FULL-DEPTH, BOTTOM-SEALED FILTER BARRIERS AND THEIR PLACE IN COMPARISON WITH OTHER MEANS OF SEDIMENT/TURBIDITY CONTROL IN DREDGING PROJECTS

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ABSTRACT

For most channel dredging and near-shore sediment removal situations, suspended sediment containment options considered for in-water work have been limited to either silt curtains (also referred to as turbidity barriers,) sheet pile walls or cofferdams. Bottom-sealed, geotextile filter barriers have often not been considered, primarily because the newer technology has not yet been utilized on a widespread basis. This paper describes the technology behind bottom-sealed filter barriers and the reasons for their use, and illustrates their demonstrated potential for cost-effectively achieving positive results. Several recent filter barrier applications are incorporated into the presentation as examples.

As a basis to compare and consider bottom-sealed filter barriers in the context of the historically common technologies for turbidity control and/or sediment containment, i.e., silt curtains and sheet pile walls, the feasibility, effectiveness and cost aspects of these technologies are briefly discussed based on studies and applications described in the literature.

For more challenging projects where silt curtains were not considered to be adequately effective, and sheet pile walls or cofferdams appeared to be the only technology considered to be adequately effective, it has nevertheless been rare that bottom-sealed filter barrier technology be considered as an alternative. However, several recent filter barrier projects demonstrate the effectiveness of this technology as an alternative to sheet pile walls. These projects include: (1) nearshore contaminated sediment removal in a Maine tidal river channel with proximal barge and tug traffic; (2) a challenging requirement of 0 NTU turbidity increase into the waters of Biscayne Bay, Florida; (3) a contaminated sediment removal in a Vancouver Harbor, British Columbia dry dock for which the filter barrier needed to be attached to the top of a sheet pile wall and maintain durability and effectiveness throughout the large tide range; and (4) a bridge pier removal and dredging project in Long Beach/Los Angeles Harbor in southern California. For none of these projects would a standard silt curtain have been effective in achieving required results.

The authors discuss design, operations and cost factors related to deployment of bottom-sealed filter barriers for various dredge operation scenarios that might otherwise call for the use of sheet pile walls to achieve required containment objectives.

Keywords: Dredging, contaminated sediment, water quality, silt curtain, sheet pile.

INTRODUCTION

For most channel dredging and near-shore sediment removal situations, suspended sediment containment options considered for in-water work have been limited to either silt curtains (SCs, also referred to as turbidity barriers,) sheet pile walls (SPWs) or SPW cofferdams (the distinction being that SPW cofferdams are adequately sealed and designed to be de-watered). Bottom-sealed, geotextile filter barriers (bottom-sealed FBs*)* have often not been considered. This paper focuses on their demonstrated potential for cost-effectively achieving positive results using bottom-sealed FBs. Several recent bottom-sealed FB applications are incorporated as examples.

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This paper is organized as follows:

- Section 1 presents a brief overview of bottom-sealed FB technology
- Section 2 provides several examples of bottom-sealed FBs and their performance based on recent applications of the technology
- Section 3 and 4 briefly address situations where bottom-sealed FBs might be utlized in lieu of SCs or SPWs or provide containment where SCs or SPW cofferdams may be infeasible but turbidity control is important.

The paper concludes with a summary overview of the range of applications for which bottom-sealed FBs may be an appropriate and effective means of sediment/turbidity control. This section adds the consideration of the efficacy of bottom-sealed filter curtains to exclude fish, marine mammals or other biota from the area of disturbance.

1. BOTTOM-SEALED FILTER BARRIER TECHNOLOGY

Bottom-sealed FBs have been used since the late 1990s for a range of applications. Recently, they have been deployed successfully for a wide range of sediment control applications, including contaminated sediment removal in tidal environments, applications with turbidity limits of 0 NTUs into an adjacent water body, an application where the barrier had to be designed for attachment on the top of a sheet pile wall terminating at approximately low water in a 4-5 m tidal range, and a large bridge demolition project. Among the many applications to date, challenges posed include: creation and maintenance of a bottom seal, anchoring, robustness and flotation – often all in the face of high-velocity currents, deeper depths, bi-directional currents and significant water elevation changes. Unlike silt curtains, which can "flare" upward in the presence of currents and which allow an accelerated passage of water beneath the curtain, all water entering or exiting bottom-sealed filter barriers must pass through them.

