Capping a Lagoon

A novel approach was taken to cost-effectively close a 4.86 ha unlined industrial wastewater sludge lagoon in North Carolina and reduce leachate production. A floating geosynthetic cover system gave crews and equipment access to the lagoon surface.

By David T. Farber, P.E., M.ASCE, and Phil Comstock

THE SYRACUSE, NEW YORK, office of O'Brien & Gere was hired by an industrial client to decommission a manufacturing facility located in North Carolina. A portion of the decommissioning process involved closing a 4.86 ha sludge lagoon that was used to store and dewater waste material from an on-site wastewater treatment facility. The record of decision required that a cap meeting the requirements set by North Carolina's Department of Environmental Quality be put in place.

The lagoon closure process would require the following:

• Installing a cover over the sludge lagoon to control odors;

• Minimizing leachate generation;

• Preventing contamination of groundwater and surface water;

• Maintaining a stable and secure site.

Determining how to cost-effectively close the lagoon proved to be a challenge. To accomplish the closure and minimize the leachate generated, the amount of precipitation allowed to seep through the sludge had to be reduced. It was first thought that this would require the sludge to be solidified through in situ stabilization methods and then be disposed of off-site or capped in place using a low-permeability cap system.

Based on preliminary testing, disposal of the sludge off-site was deemed impractical because of the sludge's characteristics, namely, significant water retention, difficulty in dewatering or solidifying the material, and significant volume.

Stabilization and capping in place, which were preferred to reduce leachate from being generated, proved to be just as difficult because of a number of obstacles. For instance, the sludge consisted of polymers used in an industrial wastewater treatment process. These polymers were part of the sludge by-product that would not freely release the water, making in situ stabilization very difficult and costly. Furthermore, the thickness of the sludge ranged from 2.13 m to 2.74 m, and the sludge could neither stand on its own (having no shear strength) nor support a work crew or the equipment needed to install a low-permeability cap system. Finally, without sludge solidification, a low-permeability geomembrane and a thin soil cap system would undergo excessive settlement, which could adversely affect the effectiveness of a low-permeability cap system.

From these considerations, it was clear that an innovative solution for closing the sludge lagoon and reducing the generation of leachate would be needed.

Finding the solution began with field activities to collect samples of the sludge at varying depths using a grid pattern. Of the samples collected, 24 were tested for moisture content, pH, and organic content. The tests yielded the following results:

• The sludge did not act or react as a soil. It had the consistency of a gel-like material that chemically affixed water to the sludge. This chemical bonding of the water molecules caused the sludge to have an extremely high moisture content. Moisture typically decreased with depth.

• The pH ranged from 6.3 to 7.9.

• Organic content ranged from 2.4 percent to 69.8 percent.

Additional tests were deemed necessary after field sampling and testing. The first test performed was bench-scale solidification to determine whether the sludge could be solidified by adding an amendment. If it could be solidified, the generation of leachate would decrease and access to the sludge surface would be possible because of the sludge's increased strength, allowing installation of a low-permeability cap system. The sludge so-

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Installation of a biaxial geogrid made of high-quality polypropylene mesh over the sludge created a surface reinforcement layer, *above,* that gave work crews access to install a lighter, floating geosynthetic cover system, *below.*

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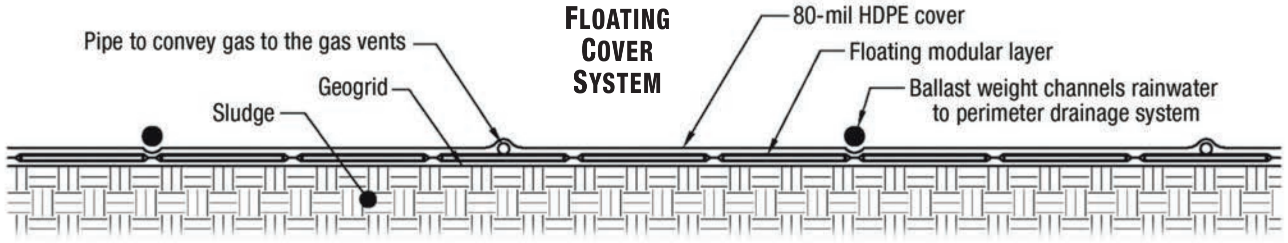


lidification testing involved taking multiple samples of the sludge and performing bench-scale solidification tests using a variety of admixtures:

- Slag cement;
- A blend (60/40) of portland cement and bentonite;
- Portland cement only;
- Agricultural lime;
- Quicklime.

The percentages of the solidification agents added ranged from 10 to 60.

