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IMPORTANT UPDATE

The following report was generated and issued by the United States Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) in March 2011. In the time since this product evaluation and report were created, both the product name and sponsoring company have changed.

The product name referred to in this report is Rapid Installment Barrier System or simply RIBS. This product name has been changed and the product is now marketed as **GRS PermaShield™**.

The sponsoring company listed in the report, Landmark Earth Solutions, Inc. (subsidiary of Leggett & Platt), is no longer producing the product that was evaluated. The evaluated product is currently produced exclusively by **Guardian Retention Systems, LLC**.

ERDC Report to Sponsor

US Army Corps of Engineers®
Engineer Research and Development Center

Evaluation of Rapid Installation Barrier System (RIBS) Flood Fighting Barrier

Donald L. Ward

March 2011

Executive Summary:

The Rapid Installment Barrier System (RIBS) from Landmark Earth Solutions, Inc. (subsidiary of Leggett & Platt) is a sand-filled geotextile bag system designed for rapid deployment. Each bag measures 2 ft along the crest of the barrier, but is delivered as a 24-ft-long unit with internal baffles separating the unit into 12 2-ft-long bags. Front to back the bags measure 2 ft wide at the top and 5 ft wide at the base forming a very stable trapezoidal structure.

A custom trailer is used to deploy the bags. One or more 24-ft-long units are loaded onto the trailer, then deployed 12 ft at a time under a hopper on the trailer which holds the bags open and directs the sand into the bags. A front-end loader loads the sand into the hopper which then fills the bags. The trailer then moves forward another 12 ft and the next set of bags is filled. A small skid-steer loader is sufficient for loading the sand; no heavy equipment is required.

Construction of a 76-ft 1-in. barrier took 17.5 man-hrs, or one-twelfth the time it took to erect a similar barrier with sandbags. Removal of the structure required only 2.3 man-hrs, or about one-quarter the time it took to remove the sandbag barrier. At low water elevations, seepage rates were higher than with the sandbag barrier. At high water, the seepage rates were comparable for the RIBS barrier and the sandbag barrier.

The RIBS barrier successfully withstood tests with wave action, debris impact, and overtopping.

According to the manufacturer, simple modifications are planned for the system, based on the observations made during the testing program, which should allow a much better seal between the barrier and the substrate and significantly reduce the seepage rates.

As tested, the barrier appears to be a cost-effective method for constructing a barrier against flood waters in a fraction of the time it would take to build a sandbag barrier. With minimal equipment and just three people, a straight barrier can be built at a rate of 100 ft in 3.6 hrs.

Cost of the geotextile bags is $420 per 24-ft long unit (3 ft high), or $17.50/ft.

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Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
Gallons (U.S. liquid) per minute per foot	2.0699 E-04	Cubic meters per second per meter

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 were 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 it causes an apparent current along the 63-deg wall.

Inside the protected 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 4). Two 4-in.-diam pumps were installed in the 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 pit when the capacity of the 4-in. pumps was exceeded.

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Figure 1. Research basin with wave machines on the left side and the test area on the far right. The test area is shown in closer view in Figure 2 and Figure 3.

Figure 2. Test area surrounded by the RIBS flood fighting barrier at the conclusion of test protocol.

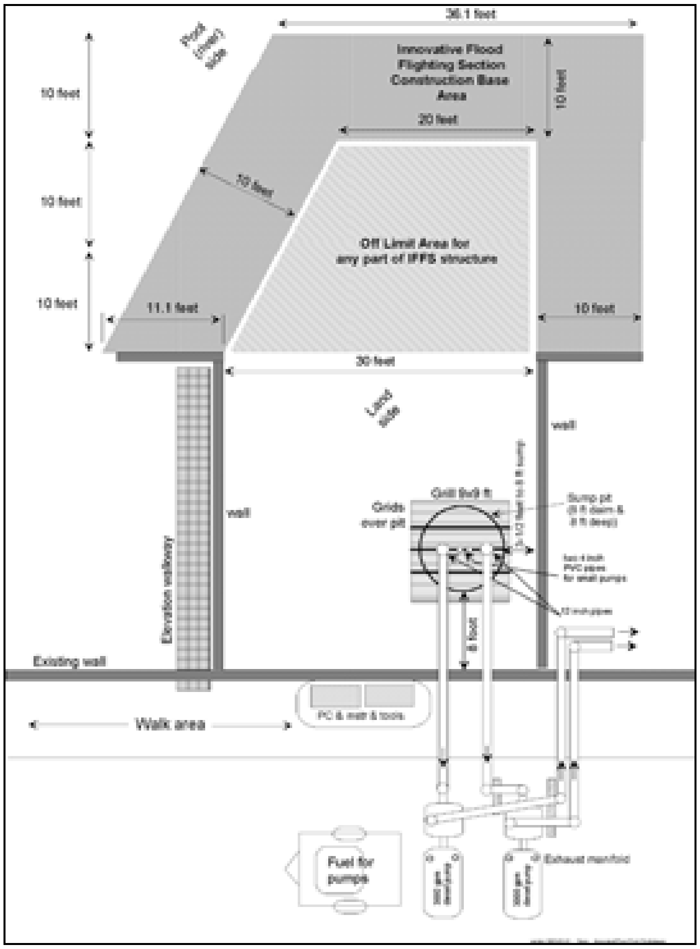

Figure 3. Layout of test area within research basin.

Figure 4. Test area after debris-impact test showing the sump in the back corner of the test area.

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 pit, and a laser 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, supplies, and personnel required to erect their product prior to testing. ERDC 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 standard testing protocol is available at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=PUBLICATIONS;243

Landmark Earth Solutions RIBS® Product Description

The Landmark Earth Solutions Rapid Installation Barrier System (RIBS) units are geotextile bags that are joined together into a 24-ft-long length that are hung from an overhead rack for rapid deployment. The bags are filled with sand to form a temporary barrier to rising flood waters. Each bag is 2 ft wide at the top expanding to 5 ft wide (front to back) at the base providing an extremely stable barrier. Each bag measures two feet along the crest, therefore there are 12 bags in a 24-ft-long unit. The units tested were 3 ft high.

The bags are made of 8 oz woven polypropylene, coated with a 1-mil-thick coating of polyethylene for waterproofing. Each bag is made with one piece that extends down the front, under the bag, and up the back. This piece is sewn to a single-layer internal baffle that separates adjacent bags along the length of the unit. Sewn seams are on the outside of the bags, and each seam consists of fabric from two adjacent bags plus the internal baffle.

Plastic pegs attached to the top of the bags allow the bags to be hung from a rack on the deployment trailer. One or more units of 24 bags is hung at the front of the trailer. Six bags (12 ft) are pulled back under the hopper located on the top of the deployment trailer. The rail system on which the bags are hung extends the length of the trailer. The rails allow the bags to be slid back under the hopper and hold the tops of the bags open for filling. A front-end loader fills the entire 12-ft-long section of bags at one time, then the trailer advances 12 ft leaving the filled bags behind. The next 12-ft of bags is filled, and the trailer advances again.

Metal clips hold adjacent 24-ft units together until the end bags are filled with sand.

Figure 5. RIBS units being filled with sand through the hopper on the deployment trailer.

Delivery

The deployment trailer and a case of bag units were trucked to Vicksburg on a flat-bed trailer. A forklift was used to unload them. The deployment trailer was then towed into the hangar with a Bobcat™ skid-steer loader. Sand was delivered by dump truck from a local source. All other supplies and equipment were brought in a van by the company personnel.

2 Testing Procedure and Results

Assembly

Assembly Method

Before constructing the test barrier, the deployment trailer required some minor work to change it from its shipping form to deployment form. The trailer was shipped with the hopper secured and the wheels inside the framework. The hopper was freed and lowered to the correct height (Figure 6), and the four wheels were moved from inside the trailer frame to outside the frame. The work took three men 24 minutes to complete. A Bobcat™ skid-steer loader was used to raise one end of the trailer for moving the wheels. The only other tool required was a ratchet set.

Figure 6. Hopper being lowered on deployment trailer.

A set of bags (one 24-ft-long unit) was loaded onto the rails of the trailer and pushed to the forward end of the rails (Figure 7), then the last 12 ft of bags were stretched out under the hopper.

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Figure 7. A 24-ft-long set of bags being loaded on the rails of the deployment trailer.

The skid-steer was used to pull the trailer into the test basin (Figure 8). The bucket of the skid-steer was placed under the goose-neck hitch on the trailer and the skid-steer backed into the basin pulling the trailer. The trailer was not connected to the skid-steer.

Figure 8. Trailer is loaded with bags and being towed to the test area.

The skid-steer dumped sand directly into the hopper, which directed the sand into the bags (Figure 9). The skid-steer had a 5-1/2-ft-wide bucket, so it was filling three bags at a time. As the bags were filled, the trailer was moved forward. The weight of the filled bags anchored the end of the set of bags, causing the next several bags to be stretched out under the hopper as the trailer moved forward.

Three men, including the skid-steer operator, erected the barrier. The other two men directed the dumping of the sand by the skid-steer, pushed sand into the corners of the bags, and compacted the sand with hand tampers to get a better seal. Tools required to fill the bags, in addition to the trailer and skid-steer, were shovels and hand-tampers.

Figure 9. Sand is dumped into the hopper which holds the bags open and directs the sand into the bags.

To make the skewed “U” shape required in the protocol, the team first constructed wall “C” (see Figure 10 for location of walls) by backing the trailer up to the wing wall and then building straight out from the wall. When the barrier was the correct length, they simply stopped filling the bags, leaving the rest of the bags in the unit empty. They then started on section “A” by backing the trailer up against the opposite wingwall. Only the first bag against the wall was filled. Next the trailer was moved forward two feet and turned slightly back towards section “C.” One more bag was filled, then the trailer pulled forward two feet and turned a little bit more. In this way a gradual curve was built so that section “A” was one continuous curve from the wall and into section “B.” The remaining straight portion of section “B” was filled three bags at a time while pulling the trailer in a straight line until it overlapped section “C.”