In a similar manner to the silt curtain (*e.g.*, DOT Types 1, 2 and 3,) bottom-sealed filter barrier technology generally incorporates a buoyant hood or collar that prevents water passage over the top of the barrier's curtain. Also similar to a silt curtain, the ends of the filter barrier's curtain prevent water from passing between the barrier and the shoreline, barge, or between the ends of the curtain if it is used as a complete enclosure.

Differences between a silt curtain, or turbidity barrier, and a bottom-sealed filter barrier include:

1. Bottom-sealed FBs extend to the bottom of the water body and maintain a seal with the bottom, regardless of water elevation changes or currents, rather than terminating above the bottom.
2. Bottom-sealed FBs are anchored in place from both the top and the bottom. See Figure 1. At the bottom they are anchored such that they do not move, even with current directional shifts or water elevation changes. Unless held in place with piles, or unless currents are unidirectional, mooring lines extend to anchors on both sides. In contrast, SCs are secured only at the top (the bottom is suspended above the seafloor.)

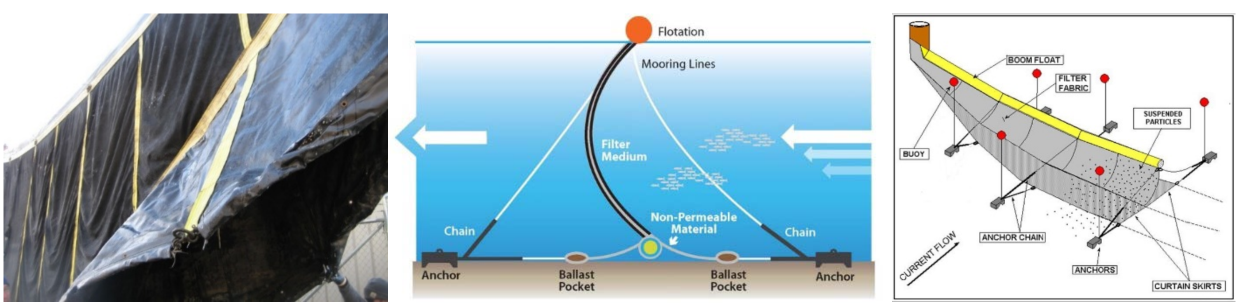

Figure 1. At full depth, bottom "T" skirt seal prevents unfiltered flow.

3. The geotextile curtain matrix of the bottom-sealed FB is permeable, and its composition can be single- or multi-layer. The geotextile composition is specifically selected to function in the project environment, factoring the water body characteristics in addition to design criteria such as specific performance objectives (e.g., turbidity goals, containment of petroleum hydrocarbons or heavy metals.) Often the primary filtering material is a custom-selected non-woven polypropylene. If the barrier must withstand strong loadings, be subject to abrasion or has a requirement for a long duration deployment or for re-use, it is often comprised of a composite of woven

and no-woven geotextiles. The SC extends down through the upper portion of the water column, is generally comprised of a single layer of impermeable geotextile.

4. Bottom-sealed FBs are built to be very robust; they must withstand the strong loads resulting from any water movement, tides or currents. SCs are not built to withstand the same kinds of loads since water moves under them and the same pressures are not imposed. For both technologies, this is manifest in the material weight and strength characteristics as well as in the method of fabrication.
5. Due to the loading considerations discussed above, configuration relative to currents is more important for FBs than for SCs.

The conditions that limit the use of bottom-sealed FBs are fewer than for silt curtains. The important parameters for which adequate understanding is required to determine the design of a bottom-sealed FB include those of the water body characteristics, operational plans and water quality requirements:

