DEVELOPMENT OF FILTER FABRIC TECHNOLOGY DETERMINED TO BE BTA FOR MINIMIZING ENVIRONMENTAL IMPACTS AT POWER GENERATING FACILITIES

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Abstract

Substantial work has been done to develop intake technologies to mitigate environmental impacts associated with the withdrawal/use of surface waters. The best technology available (BTA) to mitigate environmental impacts is influenced by several site-specific variables including water withdrawal volume, intake configuration, facility operation, source water characteristics, and economic considerations that work alone or in concert. One innovative technology that has been determined to be BTA is the Gunderboom Marine Life Exclusion System™ (MLES™), a full-water-depth filter barrier that effectively limits aquatic biota from entering cooling water withdrawal intake structures.

A filter fabric barrier system, originally designed by Gunderboom Incorporated as a sediment barrier and oil boom, has been modified and developed for use at cooling water intake structures. The filter fabric barrier technology was developed over a six year (1995-2000) period as part of a research and development program sponsored by Mirant New York LLC. The MLES™ development program was conducted at the Lovett Generating Station, located on the lower Hudson River Estuary in Tomkins Cove, NY. Lovett is a three unit, 462 MW, fossil fueled facility with a once-through condenser cooling system requiring 465 MGD of non-contact cooling water at full capacity.

Seasonal deployments, scheduled to coincide with the presence of fish eggs and larvae, were used to develop and improve the technology. The MLES™ is designed to filter the total cooling water volume required by a generating unit, while taking into consideration site water quality (sediment loading) and hydraulic conditions (tides, current velocities). Development program results led to design improvements and modifications that increased the flow through capacity of the filtering fabric, strengthened the design, maintained fabric filtering capacity through the integration of an automated Air-Burst™ cleaning system, and provided an anchor system that maintained the MLES™ under extreme flow and weather conditions.

Ichthyoplankton monitoring was conducted during the development program to measure the systems effectiveness at reducing entrainment. Paired samples were collected at protected (i.e. within the MLES™) and unprotected intakes during the 1995, 1998, and 2000 deployments. Results from the Ichthyoplankton monitoring program indicate that the Gunderboom MLES™ was greater than 80% effective at reducing entrainment. As a result of this development program, the Gunderboom MLES™ has been determined to be BTA for mitigating environmental impacts associated with the use of surface waters at cooling water intake structures.

Introduction

The standard for establishing best technology available (BTA) for minimizing adverse environmental impact at power generating facilities under Section 316(b) of the Federal Clean Water Act requires that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available (BTA) for minimizing adverse environmental impact. This determination is made on a case-by-case basis by the permitting agency that bears the ultimate burden of proof to support its decision. In New York State the Department of Environmental Conservation (NYSDEC) is the body responsible for regulating the National Pollutant Discharge Elimination System (NPDES) permit program. In New York the NPDES permit program is called the State Pollutant Discharge Elimination System (SPDES).

In 1993 the Hudson Riverkeeper Fund, Inc. (HRFI), instituted litigation against Orange and Rockland Utilities, Inc. (ORU), the then owners of the Lovett Steam Electric Generating Facility (Lovett). The lawsuit alleged that ORU violated the conditions of the SPDES permit by maintaining cooling water intake structures that do not reflect the best technology available for minimizing adverse environmental impacts.

The United States Court for the Southern District of New York, ruled in favor of the Hudson Riverkeeper Inc (Riverkeeper) mandating that technical representatives from Lovett, NYSDEC and the Riverkeeper meet on a regular basis to identify feasible mitigative alternatives that could be installed at Lovett to attain acceptable environmental impact levels. The technical representatives evaluated the environmental impacts at Lovett and concluded that impingement was relatively low, thus mitigation solutions should focus on entrainment. The technical group representatives selected the Gunderboom® System (Gunderboom®) as the primary alternative means of minimizing biological impact. The selection of Gunderboom® was based on manufacturer supplied information that stated the system had a high filtration rate (accompanied with low clogging and low potential for biological growth) and limited organism passage. After selecting Gunderboom®, ORU, Southern Energy and subsequently Mirant New York LLC (Mirant) the current owner of Lovett conducted an extensive research and development program at Lovett between 1995 and 2000 to design the Gunderboom Marine Life Exclusion System™ (MLES™). Numerous modifications and improvements were made to the MLES™ over the six-year development period. This research culminated in a MLES™ that can be effectively deployed during the seasonal period of peak biological activity. Based on ichthyoplankton monitoring studies the MLES™ is effective at minimizing entrainment and impingement and thus meets the BTA criteria for Lovett.