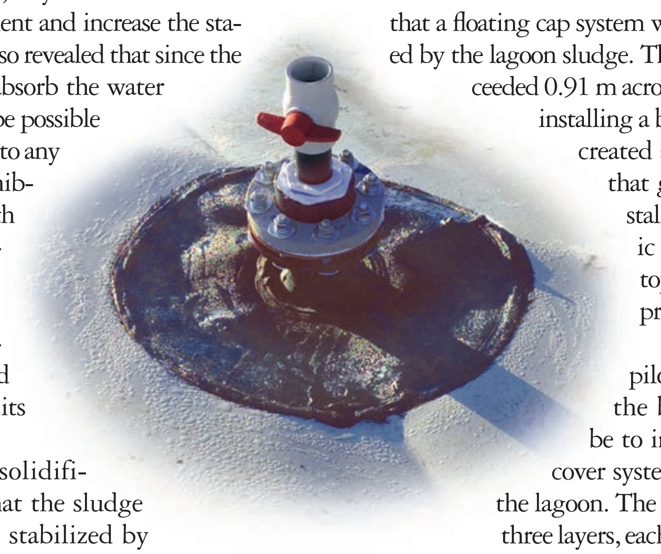
Bench-scale solidification testing revealed that the water-bonding properties of the sludge limited the effectiveness of dewatering and stabilization through solidification. The amendments typically used in the solidification process, such as cement (portland and lime), rely on the water within the sludge to activate the amendment and increase the stability of the sludge. The tests also revealed that since the admixtures were not able to absorb the water from the sludge, it would not be possible to strengthen or dry the sludge to any extent. Finally, the sludge exhibited practically no shear strength increase after amendment addition. Testing the shear strength of the amended sludge was attempted but could not be performed because the amended sludge was unable to support its own weight.

The bench-scale sludge solidification analysis established that the sludge could not be cost-effectively stabilized by amendment addition to the extent that it would support a conventional low-permeability cover system. The inability to solidify the sludge would have only a limited effect on the potential for the sludge to migrate or generate leachate on its own. Precipitation, however, if allowed to flow through the sludge, could generate leachate that would need to be collected and treated. Because the sludge would not freely give up water, it would not leach or produce leachate if the precipitation could be kept out of the lagoon. By capping the surface of the lagoon, the precipitation could be cut off and the water entering the collection system would drop to almost zero. Since the lagoon subgrade soils were compact and very dense, the sludge itself would be unlikely to migrate into them.

A pilot test for a floating cap was performed on the surface of the lagoon sludge to determine it a geogrid could be used to bridge the sludge and support a thin soil cap system. The geogrid-reinforced floating soil cap system would provide access to the top of the sludge so that a low-permeability geomembrane could be installed, thus reducing precipitation infiltration.

This test involved placing a biaxial geogrid over the sludge in a 30.4 by 30.4 m test area to create a bridging layer. Next, 0.61 m of sand was placed on top of the geogrid using a long-reach excavator. And finally, cap settlement plates were installed above the geogrid at two locations and monitored for settlement for six months. Elevation readings were taken daily for the first week and once per week thereafter.

The pilot study provided two critical pieces of information used in the design of the lagoon closure system. First, the excessive settlements recorded on the cap settlement plates indicated that a floating cap system with soil could not be supported by the lagoon sludge. The floating cap settlements exceeded 0.91 m across the pilot study area. Second, installing a biaxial geogrid over the sludge created a surface reinforcement layer that gave work crews access to install a lighter, floating geosynthetic cover system that sealed the top of the lagoon and prevented precipitation from entering.



Manually operated biogas vent ports were placed on the lagoon floating cover to remove any biogas produced by the sludge.

Based on the results of the pilot study, it was concluded that the best course of action would be to install a floating geosynthetic cover system across the entire surface of the lagoon. The cover system would comprise three layers, each with a distinct function. The layers, from the bottom, would be as follows:

- A surface reinforcement layer, namely, a biaxial geogrid made of a high-quality polypropylene mesh;
- A floating modular layer made up of Styrofoam panels encased in a high-density polyethylene (HDPE) geomembrane 40 mils thick;
- A low-permeability white HDPE geomembrane layer 80 mils thick that would minimize the infiltration of precipitation and promote stormwater runoff.

The polypropylene and HDPE materials were chosen on the basis of their chemical compatibility, long-term reliability when exposed to ultraviolet rays, and ability to be fabricated both on- and off-site.