1. <u>Water Current: Velocity Magnitude, Direction, Variability</u> – Bottom-sealed FBs have been deployed in canals, rivers and harbors with bi-directional and variable-direction currents with velocities up to approximately 3 fps.
2. <u>Bottom Type and Anchoring</u> – Bottom-sealed FBs have been deployed in soft sediments, sands and cobble-strewn substrates. Anchoring systems have ranged from dead-weight anchors to Danforth-type anchors, helical anchors and piles.
3. <u>Particle Size or Volume of Suspended Sediments</u> – Most challenging are silts and clays, both from containment/filtering perspective and from a possibility of clogging the filtering geotextile. However, most projects involving dredging that require controls involve a large component of these fine sediments and system design has always been able to address this situation. Given the large area of filter material and the barrier’s reductive impact on flow rate, the worst case is likely to be a localized fabric blinding which is not detrimental to overall flow. Whether this situation has occurred is not known, but no system has been rendered ineffective by such loss of permittivity from blinding.
4. <u>Presence of Petroleum Hydrocarbons or Other Chemicals of Concern</u> – Approaches to the presence of petroleum hydrocarbons for different situations have included, when necessary, addition of sorbent boom inside the top of the FB, and in one case involving leaching from a seawall, use of a sacrificial, removable inner oleophilic material. Beyond this, for small releases, the primary geotextile filter layer also is oleophilic.
5. <u>Level of Performance Required</u> – From “no visible turbidity plume” to restricted turbidity or TSS levels within a certain distance of the barrier at multiple depths, all the way to a zero increase in turbidity into adjacent waters, systems have been designed to achieve, and have achieved, required performance.
6. <u>Duration of Operations</u> – If operations will extend into months, or even years, adjustments to the design, including the robustness, specific geotextile layers, the materials used and the barrier construction account for conditions. If a system may have to be deployed through extended periods of high growth of fouling organisms, it may require cleaning. This can be accomplished efficiently with the use of diver- or surface-operated pressure washing, but the geotextile selection and barrier construction must be designed to allow this or the geotextile material may not stand up to the pressure.
7. <u>Concern for the Presence of Important Fish, Invertebrate or Marine Mammal Species</u> – As the barrier-enclosed area is entirely sealed, fish, invertebrates or marine mammals not already within the enclosed area are excluded unless they can pass over the freeboard of the flotation hood. Also, various techniques have been used to deploy the barrier in such a way as to limit entrapped mobile species.

The understanding of bottom-sealed filter barrier technology is best understood by consideration of the project applications that are addressed in the section below.

2. BOTTOM-SEALED FB’S -- RECENT PROJECT EXAMPLES

Four uniquely different projects involving sediment removal that were conducted during 2014-2017 incorporated bottom-sealed FBs. For each of these, either SPWs or silt curtains or both were valid alternatives. The four projects are each briefly summarized below, including: key project and water body parameters; system design; performance vs requirements; and, key differences from use of silt curtains or SPWs.

a. Contaminated Sediment Removal Onshore and Near-Shore Subtidal

In the deepwater port of Portland Harbor, Maine, the site of a former manufactured gas plant was remediated with installation of an impermeable bulkhead to contain a seep area and excavation and stabilization of impacted soil and sediment extending into the subtidal zone. A turbidity containment and fish exclusion barrier was site-specifically designed, constructed and installed as an alternative to a temporary SPW or cofferdam. See Figure 2.

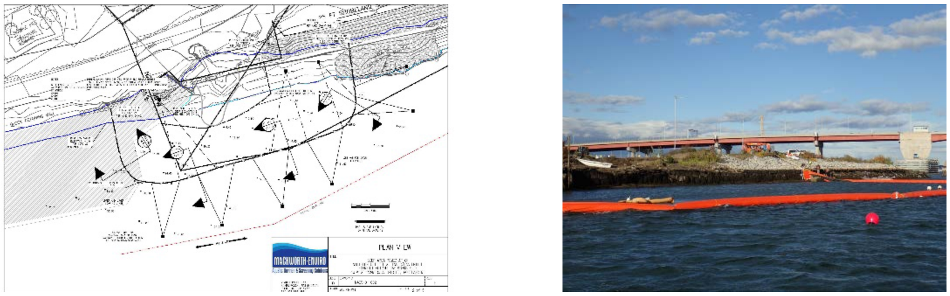

Figure 2. Filter Barrier plan view drawing and photo for Portland, Maine application.

With the large amount of water to pass into and out of the enclosed area, strong tidal currents and large vessel transit in the nearby navigation channel, as well as the concern for winter flounder spawning in close proximity to the dredging, a silt curtain was not an option.

Due to the excessive loading with tidal movement and ship traffic, the barrier was constructed of three layers: two outer layers for strength and durability, and an inner layer to provide the primary filtration of fine sediments. Flotation consisted of 2 lb (0.9 kg) density polystyrene billets, 16 in (40.6 cm) in diameter. The barrier was held in place using helical anchors which were removed upon project completion. The barrier was designed to minimize the number of anchors required. The bottom seal was achieved by incorporating an impermeable "T" bottom skirt with the outer skirt twice the length of the inner skirt. This design allowed sealing during various flow directions. At the end of each skirt a 1/2 in (1.3 cm) ballast chain was installed to ensure the skirt maintained contact with the bottom. Attachment and seals to the shoreline were achieved using a custom vertical T-shaped impermeable piece. This connected to the seawall granite blocks with a combination of 5/8 in (1.6 cm) eye bolts which were epoxied into the blocks and ballast chain. A sorbent boom was installed from shore to shore inside of this turbidity/fish exclusion barrier.

