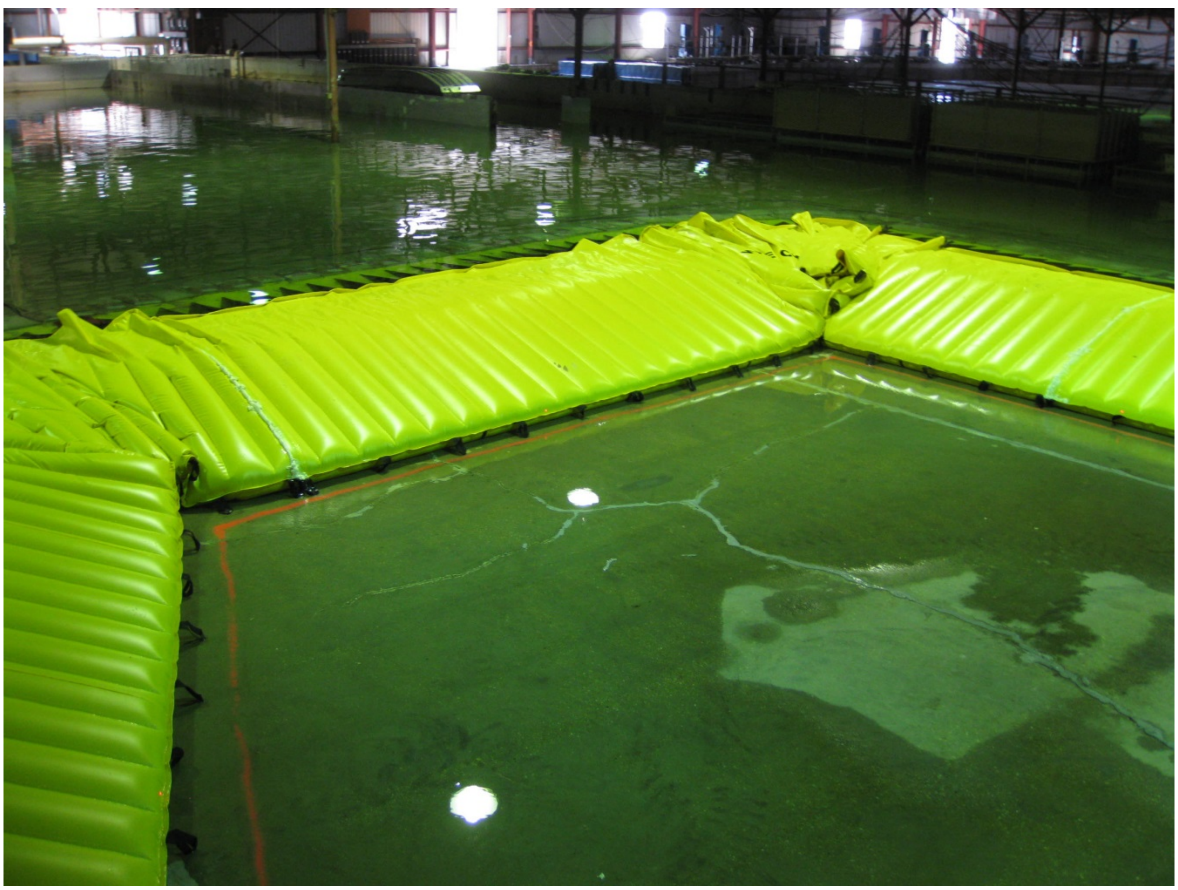
ERDC Report to Sponsor

US Army Corps of Engineers®
Engineer Research and Development Center

Evaluation of MegaSecur™ Flood Protection Barrier

Donald L. Ward

April 2015



Executive Summary:

The MegaSecur™ flood protection barrier consists of two layers of heavy vinyl fabric joined at one edge to form a “V” lying on its side. One leg of the “V” lies on the ground; flotation in the leading edge of the upper leg causes the barrier to rise with rising flood waters. Vertical panels between the two legs of the “V” provide support.

Basic installation of the barrier consists of just unrolling the 30- or 50-ft-long sections of barrier, joining the sections together with pre-attached Velcro strips, and adding some weights to the bottom edge of the barrier. For the installation reported herein, additional steps were taken to minimize seepage rates.

The barrier can go around corners simply by folding the barrier to the shape of the corner.

Installation of the 83.1-ft-long barrier took two men 8.6 man-hrs plus a third person bringing the barrier and sandbags into the test basin with a small skid-steer loader. A comparably sized sandbag barrier required more than 200 man-hrs to construct.

The MegaSecur™ barrier is designed for a maximum depth of 3.25 ft. Seepage rates at depths of 1 ft, 2 ft, and 3.1 ft were 0.13 gpm/ft, 0.28 gpm/ft, and 0.60 gpm/ft, respectively. To keep the seepage rates low, a person working in the water applied clamps as necessary to the outer upper edge of the barrier to stop localized overtopping, especially in the corners and at the ends.

The barrier was not damaged by waves although it was easily overtopped due to the low freeboard. There was some sliding of the barrier along the concrete floor of the test basin by large waves (10- to 12-in wave heights).

Additional flotation was required to keep the barrier from being overtopped in a strong current.

At the conclusion of the tests, the barrier was removed in 2.3 man-hrs, essentially undamaged, and completely reusable.

Contents

Figures and Tables

Figures

Tables

Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
$feet^2$	0.0929	$meters^2$
gallons (U.S. liquid)	0.003785412	cubic meters
gallons (U.S. liquid) per minute per foot	0.00020699	cubic meters per second per meter
pounds (mass)	453.59237	grams
pounds (force)	4.448222	Newtons

1 Introduction

Background on Testing Program

Early in 2004, Congress tasked the U.S. Army Engineer Research and Development Center (ERDC) to "devise real-world testing procedures for ... promising alternative flood-fighting technologies...." Through the General Investigation Research and Development Program, ERDC conducted research and developed a laboratory procedure for the prototype testing of temporary barrier-type flood-fighting structures intended to increase levels of protection during floods.

The test facility was laid out along the perimeter wall of a reservoir with dimensions of 115 ft by 185 ft by 4 ft deep (Figure 1). The test facility was reconfigured specifically for innovative flood-fighting experiments by allowing levees to be constructed against two wall abutments with a 30-ft opening between the walls (Figure 2). A geometric testing zone footprint was laid out on the concrete floor and all levees are required to be constructed within this given footprint. One side of the footprint abuts the concrete wall at a 90-deg angle, and the other side abuts the concrete wall at a 63-deg angle (Figure 3). The purpose for having two different angles is to simulate real-world geometric variability and demonstrate constructability and geometric flexibility of each vendor's product. Additionally, the unsymmetrical geometry allows wave loading variability during hydrodynamic testing, and causes an apparent current along the 63-deg wall.

Inside the test area (leeward side of the levee), an 8-ft diameter by 8-ft-deep circular pit was installed to catch any seepage or overflow water from the structure (Figure 3). Two 4-in.-diam pumps were installed in the seepage pit to pump the accumulated water back into the wave basin. Two 12-in.-diam pumps (12 in. intake and 10 in. output) were also installed to pump excess water out of the seepage pit when the capacity of the 4-in. pumps was exceeded.

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

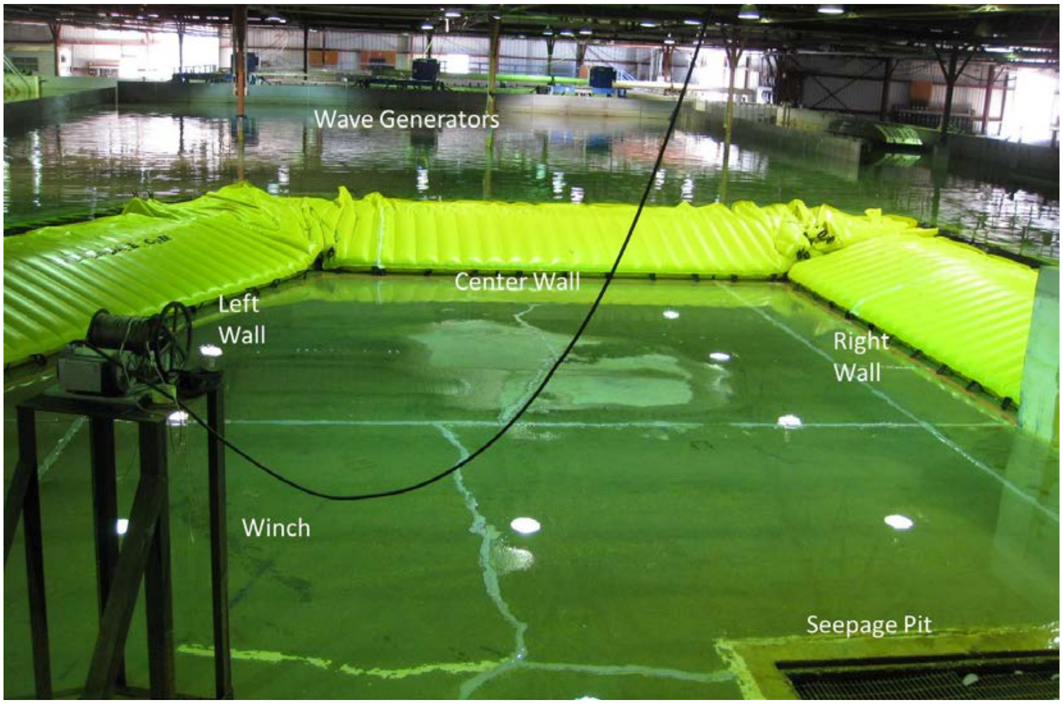


Figure 1. Looking into the research basin from the test area. The wave generators are at the far end of the basin, the winch for the debris impact test is lower left, and the seepage pit is to the lower right.

Figure 2. Looking into the test area of the research basin. The vertical white pipes extend down into the seepage pit.

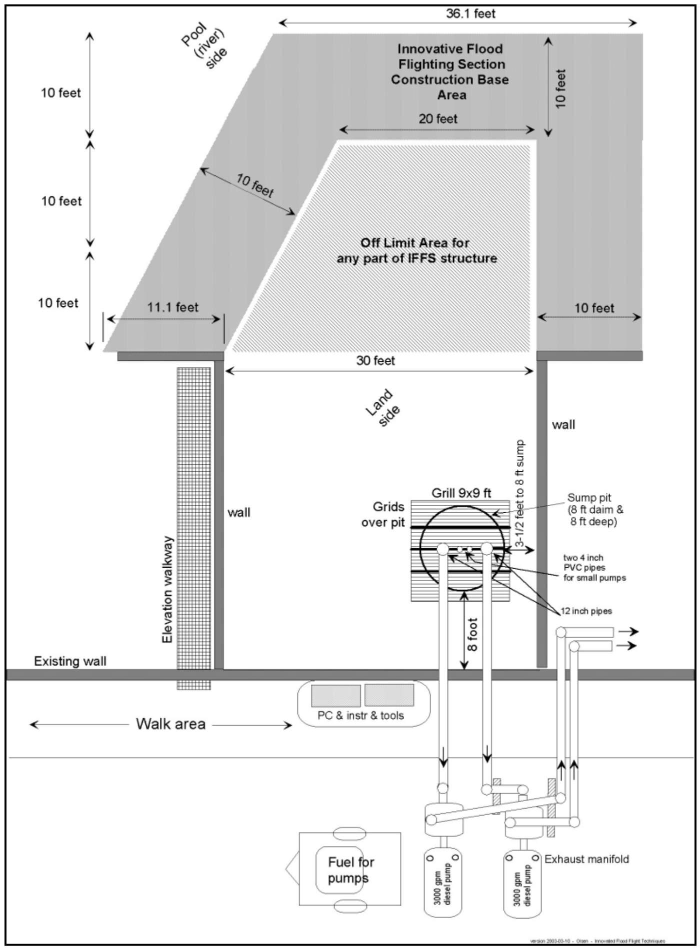


Figure 3. Layout of test area within research basin.

The test area was instrumented with a series of lasers to measure any movement of the flood-fighting barrier, a laser to measure changes in water surface elevation within the seepage pit, and an additional laser was placed to measure water surface elevation within the basin.

In the research basin tests, products were tested in a controlled laboratory setting but under conditions that emulated an impending flood overtopping a levee along a riverbank with moderate flow. Vendors were required to arrive at the test facility with all equipment and supplies required to erect their product prior to testing. The Vendor could use his own people or ERDC personnel (after receiving training from the vendor) to construct the barrier. The ERDC testing engineer did not assist with the construction but observed and documented the selected protocol-defined metrics associated with the construction including time required to install the test walls and any special equipment requirements. After construction, the Vendor was not allowed to adjust the structure during any of the tests specified in the protocol. The protocol does allow the Vendor access to the structure a maximum of three times between tests for a limited length of time if such access is required. Any such access to the structure was recorded.

A copy of the Standardized Testing Protocol is available at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=PUBLICATIONS;243

MegaSecur™ Product Description

The MegaSecur™ flood protection barrier is an innovative barrier made of heavy duty vinyl fabric that requires no assembly, filling, or anchoring. The barrier can be deployed simply by unrolling it in place, fastening multiple sections together with pre-attached Velcro fasteners, and securing the ends. As the flood waters come up onto the barrier, the weight of the water on the bottom layer holds the barrier in place and a strip of foam flotation in the upper layer causes the barrier to rise with the water level.

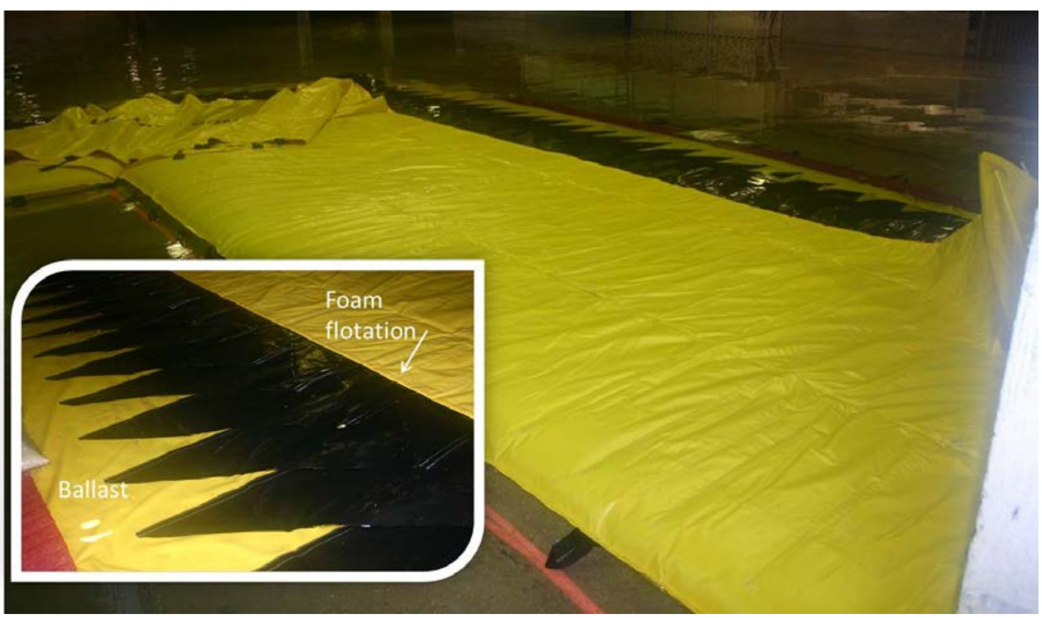


Figure 4. The barrier rising with the rising water level, from inside the test area. The insert shows the outer edge of the barrier looking in towards the test area.