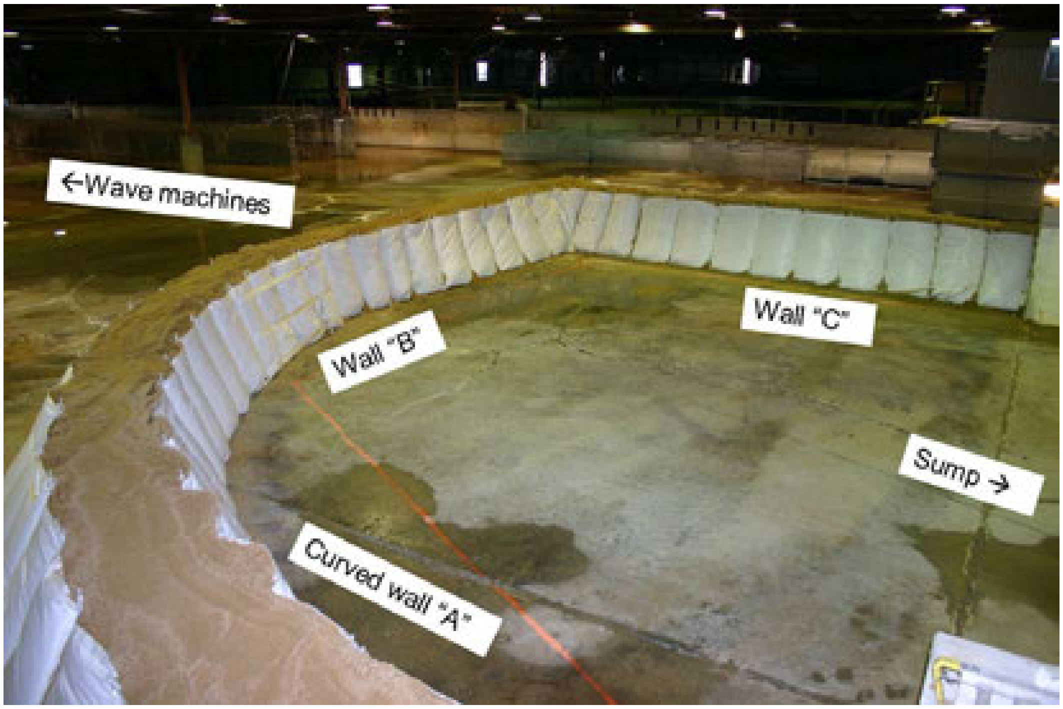

Figure 10. RIBS barrier erected in test area.

To complete the connection between section "B" and section "C," a portable frame was placed along section "C" and across the end of "B." The portable frame had runners that supported the plastic tabs on the bags in the same way that the bags had been supported in the trailer (Figure 11). Excess bags in section "C" were cut off with a box cutter. The end of section "B" was extended one extra bag; the rest of the bags in the unit were cut off with a box cutter. Turnbuckles secured the bags from adjacent units.

Figure 11. Portable frame used to hold bags open and in place where deployment trailer cannot be used.

The units are built with three straps on each side at one end of a 24-ft-long unit and three D-rings at the other end (Figure 12). Wire ties and vice-grip clamps were used to temporarily join the end bags from two adjacent units until they were full of sand (Figure 13). The straps from one unit are then run through the D-rings on the adjacent unit to form a secure connection, and the clamps are removed.

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Figure 12. Straps fastened to "D" rings connect adjacent sets of bags.

Figure 13. Baling wire around the mounting pins and vice-grip clamps hold adjacent sets of bags together.

To connect to the wingwalls, expanding foam sealant was sprayed in the gap between the wall and the bags (Figure 14). Sealant was also used at the junction between wall "B" and wall "C".

Figure 14. Expanding foam sealant completing the seal with the wingwall.

Summary of Assembly

Assembly of a 76-ft 1-in.-long barrier (measured along the structure centerline) was completed by 3 men in 5 hrs 50 min, including 24 min to set up the deployment trailer, for a total of 17.5 man-hrs. Equipment used included a custom deployment trailer, a small skid-steer loader, shovels, tampers, clamps, box cutter knife, a portable frame and turnbuckles for the 90-deg corner, and a ratchet set for the trailer. Supplies used included sand and expanding foam sealant.

Hydrostatic Tests

One Foot Depth

Seepage

The following morning, pumps were turned on and water pumped into the test basin to a depth of 1.0 ft. Depth was reached at 1014 hrs. Seepage rate at that time was about 0.37 gallons per minute per linear foot of structure (gpm/ft, measured along centerline of structure crest). The seepage rate increased to about 0.39 gpm/ft during the following hour, then gradually decreased to 0.31 gpm/ft by the end of the 22 hr test. Seepage rates during the first two hours of the test are shown in Figure 15; seepage rates during the final two hours of the test are shown in Figure 16.

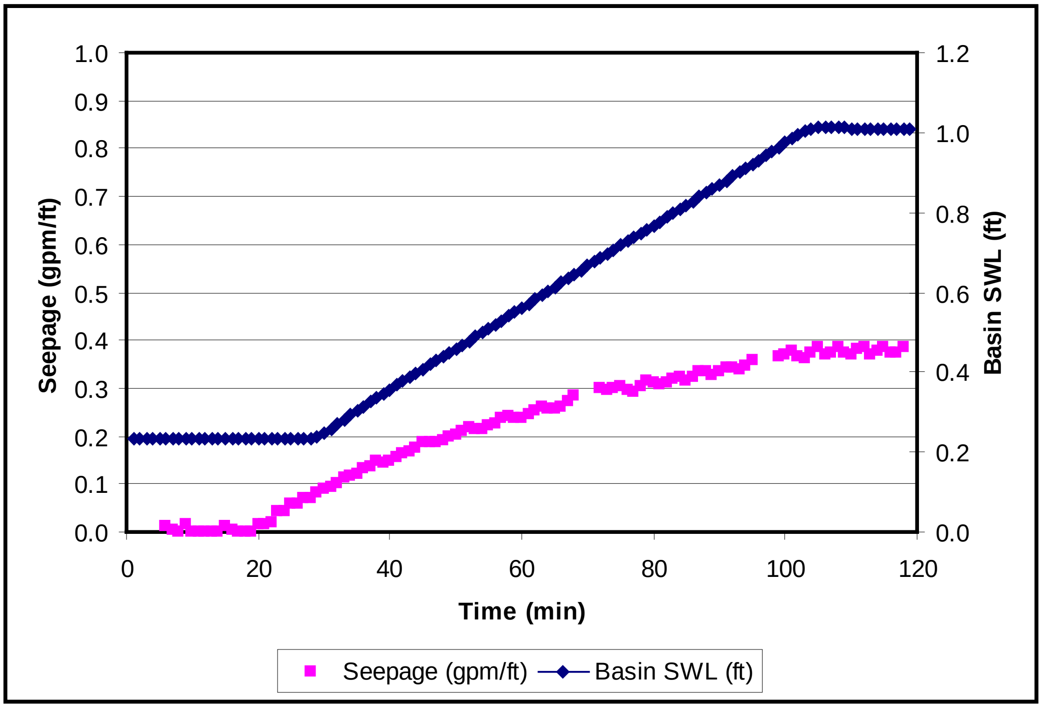

Figure 15. Seepage rates during filling to one-ft depth.

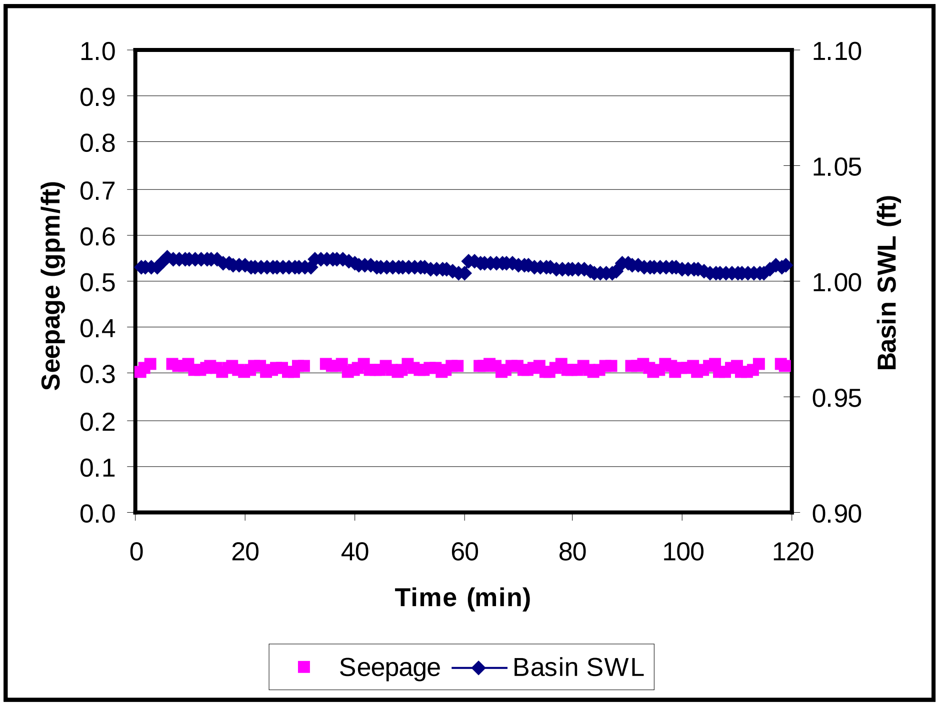

Figure 16. Seepage rates during final 2 hours of 22 hour test.

