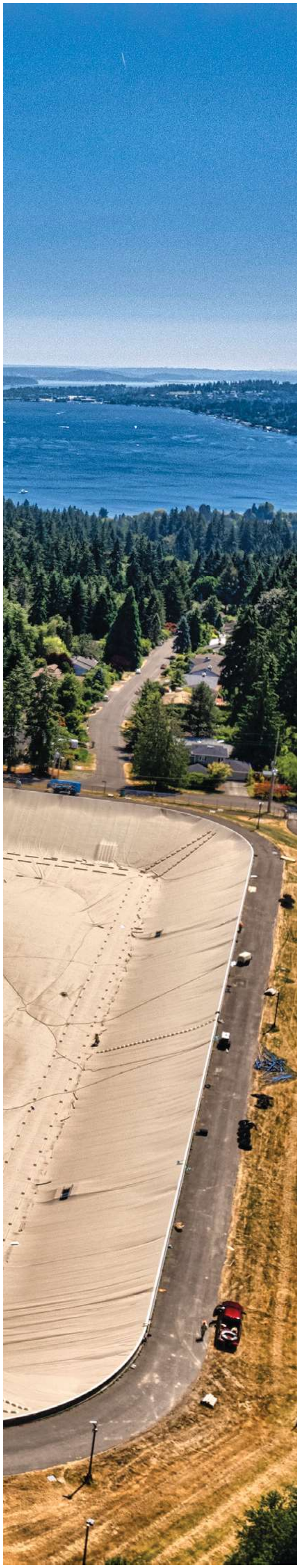

Lake Forest reservoir relining and floating cover

By Brian Fraser, MBA, Douglas Hilts, P.E., and Robert Emmons

Geosynthetic floating covers provide a highly sustainable and economical method of protecting and treating fresh and potable water. They are designed to protect fresh water from environmental contamination while eliminating water losses due to evaporation. Case in point is the Seattle Public Utilities, Lake Forest potable water storage reservoir. The reservoir was first built in 1962 as an open-top, concrete-lined 60-million-gallon (227-million-l) containment facility for potable water storage.

In 2002, the reservoir underwent multiple modifications and improvements, which included a 28 foot (8.5 m) vertical cast-in-place reinforced concrete center divider wall and the installation of a geomembrane liner and floating cover. With the divider wall, the reservoir was separated into two independent operating cells, each approximately 288 feet wide by 671 feet long by 24 feet deep (87.8 m × 204.5 m × 7.3 m). The reservoir operates as a potable drinking water storage facility and provides emergency water supply. A 45-mil (1.143-mm) reinforced polypropylene geomembrane liner and floating cover were installed in 2002 and were experiencing problems that required replacement.

In May 2021, phase 1 construction began on the new replacement geomembrane liner and floating cover system for the east cell of the Lake Forest reservoir and was completed in September 2021. Phase 2 included the installation of a new geomembrane liner and floating cover system on the west cell. This construction was completed September 2022.

Project challenges

The construction challenges included developing a revised floating cover design and installation plan to address the issues with the 28 foot (8.5 m) vertical divider wall. To address the vertical wall configuration and shape of the reservoir, the design

PROJECT HIGHLIGHTS

LAKE FOREST RELINING AND FLOATING COVER

LOCATION
Lake Forest Park, Wash.

OWNER
Seattle Public Utilities

CONTRACTOR
Layfield USA

CONSTRUCTION COMPANY
Layfield USA

ENGINEERS
Hilts Consulting Group

GEOSYNTHETIC PRODUCT
CSPE

GEOSYNTHETIC MANUFACTURER
Burke Industries

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All figures courtesy of Seattle Public Utilities.