Delivery

The MegaSecur™ flood barrier was shipped to ERDC on two pallets. Two pallets of pre-filled sandbags were already at ERDC. The shipped units included two models: model WL-3930 is 39 in. high and 30 ft long, and model WL-3950 is 39 in. high and 50 ft long. Also included on the pallets were all tools and supplies required to assemble the test barrier.

2 Testing Procedure and Results

Assembly

A Bobcat™ skid-steer loader was used to carry one of the pallets of MegaSecur™ barrier sections into the test basin, and the pallets of pre-filled sandbags. The Bobcat™ was also used to carry the pallets of sandbags around the border of the barrier for ease in placing the sandbags, but was otherwise not needed for construction of the barrier.

Each section of barrier comes in a carrying case that can be easily handled by two people (Figure 5). The barrier is removed from the case, rolled out in place, and unfolded to its full size.

Figure 5. A 50-ft-long section of the barrier rolled up in its carrying case can be carried by two people.

Adjacent units were fastened together with a double layer Velcro strip on both the top and bottom layers of the barrier (Figure 6).

Figure 6. Adjacent sections of the barrier are fastened together with pre-attached double layers of Velcro fastener.

The two corners in the planform of the Protocol (one 90 degree corner and one 63 degree) were accomplished by simply folding the barrier (Figure 7). Sandbags helped hold the edge in place while it was being folded.

At the wingwalls, the barrier was just laid up over the wall and anchored against the walls with some sandbags (Figure 8).

Figure 7. Corners were accomplished by simply folding the barrier.

Figure 8. At the wingwalls, the barrier was just laid up over the wall.

A roll of fabric divided into segments and filled with small gravel is used to weight down the outer edge of the barrier (Figure 9). The darker red color beneath the pink roll of gravel in Figure 9 is a row of small metal weights sewn into the outer edge of the barrier.

Figure 9. The pink fabric is a roll of pockets filled with small gravel to help hold down the outer edge of barrier.

The completed barrier for a "typical" installation is shown in Figure 10.

Figure 10. Completed typical installation, looking into the test area.

The MegaSecur™ barrier is designed to hold back up to 39 in. depth of water while keeping the amount of water that passes under, through, or over the barrier "manageable" by means of small pumps. However, for the installation tested herein, the Vendor chose to take additional steps to reduce the seepage rates.

For these tests, the Vendor chose to use expanding foam sealant under the outer edge of the barrier to improve the seal to the floor and reduce seepage under the barrier (Figure 11). Expanding foam was also used at the base of the wingwalls to improve the seal, and a thin strip was placed over the Velcro seams between units (Figure 12).

A row of sandbags was added to the outer edge of the barrier, with additional sandbags placed at the ends and at the corners. Finally, dowels were added to hold the barrier open at the ends and corners (Figure 13). The vertical panels in the barrier are made with a pair of holes in each panel, one near the top and one near the bottom, to hold the dowels.

Figure 11. A strip of foam sealant is placed under the outer edge of the barrier to reduce seepage.

Figure 12. A strip of foam sealant is placed along the Velcro seam to reduce seepage.

Figure 13. The completed installation with the addition of foam, sandbags, and dowels.

The basic installation shown in Figure 10 took two men 1 hr 58 min to install, plus a third man on a Bobcat™ skid-steer loader to bring the pallets into the basin (23 min) for a total assembly time of 4.3 man-hrs. The enhanced assembly shown in Figure 13 took two men 4 hr 3 min plus one man on a Bobcat™ (30 min) for a total assembly time of 8.6 hrs.

The left wall of the barrier was 27.3 ft long, the center wall was 30.7 ft long, and the right wall was 25.1 ft long for a total length of 83.1 ft. The design maximum depth for the barrier was 3.25 ft (39 in.).

Hydrostatic Tests

Seepage through floor

During recent tests with another product, seepage through cracks in the basin floor was observed in the test area (Figure 14). These cracks had been sealed but the cracks had apparently re-opened due to freeze/thaw cycles. An attempt was made to re-seal the cracks, but the attempt was not successful probably due to cold temperatures keeping the sealant from flowing into the cracks sufficiently to get a good seal. Therefore, measurements were made of all significant leaks, then the total quantity was adjusted for additional minor leaks not measured. The result was a seepage rate through the floor that added 0.015 gallons per minute per foot of barrier length (gpm/ft) at a basin depth of 2 ft. Starting with zero seepage at zero depth, linear interpolation was used to estimate seepage rates at other depths. All seepage rates given in this report have the estimated floor seepage subtracted from the measured seepage.

Figure 14. Seepage water coming up through a crack in the floor of the test area.

One Foot Depth

The pumps were turned on to flood the basin at 12:57 and a depth of 1 ft was reached at 14:24. Water depth in the basin is measured by a laser reflecting off a float at the bottom of a standpipe. Water depth in the basin had to reach about 0.2 ft before the float was lifted off the basin bottom, therefore the first 0.2 ft of depth appears constant in Figure 15 but actually starts at 0.0 ft.

Seepage

The measurement of “seepage” in this facility is calculated from the change in water surface elevation within the seepage pit during a test. The measured seepage therefore includes any water that passes under the barrier into the test area, or over the barrier, or through the barrier.

Seepage rate during filling of the basin and during the first two hours of the test are shown in Figure 15 and during the final two hours of the 22-hr test in Figure 16. Seepage reached a peak of about 0.16 gpm/ft at 14:40 and averaged 0.13 gpm/ft during the final two hours of the test.

For the most part, as the water level was rising the flotation in the top layer of the barrier was sufficient to keep the barrier above the water level. However, water did overtop the barrier in small localized areas and it was necessary to raise the outer edge of the barrier above the water to obtain the smallest possible seepage rates. This was especially true in the corners where the weight of the fabric in the folds hindered the rising of the upper edge of the barrier, or at the ends where the vertical sections going up the wingwalls prevented the top of the barrier from rising normally (Figure 17). This overtopping usually occurred only when the basin depth was being raised. Raising the outer edge was accomplished by a person in waders walking the perimeter.

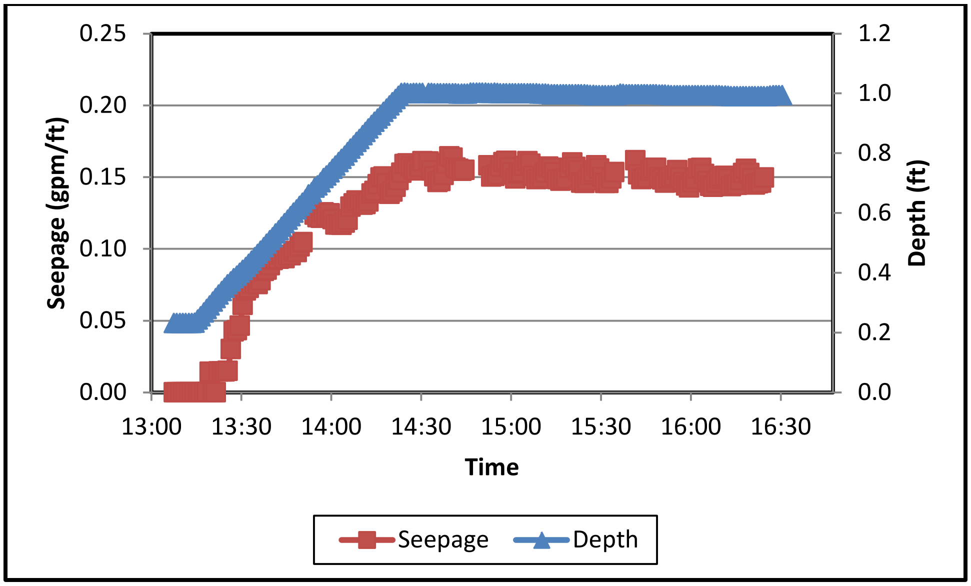


Figure 15. Seepage rates during filling and first two hours at one-ft depth.

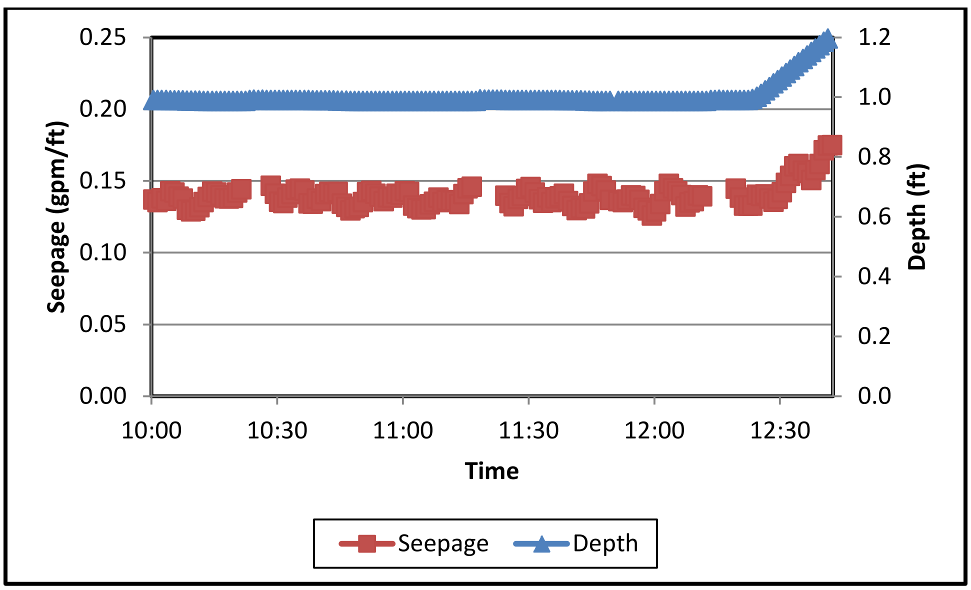


Figure 16. Seepage rates at end of 22-hr test.

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

Figure 17. Raising the outer edge of the barrier to shut off a rivulet of overtopping near the wingwall.

Movement

The barrier was laid out in a modified "U" shape with a left wall, center wall, and right wall (when viewed from the test area looking out into the basin) (Figure 1). A distance-measuring laser was aimed at each of the three walls of the barrier at the approximate midpoint (horizontally) of the wall. Because the sloped back of the walls rose up and down with the water level, the lasers were aimed at the bases of the walls in an area that was nearly vertical and should stay in place (Figure 18). Any sliding of the barrier on the concrete was recorded by the lasers.

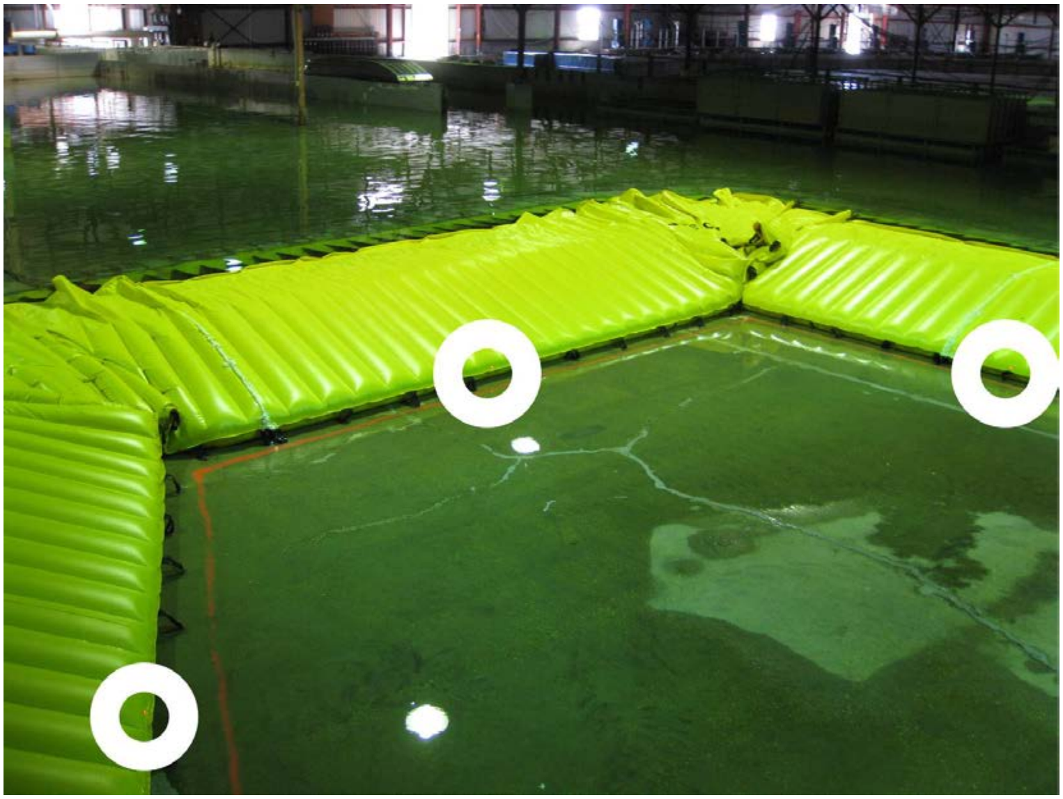


Figure 18. The red dot in the middle of each of the white "doughnuts" is the beam from the distance measuring laser.