Adjustments to the system, which were implemented early in the deployment, included the addition of a beefed-up shoreline anchor system at one terminus and additional short shoreline barrier attachments to accommodate higher tidal heights. Inspections, including periodic dive inspections, confirmed that the containment barrier was intact and the bottom sealed throughout the project. The turbidity/fish exclusion barrier met all requested objectives, including: 1) prevention of winter flounder or other fish from entering into the remedial construction zone thus providing partial relief from time-of-year restrictions due to spawning; 2) protection of the Fore River waterway from contamination; and 3) substantial cost savings over sediment excavation behind a temporary cofferdam. No exceedances, violations or breaches in the integrity of the barrier occurred after the early steps to improve the seal to the shoreline.

b. Turbidity Control System to Achieve 0 NTU Increase into Adjacent Waters

Dredging of three new tidal creeks into an existing bermed marsh habitat required that turbidity in the adjacent Biscayne Bay was not increased. The environmental mitigation project created fish and crocodile habitat in the Everglades area of southeastern coastal Florida.

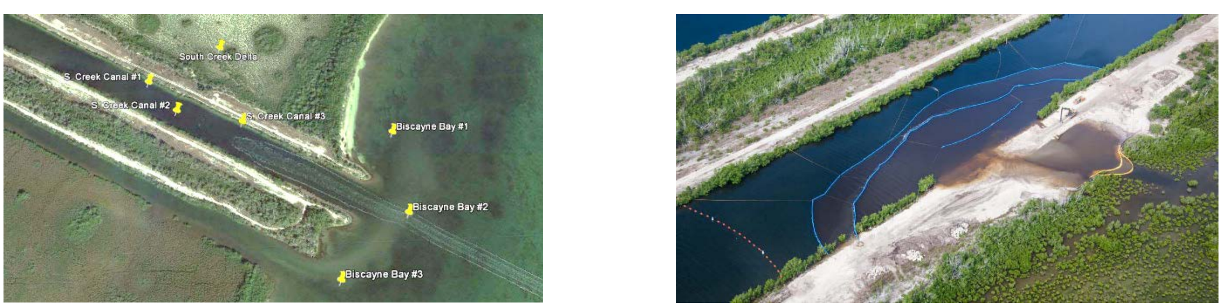

Figure 3. Aerial view of mitigation project showing proximity of tidal creeks to Biscayne Bay, and the multi-barrier turbidity control system.

Challenges for this system included:

- Channel mouth contiguous with Biscayne Bay Aquatic Preserve thus requiring a zero NTU increase in Biscayne Bay turbidity
- Max 29 NTU 30 ft (9.1 m) from work area

Additional complicating factors included:

- High content of clay particles – extremely dispersible
- High flows – sudden and significant, would come when the canal berm was excavated, releasing all the water accumulated in the new creek alignment as well as draining from the marsh
- Need for the construction contractor to be able to reef and move the entire system (essentially three projects with one barrier system)
- Avoidance of diving for inspection or O&M due to the presence of crocodiles.

A SPW system might have temporarily controlled the release of sediment during breaching of the berm (largely clay) into the adjacent canal but would not have functioned to accept the huge release of accumulated water in the creek from the surrounding marsh area and would have posed its own problems upon removal.

At the Florida site, because of the stringent water quality requirements and the presence of high concentrations of clay particles, difficulty was anticipated in achieving the requited level of containment with a single filter barrier. Lab bench-scale testing was conducted to assess various geotextiles and flow rates. Based on these tests, a system of three types of barriers was designed:

- A diversion barrier at the mouth of each new creek to dissipate jet flow
- A filter barrier anchored on shore for diffusion of the plume and filtration to the degree possible, and,
- An impermeable silt curtain to force any residual solids near the bottom in order to reduce the distance for those solids to settle to the bottom.

See Figure 3.

Computational fluid dynamics (CFD) modeling was used to refine and verify the design, including determination of the optimum depth of the bottom of the silt curtain to minimize any resuspension due to water velocity increases.

First, the diversion barrier extended 10 ft (3.1 m) down from the water surface. Next was the bottom-sealed FB, which consisted of an impermeable collar that extended several feet below the water surface. The lower portion consisted of fine-filter materials. This curtain was anchored with lightweight, fluke-style anchors, removing the need for divers to enter the water. Third, the outer silt curtain was designed to maintain a 24 in (61.0 cm) clearance above the channel bottom. The primary filter barrier and outer silt curtain both had reefing capabilities, which allowed depth adjustments and assisted with movement of the systems from one creek site to the next without their removal from the water.