The following sections provide a description of the Gunderboom MLES™, a brief history detailing the research and development sponsored by ORU, Southern Energy, Mirant, and Gunderboom and a summary of the system effectiveness monitoring conducted during 1995, 1998 and 2000. The information developed over the study period is then presented to support the use of the Gunderboom MLES™ as BTA at Lovett.

Site Description

The Lovett Generating Station is located on the west bank of the Hudson River at River Mile (RM) 42, in Tomkins Cove, Rockland County, New York. The station consists of three fossil-fueled, steam electric units (Units 3, 4 and 5), having net generating capacities ranging from 63 to 202 MWe for a total of 462 MWe for all units combined (Figure 1) with once-through condenser cooling system requiring 465 MGD of non-contact cooling water at full capacity.

What is a Gunderboom MLES™?

The Gunderboom MLES™ is a full-water-depth aquatic filter barrier that limits aquatic biota entering water intake structures (Figure 2). The MLES™ is a permeable fabric curtain consisting of polyester fibers. The MLES™ is constructed of two layers of fabric that are subdivided into vertical cells or pockets. A sufficient amount of filter fabric is designed into the boom to accommodate water level fluctuations (e.g. tides) up to the design high-water condition. A flotation hood, along the top of the entire length of the boom keeps the system afloat and maintaining complete coverage through the water column (Figure 3). The MLES™ is fixed in position by an anchoring and mooring system. A heavy skirt constructed of durable, impermeable, rubberized material is attached to the bottom of the MLES™ fabric to create a seal with the substrate and prevent aquatic organisms from passing under the MLES™. The system is also equipped with a compressed air cleaning system described by Gunderboom Inc. as the AirBurst™ technology. The AirBurst™ cleaning system provides a burst of air at the base of the fabric. Because every facility is different the Gunderboom MLES™ can be designed for site-specific physical and biological constraints.

Gunderboom® Background

Gunderboom Inc. aquatic filter barrier technology has been under development since 1986, when the first Gunderboom® aquatic filter barrier was designed to prevent sedimentation impacts on a salmon spawning area during dredging of a harbor in Homer, Alaska. The first system consisted of a fabric curtain barrier suspended from a floating boom, a bottom chain, and anchors to maintain the boom in position. This design continues to be used on dredging and dredged material disposal projects. In addition, Gunderboom Inc. continued to expand the technological applications to include the control or containment of stormwater-elevated levels of suspended sediments and pathogenic microbes (e.g., bacteria, protozoans) in water supply reservoirs and at swimming beaches. Further, Gunderboom Inc. is engaged in evaluations of the technology to control levels of suspended solids in discharges from industry, mining operations, settling ponds and retention basins. There are a number of different applications for this filter barrier curtain technology, all with the objective of preventing the migration of particulates within a body of water.

Lovett Gunderboom MLES™ Development

The evaluation of the Gunderboom® fabric was initiated in 1994 with small-scale tests to obtain preliminary information on filtering capacity and the potential for fabric clogging. The following year a Boom was constructed utilizing a single ply of filtering fabric and was deployed at the Lovett Unit 3 intake from 23 June to 25 August (Photo 1). During this initial deployment, the Boom was overtopped as a result of sediment build-up on the fabric that reduced filtering capacity. The length of the flotation that was overtopped gradually increased so that within several weeks of deployment it was estimated that the Unit 3 required flow was passing over the top of the boom. It is important to note that boom overtopping is a design characteristic calculated to relieve stress on the boom and minimize the potential for fabric failure. Observations of the initial deployment showed that the fabric was rugged and did not develop holes or tears due to stress over the deployment period; however, sediment build-up was evident over the entire filtering area. Initially it was thought that the tidal action in the Hudson River, coupled with wave action, would resuspend any sediment on the Boom. This was the first installation of a Gunderboom® system at a unidirectional flow facility. Based on past experience with passive system applications, Gunderboom Inc. selected Danforth type anchors for the initial deployment. The stress of the sediment accumulating on the fabric caused these Danforth anchors to destabilize and move in the muddy bottom substrate of the Hudson River (Table 1).