Movement of the barrier as recorded by the distance-measuring lasers during filling to the one-ft depth is shown in Figure 19. Normally, values are adjusted relative to the initial values at the completion of construction and before adding water to the basin. However, distance to the MegaSecur™ barrier could not be measured until the water had raised the barrier sufficiently to provide a vertical surface at which to aim the lasers. The distances in Figure 19 and other figures of movement were therefore referenced to the location of the barrier at a basin water depth of one ft. Any movement of the barrier into the test area was indicated by a positive value and movement out into the basin was given as a negative number. Gaps in the recordings were caused by people walking between the lasers and the barrier.

The lasers have a resolution of about 0.003 ft (1 mm); measurements smaller than 0.003 ft were obtained by averaging the roughly 20 measurements taken per second to obtain one-minute averages. There was basically no discernable movement of the barrier with the maximum movement being 0.004 ft for the right wall by the end of the test (Figure 20).

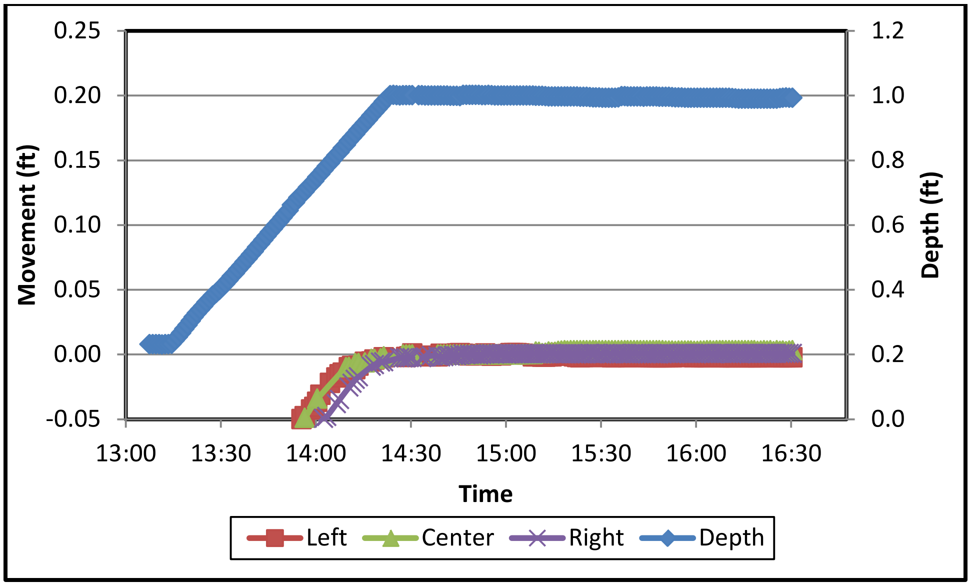


Figure 19. Movement of MegaSecur™ barrier during filling of basin to one-ft depth and first two hours at depth.

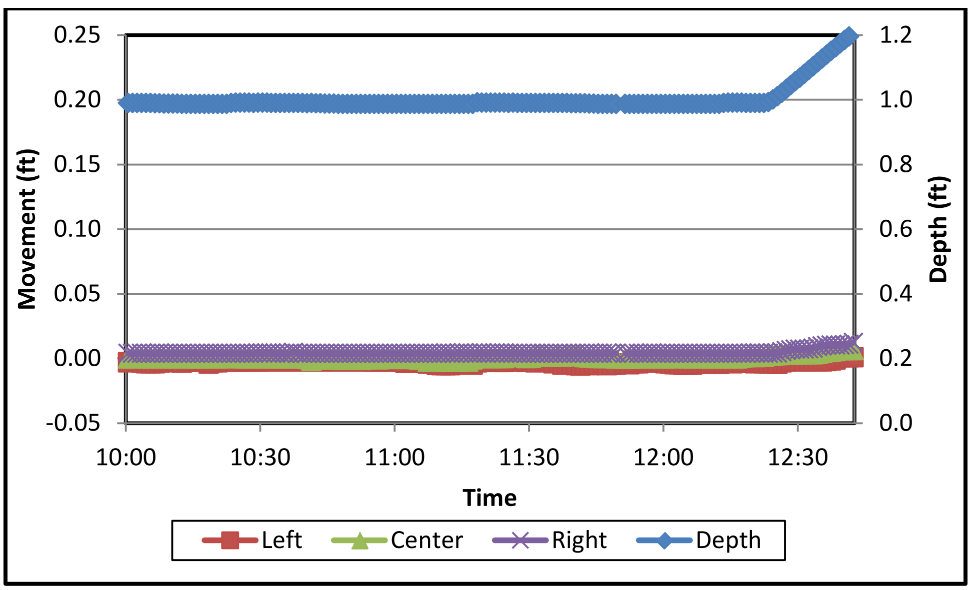


Figure 20. Movement of MegaSecur™ barrier at end of test at one foot water depth.

Two Foot Depth

Seepage

The pumps were turned on Wednesday at 12:24 to raise the water to a basin depth of 2.0 ft. Water level was reached at 13:53. Observed seepage was mainly at the ends next to the wingwalls, in the corners, and through the seams between units. There was considerable overtopping of the 90 degree corner as the water depth reached 1.9 ft causing the "seepage" (actually seepage plus overtopping) to spike to nearly 0.6 gpm/ft (Figure 21). The seepage rate was reduced by raising the outer edge where the overtopping was occurring and placing clamps on the outer edge to hold it higher than the basin water (Figure 22). In addition, a sheet of plastic was placed over the Velcro seam inside the barrier on the center wall with fabric rolls filled with small gravel added as weights to hold the plastic in place. With these repairs, the seepage level dropped to an average of 0.35 gpm/ft between 15:00 and 16:00 hours.

The next day ERDC was shut down as freezing rain produced hazardous driving conditions, but opened again the following day. That morning the seepage rate was down to 0.28 gpm/ft for the final two hours of the test (Figure 23).

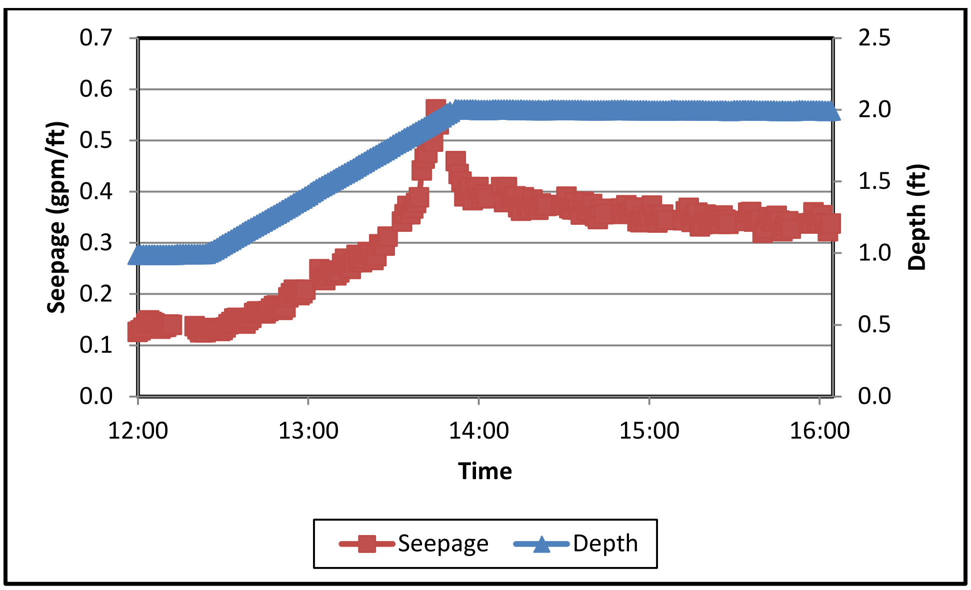


Figure 21. Seepage rate as depth in basin was increased from 1 ft to 2 ft.

Figure 22. A clamp is placed to raise the outer edge and shut off the water flowing down the seam.

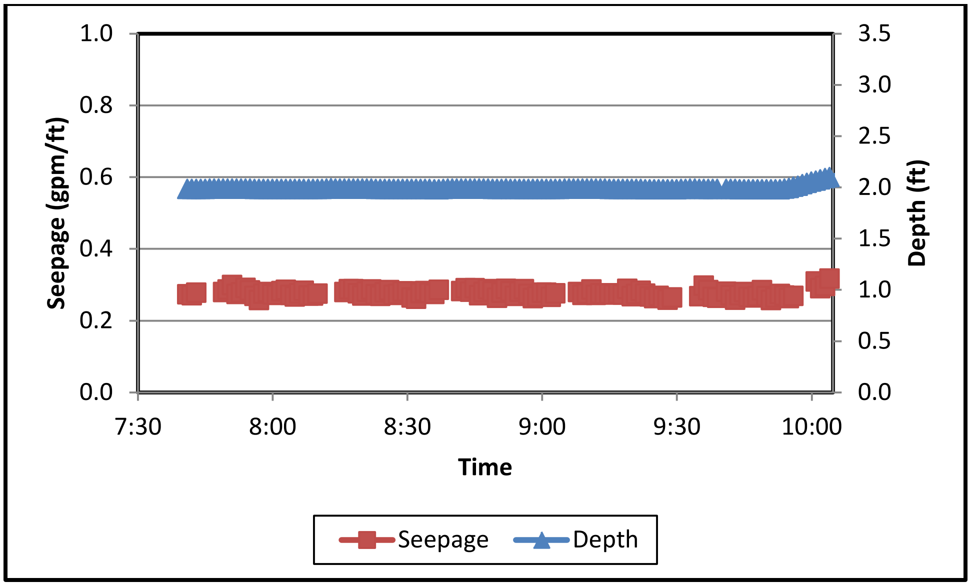


Figure 23. Seepage rate in basin during final 2 hrs of test at basin depth of 2 ft.

Movement

Movement of the barrier during filling to 2-ft depth is shown in Figure 24 and at the end of the 22-hr test in Figure 25. By the end of the test, the left wall had moved inward 0.014 ft, the center wall had moved inward 0.016 ft, and the right wall had moved inward 0.027 ft. For perspective, one-quarter inch is about 0.021 ft, so movement of each wall is on the order of one-quarter inch. There is no indication that any of the walls slid on the concrete floor of the basin. It is probable that as the upper surface of the barrier rose with the rising water it caused a minor shift in the areas where the distance-measuring lasers were pointing (Figure 18).

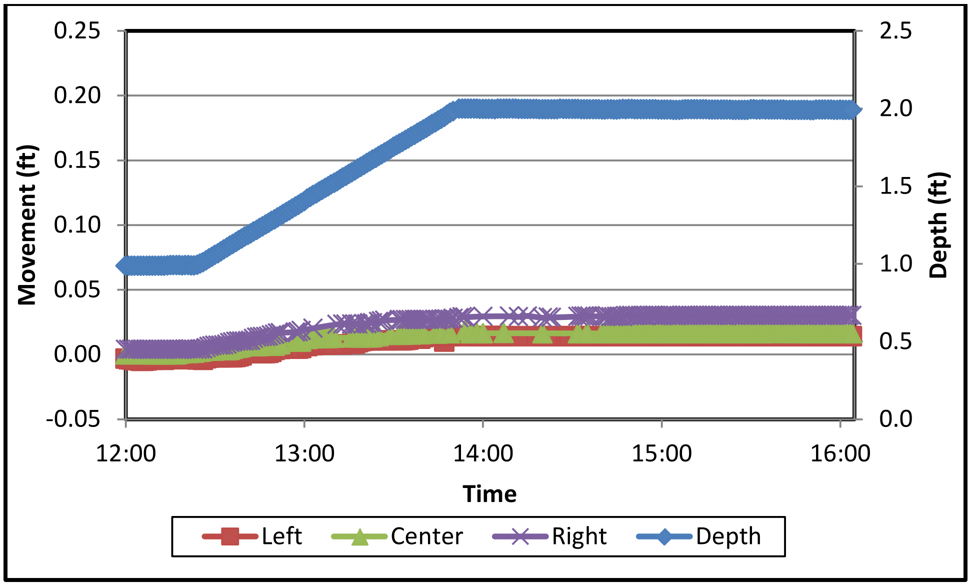


Figure 24. Movement of MegaSecur™ barrier during filling from basin depth of one ft to basin depth of two ft.

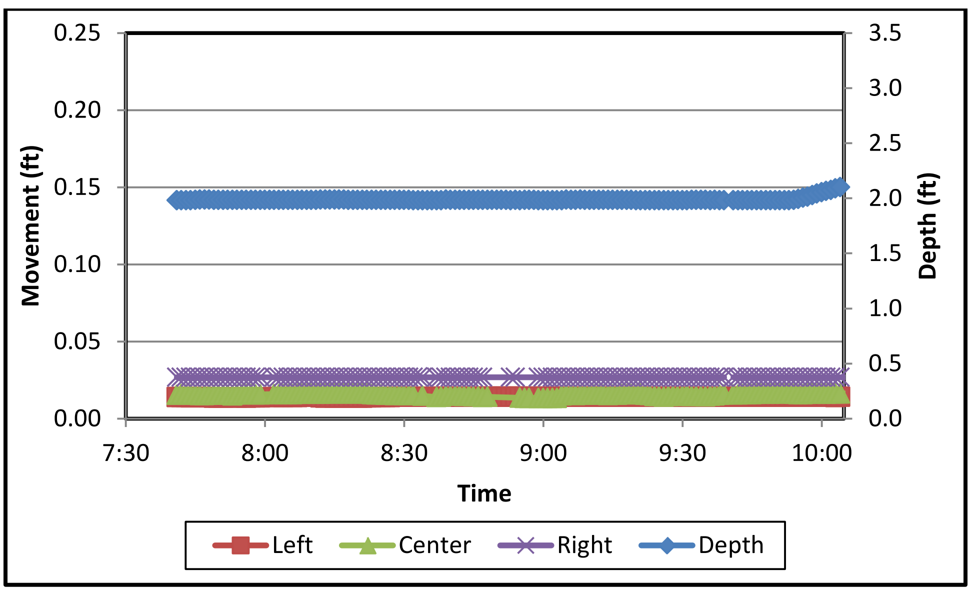


Figure 25. Movement of MegaSecur™ barrier at end of test at 2-ft basin depth.

95% of Design Depth

The MegaSecur™ barrier is designed for depths up to 3.25 ft (39 in.). For the 95% test, the depth was therefore raised to 3.09 ft. Pumps were turned on at 9:54 and the water level was reached at 11:35.

Seepage

As the water level in the basin rose, there was some overtopping particularly at the ends and corners of the barrier. Seepage rate rose as high as 0.75 gpm/ft before the addition of more clamps to the outer edge of the barrier stopped the overtopping. Seepage rate then came back down to an average of 0.66 gpm/ft between 13:30 and 14:30 (Figure 26), and down to 0.60 the following morning (Figure 27).