Movement

Movement of the barrier as recorded by the distance-measuring lasers during filling to the one-ft depth is shown in Figure 17. All values have been adjusted as relative to the initial values at the completion of construction (before adding water to the basin). The scale of the ordinate is plus/minus 0.02 ft, or plus/minus one-quarter inch. Positive values indicate movement away from the laser (out into the basin) and negative values indicate movement into the test area. Where lines drop below the graph and appear as large movements into the test area, it is actually where a person in the test area walked between the laser and the target. Values shown in Figure 17 are one-minute averages; therefore a person quickly walking through the laser beam will appear as a small movement of the barrier. Because the hydrostatic pressure on the barrier is increasing at a constant rate, any movement of the barrier should show as a constant or steadily decreasing value (increasing value in the negative direction). No movement of the barrier is indicated in Figure 17.

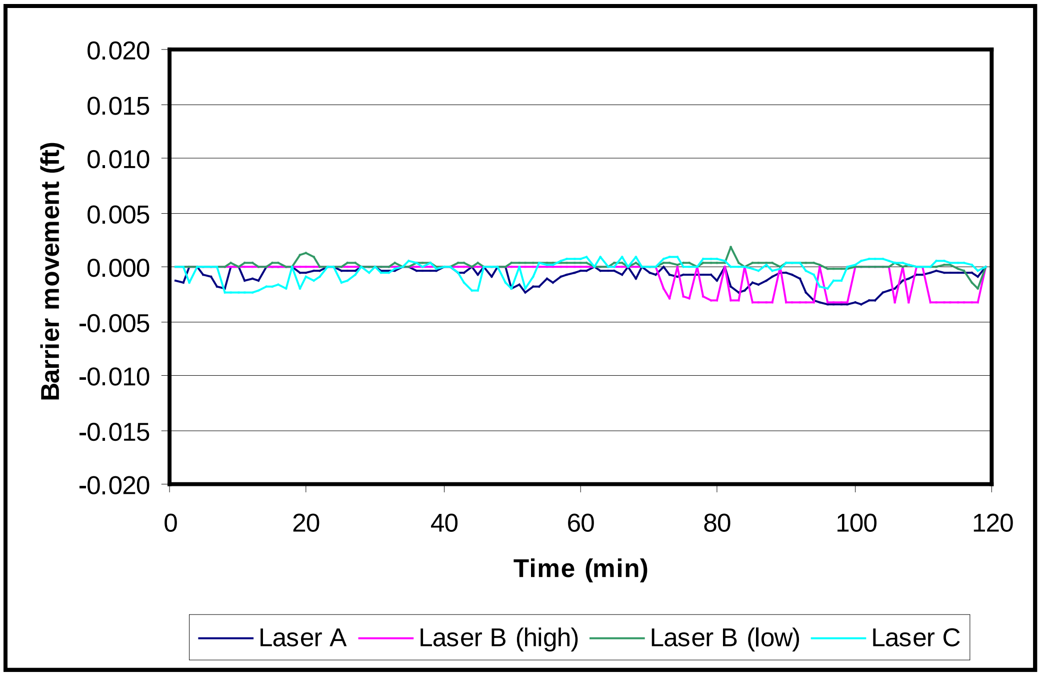

Figure 17. Movement of RIBS barrier during filing basin to one-ft depth.

Repair 1

Most of the seepage observed during the test with basin still water level (SWL) at 1 ft was coming through just a few of the seams between bags. The test was halted while a concrete crack sealant was applied both inboard and outboard of the seams with the most seepage. The sealant was mixed inside the test area using a shovel and plastic gloves (Figure 18) and placed both inside and outside the barrier on the seams where the seepage was highest (Figure 19).

The repair took 1 hr 36 min, or 4.8 man-hrs. The sealant reduced the seepage rate to 0.20 gpm/ft. The amount of time required to make the repair exceeded the limit allowed by the Standardized Testing Protocol, therefore test results reported after this repair are not in compliance with the testing protocol.

Figure 18. Concrete crack sealant being mixed in the test area.

Figure 19. Concrete crack sealant applied to joint where seepage was high.

Seepage rates recorded during two hours following the repair are shown in Figure 20.

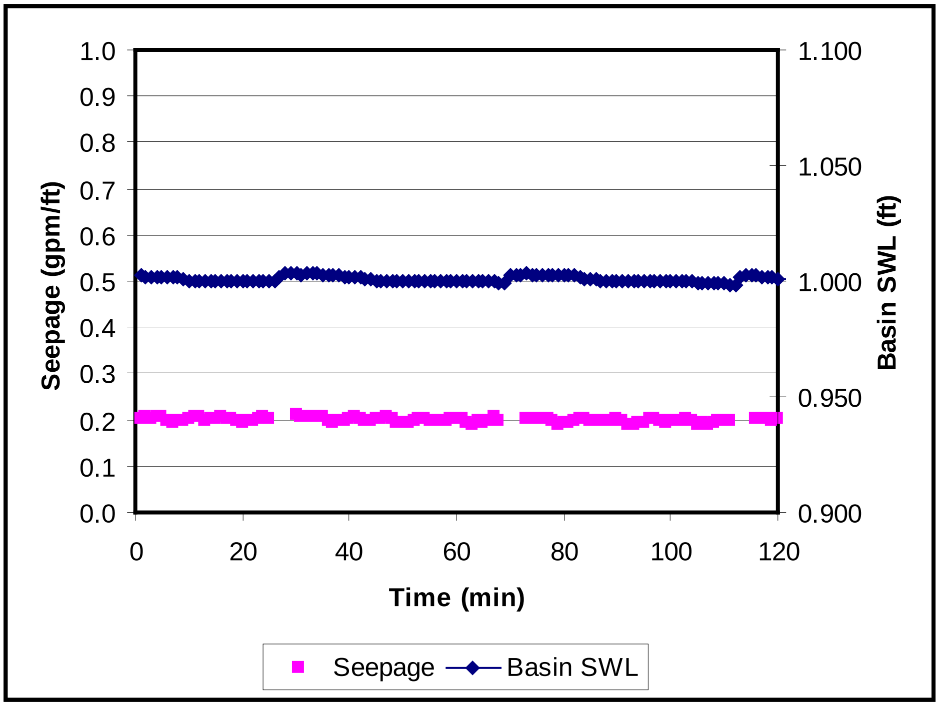

Figure 20. Seepage rate after placing concrete crack sealant at seams that had the most seepage.

Two Foot Depth

Seepage

The pumps were turned on at 1444 hrs to raise the water to a basin depth of 2.0 ft. Water level was reached at 1606 hrs. Seepage rate at the time the depth was reached was 0.41 gpm/ft. Seepage rate remained generally constant over the duration of the test, increasing to 0.42 gpm/ft during the first hour at depth and gradually dropping to 0.40 gpm/ft by the end of the test. Seepage rates during the start of the test are shown in Figure 21; seepage rates at the end of the test are shown in Figure 22.

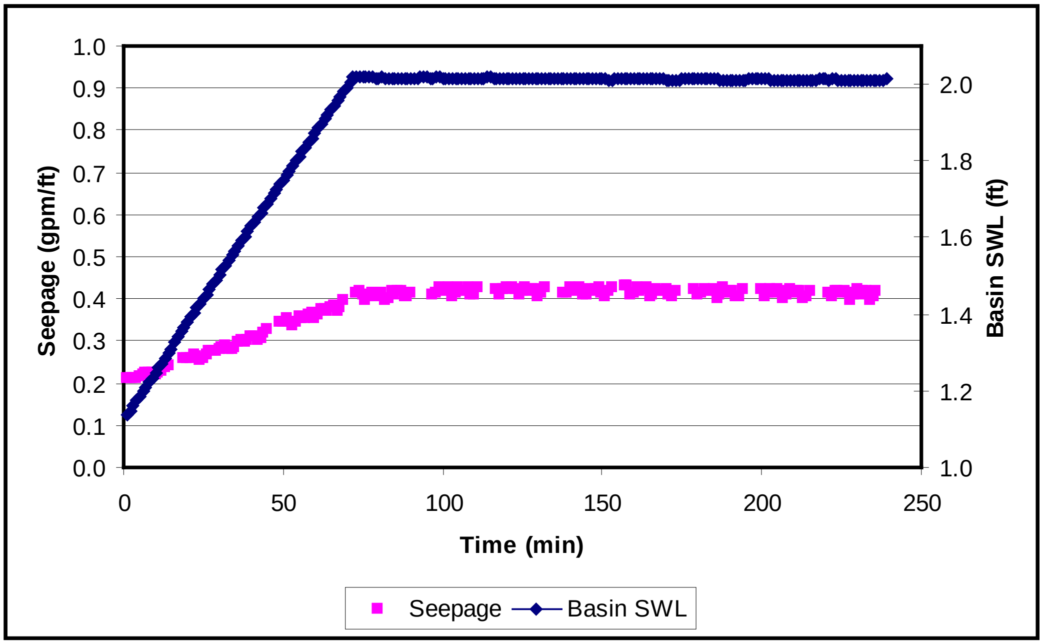

Figure 21. Seepage rate as depth in basin is increased from 1 ft to 2 ft.