In response to the clogging identified during the 1995 deployment, Gunderboom Inc. developed the AirBurst™ Technology cleaning system. The 1996 deployment tested the AirBurst™ Technology as well as spud-type anchors. For the AirBurst™ cleaning system to operate properly, two-plies of Gunderboom® fabric of were sewn together forming an internal pocket where the air was released (Photo 2). The AirBurst™ system consisted of a compressed air hose connected to a diffuser located in the bottom of each cell. A timed burst of air into one cell at a time provides cleaning by "shaking" the fabric material, by the diffusion of small bubbles through the pores of the fabric and by an induced upwelling of water around the boom created by the expanding air as it rises through the water column.

The boom was fully deployed in front of Lovett's three independent cooling water intake structures (Units 3, 4 and 5) on 5 September (LMS 1997). A few hours after deployment several anchors on the north end were dislodged and moved. This resulted in the boom tearing loose from the rigid sheet-pile mooring at the northern end of the facility. Preliminary observations indicated that the AirBurst™ cleaning system had good potential at limiting sediment build-up on the boom fabric and maintaining fabric-filtering capacity. Gunderboom Inc. determined that the anchoring system (spud-type), based on the pre-deployment sediment geotechnical tests, was not appropriate for maintaining the boom position. In addition, engineers and scientists involved in the development and testing of the Gunderboom® system determined that the northern terminal connection was not appropriate and that a gradual termination point, such as the mooring cell used in the 1995 system was the best attachment technique in a dynamic environment.

ORU engineers developed a "dead weight" anchoring system to anchor the next generation of Gunderboom. The goal of the 1997 Gunderboom system evaluation was to deploy the "dead weight" anchors and to further test the AirBurst™ system. The boom deployed during 1996 was modified for deployment around Unit 3 in 1997. The modified boom was deployed from 22 September to 6 October 1997 (LMS 1997). During the deployment, the dead weight anchors successfully maintained the position of the Boom and the AirBurst™ system installation was determined to be effective at maintaining the fabric filtering capacity.

After the 1997 deployment, fabric improvements were evaluated that would improve filtering capacity while not compromising the fabric's exclusion potential and maintaining the structural integrity of the boom. Evaluation of a perforated filter fabric began in the winter of 1997-1998. This research determined that a perforated fabric could continually pass water at a minimum capacity of 5 gpm/ft^2 with regularly scheduled cleanings better than the fabric without perforations.

A two-ply boom now called the Gunderboom MLES™ with perforations in the upstream and downstream fabric plies was tested at Lovett Unit 3 during 1998 (Photo 2). Perforations or pores had an Apparent Opening Size (AOS) of 0.5 mm in diameter on 6.4-mm centers. The AOS is the industry standard test for measuring geotextile pore size. During MLES™ manufacturing the pore alignment was offset between the two fabric layers. In addition, covered slits were placed in the downstream layer to permit sediment to pass through. The same dead weight anchors used in the 1997 deployment were used in 1998.

The 1998 boom was deployed from 11 June to 2 September. During this deployment the AirBurst™ system effectively dislodged sediments from the boom. A dive inspection in early August determined that a section of the fabric had pulled free from the bottom for a length of approximately 8 to 10 feet. This likely resulted from a build-up of sediment on the Gunderboom during evening hours when monitoring crews did not operate the manual air cleaning system. Loosening a nylon support strap that had pulled on the flotation and operating the AirBurst™ system on a full-time basis essentially corrected the situation. Some algal growth was noted on the MLES™ fabric, only near the surface or photic zone. The results of the deployment indicated that the biological growth did not adversely affect the filtering capacity of the boom fabric. In addition, through 1998 a manual AirBurst™ system had been used, however, this proved to be labor intensive and it was determined that an automated system needed to be designed and incorporated into future Gunderboom MLES™ to make the technology effective.