There were no significant operational challenges to this system. The contractor was able to reef the system components, move them to subsequent creek sites and redeploy. Regulatory compliance required frequent water sampling of three points immediately outside of the silt curtain and three in the Biscayne Bay no-turbidity increase area at the mouth of the outlet channel. Each was sampled during operations at near-surface, mid-depth and near-bottom locations. Water quality results achieved compliance through the duration of the project for all three creeks.

c. SPW-Mounted (Bottom-Sealed) FB

Remediation of a major commercial dry dock on Vancouver Sound (Esquimalt Graving Dock), the largest non-military dry dock on the west coast of the Americas, required removal of highly contaminated sediment with a rigid requirement that the operation not re-contaminate sediments outside a temporary SPW that had been constructed when the adjacent waters were remediated. (The project is the subject of one or more papers in the WEDA 2017 Summit.) The SPW was to be re-driven from above high water to approximate low water and a barrier designed, fabricated and installed to follow the tidal height up and down while maintaining a seal to the SPW and allowing the tidal water volume to pass in and out of the enclosed dry dock area. It also was required to have a structure to allow the passage of barges or other vessels ingress and egress.

Particular challenges for this system included:

- Attachment of a flexible, geotextile barrier to the top of a sheet pile wall (never done before to our knowledge!)
- Design of an effective attachment mechanism and design to protect against chafe and cut of material in contact cut edges on the wall
- Requirement to contain suspended sediments including clay size particles despite a relatively small filter area (compared to a system where the curtain extends to the seafloor,) especially given the high range of tide level which can reach up to approximately 16 ft (5 m) at spring tides
- The high tide range level and large volume of water within the area enclosed by the TRB exiting and entering causing significant loads on the barrier far exceeding most other bottom-sealed barrier systems
- Incorporation of specialized panels to transition from a full-depth barrier along the shoreline to the SPW-top barrier and for 90-degree corners on the SPW
- Requirement of barge and equipment entrance and egress
- Need for internal barrier sections to separate dredged areas once completed from recontamination by next phase remediation operations.

A bottom-sealed (to the top of the SPW) FB system was designed that provided overall containment with a SPW-mounted system, two intermediate barriers for inter-containment area sectioning, an ultra-hazardous containment barrier, two barge gates, and a full-depth, bottom-sealed FB to the shoreline. The SPW barrier consisted of a double heavy duty inverted T skirt with connection points at the apex of the T. These connections points matched shackle points on top of the SPW. Pile hoops were also designed to connect the top of the SPW barrier to wood pilings that were part of the original pier structure. SPW-top barrier was produced in 100 ft (30.5 m) sections which were linked together to create a positive containment area around the entire perimeter of the project. Intermediate barriers were designed with a specialized vertical T connector that would allow them to be connected to either the SPW barrier or the SPW under the existing pier structure. These barriers could be placed where needed and included depth control with reefing lines giving them maximum flexibility with the ultimate locations. Barge gates consisted of separate SPW sections that were designed to easily detach from the SPW barriers and be submerged using a crane-lowered specialized “submergence structure” as the vessel passed overhead. Re-attaching to the SPW barrier required four shackles to be connected. Part of the overall system consisted of a more traditional barrier as it followed the contours of the harbor floor; however, this traditional barrier connected in an innovative manner to the barrier sitting on top of the SPW.

There were installation challenges; first, adjustments were required to accommodate an alignment correction for the full-depth section to the shoreline, including diver installation regarding barrier position and impacts from the associated water depth. This resulted in the attachment of a field-installed extension to the original bottom of the barrier. Installation procedural adjustments were made by the dive crews, who engaged in the onsite matters involved in making the adjustments. Additionally, an operational phase challenge occurred when a bow thruster was used in close proximity to the barriers by a large cruise ship coming into the dock. Other than these aspects, the system remained in place for a full year with no damage or major repairs required.

Regarding compliance with water quality objectives, the extensive water quality monitoring program for this project included multiple monitoring locations at 25 m (“early warning”) and 100 m (compliance point) from the barrier during the full-year construction period, with operations 20 hours per day. Of over 20,000 water quality readings, less than 1% exceeded the project turbidity increase of 2.5 NTU over background at 25 m or 100 m from the TRB. From among this low percentage, the vast majority of the exceedances were at the 25 m monitoring stations directly outside of the barge gates after they had been opened to allow passage of equipment (barges, conveyor, etc.) out from the remediation area. (Norman Healey, Azimuth Personal Communication, January 2017.) Data from sediment chemistry performance monitoring also provided evidence that the TRB system was generally very effective in preventing the escape of contaminated particulate matter to the water column and seabed in the previously dredged areas that surround the dry dock remediation area.

d. Bridge Pier Demolition and Sediment Removal, Los Angeles, California

The initial design for a bridge demolition associated with new bridge construction in southern California called for temporary SPW cofferdams to contain materials from the demolition of four, large reinforced concrete bridge piers and contain sediments from associated dredging. Project permits required that the demolition must maintain certain stringent water quality objectives. When cofferdams proved to be infeasible, the permitting agency evaluated and approved the use of bottom-sealed FBs (“Enclosed Turbidity Control Curtains”) for this purpose.