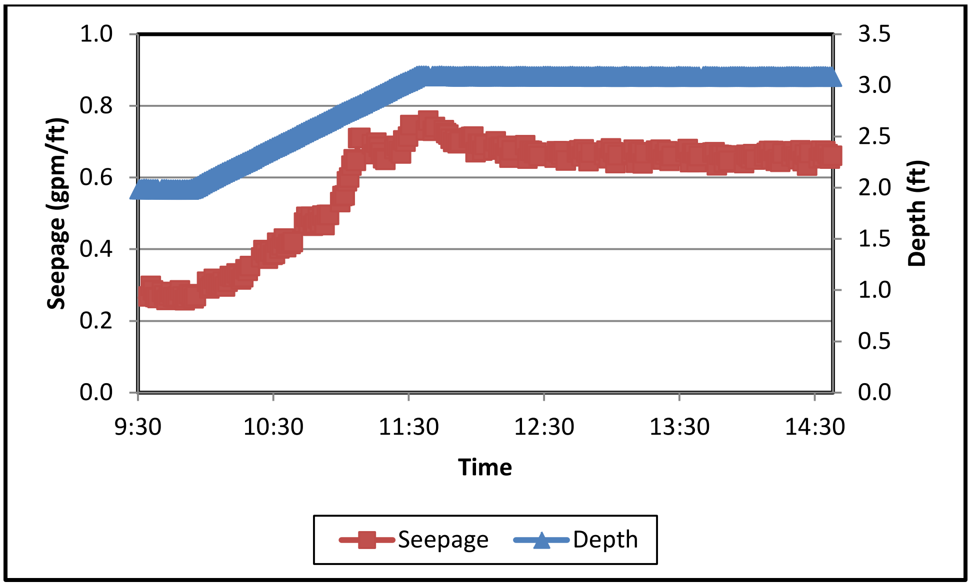


Figure 26. Seepage rates and depths as basin water level is raised to 95% of structure design depth.

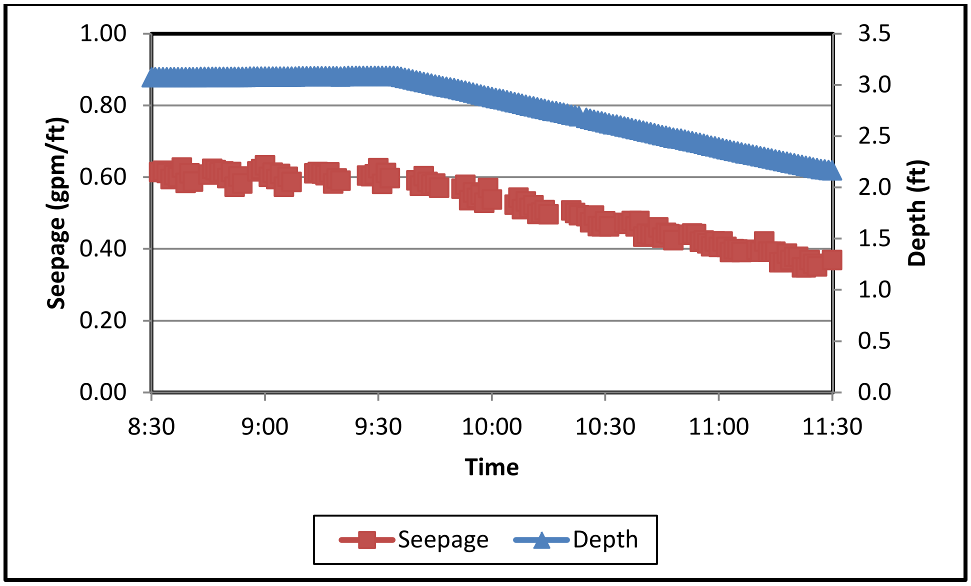


Figure 27. Seepage and water depths during end of 95% depth test and lowering water for small waves test at low water.

Movement

Movements of the barrier during raising the water level to 95% structure design depth and during the first hours of the test are shown in Figure 28 and during the final hour of the test in Figure 29. By the end of the test, the left wall had moved inward 0.024 ft, the center wall had moved inward 0.025 ft, and the right wall had moved inward 0.043 ft. Again, there was no indication of sliding or any movement other than adjustments in the wall due to the lifting of the upper fabric by the rising water. However, when the water level was brought back down at the end of the test, the measurements did not change (Figure 29).

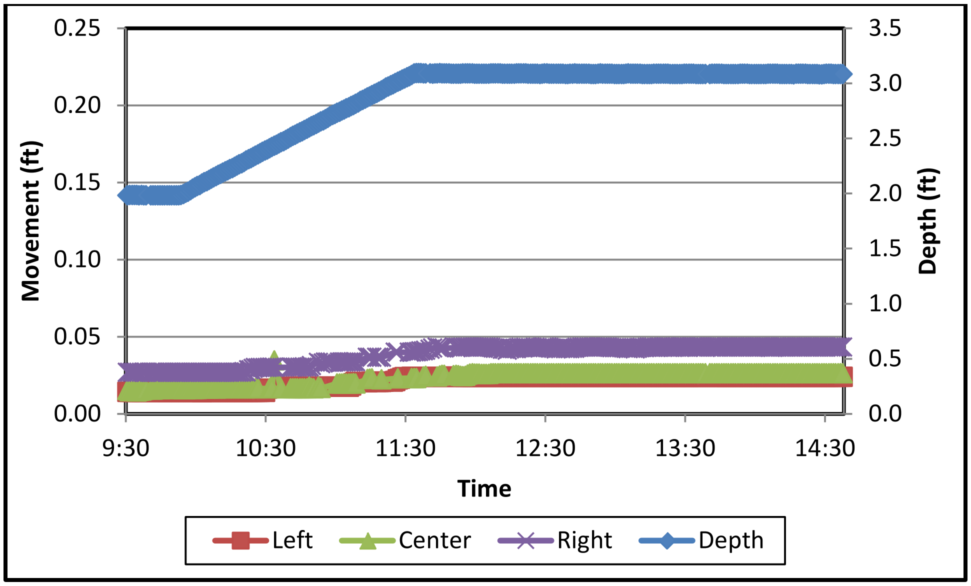


Figure 28. Movement of barrier during raising of basin water level to 95% structure design depth and first hours of test.

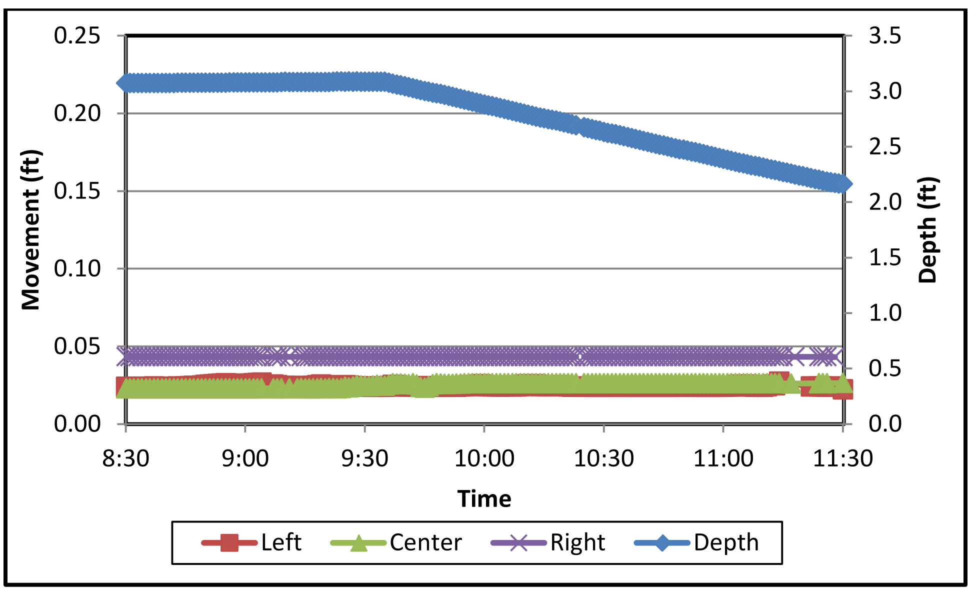


Figure 29. Movement of barrier during end of test at 95% depth and lowering water for small waves test at low water level.

Hydrodynamic Tests

Hydrodynamic tests included tests with waves, an overtopping test, and a riverine current test. The wave tests included small (2 in.), medium (6- to 8-in.), and large (10- to 12-in.) wave heights, all with a 2-sec wave period. All wave heights were run at low water (67% of structure design depth) and repeated at high water (80% of structure design depth). For the MegaSecur™ barrier, the structure design depth was 3.25 ft (39 in.) and the waves were therefore run at depths of 2.18 ft (low water) and 2.60 ft (high water). The purpose of the different depths is that at the low water the structure is subjected to the full impact force of the waves, while the high water will test if the structure can withstand some wave overtopping.

Waves

Low water, small waves

The Protocol calls for running the small waves at low water for 7 hrs. The waves were started at 11:36. A computer communication error halted the test after 2 hr 26 min; the waves were started again at 15:27 and run for another 30 min before stopping for the day (Figure 30).

Because the upper layer of the barrier is lying right at the still water level, even the small waves were able to cause overtopping. Overtopping was greatest over the center wall which is hit by the full force of the waves, but some overtopping of the left wall and very little over the right wall was observed. At the start of the waves test the seepage rate was 0.36 gpm/ft; overtopping raised the seepage to 0.58 gpm/ft in the first 15 min of the test. "Pumping" by the waves of the water passing under the center wall was also evident. The Vendor added support dowels to some of the vertical panels of the barrier and added more clamps to raise the outer edge of the barrier above the waves, bringing the seepage down to an average of 0.37 gpm/ft.

The seven hour test was continued for 2.5 hrs the following day. The seepage rate before starting the waves was 0.30 gpm/ft and increased to 0.37 gpm/ft when the waves were started. After the first hour of testing the seepage rate gradually rose to 0.48 gpm/ft, then dropped again after the waves were stopped to 0.33 gpm/ft (Figure 31)

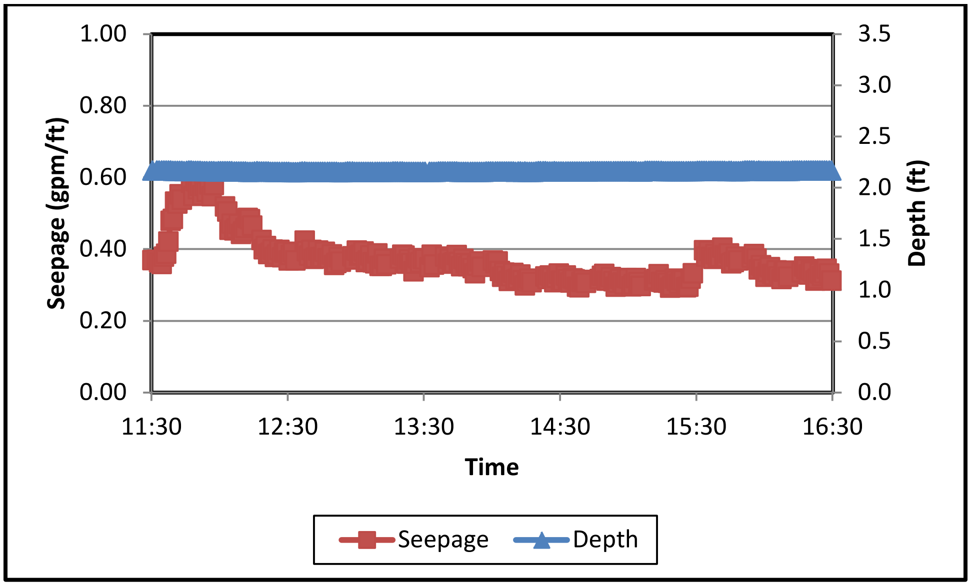


Figure 30. Seepage rate during small waves test at basin depth of 2.18 ft.

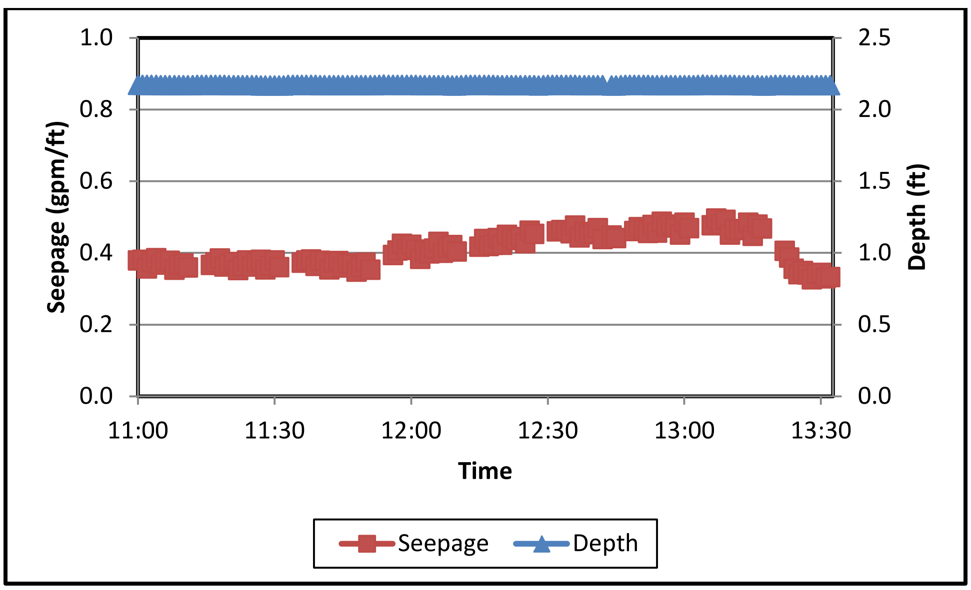


Figure 31. Second day continuation of small waves test at low water.

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

The following day the final 1 hr 39 min of the test was completed with the waves started at 7:52. Before starting the waves the seepage rate was 0.35 gpm/ft, averaged 0.45 during the waves, then dropped again at the end of the test.