A two-ply Gunderboom MLES™ with an automated AirBurst™ cleaning system was deployed at Lovett Unit 3 (62 MGD) during 1999 (LMS 2000). The automated system included strain and head differential gauges to continually monitor the system. The difference between inside and outside water levels (i.e. differential of hydraulic head) created a force that moved water through the fabric and provided a continuous measure of system performance. The second measurement was the load or strain on a subset of the mooring lines with the sensors located between the anchors and the boom. Observations from the 1999 deployment showed that the system incorporating perforated material, in conjunction with the automated AirBurst™ system, was indeed effective at keeping the boom from clogging and overtopping due to sediment clogging/biological growth. The head differential and strain gauges accurately provided information on fabric loading.

The refinements made to the 1999 MLES™ and AirBurst™ systems confirmed that the MLES™ filtering capacity could be maintained over extended time periods and that the automated cleaning system allowed the MLES™ to operate unattended.

The same boom deployed at Lovett Unit 3 during 1999 was serviced and re-deployed at Lovett Unit 3 during 2000 during two separate periods (LMS 2001), the first from 10 May to 1 September and the second from 12 October to 15 December. The goals of these deployments were to refine in-field maintenance of the MLES™, test new mooring hardware, monitor operational effectiveness of a computerized and automated AirBurst™ cleaning system and test the effectiveness of zippers to join boom sections. During both deployments the automated Air-Burst™ cleaning system maintained the boom, allowing operation to continue unattended around the clock. Gunderboom Inc. determined that integrating the Air-burst™ into facility operations and incorporating redundancies (i.e. alternate air sources) into the system are essential to the system operation. Furthermore, the zipper test proved that sections of fabric could be separated during deployment, ultimately allowing for the maintenance or removal of panels without removing the entire boom.

During MLES™ development at Lovett, numerous pilot and ancillary studies were conducted that were important to overall the development of the technology. Support studies include: bench-scale fabric flow testing, in-situ test of the automated air burst system and zipper fastening system, multiple studies to determine if ichthyoplankton impinge on the fabric, forensic exams of the boom following deployments and biological analysis related biofouling. These studies coupled with the aforementioned research conducted from 1995-2000 helped to develop an automated system that can be maintained at power generating facilities to meet water requirements of once through condenser cooling.

Ichthyoplankton Monitoring

Coupled with the physical performance monitoring of the Gunderboom MLES™ at Lovett, the effectiveness at minimizing entrainment was determined through ichthyoplankton sampling conducted during the 1995, 1998 and 2000 deployments. Effectiveness was measured by collecting simultaneous samples at a station located inside the Gunderboom MLES™ and at a station located outside the Gunderboom MLES™. The Unit 3 (protected by boom) and Unit 4 intakes (ambient conditions) were selected for sample collection as they are structurally similar and are located very close to each other.

Paired samples of approximately 30 minutes duration were collected at each intake sequentially at three depths (surface, mid-depth and bottom). Because each MLES™ deployment focused on improving different facets of the technology, deployment dates varied from year to year ultimately influencing the dates that ichthyoplankton monitoring was conducted (Table 2). During 1995 sampling was conducted over a 24-hr period, thereafter (i.e. 1998 and 2000) sampling was conducted between 1900 and 0700, historically the period of the highest entrainment at Lovett.

Sampling was conducted using a standard net/barrel, pumped ichthyoplankton sampling system. Water was pumped at 1.1 m^3/min (300 gal/min), with the volume sampled monitored with inline flow meters. Water was filtered with a 505 µm nylon plankton net, washed into a sample jar and preserved. In the lab, all fish eggs and larvae were separated from other materials, identified on morphometric and meristic characteristics and enumerated. Counts and sample volumes were used to determine egg and larval densities in each sample. Effectiveness was calculated based on a ratio of the density of organisms inside (Unit 3) the Gunderboom® fabric compared to the density of organisms outside (Unit 4) the Gunderboom® fabric.

Variability in the annual ichthyoplankton monitoring results was influenced by the deployment schedule and specific events, as described in the previous section that occurred during each deployment. The ichthyoplankton results often tracked specific events or problems identified during each deployment. The results of the ichthyoplankton monitoring program were used to identify problem areas and ultimately improve the performance of the Gunderboom MLES™. The specific results of the ichthyoplankton monitoring program for each year are described below.