FIGURES 2–3 Installation underway of double trough system on 28-foot divider wall

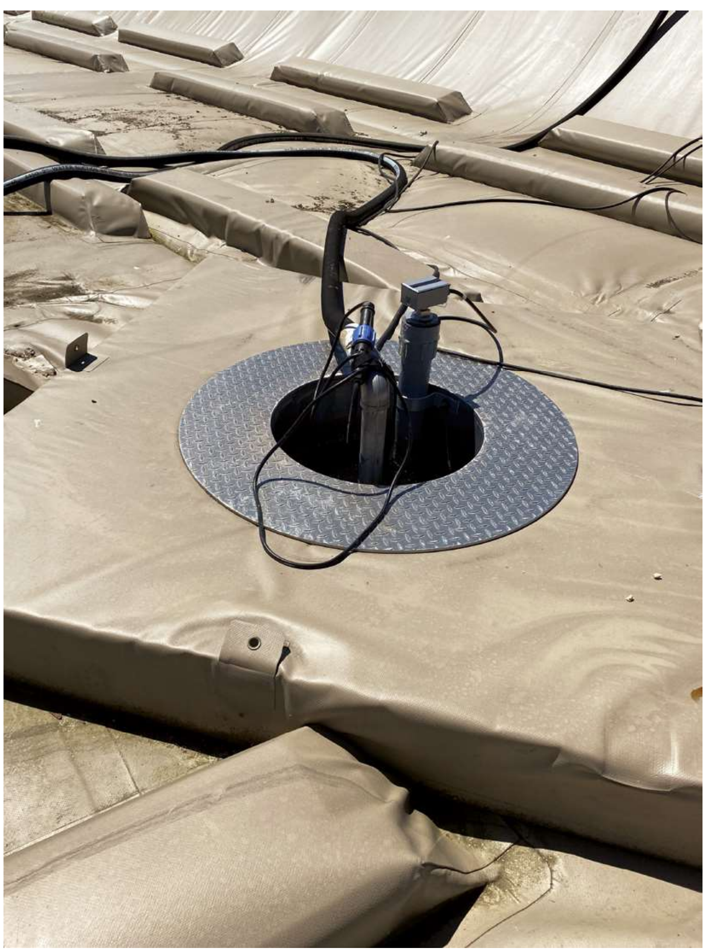


FIGURE 4 East cell divider wall trough in full service

engineer selected a weighted tension cover system. This system uses a series of designed troughs in conjunction with surface floats and ballast weights to supply the required cover tensioning, provide buoyancy in the floating cover and create rainwater collection troughs to drain surface water adjacent to the vertical divider wall. To handle the additional material slack developed in the floating cover from the 28 foot (8.5 m) vertical divider wall during the different reservoir operating levels, a special double trough system was designed and installed. The installation required that large custom-size panels be fabricated in the factory. These panels then needed to be lifted onto the vertical wall on-site to be vertically welded together. The joining of the panels required 3 inch (7.62 cm) wide field seams. The perimeter parapet wall required each fabricated panel to be lifted above the wall for deployment of the factory-produced panels and anchorage to the top of the perimeter wall. The geomembrane liner was anchored at the base of the perimeter wall and the floating cover was anchored to the top of the perimeter wall. The mechanical attachment consisted of stainless steel concrete anchors and stainless steel batten bars with rubber gasket material. The welding on-site was done primarily by thermal wedge and performed in compliance with the Geosynthetics Research Institute GM19 standards, and engineers specified field factory and seam strength requirements.

The weight tensioned floating cover system in both reservoir cells also required various additional appurtenances including access hatches, air vents, access stairways, double material over existing concrete stairs on slope and a pump surface water removal system. **Figure 2** shows the installation of the divider wall trough system on the west cell. **Figure 3** shows the east cell wall trough system in application at close to full operating level of the reservoir.