Design challenges for this particular system included:

- Design of a system that could be deployed under the pile-supported trestle structure from which the pier demolition would be completed
- Very limited space between the trestle platform, piers and an adjacent railroad bridge
- Maintenance of adequate space for transit of commercial vessels through a channel between two of the piers
- Schedule demands that led to design based largely on assumptions about the alignments, bottom conditions and water currents.

The design of the bottom-sealed FB system balanced, as much as possible, the distance of the barrier from direct demolition activities while preventing impacts to the channel and using trestle piles to maintain barrier positioning. CFD modeling was used to assist in designing the barrier alignments. Anchoring required the use of adjacent pilings in both perpendicular and spring line arrangements. This limited excessive movement of the curtain against the pilings (See Figure 4). Pilings that were expected to be in contact with existing piles, most covered with dense marine fouling, were sleeved with custom-designed pile wraps, which were fabricated from heavy impermeable materials. Divers installed these wraps as needed. The majority of the full-depth filter barrier was comprised of a single layer of filter fabric, with the upper 6 ft (1.8 m) consisting of an impermeable material. This construction was designed to collect surface hydrocarbons in a more effective manner. Flotation included 16 in (40.6 cm), fully-enclosed foam billets.

Though challenging, installation of the barriers around three separate bridge piers was accomplished as planned. Operational challenges resulted in the need for reinforcement panels and in-place repairs due to: 1) significant construction debris on the bottom, especially between the railroad bridge pier and the near side of the trestle; 2) damage to the barrier as the result of driving additional pilings, including angled batter piles, to add support to the trestle structure for use of larger demolition equipment, 3) greater current velocities than anticipated on the basis of available site knowledge.

Compliance with very stringent permit limitations for turbidity increase above ambient has been monitored daily during operations by comparison of up-current and down-current sample sites 100 ft (30.5 m) from the barriers with near-surface, mid-water and near-bottom measurements. Despite only a 30% increase exceedance allowance above ambient and relatively low ambient readings (generally ranging from <1 to 3 NTU), there have been no exceedances that were determined to be the result of operations through over 10 months of demolition activities (late May, 2016 through March, 2017).

Figure 4. Sediment containment full-depth filter barrier for bridge demolition project.

3. APPLICATIONS WHERE BOTTOM-SEALED FB’S MIGHT BE BENEFICIAL IN LIEU OF STANDARD SC’S

Bid specifications for coastal, freshwater or offshore dredging, construction or remediation projects often require the deployment of “silt curtains” or “turbidity barriers,” usually for the objective that these will provide containment for disturbed sediment on the bottom or suspended in the water column. It is typically assumed that the level of containment provided by these is the best available, short of SPW installation.

In certain cases, lesser-known bottom-sealed FBs may be a preferred alternative due to greater containment capabilities and lower cost to the overall project. Conditions where project costs can go up without bottom sealing and anchoring, and where FBs may be more advantageous include:

- Water conditions are so dynamic that SCs require excess hours for maintenance, restoration of position or replacement due to damage
- Likelihood of sediment release that exceeds water quality performance criteria and causes operations to be suspended, creates additional costs, or compromises continuity of operations, with associated issues of potential permit violations.

SCs are effective in containing sediments in low-velocity waters where water elevation change is also minimal, or where performance requirements are limited or not stringent. In appreciable currents or with water level elevation changes such as occur in a tidal environment, moving water will pass under a silt curtain. This typically occurs at a significantly greater than ambient velocity, which can (1) transport suspended sediments underneath and (2) erode or scour existing surface sediments, adding suspended sediments.