In 1995 a total of 5589 fish larvae were collected in 162 samples, with 725 (13.0%) collected at Unit 3 (inside boom location) and 4864 fish larvae (87.0%) collected at Unit 4 (outside boom location). Bay anchovy larvae were the dominant species collected, with a total of 3777 individuals representing 67.6% of the total. Of the 3777 bay anchovy larvae identified in the samples, 536 individuals (14.2% of the total) were collected within the Boom and 3241 individuals (85.8% of the total) were collected outside the Boom. Over the entire Gunderboom® effectiveness monitoring period, inside ichthyoplankton concentrations (Unit 3 intake) compared to outside Gunderboom® System ichthyoplankton concentrations (Unit 4 intake) indicated that the Gunderboom® System was approximately 84% effective at limiting the passage of ichthyoplankton, even with surface water spillage during most of the evaluation period.

During ichthyoplankton monitoring in 1998, a total of 2645 individual fish eggs, larvae, and early juveniles were collected at the Unit 3 intake and 6343 at the Unit 4 intake. Bay anchovy again dominated (68%) catches with densities ranging from 5-2000 / 1000 m^3. Prior to loss of the bottom seal the boom was 76% effective at reducing ichthyoplankton from entering the facility. The bottom seal loss resulted in 29% overall deployment period effectiveness. This experience resulted in the development of the heavy rubberized bottom skirt to maintain the bottom seal integrity.

In 2000 a total of 40,404 individual fish eggs, larvae and early juveniles were collected, 8438 at the Unit 3 intake and 31,966 at the Unit 4 intake. Striped bass dominated the catch (73.6%). Daily densities ranged from 0-65,000 / 1000 m^3. Ichthyoplankton monitoring during the 2000 deployment showed that Gunderboom MLES™ reduced the percentage of fish larvae (82%), yolk-sac larvae (87%) and post yolk-sac larvae (79%) (ASA 2000). The overall effectiveness of the boom was approximately 80% during the 2000 deployment.

Conclusion

The Gunderboom MLES™ development program resulted in a BTA determination for Lovett by the NYSDEC based on six years of in-situ research and development. The system has proven longevity and durability, and can operate for extended periods. Furthermore, the MLES™ has been proven to have minimal environmental or visual impact compared to other alternative technologies. These factors coupled with the high level of biological protection provided by the Gunderboom MLES™ support this technology as BTA for the Lovett Generating Station. The Gunderboom MLES™ has proven that is can be > 80% effective at limiting the passage of ichthyoplankton. Although, this level of protection was periodically compromised, extensive improvements made since 1995 have advanced the effectiveness of the MLES™ system. The improvements made to the boom included, increasing the flow through capacity of the fabric, strengthening the design, integrating an automated cleaning system, and designing an anchor system that can maintain the MLES™ in the high currents of the Hudson River.

In 2004 a Gunderboom MLES™ will be deployed seasonally in front of the Lovett cooling water intakes for Units 3, 4 and 5 as stipulated by the Lovett SPDES permit. The system will be fully integrated into the operation of the Lovett Generating Facility. Based on the ichthyoplankton data collected at Lovett and the full integration of the MLES™ into plant operations, NYSDEC is requiring an overall 80% Gunderboom MLES™ effectiveness value.

The Gunderboom MLES™ has recently been specified as BTA at two proposed new power-generating facilities on the Hudson River. These new facilities will require relatively low flow rates (6-8,000 gpm) by incorporating hybrid wet cooling tower technology. The hybrid wet cooling tower technology in combination with the Gunderboom MLES™ is expected to achieve the equivalent of dry cooling tower impacts on aquatic life.

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Table 1. Gunderboom MLES™ development summary.