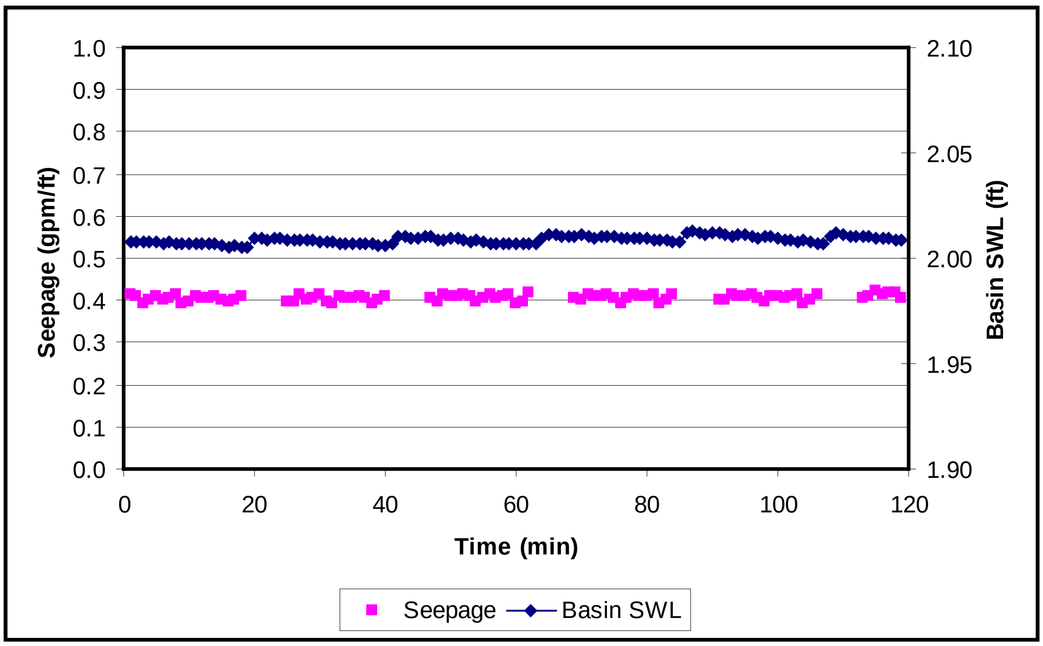

Figure 22. Seepage rate in basin during final 2 hrs of 22 hr test at basin depth of 2 ft.

Movement

Movement of the barrier during filling to two ft depth is shown in Figure 23. The initial values shown indicate that the barrier had moved inward about three-thousandths of a ft, or about 1/32 in., along walls "A" and "B", while indicating a very slight movement outward (less than 1/64 in.) on wall "C", prior to the start of the test. This movement is probably due to settling and compacting of the sand, or possibly due to pressure on the fabric from water that has seeped into the bag. After filling the basin to a depth of 2 ft (the 2-ft water level is reached at minute 71), wall "C" moves outward to about .004 ft (less than 1/16 in.) while there is no movement indicated on walls "A" or "B". No movement of the bags could be visually discerned.

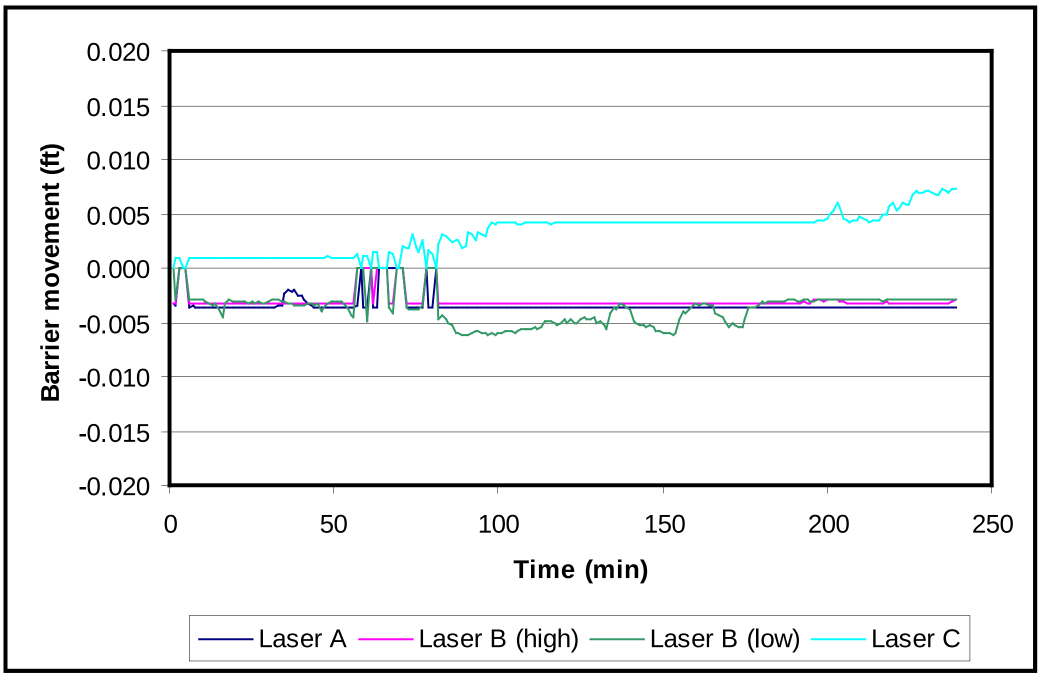

Figure 23. Movement of the RIBS barrier during filling from basin depth of one ft to basin depth of two ft.

Basin depth at 95% of structure height

Seepage

Although the bags were approximately 35 in. in height, there were some low areas where the full height was not achieved. The customer selected

32 in. as the design height of the RIBS barrier. The water level in the basin was therefore raised to 95% of 32 in., or 30.4 in. depth (2.53 ft). Seepage rate at the start of the test was 0.51 gpm/ft, increasing to about 0.53 gpm/ft before dropping back to 0.50 gpm/ft by the end of the test. Seepage rates during the start of the test are shown in Figure 24; seepage rates at the end of the test are shown in Figure 25.

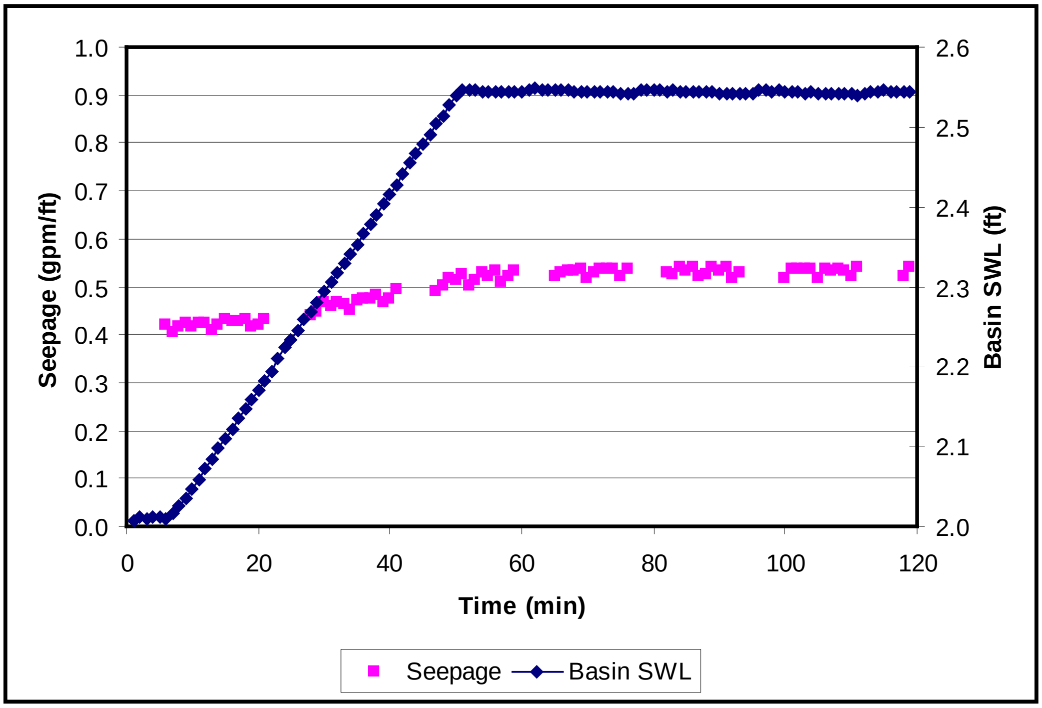

Figure 24. Seepage rates as basin depth is increased from 2 ft to 95% of structure height.

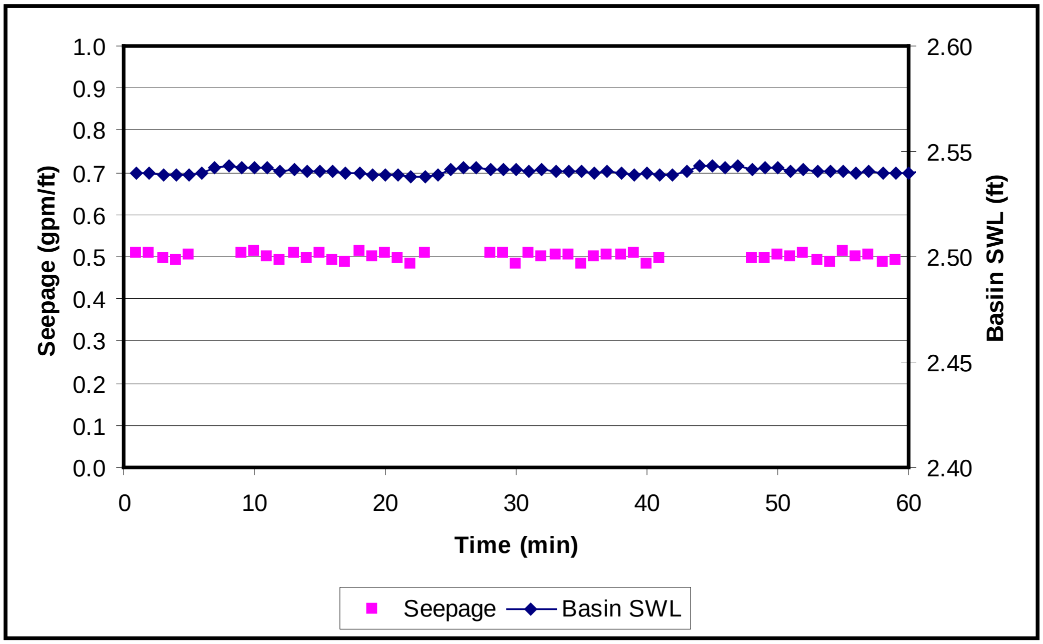

Figure 25. Seepage rates during final hour of testing at a basin depth of 95% of structure height.