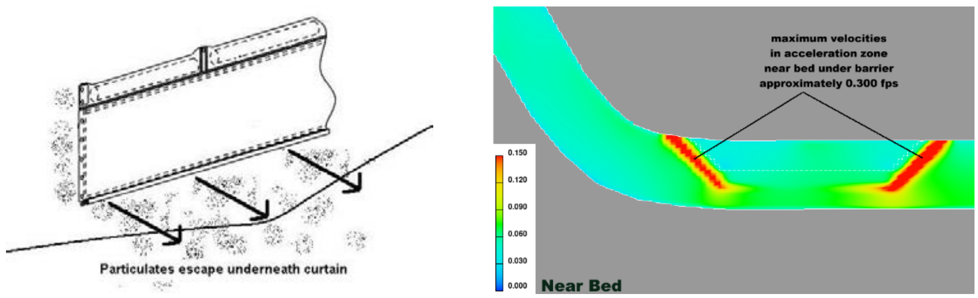

Figure 5. Illustration of sediment movement underneath a SC, and CFD model results showing elevated velocity of water current underneath a silt curtain.

Modeling studies (computational fluid dynamics or CFD, see Figure 5), show that the presence of a silt curtain terminating 2 to 4 ft (0.6 to 1.2 m) from the bottom in a specific tidal canal would increase velocity from ambient to multiples of the ambient velocity. This increased velocity can not only accelerate the movement of suspended-sediment-laden water from under the barrier, but can also exceed the excitation velocity of bottom sediments settled from the dredging and cause scour of existing sediment.

This may be acceptable from an environmental regulatory perspective if: 1) preventing a visible surface plume is the only concern; and/or 2) limiting any increase in turbidity above a certain level in the water column will suffice and can be achieved with a silt curtain; and/or 3) water quality monitoring requirements are structured in a way that monitoring does not effectively detect exceedances when they occur. In other cases, ineffective silt curtains may cause water quality objective exceedances either under certain tides or flow conditions or as a result of specific dredging or materials removal at the time. In addition to permit violations, these exceedances can cause work stoppages with an associated increase in project duration and costs. Exceedances can also add cost due to time lost from troubleshooting, modifications, reporting and additional water quality sampling.

4. APPLICATIONS WHERE BOTTOM-SEALED FB’S MIGHT BE UTILIZED IN LIEU OF SPW’S

In isolating an area for environmental dredging, SPW cofferdams utilized for contaminated sediment removal can provide very effective containment of contaminants. For some potential applications, there may be a concern about releases during or as the result of SPW removal at completion of the dredge operation. For most cases, this is addressable by the positioning and design of the SPW such that its location extends an adequate distance from the contaminated sediment or by a secondary control, such as use of SCs during the removal operations. There are also situations where there may be too much area to contain, or the water too deep or other factors impeding the use of SPWs. SPW effectiveness and feasibility considerations are outlined below based on consideration of several projects for which information was readily available. This discussion if followed by considerations of factors for which bottom-sealed barriers may be determined as an effective alternative technology.

a. Effectiveness and Feasibility of Applications of SPWs and SPW Cofferdams

Sheet pile walls have been used at many environmental dredging sites, primarily to prevent spreading contaminants (not just turbidity/suspended solids) as a result of dredging. In such cases, superior containment of SPW relative to silt curtains has justified the substantially higher cost of SPWs. SPWs may be designed to be installed and not be 100% watertight, they may be watertight but operated with water contained inside or they may be constructed to be watertight and then de-watered (SPW cofferdams). Only when watertight can they be considered as effectively containing suspended sediments and chemicals, and such non-watertight systems may also require secondary containment systems. (These distinctions were not considered in developing the following assessment or in presenting representative costs.)

One significant application of SPW is the recently completed remediation of sediments at the Esquimalt Graving Dock in Victoria, BC. A presentation on that project included description of the design of the SPW (Wang and Mylly, 2012).

Although SPW is clearly superior to silt curtains for containment during the dredging operation, several real or potential negative effects of SPW exist. A conference presentation (Laplante et al, 2012) identified several of these, including the following:

- Driving contaminants deeper as a result of the pile driving process
- Concentrating contaminants within the enclosure during the project as a result of limited water exchange (“sacrificing” water quality within the enclosure)
- Releasing contaminants when the SPW is pulled out from the bottom
- High cost

A further complication of removing the SPW when the project is complete was identified in a completion report for a large PCB removal project on the St. Lawrence River (Bechtel Environmental, 2002): king piles that supported the SPW structure could not be removed, and needed to be sheared off at the mudline, adding to the cost of the project.