Year	Primary Testing	Significant Results or Accomplishments
1995	Gunderboom® System Concept	Ichthyoplankton monitoring identified that system was effective as skimmer weir to reduce ichthyoplankton entering the intake water. Improvements were required to remove sediment build-up and to replace the Danforth type anchors.
1996	Manual AirBurst™ cleaning system test	Successful test of 2-layered fabric system and positive initial results of the manually operated AirBurst™ system. Spud-type anchor system was not sufficient for this particular application
1997	Dead Weight Anchoring System	The dead weight anchors successfully maintained the boom position and the manual AirBurst™ provided promising results but was labor intensive.
1998	Automated AirBurst™	Small-scale system tests successful when the AirBurst™ was services by routine maintenance.
1999	Automatic AirBurst™ for extended periods, Design enhancements for longevity	Automated AirBurst™ allowed the system to operate for extended periods. Inner and outer skirts of rubberized material were added to the MLES™ base to help maintain the seal.
2000	Improve field maintenance procedures, improve mooring hardware and test new zipper connections	Additional design enhancements including, reuse of the 1999 boom, mooring point attachment hardware redesign, in-field repair and modification system, zipper connection successful to allow boom to be fabricated, replaced in sections.

Table 2. Ichthyoplankton monitoring sampling characteristics.

Year	Sample Period	Sample Times	Sample Frequency	Duration (min.)	Average Volume
1995	25 June – 29 July	24 Hrs	Every 4 Hrs	30	34.07 m^3
1998	11 June – 31 Aug	1900-0700	5 Per Date	20	23.2 m^3
2000	11 May – 25 Aug	1900-0700	5 Per Date	20	21.87 m^3