Movement

Relative to the position of the bags after construction (before adding water to the basin), walls "A" and "B" had moved inward about 0.005 ft (1/16 in.) by the end of the 22 hrs with a basin depth of 2 ft, and wall "C" had moved outward about 0.01 ft (1/8 in.) (Figure 26). By the end of the first 2 hrs from start of filling to 95% of structure height, wall "A" had moved inward another 1/16 in. and wall "C" had moved outward another 1/16 in. By the end of the 22 hrs test, wall "A" indicated movement on the order or 0.015 ft (3/16 in.) inward, wall "B" indicated movement of 1/8 in. inward, and wall "C" indicated movement of ¼ in. outward (Figure 27).

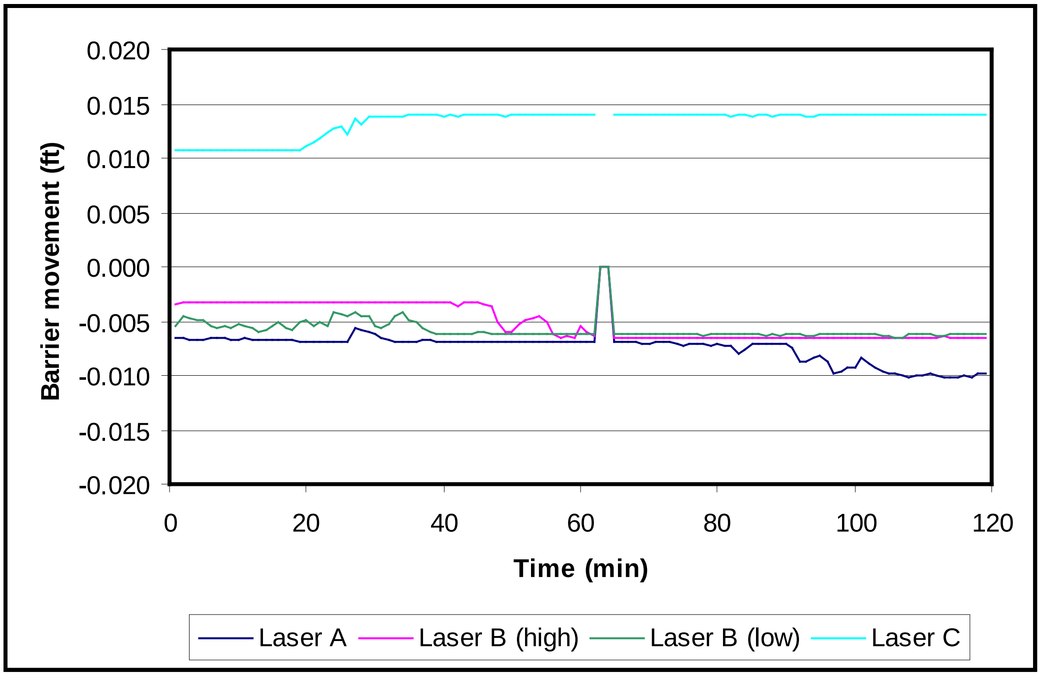

Figure 26. Movement of RIBS barrier during filing to 95% of structure height.

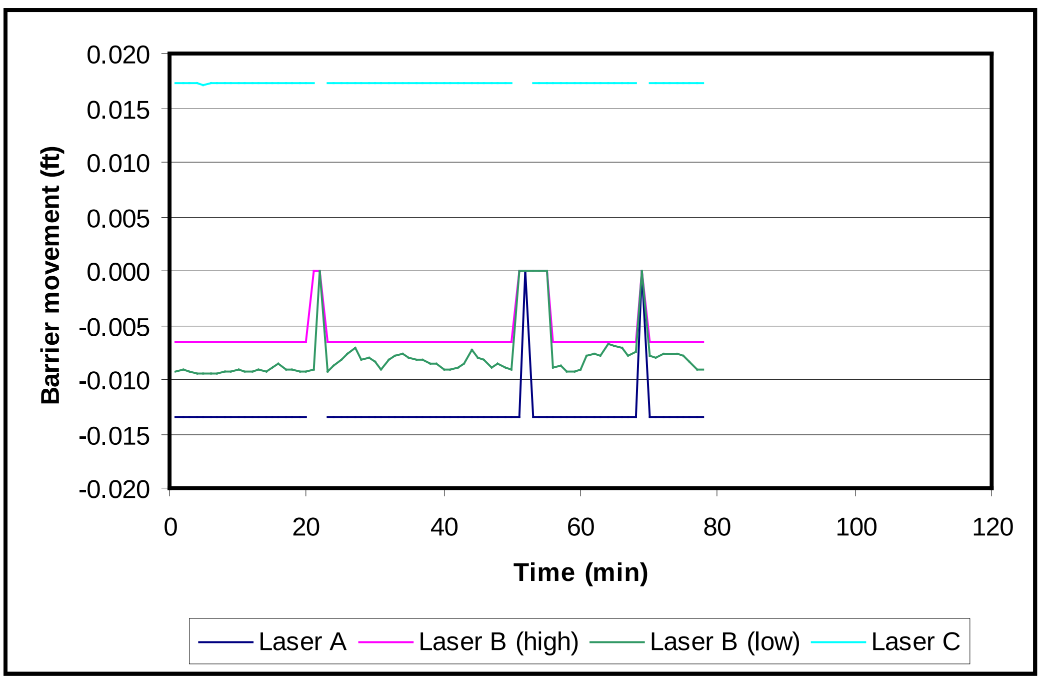

Figure 27. Movement of barrier by end of test at 95% of structure height.

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Movement of Barrier during Hydrostatic Tests

There was no apparent movement of the barrier as the water in the basin rose during any of the tests, however the distance measuring lasers recorded small movements of the targets. Readouts from the distance-measuring lasers indicate minor movement, probably due at least in part to settling of the sand and buildup of water behind the fabric as the sand becomes saturated. On both wall "A" and wall "B", the movement of the inner wall of the barrier was on the order of 0.01 ft, or about one-eighth in. (Table 1).

There are three ways that the targets can move: sliding of the barrier, tilting of the barrier, or expansion of the sand/water fill inside the barrier. Figure 27 shows that there was more movement of the lower target on wall "B" than on the upper target. If movement was by sliding, the two targets would move the same amount. If movement was by tilting, the upper target would move more than the lower target. It therefore appears that seepage of water into the bags created a slight distortion of the bag either by water pressure or by settling of the sand.

Movement of wall "C" was a surprise as it appears that it moved away from the laser, or out into the basin, a distance of about 0.02 ft (one-quarter in.). Because the hydrostatic pressure is pushing the wall inward, it is not likely that the wall actually moved outward. It is probable that the bag at which the laser was pointing changed shape slightly under pressure from the rising water in the basin or as the sand became saturated. The side of the bag on which the laser was placed was a curved surface, and a small change in shape of the bag could have twisted the target slightly making it appear to have moved outward.

In any case, no change in distance to any wall greater than one-quarter inch was recorded during the 3 days of hydrostatic testing. There was no indication of instability or impending instability of the barrier.

Table 1. Distances to targets at start of testing and at end of each 22-hr depth test.

	Wall "A" (ft)	Wall "B" High (ft)	Wall "B" Low (ft)	Wall "C" (ft)
Start	40.943	49.881	49.488	38.001
1 ft	40.941	49.877	49.483	38.004
2 ft	40.938	49.877	49.481	38.014
2.53 ft	40.930	49.874	49.478	38.020
Difference (start to 2.53 ft depth)	0.013	0.007	0.010	-0.019

Hydrodynamic Tests

Hydrodynamic tests included tests with waves and an overtopping test. The waves 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 the wave heights were run at low water (67% of structure height) and repeated at high water (80% of structure height). The high water level insured that some of the waves would overtop the structure.

For the overtopping test, water in the basin was raised until it flowed over the structure at an average depth of 1 in. Depth in the basin to achieve this flow depth is typically 2 in. higher than the barrier.

Low water, small waves

The basin was drained for the weekend after the hydrostatic tests. The following Monday, the basin was filled to a depth of 67% of structure height, or 21.3 in. (1.78 ft). The desired SWL was reached at 1035 hrs.

Monochromatic waves with a period of 2 sec and a height of approximately 2 in. were started at 1045 hrs and run for 7 hrs. No overtopping or movement of the barrier was observed, and there was no apparent washout of the sand. Seepage rate was 0.36 gpm/ft. Seepage rates during the first 2 hrs of the test are shown in Figure 28.