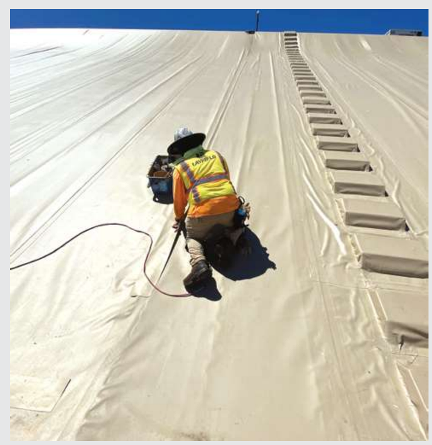
The rainwater removal system was designed for a 10-year, 24-hour duration and 25-year, 24-hour duration storm event. The number and size of the rainwater removal system pumps was based on a 48-hour and 72-hour removal capacity. Each cell has five submersible sump pumps housed in perforated aluminum sump cans located in the rainwater collection troughs. The surface water is pumped to the top of the reservoir perimeter and discharged into pipes located outboard of the perimeter parapet wall. **Figure 4** shows one of the aluminum sump cans located in the east reservoir cell. **Figures 5–10** show additional installation and inflating testing performed during phase 2 on the west cell.

Geomembrane fabrication

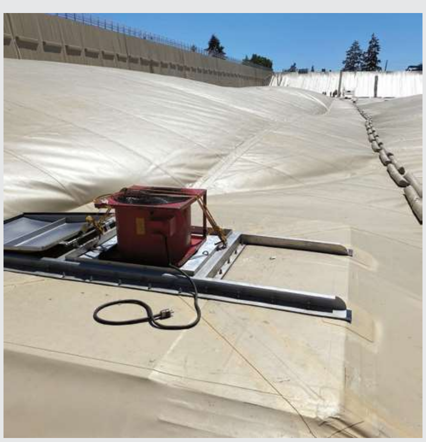
The Lake Forest reservoir required substantial prefabrication of the geomembrane liner, floating cover and appurtenances. The project required approximately 850,000 square feet (79,000 m^2) of prefabricated geomembrane panels. This included a large amount of custom-sized fabricated panels to address the divider wall and various curves and slopes of the reservoir. The prefabrication

The installation required that large custom-size panels be fabricated in the factory. These panels then needed to be lifted onto the vertical wall on-site to be vertically welded together.

FIGURE 5 Rainwater removal system



FIGURES 6–7 Crews installing fabricated entry stairways and welding floating cover seams



FIGURES 8–9 Inflation via access hatch and west cell cover undergoing inflation inspection

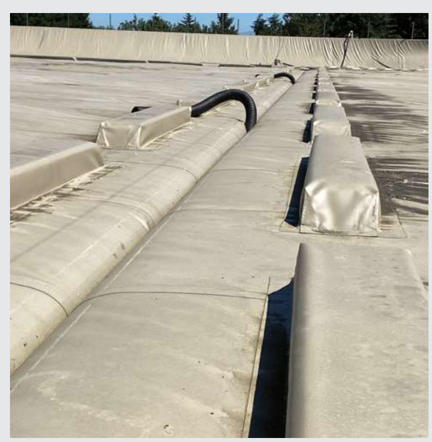


FIGURE 10 East cell trough and floats in service

of the geomembrane liner, cover and components resulted in substantial reduction in the amount of required field welding, construction time and installation cost. Prefabrication typically results in a major reduction of installation time and construction cost. We estimate that the prefabrication of the liner and cover system reduced field welding time by over 50% on the Lake Forest project. This was also important considering the highly inclement weather conditions typically experienced in the Seattle and Puget Sound region of western Washington.

The Fabricated Geomembrane Institute (Stark et al. [2020]) has previously compared factory and field-welded thermal geomembrane seams for a large off-stream water reservoir project. This comparison showed that factory-welded seams exhibit higher seam peel and shear strengths, less variability and more consistency than field-welded thermal seams. The compiled test results showed that factory seams are about 10% stronger than field seams. Factory fabrication can typically result in about 75% fewer field seams on a project.