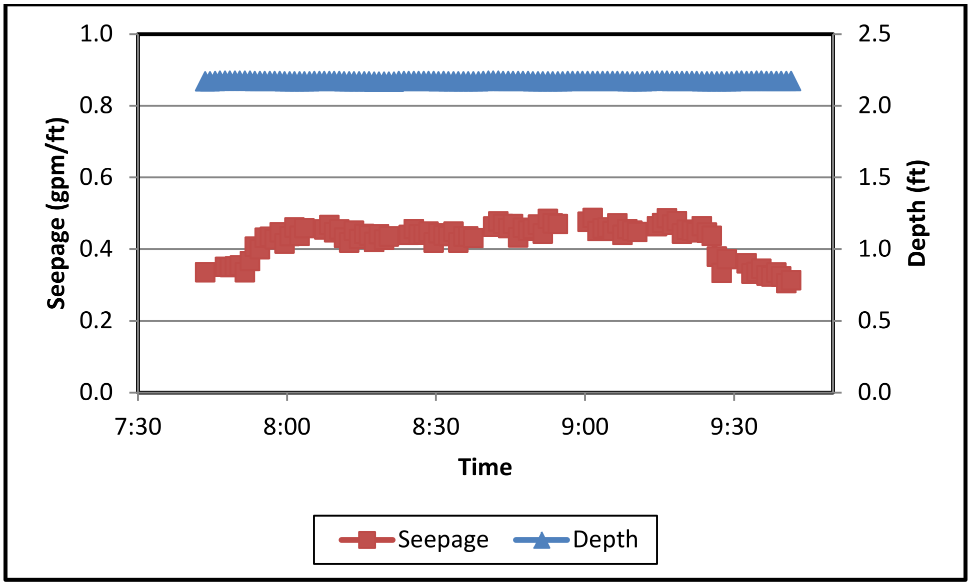


Figure 32. Third day completion of small waves test at low water.

Movement of the barrier is shown during the first day of testing in Figure 33, second day of testing in Figure 34, and third day of testing in Figure 35. There was no significant movement. Between the beginning of the test and the end of the test the left wall did not move, the center wall moved inward 0.001 ft, and the right wall moved inward 0.003 ft.

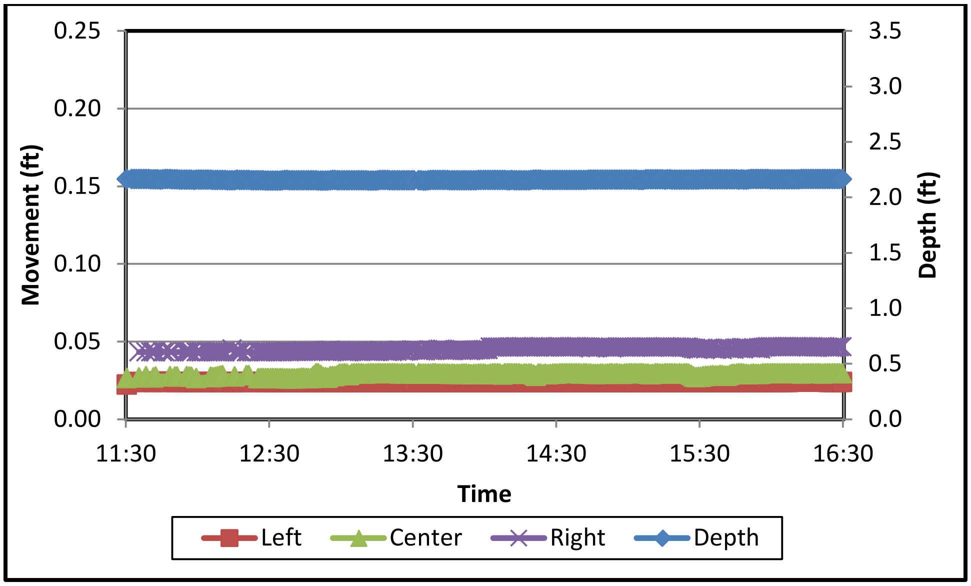


Figure 33. Movement of barriers during small waves test at basin depth of 2.18 ft.

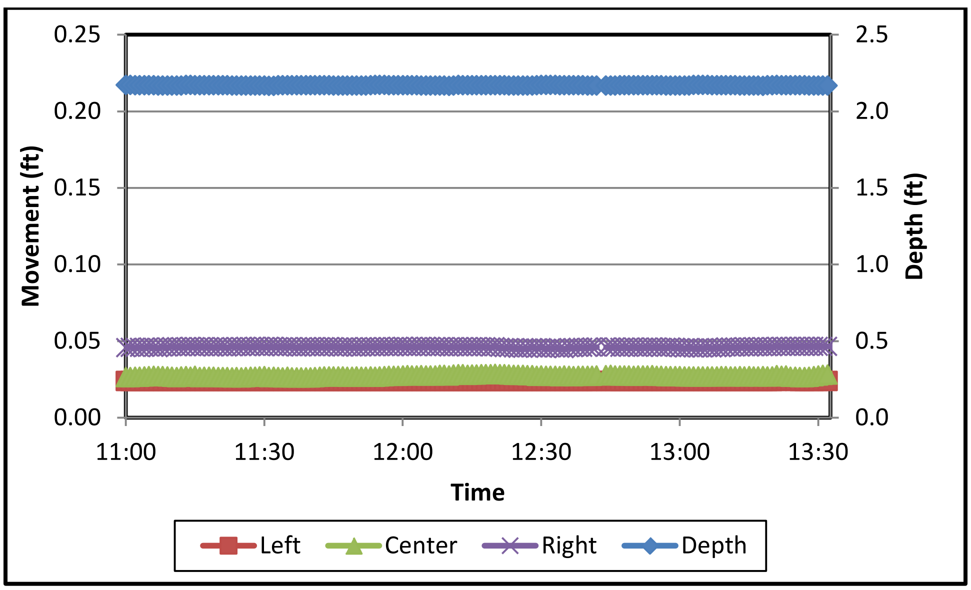


Figure 34. Second day continuation of small waves test at low water.

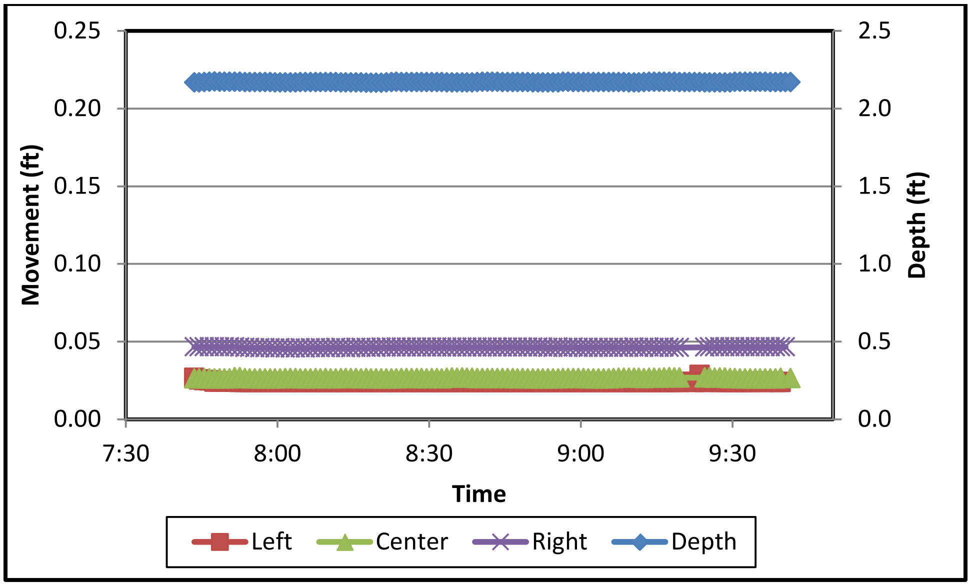


Figure 35. Third day completion of small waves at low water.

Low water, medium waves

With the basin water depth kept at 2.18 ft, monochromatic waves with a period of 2 sec and a wave height between 6 and 8 in. were run for 30 min. Because wave energy will build up in the basin from reflected waves, the 30 min test was run as three separate 10-min runs with a stilling period between the runs (the small waves could be run as one continuous 7-hr run due to the low level of energy involved). In Figure 36 (seepage) and Figure 37 (movement), the waves were run from 10:49 to 10:59, 11:10 to 11:20, and 12:00 to 12:10. Both figures show 10-sec averages of the data instead of the 1-min averages that have been used in earlier figures in this report to more clearly display the data.

Some overtopping was observed in each of the three runs in the corners at the ends of the center wall, and to a lesser extent along the center wall. Water passing beneath the barrier was seen to “pulse” with the wave action. Average seepage plus overtopping for each of the three runs was 1.12, 1.24 and 1.26 gpm/ft respectively (Figure 36).

There was no apparent movement of any of the three walls, although analysis of the data shows that the center wall moved from about 0.027 ft inward from its original location to 0.033 ft inward over the course of the three runs. That is a total movement of about one-sixteenth in. (Figure 37).

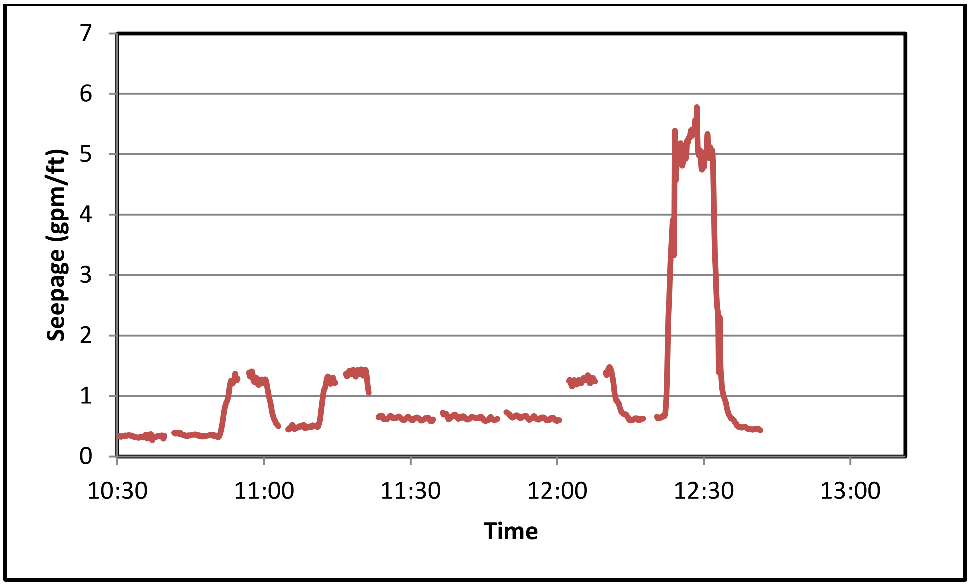


Figure 36. Seepage rates during tests with 6- to 8-in. wave heights and 10- to 12-in. wave heights with basin depth at 2.18 ft.

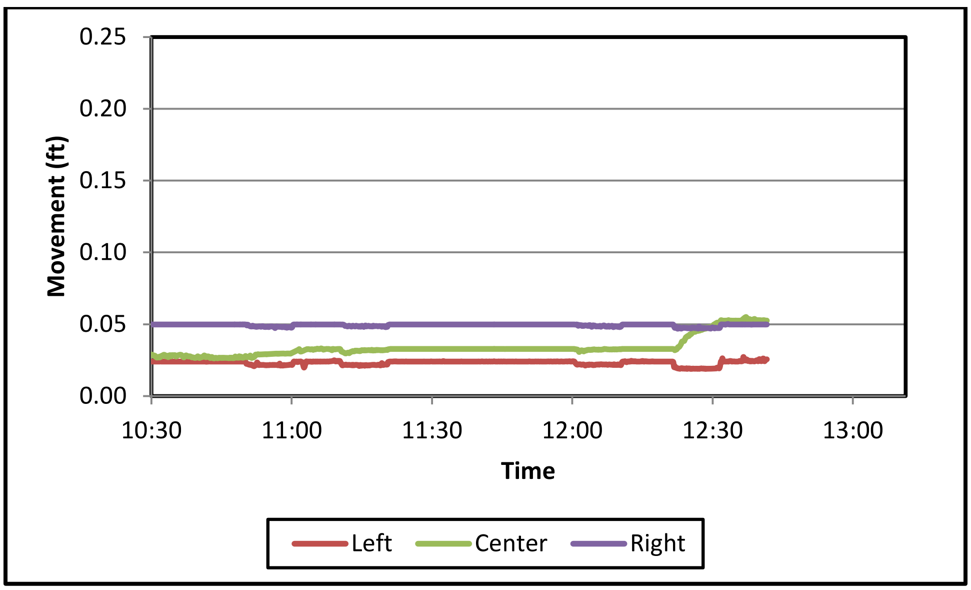


Figure 37. Movement of barriers during tests with medium and large waves at 2.18 ft depth.

Low water, large waves

With the water level remaining at 2.18 ft, large waves with a wave period of 2 sec and a wave height of 10- to 12-in. were run for 10 min. In Figure 36 and Figure 37, the large waves were run from 12:22 to 12:32.

There was massive overtopping of the center wall and in the corners at the ends of the center wall. It appeared that a wave crest would place water on top of the wall, then the next wave would throw the water back over the barrier. Average seepage plus overtopping for the run was 4.6 gpm/ft, with an average of 5.1 gpm/ft for the middle 5 minutes, and a peak of 5.8 gpm/ft (based on 10-sec averages).

The center wall of the barrier moved inward during the early part of the run, from 0.033 ft to 0.053 ft or about one-quarter inch.

Although cyclic movement of all three walls was observed, there was no damage to the barrier.

The barrier is shown in Figure 38 during the test with large waves at the low water level.