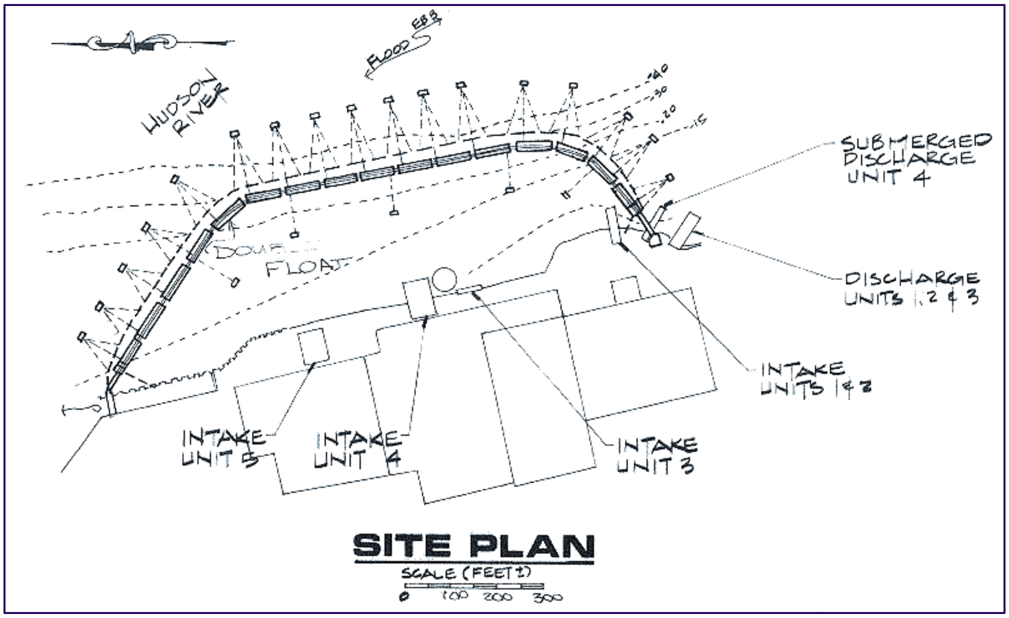

Figure 1. Site plan and drawing of the 1996 full facility deployment

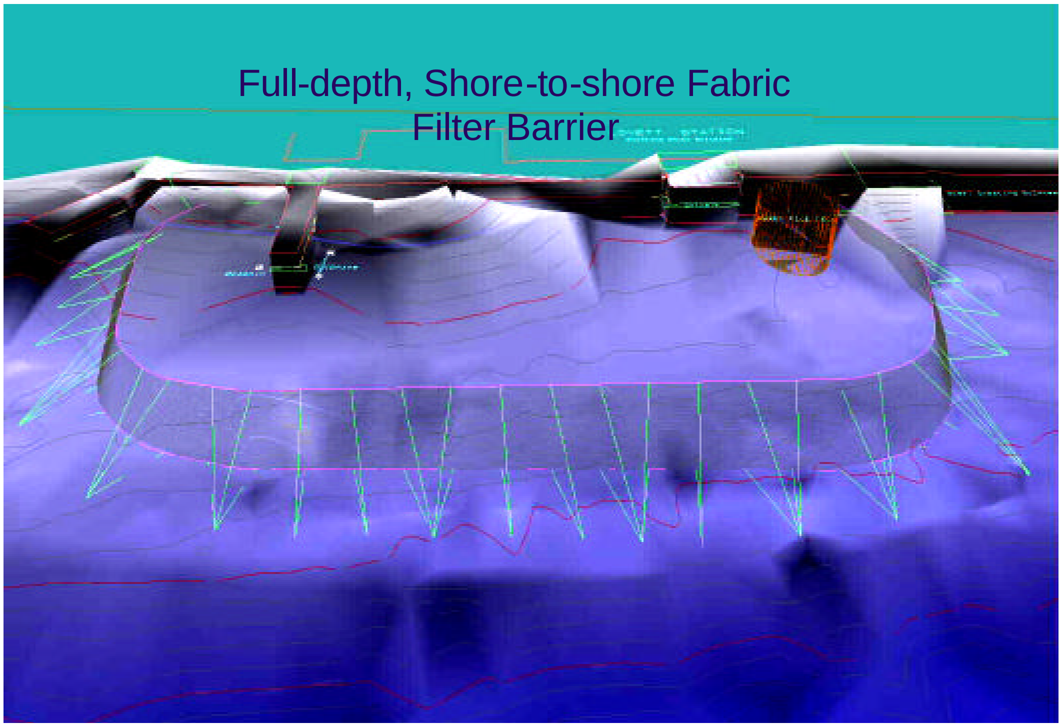

Figure 2. Three-dimensional depiction of the Gunderboom MLES™

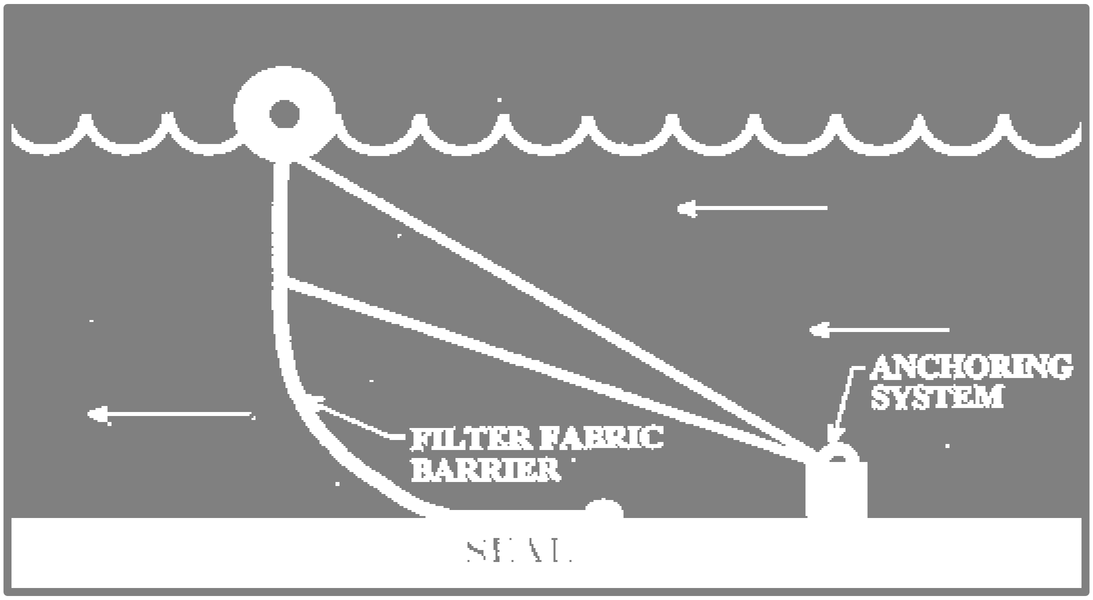

Figure 3. Cross section view of the Gunderboom MLES™

Photo 1. Lovett 1995 Gunderboom MLES™ at the Lovett Generating Station, Tomkins Cove, NY.

Photo 2. Lovett 1998 Gunderboom MLES™ Deployment with AirBurst™ Technology at the Lovett Generating Station, Tomkins Cove, NY.