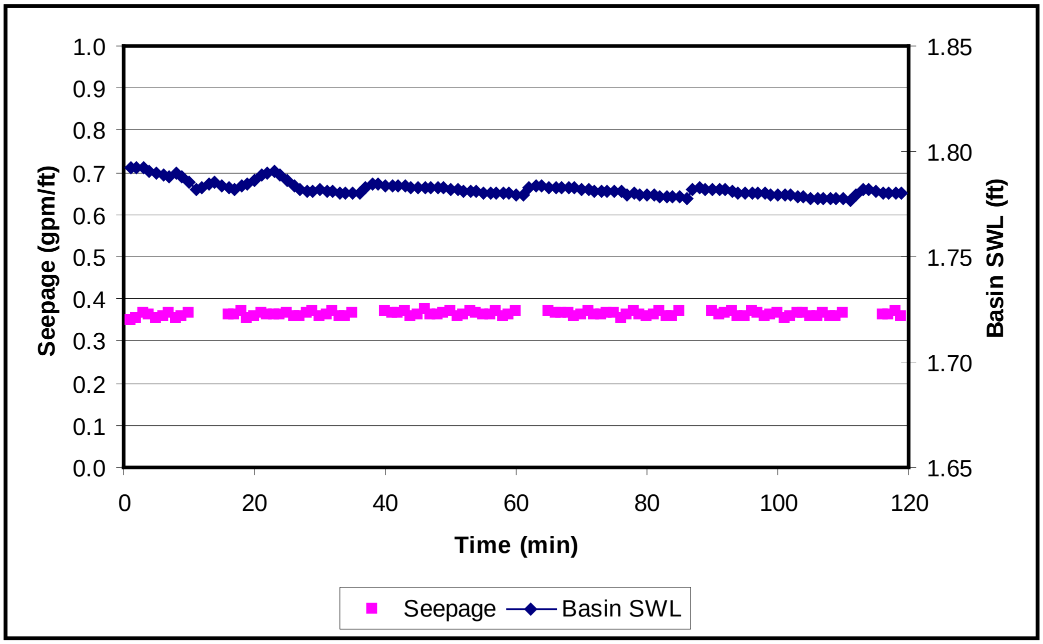

Figure 28. Seepage rates during first two hours of small waves at basin depth of 67% of structure height.

Low water, medium waves

With the basin SWL kept at 67% of structure height, 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 wave energy, the 30 min. test was run as three separate 10-min runs with a stilling period between the runs. In Figure 29, the waves were run between minutes 2 and 12, minutes 28 to 38, and minutes 58 to 68.

Minor overtopping was observed over wall “B”, but most of the water that overtopped the front of the barrier just seeped into the sand. No damage was observed. There was no observed movement of the barrier and no washout of the sand.

Seepage rates decreased as the barrier absorbed water from the overtopping and/or the sand became more compacted by the wave action. At the start of the test the seepage rate was 0.33 gpm/ft but dropped to 0.26 gpm/ft by the end of the test.

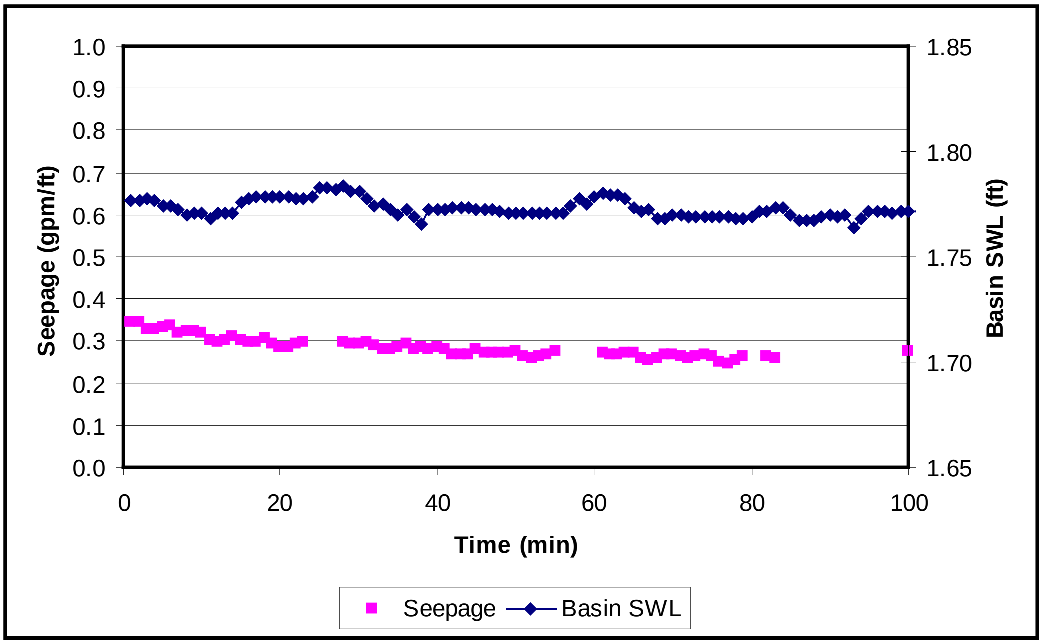

Figure 29. Seepage rates during tests with 6- to 8-in. wave heights and 10- to 12-in. wave heights with basin depth at 67% of structure height.

Low water, high waves

With the water level remaining at 67% of structure height, large waves with a wave period of 2 sec and a wave height of 10- to 12-in. were run for 10 min.

The large waves caused significant overtopping along the entire straight section of wall "B" (Figure 30), causing some washout of sand along the outer wall of the barrier (Figure 31). Other areas of overtopping included wall "A" adjacent to the wingwall and about 5- to 7-ft out from the wingwall, both areas of which had minor washout along the outer wall of the barrier.

Figure 30. Overtopping of wall "B" during test at low water with large waves.

Figure 31. Washout along outer wall of wall "B" after test at low water with large waves.

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The extra bag on the end of wall “B” that extended out past wall “C” showed no evidence of damage (Figure 31).

None of the washout posed any threat to the structure. No movement of the structure was observed.

In Figure 29, the large waves were run between minutes 82 and 92. The overtopping was too high to allow measurement of seepage rates. At the end of the test, the seepage rate was 0.25 gpm/ft, or about the same as at the end of the test with medium wave heights.

High water, small waves

The basin water level was raised to 80% of the structure height, or 25.6 in. (2.13 ft) for the high water wave tests. Monochromatic waves with a period of 2 sec and 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 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 32, the small waves were run between minutes 45 and 105. Seepage rate at the end of the run was 0.26 gpm/ft.

High water, medium waves

The barrier was tested with three 10-min bursts of medium (6- to 8-in. wave heights, 2-sec period) while the basin SWL was at 80% of structure height. In Figure 33, the waves were run from minute 1 to minute 11, minute 25 to 35, and minute 52 to 62.

There was significant overtopping of the barrier, especially along the straight portion of wall “B”. Although sand was washed out from wall “A” and wall “B”, there was no danger to the barrier. Wall “C” had no overtopping or damage.

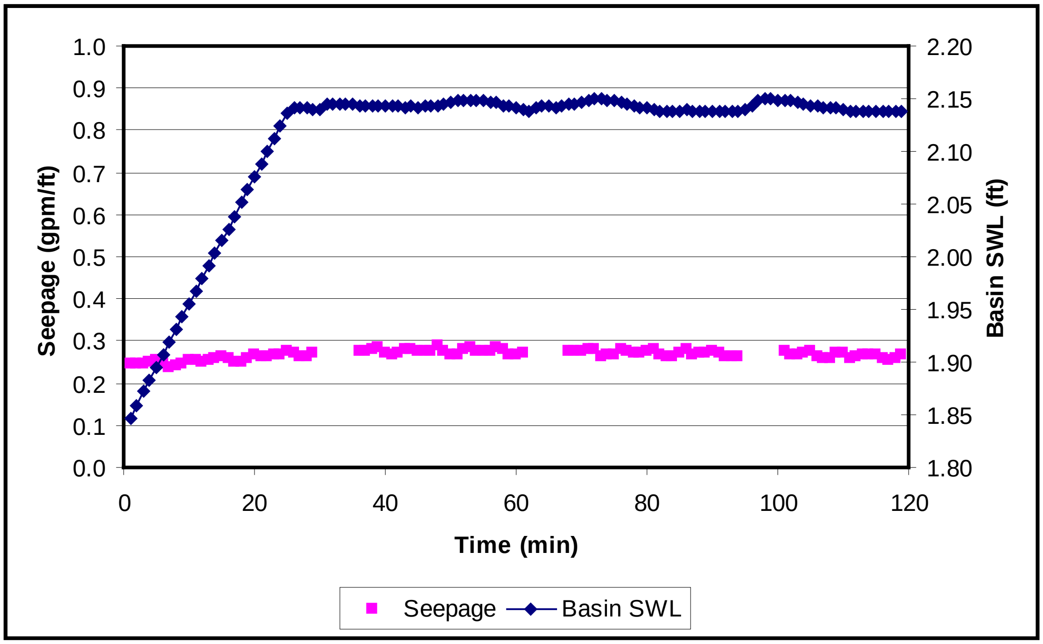

Figure 32. Seepage rates while filling the basin from 67% of structure height to 80% structure height, and while running the small waves.

In general, the sand in the washout areas was taken down to the level of the internal baffles, then stabilized. The top edge of the internal baffles is lower than the outer walls of the bags, and also can sag somewhat in the middle of the bag. As seen in Figure 34, the sand is pushed in towards the inner wall but scoured out along the outer wall.

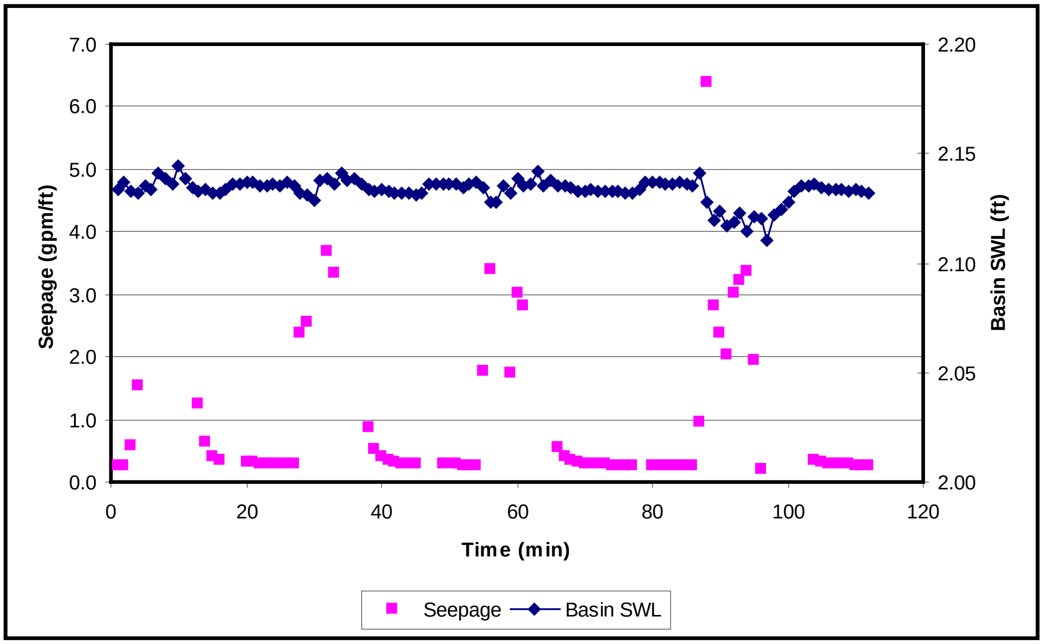

Figure 33. Seepage and water levels during tests with medium wave and large waves at high water.