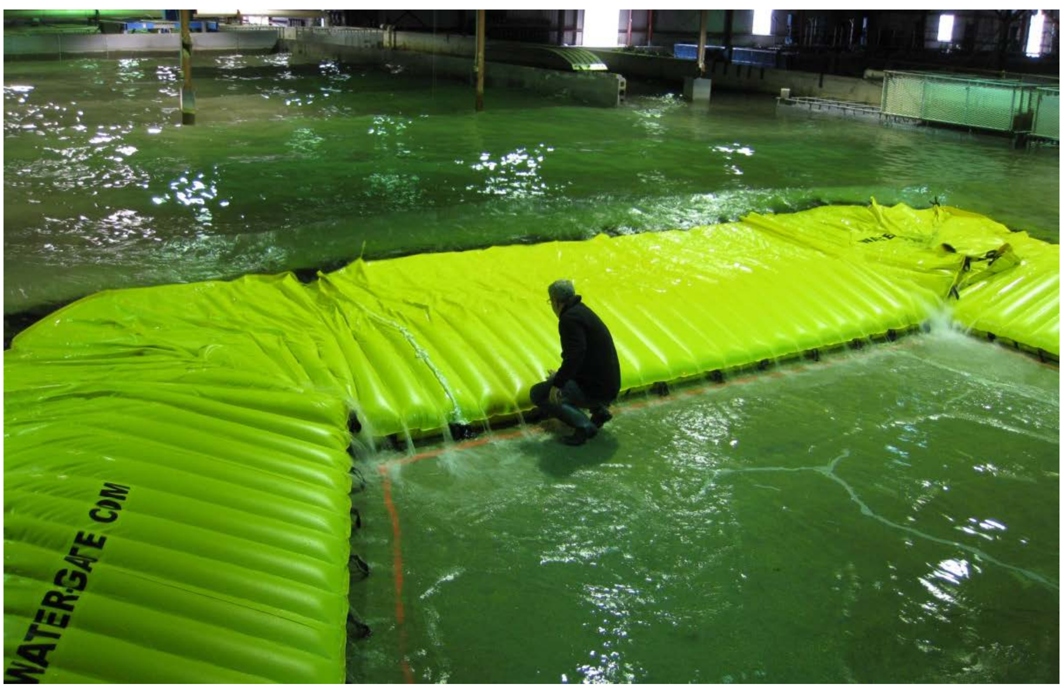


Figure 38. Barrier during test with large waves at low water.

High water, small waves

The basin water level was raised to 80% of the structure design depth, or 2.60 ft, for the high water wave tests. Monochromatic waves with a period of 2 sec and wave height of about 2 in. were run for a period of one hour. There was no damage to the structure noted. Instead of running the small waves test for the full 7 hrs, the testing engineer has the option of stopping the small waves test at high water at any time after a minimum of 1 hr. Because no damage to the structure was observed and there was no indication that continuing to run the small waves would have any effect on the structure, the test was stopped after one hour. In Figure 39 (seepage) and Figure 40 (movement), the small waves were started at 13:50.

Prior to starting the waves, the Vendor added additional clamps to the outer edge of the barrier to lower the overtopping that occurred when the water level was being raised. With the waves on, overtopping was observed at the 63-degree corner, a small amount near the left wingwall, and a small amount over the center wall.

A computer communications error shut down the test after 44 min 22 sec. The computers were re-booted and the test resumed at 15:08 and ended at 15:24.

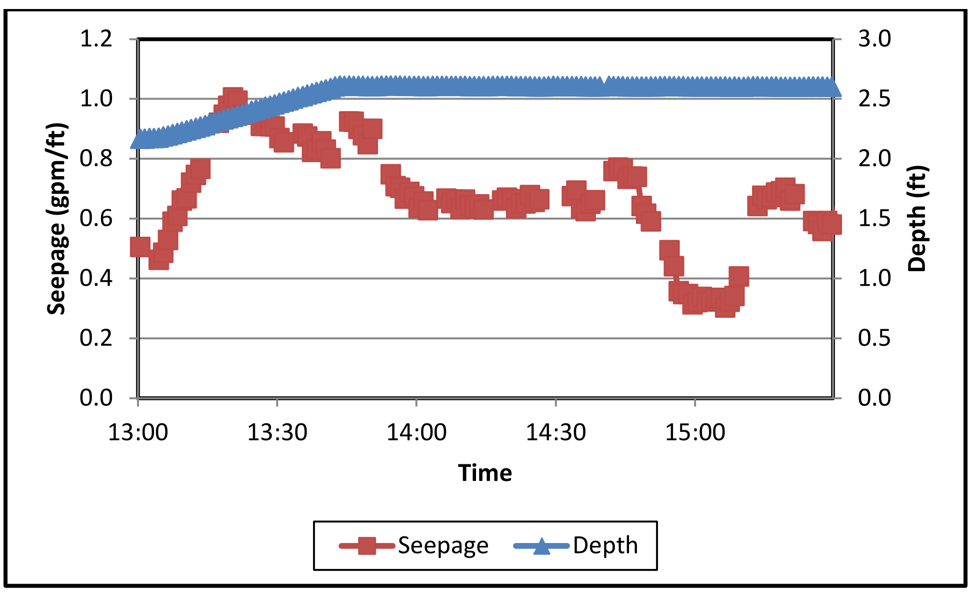


Figure 39. Seepage rates during the high water tests with small waves.

Movement of the barrier was minimal, with no wall moving more than 0.001 ft (Figure 40).

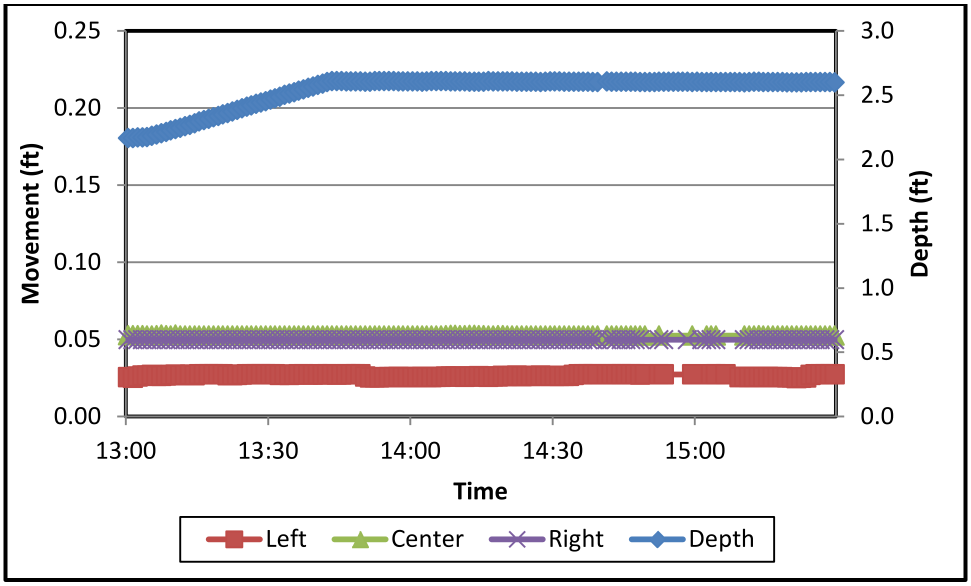


Figure 40. Movement of barriers during the high water waves tests with small waves.

High water, medium waves

The barrier was tested with three 10-min runs of medium waves (6- to 8-in. wave heights, 2-sec period) while the basin water depth was at 80% of structure design depth. In Figure 41 (seepage and overtopping) and Figure 42 (movement), the waves were run from 15:31 to 15:41, 15:52 to 16:02, and 16:12 to 16:22. Average rates of seepage plus overtopping for the three runs were 3.5, 4.1, and 4.2 gpm/ft, respectively.

Prior to the three runs, the barrier walls were inward 0.027 ft, 0.52 ft, and 0.50 ft for the left, center, and right walls, respectively. At the end of the three runs, the left and center walls had not moved but the right wall was at 0.043 ft inward from the initial values (Figure 42).

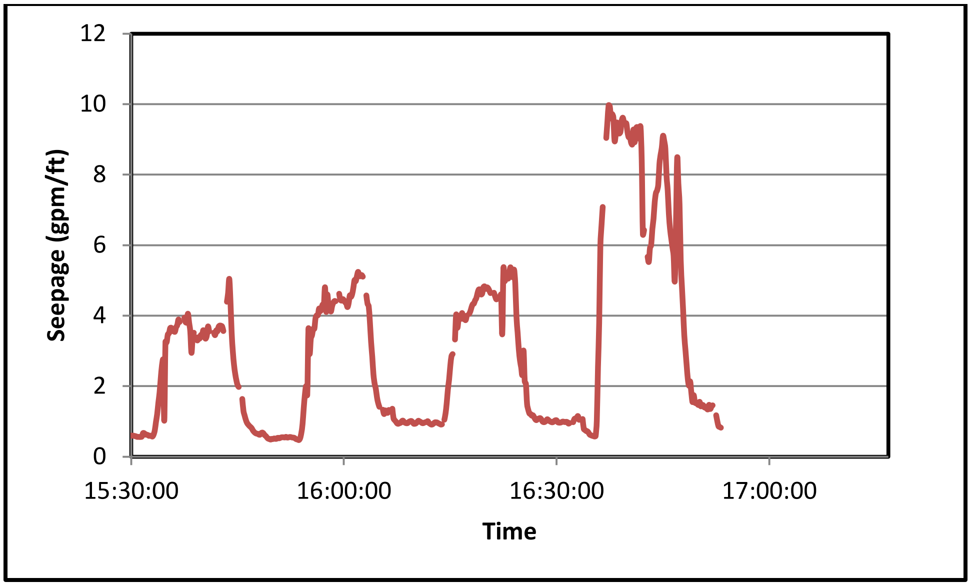


Figure 41. Seepage plus overtopping rates for tests with medium and large waves at high water.

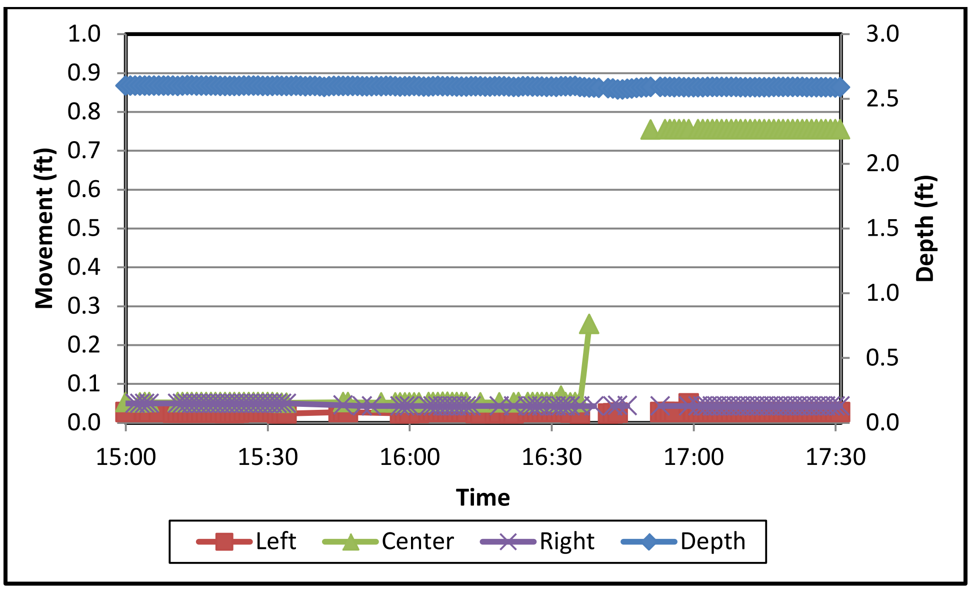


Figure 42. Movement of barrier during tests with medium and large waves at high water.

High water, large waves

The barrier was tested with one 10-min series of large waves (10- to 12-in. wave height, 2-sec wave period) while at a basin depth of 80% of structure design depth. In Figure 41 and Figure 42, the waves were run from 16:34 to 16:44. Average seepage plus overtopping during the run was 8.3 gpm/ft.

The center wall of the barrier started moving at 16:38 and stabilized at 16:45. During this time the center section of the middle wall had moved inward from 0.052 ft to 0.757 ft, or a slide of about 0.7 ft. There was no change to left and right walls from the end of the tests with medium waves (Figure 42).

The barrier is shown during the test with large waves at high water in Figure 43.

During all of the tests with waves, the barrier appeared stable and solid.

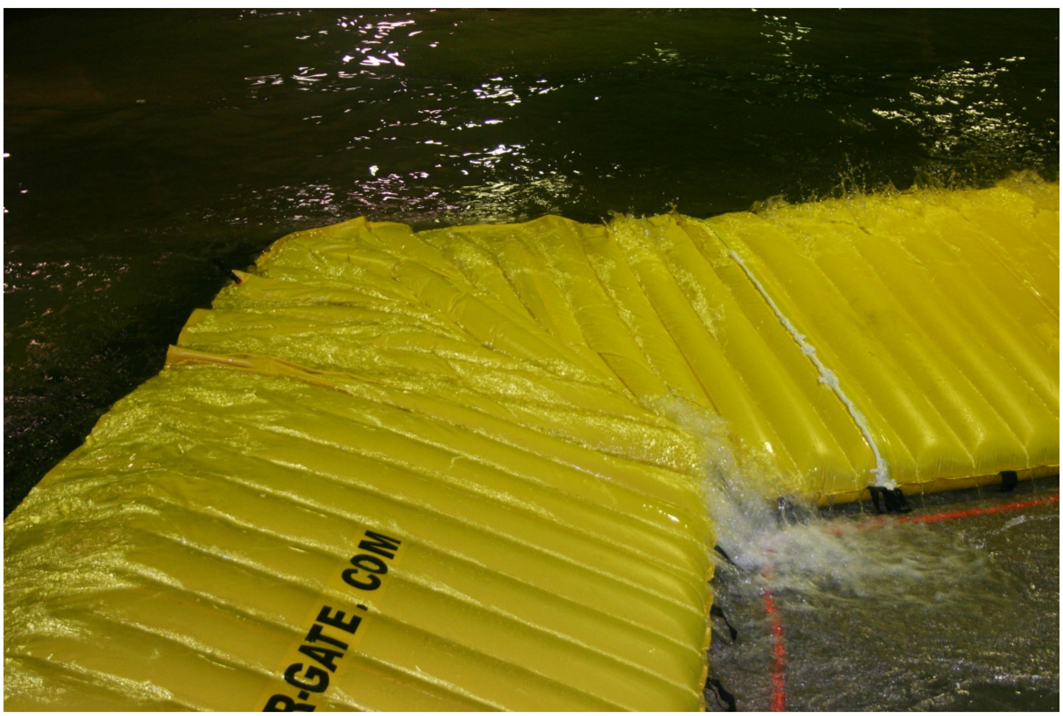


Figure 43. Barrier being overtopped during test with large waves at high water.

Overtopping

The Protocol calls for the water level to be raised until water is flowing over the top of the barrier at an average depth of 1 in. Typically, this depth of flow is obtained when the basin depth is about 2 in. higher than the barrier wall.

The overtopping was estimated to average 1 in. across the barrier at 15:30 with a basin depth of 3.50 ft. This was too deep and the pumps were not able to keep up with the overtopping. The depth was therefore lowered slightly between 15:36 to 15:38 and again from 15:43 to 15:46 to a depth of 3.47 ft. This depth was maintained for the next 1 hr.

There was no noticeable movement of the barrier during the overtopping test (Figure 44).

The barrier is shown in Figure 45 during the overtopping test. There was no apparent damage to the barrier.