Bid documents and feasibility studies comparing containment options have shown the relatively high cost of SPWs. SPW costs vary widely depending on the size of the project (length and depth of SPW), specific structural design, steel thickness, and other factors. Some examples are provided below (all data refer to SPW components delivered to the site, plus installation, with credit for salvage/reuse value of the components removed after the project):

- Portland, OR Harbor: $19.80/ square foot (sf) (LaPlante et al, 2012)
- Florida DOT cost estimating guide: $16-$22/sf (Florida DOT, 2017)
- Seattle, WA cost estimating guide: $11-$13/sf (Seattle, 2017)
- Palm Beach County, FL: $43/sf (Palm Beach County, 2017) (Note: a permanent installation.)
- Portland, ME Harbor: $45 to $50/sf or $1800-$2000/lf plus mob/demob (preliminary Engineer’s Estimate)

It is important to note that the cost per square foot applies to the full height of the sheets, including that in the water column as well as driven into the sediment below. For example, for the Palm Beach County project referenced above, the sheet pile is in open water, 10 ft embedded in bottom and 20 ft above bottom, 30 ft total, 480 ft long. The total bid by the successful bidder amounted to $1,295 per linear foot of SPW.

In summary—the most significant consideration for SPWs is their cost with secondary considerations of impact to project schedule and potential contaminant release issues during SPW removal.

b. Bottom-Sealed FB Deployment Where SPWs Are Too Costly or Not Feasible

In only a few situations in recent years has bottom-sealed FB technology been considered as a replacement for sheet pile walls. There is little doubt that, if determined to be feasible for the location (see Section 2.b. above for a list of seven (7) key factors regarding design feasibility,) a bottom-sealed FB system could almost always be designed, fabricated and installed in much less time than a SPW and that the cost will likely to be at least 70% less than the corresponding SPW. The key questions to be resolved for a bottom-sealed barrier to be deployed in place of a candidate SPW are straightforward:

1. Will the bottom-sealed FB be as effective or adequately effective for containment of sediment/turbidity or chemicals of concern as an alternative to the SPW?

2. Will the FB cause scouring or other adverse impact not otherwise resulting from use of an SPW?
3. Can the FB be designed, installed and removed such that removal of the FB will not create a release of significant sediment or chemicals of concern that is considered to be detrimental to the water body or at least be no more than the release that would come from removal of the SPW? (As for a SPW, it is also conceivable that a secondary containment could be incorporated into the removal process).

In summary—there are few situations where a SPW could be deployed for containment that a bottom-sealed barrier cannot. These are more likely to be ones where the currents are excessive, such as 3 fps or, perhaps, the contaminants are so toxic that a de-watered SPW (i.e., a SPW cofferdam) is the only safe way to remove them. The project examples in Section 1 above demonstrate the flexibility and some of the range of situations in which bottom-sealed FB systems can be effective, in lieu of both SPWs as well as silt curtains.

CONCLUSIONS

Silt curtains are effective for turbidity control and containment in limited situations, not including those with water currents or tidal exchange, as water will pass under the curtain and dredge materials and suspended sediments will also move out unless there are only quickly settled, larger particles. If the release of turbidity, suspended sediments or chemicals is not critical, silt curtains may be adequate for containment. (See Table 1 for a comparison among bottom-sealed filter barriers, silt curtains, and sheet pile walls).

Table 1. Relative Advantages and Disadvantages of Silt Curtains, Sheet Pile Walls, and Bottom-Sealed Filter Barriers

	Silt Curtains	Sheet Pile Walls	Filter Barriers
Effectiveness	Acceptable, depending on currents and water quality goals	Excellent	Excellent
Cost	Lowest	Very high	Moderate
Time to Implement	Short	Very long	Short

In contrast with silt curtains, bottom-sealed FB designs will actually contain suspended sediments or contaminants if there is any water movement or water level fluctuations. Also in contrast with silt curtains, bottom-sealed FBs can be utilized even in areas of high current velocities, bi- or multi-directional currents, substantial tidal height fluctuations, and vessel traffic.

SPWs and SPW cofferdams offer a feasible way to contain sediments and chemicals in many situations. There can be issues with removal and potential disturbance of release of mobile contaminants deep in the sediments. The primary issue with SPWs is the cost and impact to project schedules.

Bottom-sealed FB systems can, in many circumstances, achieve the objectives of SPWs. Their cost is likely on the order of 70% less or even greater. Their presence will likely have less effect if scouring is an issue and their removal can be conducted in a way to have less potential for release of contaminants.

Unlike silt curtains and like SPWs, bottom-sealed FBs also exclude organisms from the area of operation, including fish and marine mammals.

Effective designs for bottom-sealed filter barriers can be and have been developed and implemented for many different situations, even if the specific design has not been previously employed. The bottom-sealing mechanism may vary as will the composition of the geotextile or composite geotextiles incorporated into the curtain.

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