Figure 34. Wall "B" showing washout along outer wall of barrier at conclusion of test with medium waves at high water.

High water, large waves

The barrier was tested with one 10-min burst of large (10- to 12-in. wave height, 2-sec wave period) while at a basin SWL of 80% of structure height. In Figure 33, the waves were run between minutes 86 and 96. Massive overtopping of the structure occurred along the straight portion of wall “B” and along the middle portion of wall “A”, with lesser overtopping where wall “A” meets the wingwall.

Figure 35 shows the overtopping along wall “B” and over the extra bag that extends past wall “C”. The force of the waves folded over the top inch or two of the inner wall in between the bulkheads allowing additional sand to be lost, but still only an inch or two. The sanctity of the barrier was never endangered.

The extra bag at the end of wall “B” was thought to be a weak point, but actually performed very well. Some sand was lost from the extra bag back to the inner bulkhead, but the scour did not continue beyond the last inner bulkhead.

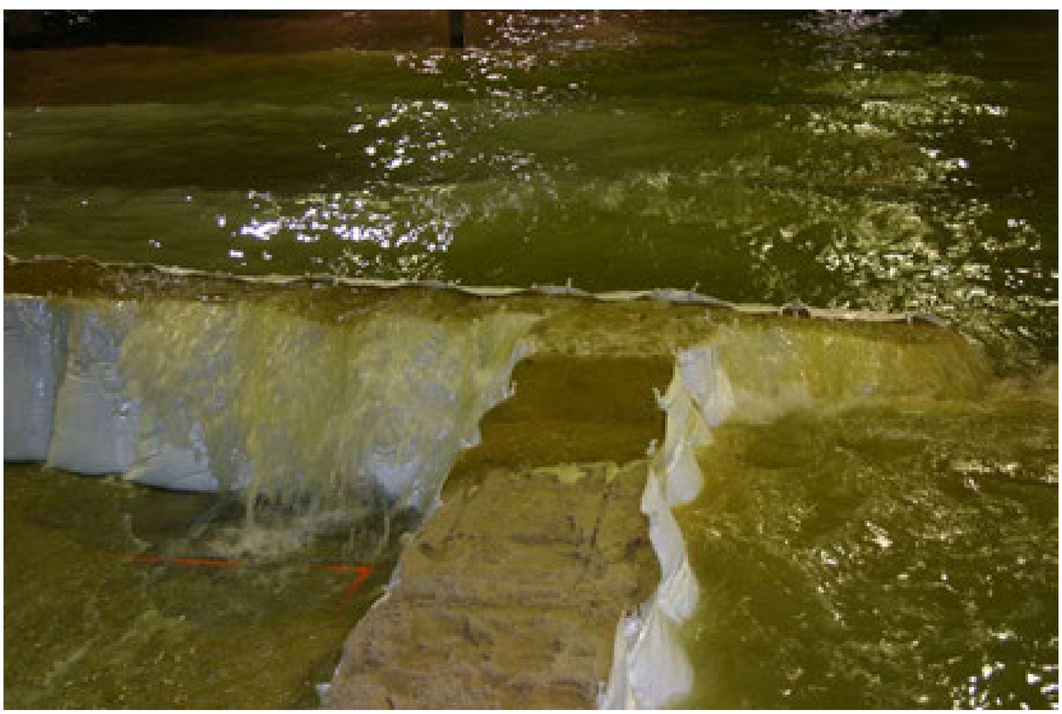

Figure 35. Overtopping along wall "B" during test with large waves at high water.

Along the curve of wall “A”, the overtopping was concentrated in an area about 5 ft out from the wingwall (Figure 36). Not only did overtopping flow over the inner wall at this point, but overtopping water collected along much of wall “A” flowed along the top of the barrier and flowed over the inner wall at this point.

Figure 36. Wave overtopping along wall "A" during test at high water level with large waves.

At the conclusion of the tests with waves, the bags had lost a couple inches of sand but were still stable and secure.

Figure 37. At the conclusion of the waves tests, looking along wall "B" towards the curve of wall "A".

Movement of Barrier during Waves Tests

Tests with the small waves had no effect on the barrier at low or high water, and laser recordings of these tests will not be included here.

Barrier movements during tests with medium and large waves during tests at low water are shown in Figure 38. Tests with medium waves were run between minutes 2 to 12, 28 to 38, and 58 to 68. Large waves were run from minute 82 to 92. There is no movement of any wall indicated during the tests with medium waves. Laser “A” and Laser “B (high)” indicate movement inward on the order of 0.002 to 0.003 ft during tests with the high waves. Laser “B (low)” indicates movement inward of about 0.006 ft. It is not expected that the lower portion of the middle wall should move inward more than the upper portion of the wall. It is probable that the overtopping that occurred during the tests with large waves caused the bag to fill with more water, which pushed out the fabric at the lower part of the bag.

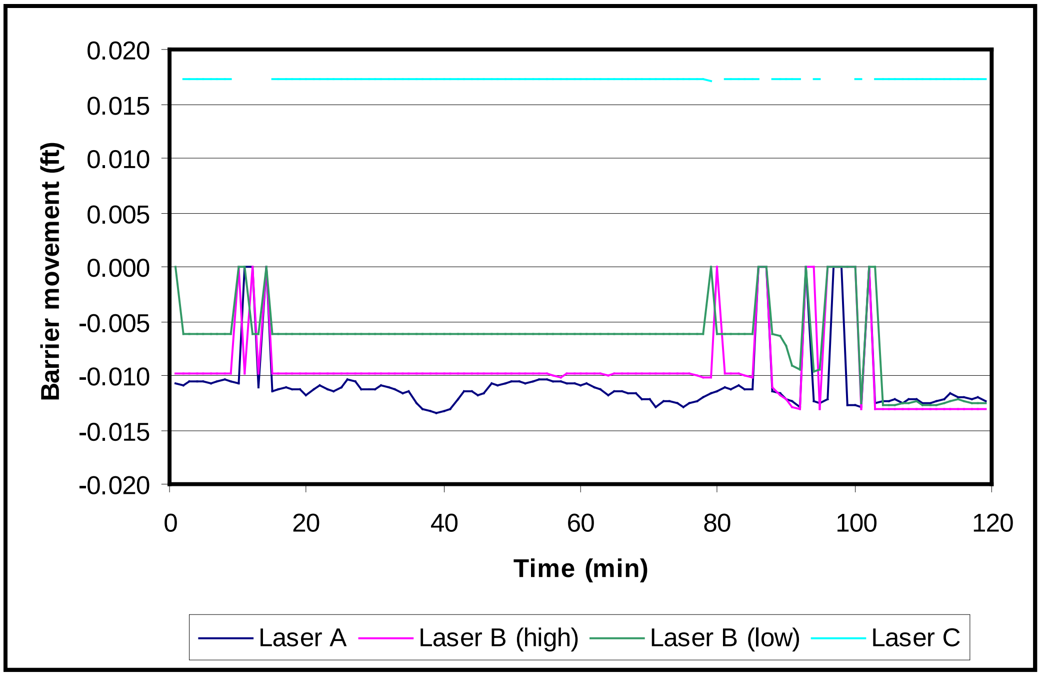

Figure 38. Movement of the barrier during testing at low water with medium and large waves.

Movement of the barrier during tests at high water with medium and large waves is shown in Figure 39. Note that the scale of the movement has been changed from previous charts of barrier movement to show movement inward of up to 0.04 ft (about ½ in.). Medium waves were run during minutes 1 to 11, 25 to 35, and 52 to 62. Large waves were run between minutes 86 and 96. Most of the apparent "movement" recorded by the lasers is seen to be during the times between wave runs, and indicates movement of people crossing in front of the lasers between wave runs.

In Figure 39, it appears that wall "A" is moving inward nearly one-half inch during the waves tests. However, Figure 36 showed overtopping of large waves at high water running across wall "A" in the vicinity of the laser target. The flow of water from tests at both medium and large waves knocked down the top couple of inches of the inner wall of the barrier in that area, forming a channel through which the overtopping could cross the inner wall of the barrier. It is probable that the overtopping water pressure on the inner wall caused a shift in the fabric to which the laser target is attached. There was no apparent movement of the barrier wall.

Because there is little direct impact of waves on the side walls (walls "A" and wall "C"), it is doubtful that wall "A" actually moved ½ in. inward.