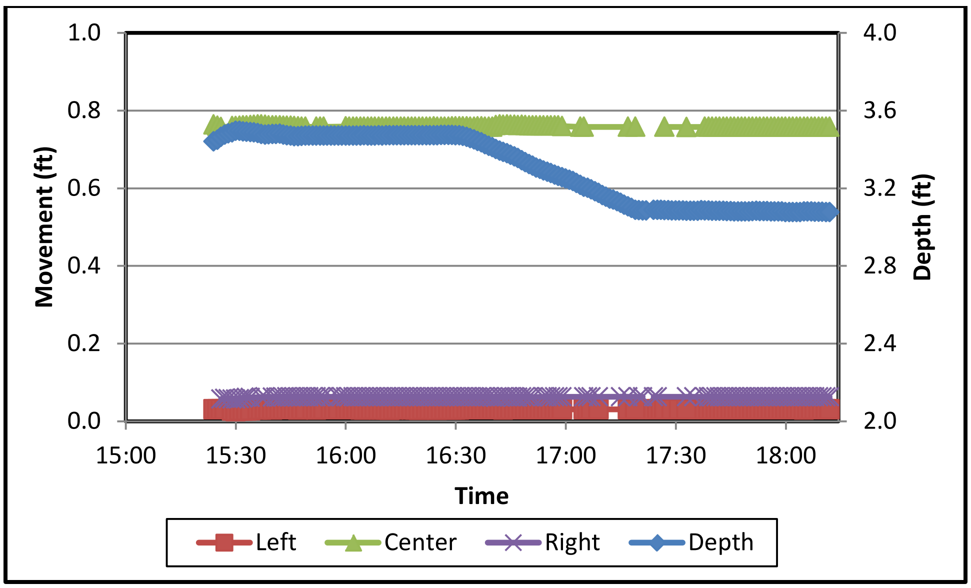


Figure 44. Movement of the barrier during the overtopping test and the final static water test.

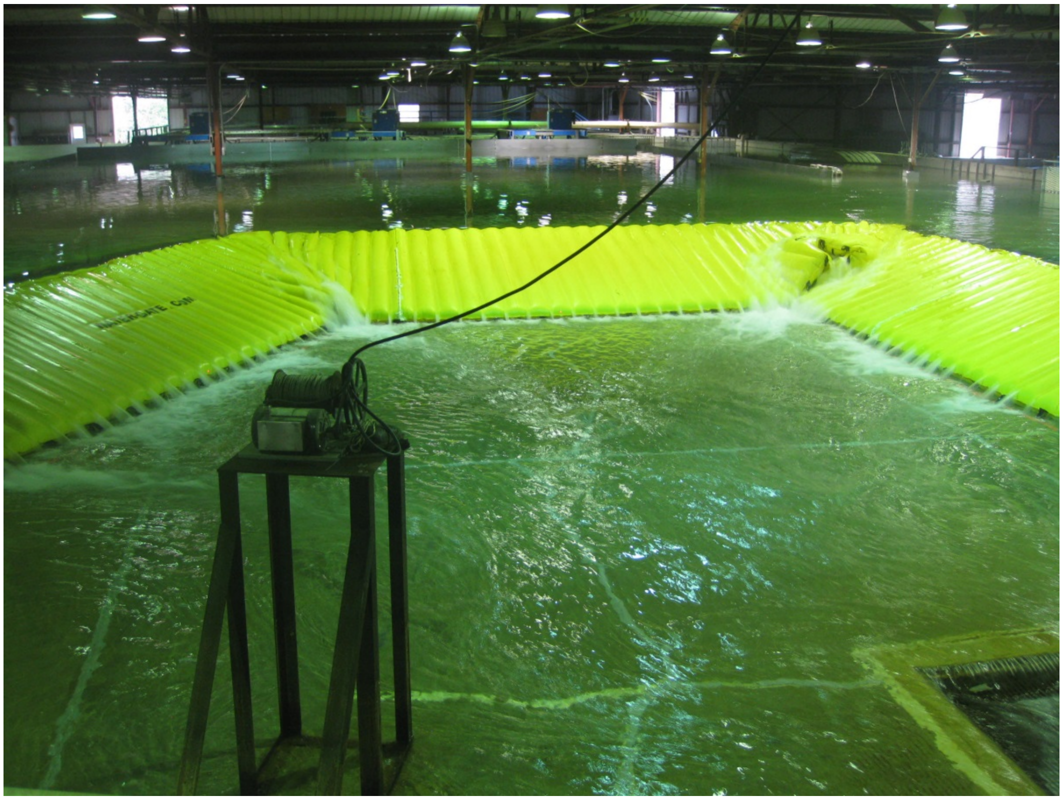


Figure 45. Overtopping of the barrier.

Final 95% Depth Static Water Seepage Test

A final static water seepage test was conducted at a depth of 95% of the structure design depth to demonstrate that the various tests conducted had not damaged the ability of the barrier to hold back the floodwaters. There was a concern that the riverine current test described below would affect the way the barrier was connected to the wingwall and possibly affect the seal to the basin floor due to the setup of the test and not due to any fault of the barrier. The final static seepage test was therefore conducted prior to the riverine current test.

Figure 46 shows the water level coming down from the overtopping test then maintained at 95% of design height (3.1 ft) for the static seepage test. For the period from 17:17 to 18:17, the average seepage rate was 0.55 gpm/ft. In the initial test at 95% structure design depth, the seepage rate was 0.60 gpm/ft.

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

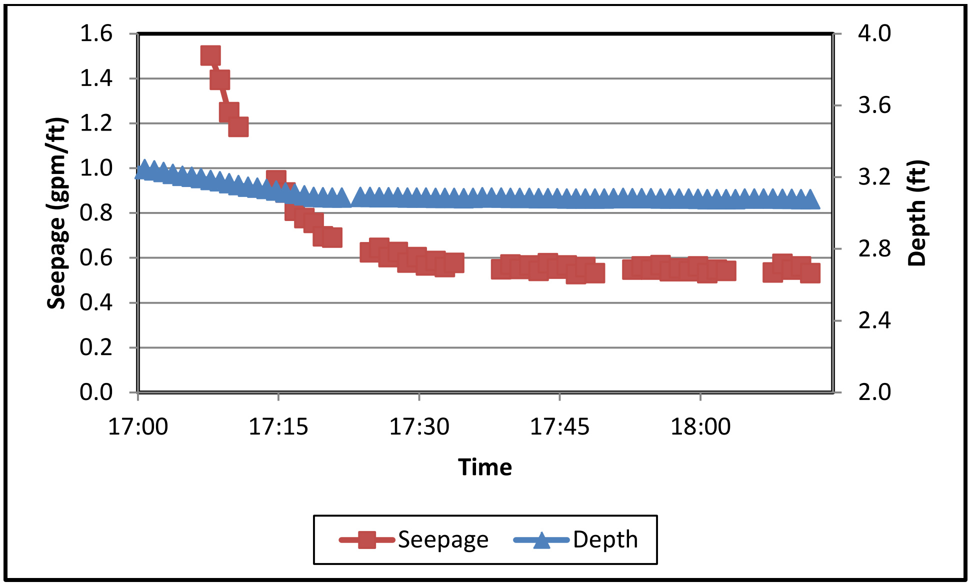


Figure 46. Seepage rates as water is brought down to 95% depth from the overtopping test, then maintained for the final static seepage test.

Riverine Current Test

The basin was drained overnight so that the Bobcat™ skid-steer loader could enter the basin to install a guide vane along the right wall of the barrier. The guide vane directed water flow from a manifold over to as close to the barrier as the guide vanes could be placed in order to restrict the flow and increase the flow velocity through the reduced cross section. In Figure 47, taken from standing on the right wingwall, the manifold is outside the picture to the lower right and flow is directed along the barrier towards the top of the picture.

The strong current traveling along the face of the barrier caught on the vertical panels inside the barrier, pulling the upper layer down and allowing the barrier to be overtopped, flooding the test area. The test was halted to allow time for the test area to be pumped out.

Before starting the current again, pieces of Styrofoam were clamped to the upper layer of the barrier to increase the flotation (Figure 47). The additional flotation was sufficient to prevent the barrier from being overtopped and the barrier then withstood the current without any problems. Maximum velocity measured at the end of the guide vanes was 4 feet per second (fps). The target velocity was 7 fps but due to the shape

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

of the barrier's vertical panels the guide vanes could not be placed close enough to the barrier to reduce the cross section sufficiently to obtain the target velocity.

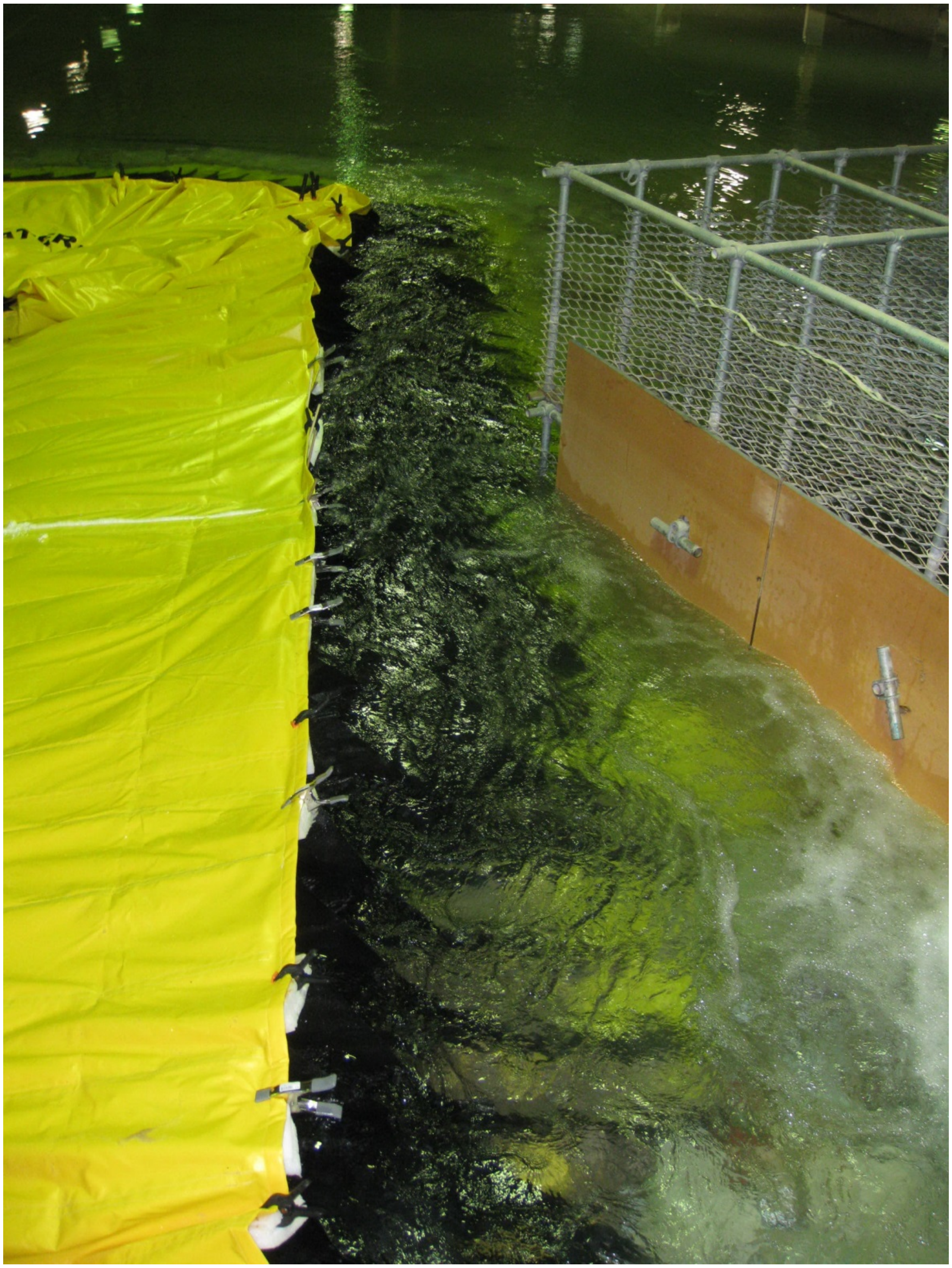


Figure 47. Barrier during the current test. Pieces of Styrofoam are seen clamped to the upper layer for flotation.

Debris Impact Test

The debris impact test is conducted at the same water depth as the low water wave tests, and was therefore conducted after the low water wave tests and prior to raising the water level for the high water wave tests. It is included here in the report so that the hydrodynamic tests could be kept together in one section.

To test flood protection structures for their ability to withstand impact from debris carried by the current in an actual flood, a debris impact test is included as part of the Standardized Testing Protocol. The debris impact test involved towing two logs into the barrier with a winch located inside the test area (Figure 48). The logs were towed in at a 20-deg angle at a speed of 5 mph (7 fps), and power to the winch was cut just prior to impact with the structure. Both logs were 10-ft-long and cut from a creosote-coated telephone pole. The smaller log was 12 in. diameter and weighed 610 lbs dry; the larger log was 16.5 in. diameter and weighed 790 lbs dry. Both logs had been soaking in water for 1-1/2 weeks prior to testing and undoubtedly had increased in weight.

The two logs were towed into the structure one at a time, the smaller log first. The test with the smaller log is shown in Figure 49. The piece of plywood on top of the barrier was to protect the fabric from the cable. The log struck directly on one of the vertical panels inside the barrier, causing a small tear in one panel (Figure 49, insert). No other damage was found.

The large log is shown in Figure 50 after impact. The log hit between the vertical panels and caused no visible damage.