The reinforcement layer stabilized the surface of the sludge and facilitated the installation of the two other layers of the cover system. It was placed directly on top of the

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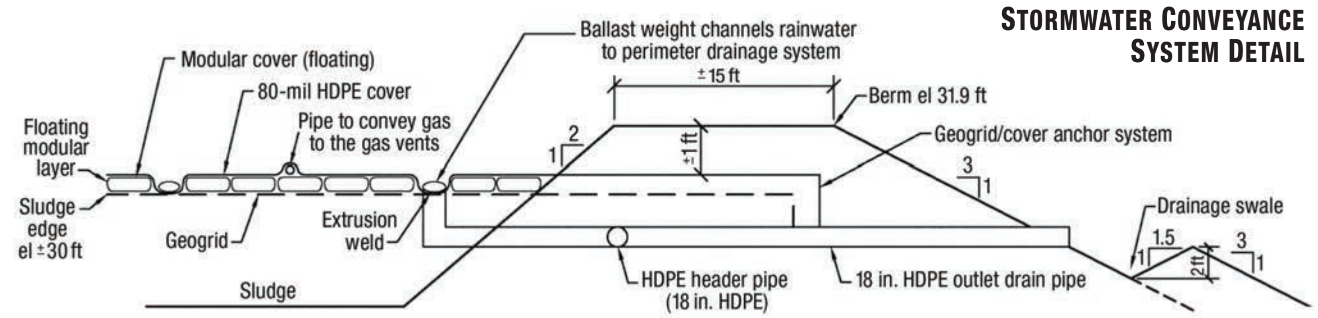

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sludge across the entire lagoon surface and anchored along the edge of the lagoon. The mesh had a minimum rib thickness of 1.78 mm and a normal aperture (mesh opening) dimension of 25 mm.

Engineers at Industrial & Environmental Concepts, Inc., of Lakeville, Minnesota, and the Syracuse, New York, office of O'Brien & Gere developed and fabricated the floating modular layer that was placed on top of the surface reinforcement layer. The modular layer keeps the low-permeability HDPE geomembrane layer above the surface.

Most of the floating modular layer was fabricated off-site at Industrial & Environmental Concepts' shop. This layer comprised a network of Styrofoam panels 5.08 cm thick, each encapsulated in watertight casings of HDPE geomembrane 40 mils thick. These modular floats were arranged in a contiguous grid that covered the entire surface of the lagoon. The floats were connected to one another by thermally welding strips of geomembrane. Cables were used to anchor the floats to the lagoon berms. The floats were fastened to the cables with a loop of geomembrane thermally welded to each casing. To ensure that the floats could move with the sludge and the limited amount of biogas could travel to the vent ports, the boundaries between casings were not sealed.

A white HDPE geomembrane 80 mils (2.03 mm) thick was used for the low-permeability layer to minimize infiltration and promote runoff. This color and thickness were chosen because they would minimize the expansion and contraction of the geomembrane during construction, as well as over time, and would increase long-term durability.

The low-permeability geomembrane layer was assembled by welding sections of HDPE sheets together to create a geomembrane covering for the entire lagoon surface. The floating modular layer, combined with the surface reinforcement layer, provided a stable work surface that made it possible for the geomembrane layer to be installed using conventional crews and lightweight equipment. It took approximately four months to install the floating geosynthetic cover system over the entire lagoon.

Once the low-permeability geomembrane layer was in place, a series of stormwater conveyance channels were installed to keep stormwater off the lagoon's floating geosynthetic cover system. These conveyance channels were formed from a series of weights (sandbags and closed-end pipes filled with sand) installed in a grid pattern that matched the gaps between the Styrofoam panels. Stormwater is directed to the edge of the lagoon in the channels created by the weights. Once the stormwater is channeled off the cover system, it is conveyed to riprap aprons and grass-lined drainage channels located off the lagoon.

Based on the sludge makeup, it was predicted that a very limited amount of biogas would be produced for a short time after the floating cover had been put in place. A passive vent system could not be installed because of the risk of wind or air blowing back under the cover and creating an unstable uplift condition. The solution for this was to install six manually operated valves to release the biogas that would be generated after construction. The sludge produced a limited amount of biogas during the first six months after capping. With the removal of precipitation, the sludge has not produced any additional biogas since that time.

As more industrial and municipal facilities modify their processes or look to close aging sludge lagoons, the need for a cost-effective closure method that does not require sludge handling or stabilization and that can be implemented in a relatively short time frame will become more pressing. A floating geosynthetic cover system can be used either as a temporary cover or as a means of permanently closing a lagoon system in a way that also manages leachate generation. This project demonstrated that a sludge lagoon can be closed in a cost-effective manner using a floating geosynthetic cover as an alternative to the more traditional approaches of sludge solidification or dewatering and off-site disposal. **CE**

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PROJECT CREDITS **Project management, civil/geotechnical engineering, sludge investigation, construction management, and cost estimating:** O'Brien & Gere, Syracuse, New York, office **Floating cover installation:** Industrial & Environmental Concepts, Inc., Lakeville, Minnesota **Laboratory testing:** JLT Laboratories, Inc., Canonsburg, Pennsylvania