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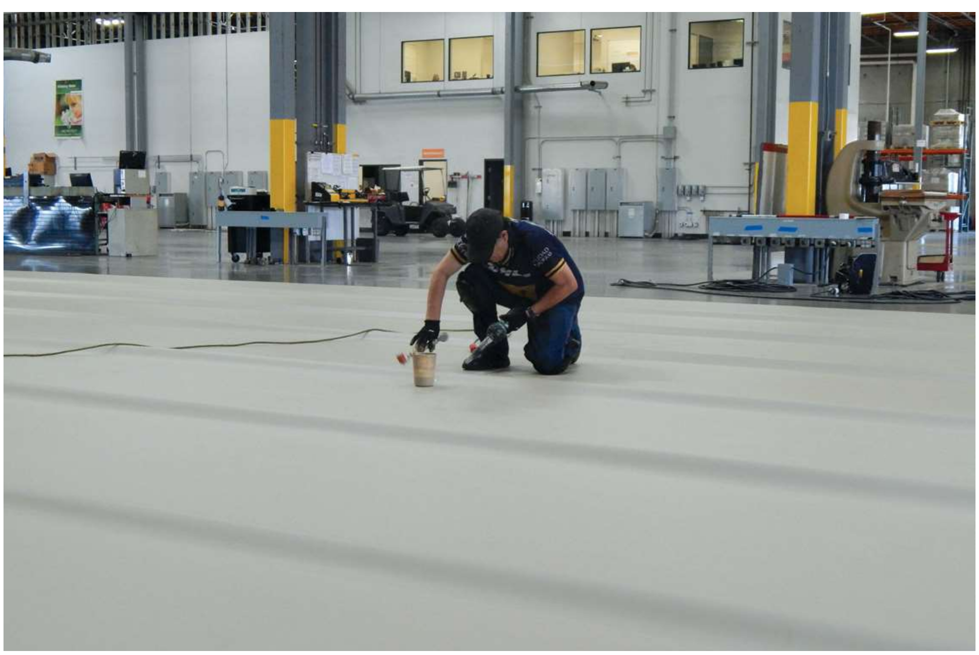
FIGURE 11 Factory fabrication of CSPE panels in Lakeside, Calif. plant



Material selection

The material selection process was a very important factor for the geomembrane liner and floating cover portion of the project. The owner has reported leakage and the existing reinforced polypropylene (RPP) material was showing signs of stress cracking and premature degradation. This included various cracks located around folds and creases (see **Figures 12** and **13**). Unfortunately, the extent of damage on the geomembrane liner could not be fully determined until the reservoir was taken out of service and the floating cover system was removed. The type of cracking in the material folds is often associated with multiple factors including prolonged UV exposure, continuous exposure to chlorine used for potable water disinfection and stress concentrations at upstanding folds resulting from hydrostatic pressure. Chemicals used for disinfectants in municipal water treatment include chlorine and chloramines and can function as accelerators in breaking down or leaching out the protective antioxidant packages of protective antioxidant packages in various polyolefin and PVC geomembrane-based formulations resulting in environmental stress cracking and premature material failure (Mills 2011).

After a detailed review process and consideration of available materials, the owner selected chlorosulfonated polyethylene (CSPE) for the replacement geomembrane material. CSPE is a highly flexible geomembrane that has been on the market for more than 50 years with a long-established history of proven performance in municipal water containment applications using chlorine and other disinfectants. The CSPE geomembrane material is also noted to have excellent UV resistance and is backed by a 30-year manufacturers weathering warranty.

Conclusion

The relining and cover replacement of the Lake Forest project incorporated many of the current best practices outlined in the American Water Works Association (AWWA) Manual M25, Flexible-Membrane Covers and Linings for Potable-Water Reservoirs. As the owner required a 30-year service life for the liner and cover, the material selection of the CSPE material with its 50-year proven record in potable water reservoir was an important choice. The project also incorporated an important weighted tensioned floating cover design, including strategically located custom troughs designed to manage the water service levels and center divider wall. Factory prefabrication of the materials and appurtenances was essential, ensuring high quality as well as reduced installation risk and costs. With the integration of a site-specific operation and maintenance program including regular planned inspections, all stakeholders involved are confident that the new Lake Forest reservoir liner and floating cover system will perform very well and achieve its expected 30-year service life. This project is another good example of engineered geosynthetic floating covers being used to protect our environment.

FIGURES 12–13 Surface cracks found in the RPP liner material folds and creases

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