harbor cleanup. Some issues to consider during Portland Harbor remedial design and construction include the following:

- Balancing cap permanence (armor stone) against habitat requirements for permitting.
- Working around existing structures to allow for ongoing and future public and private use.
- Design and construction should allow for adaptive management; new issues and unknowns will come up. Change is difficult to avoid so prepare for it.
- Administrative portion of work (permitting, easements, regulatory orders) takes time, patience, and persistence.
- Working in the fish window puts importance and limitations on schedule.
- Many stakeholders to balance, often with conflicting objectives.
- An approach for one project may not work for another.
- Need a good team to deliver and work through issues.