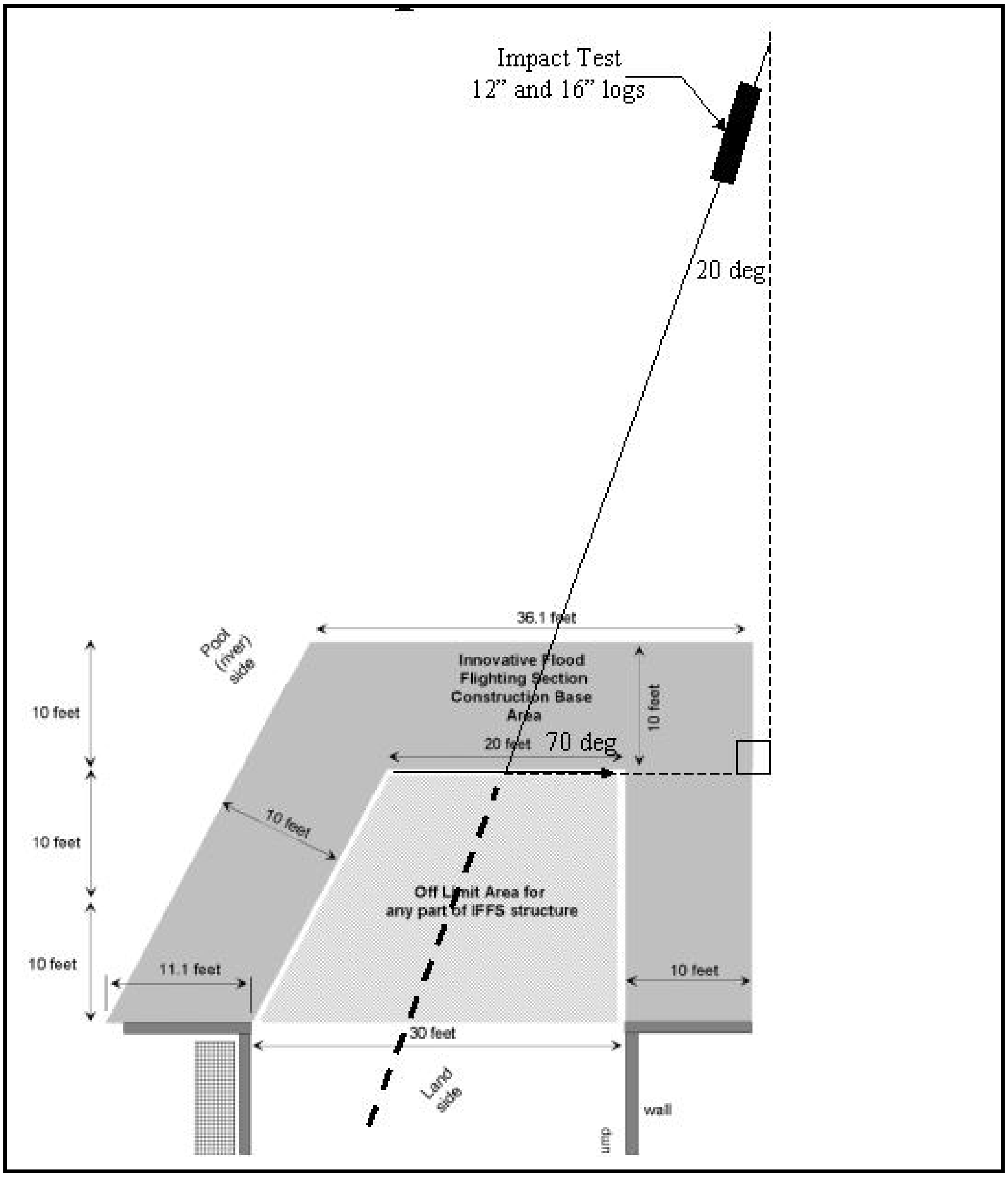


Figure 48. Setup for debris impact tests.

Figure 49. Barrier after being struck by small log. Insert shows tear in vertical panel.

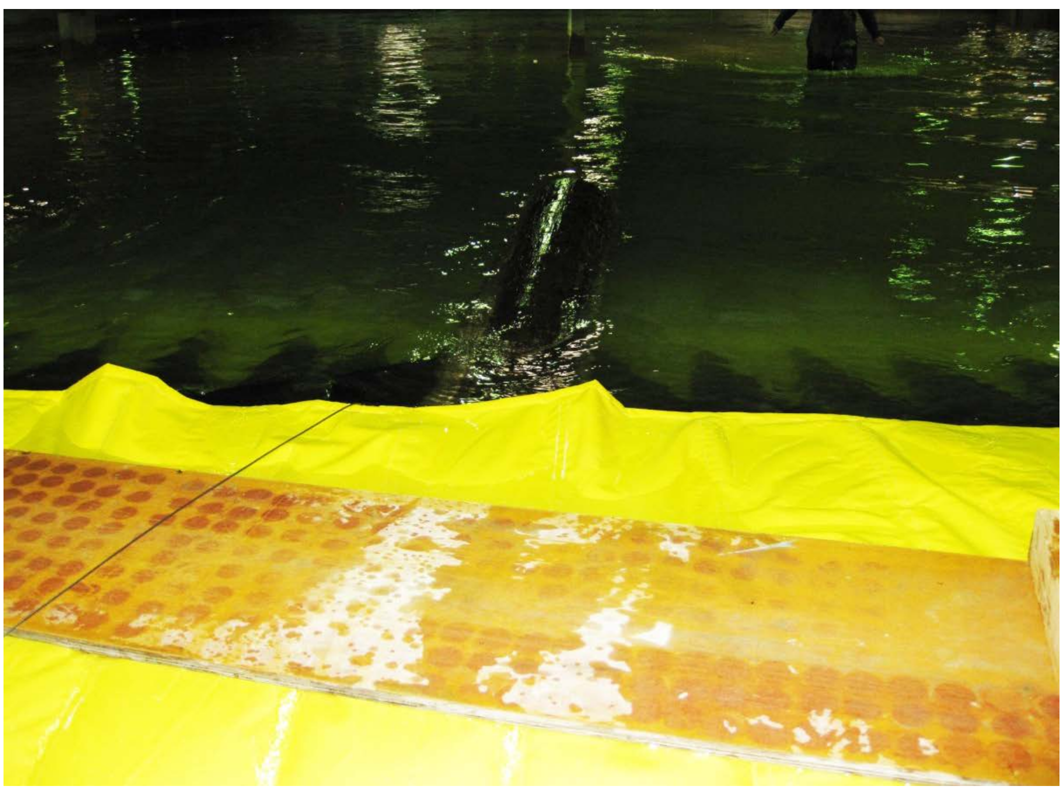


Figure 50. Barrier after being struck by large log. No damage was found on the barrier.

Movement of the barrier during the debris impact tests is shown in Figure 51. The figure shows 1-sec averages of the distance-measuring lasers. The figure has been filtered to remove large apparent motion caused by people walking between the laser and the barrier. The resolution of the lasers is 1 mm, or about 0.003 ft. The lasers were recording at about 20 Hz, so each data point is the average of about 20 readings. The small log impact occurred around 12:47 and the large log at 12:53. Examination of the raw data file showed no movements greater than 1 mm from either impact.

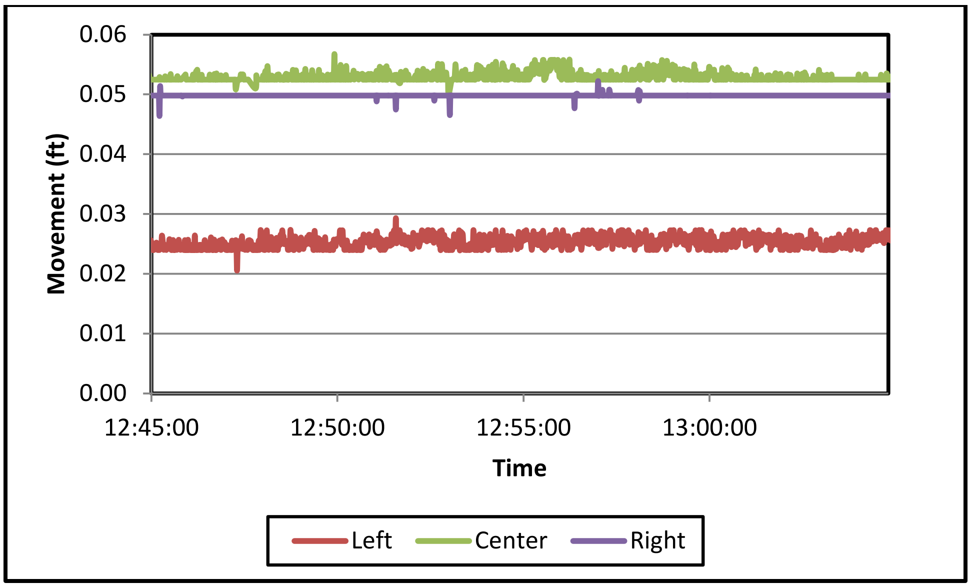


Figure 51. Movement of the barrier during the debris impact tests.

Disassembly

Disassembly consisted of detaching the Velcro seams holding the three sections of barrier together and laying each section out straight. Then a quick tug on the seam of each of the vertical panels was sufficient to get the panels to lay flat (Figure 52). The barrier was folded lengthwise in quarters (Figure 53), rolled up (Figure 54), and packed into a carry bag. Two people completed the disassembly and packing in 60 minutes, plus one person driving a Bobcat™ skid-steer loader for 18 minutes to remove the sandbags. Complete removal of the barrier took 2.3 man-hrs.

Figure 52. A tug on the seam of each of the vertical panels allowed the panels to lay flat.

Figure 53. The barrier is folded lengthwise.

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

Figure 54. The barrier is rolled and will be packed into a carry bag.

3 Summary

Construction Times and Seepage

Times for construction and disassembly are shown in Table 1 along with seepage rates.

Table 1. Summary of tests with MegaSecur™ flood protection barrier.

Test	Measurements
Construction/Repairs/Disassembly	
Construction (man-hrs)	8.6
Disassembly (man-hrs)	2.3
Hydrostatic Seepage Rates (gpm/ft) Corrected for Floor Seepage	
1.0 ft Head	0.13
2.0 ft Head	0.28
3.1 ft Head (initial test)	0.60
3.1 ft Head (final test)	0.55

The seepage rates listed are the average of the last two hours of the hydrostatic tests. Estimated seepage rate through the floor has been subtracted from the measured seepage rates shown in Table 1.

Other Factors

Constructability and Re-usability

No large power equipment was needed to construct the barrier indicating that it is suitable for areas where heavy equipment may not have access. Although the Bobcat™ was used to carry the sandbags, the sandbags could have been carried with pickup trucks or even wheelbarrows.

Supplies used included expanding foam sealant and pre-filled sandbags.

The barriers are completely reusable. After cleaning the barriers, the Vendor recommends hanging them to dry, then re-rolling them for storage.

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

Environmental

Because the main parts of the barrier are reusable, the environmental impact is minimal. The MegaSecur™ sections, the wooden dowels for the vertical panels, and the rolls of gravel are all reusable. The sand bags may be reusable if not damaged. It is possible that the sandbags will absorb contaminants from flood waters and require special disposal, but not the MegaSecur™ sections.

Additional Information

The units tested at ERDC were the WL-3930 and WL-3950. Additional information is available on the Vendor's website at www.megasecur.com .

Comparison to Sandbags Baseline Data

Table 2 compares measured parameters from the MegaSecur™ flood protection barrier tests reported herein to baseline data collected in 2004 with a sandbag barrier following the same protocol. The sandbag barrier had a working depth of 3 ft while the MegaSecur™ had a working depth of 3.25 ft, and the lengths of the barriers were similar. The sandbags took twenty-four times the man-hrs to construct and four times as long to remove.

Seepage rates of the MegaSecur™ barrier were higher than the sandbag barrier, and required some tending to keep the outer edge elevated especially when the basin depth was being increased.

Sand was washed out of the sandbags during the waves test causing significant damage that had to be repaired, then the sandbags failed during the first minutes of the overtopping test when the top layer of bags was washed off the crest of the barrier then damage progressed further down into the sandbag mound with additional bags being washed off into the test area (Pinkard et al., 2007)[1]. In contrast, the MegaSecur™ barrier withstood all tests with essentially no damage.

[1] Pinkard, F., T. Pratt, D. Ward, T. Holmes, J. Kelley, L. Lee, G. Sills, E. Smith, P. Taylor, N. Torres, L. Wakeley, and J. Wibowo. 2007. "Flood protection Structures Demonstration and Evaluation Program: Laboratory and Field Testing in Vicksburg, Mississippi," ERDC Technical Report TR-07-3, July 2007. 306 pp.

Table 2. Comparison of MegaSecur™ flood protection barrier to sandbag baseline data.

	MegaSecur™	Sandbags
Install/Remove	**Man-Hrs**	
Construction	8.6	205.1
Repair 1	N/A	2.0
Repair 2	N/A	2.0
Repair 3	N/A	2.0
Disassembly	2.3	9.0
Depth (ft)	**Seepage (gpm/ft)**	
1.0	0.13	0.05
2.0	0.28	0.23
2.85		0.53
3.1 (initial test)	0.60	
3.1 (final test)	0.55	

Damage, Seepage, and Overtopping

One of the logs in the debris impact test hit directly on one of the vertical panels, causing a small tear in the fabric. Other than that, there was no damage to the MegaSecur™ units.

The only other damage was to some of the sandbags that tore while they were being placed or removed.

Seepage rates were higher than obtained with the sandbag barrier at the 1 ft depth, then fairly consistent with the sandbags at greater depths. However, to prevent the MegaSecur™ seepage rates from being greater required the placement of expanding foam under the leading edge of the barrier and at the ends on the wingwalls, and entering the water to tend to the upper leading edge of the barrier especially when the water level was rising. Problems with the MegaSecur™ barrier being overtopped were mainly confined to the corners of the barrier. Overtopping of the barrier at depths lower than maximum design depth could probably have been

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.

greatly reduced if the upper layer of the barrier had been supported by more of the dowels inserted in the vertical panels of the barrier.

Because the upper layer of the barrier lies directly on the water and there is no freeboard, waves were able to easily wash over the barrier. The waves did no damage to the barrier, but there was far more overtopping of the MegaSecur™ barrier during tests with waves than was observed with the sandbag barrier or other barriers with more freeboard.

Lateral forces on the vertical panels caused by a large current flowing along the barrier were able to pull down the upper layer of the barrier and cause the barrier to be overtopped. Clamping pieces of Styrofoam to the upper layer of the barrier provided sufficient additional flotation to prevent the overtopping.

4 Conclusions

The MegaSecur™ flood protection barrier was extremely quick and easy to install and remove, was durable, and completely reusable. Seepage rates were similar to those of a comparably-sized sandbag barrier. The barrier was not damaged by waves and had only a small tear in a vertical panel from debris impact testing.

However, the barrier required frequent tending to keep the front edge from being overtopped, especially in the corners and at the ends. Dozens of small clamps were applied at various times to stop localized overtopping. Without the clamps and the frequent tending, the seepage rates would have been considerably higher, although still manageable with a series of small pumps.

The barrier required additional floatation to function in a strong current without overtopping.

Evaluation of MegaSecur™ Flood Protection Barrier, US Army Engineer Research and Development Center Coastal and Hydraulics Laboratory, Donald L. Ward, April 2015.