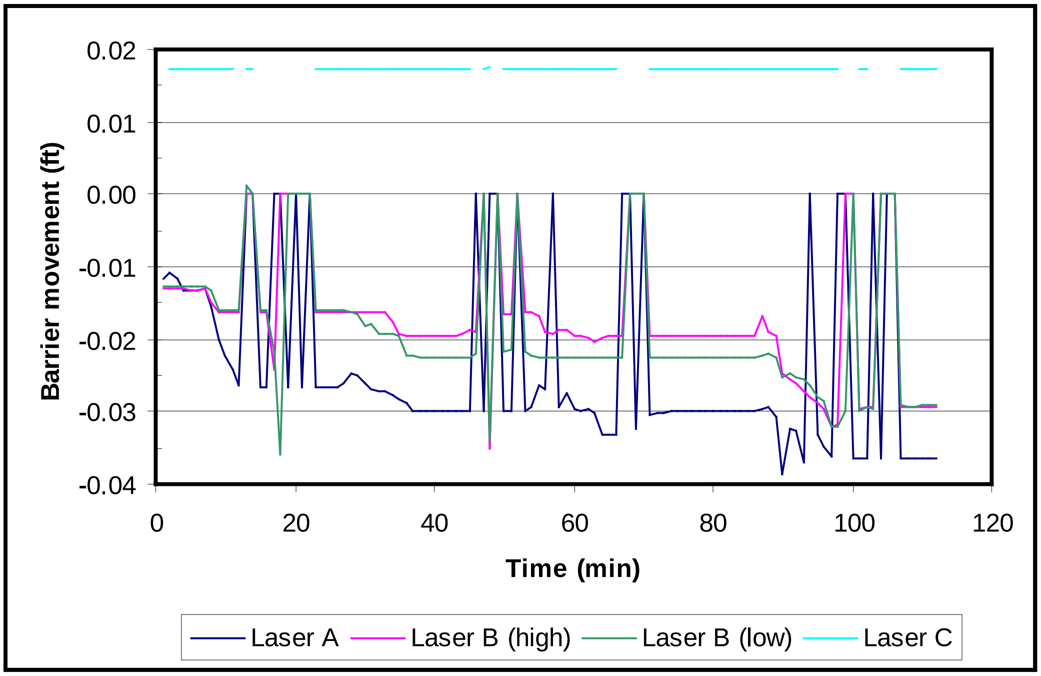

Figure 39. Movement of the barrier during medium and large waves tests at high water.

Wall "B" is directly impacted by the incident waves. The two lasers on wall "B" indicate movement inward of about 0.003 ft after each of the first two runs with medium waves, and 0.01 ft during the large waves. During tests with the medium waves, the lower laser on wall "B" shows more movement than the upper laser, which indicates a distortion of the fill rather than actual movement of the wall. With the high waves, total movement of the upper laser on wall "B" catches up to the movement indicated by the lower laser. This could indicate that the bag is now evenly distended at the upper and lower targets, or that the bag tilted inward slightly. Total movement shown for wall "B" is on the order of 0.03 ft for all the waves, or about 3/8 in.

There was no effect on wall "C" from the wave tests.

End result was that there was no apparent movement of the barrier and the lasers showed targets on the inside wall of the barrier shifted by less than ½ in. during the waves tests. Movement of the targets may have been due to water build-up inside the bags causing a bulge in the fabric and/or any actual movement of the barrier. Movement of less than ½ in. on a 36-in.-wide barrier is not significant and the barrier was found to be completely stable.

Debris Impact Test

To test the flood fighting structures for their ability to withstand impact from debris floating by in an actual flood, a debris impact test was conducted as part of the Standardized Testing Protocol. The debris impact test involved towing two logs into the structure with a winch located inside the test area (Figure 40). The logs were towed in at a 20-deg angle at a speed of 5 mph (7 ft/sec), 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. A piece of plywood was placed on top of the barrier to protect the plastic and fabric from being torn by the cable (Figure 41).

The two logs were towed into the structure one at a time, the smaller log first (Figure 41 and Figure 42). Neither log caused any noticeable damage to the structure,

The debris impact test was conducted at a water depth of 66.7% of structure height, or 2.23 ft.

Examination of the file from the distance-measuring lasers showed that wall "B" of the barrier moved inward 0.003 ft (1 mm, the smallest resolution recorded by the lasers) when struck by the smaller log. The upper laser recorded the movement first, and the lower laser recorded the movement 0.14 sec later. The barrier remained stable in the new location. No movement was recorded when the barrier was struck by the larger log, and no changes in seepage rates were observed.

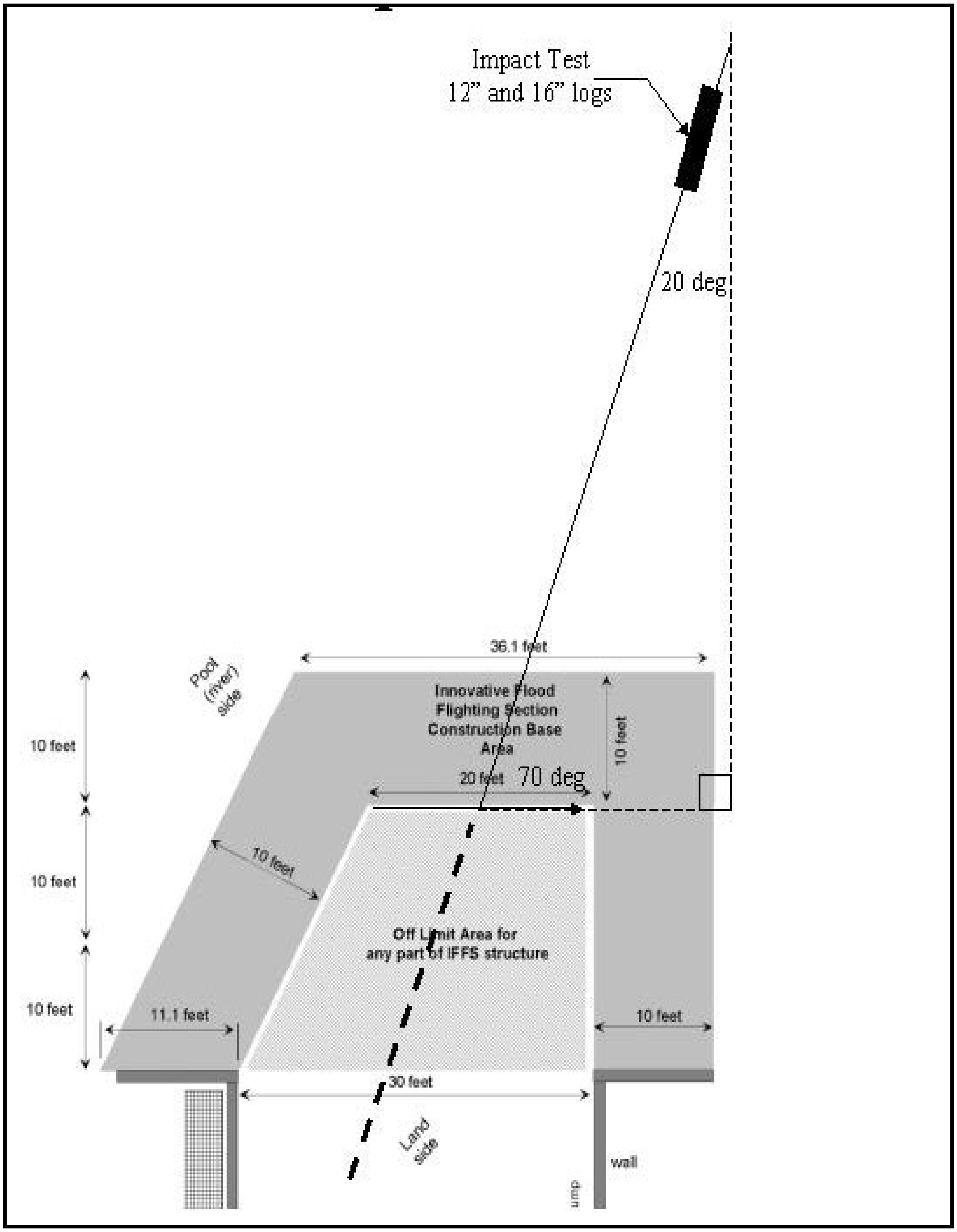

Figure 40. Setup for debris impact tests.

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Figure 41. Immediately after log impact on barrier. The plywood on top of the barrier is to protect the barrier from the tow cable.

Figure 42. No damage to the barrier could be found.

Overtopping

The water level in the basin was raised until the barrier was overtopped by approximately 1 in. of water. Generally, the basin SWL is raised to 2 in. above the barrier in order to get a depth of 1 in. flowing over the barrier. The RIBS did not have an even elevation of structure height due to the washout that occurred during the wave tests. Depth of flow over the barrier varied from zero over most of wall "C" to over 2 in. along much of wall "B" as the test engineer tried to get an average depth of 1 in.

Overtopping started along the curve of wall "A" that had the most overtopping during the large waves at high water level (Figure 36). The material on the inner wall of the curve was able to fold over towards the interior of the test area at the seams allowing water to pass over the barrier at the seams. Water was flowing over the outer fabric of wall "B" but had not yet topped the inner wall. Overtopping gradually spread to more seams on the curve of wall "A". Basin SWL at start of overtopping was 2.63 ft (31.5 in.).

The basin SWL approximated an average height of the structure at a depth of 2.75 ft. Desired basin depth for test should therefore be 2.91 ft for 2 in. above average structure height. Water was brought up to 2.95 ft, then lowered to 2.91 ft. At this point flow over the barrier was more than 6 in. deep in some areas with no overtopping in other areas. In Figure 43 two areas along the curve of wall "A" have water flowing at several inches deep, most of wall "B" is between 1 and 2 in. deep, and there is no overtopping of wall "C".

After one hour of overtopping with an average depth of flow of 1 in., there was one scour hole-10 in.-deep along the inner wall on the curve of wall "A" and about 6-in.-deep at the point of maximum flow over the inner wall. Wall "C" had shown very little overtopping and no damage. The extra bag at the end of wall "B" had scoured to the height of the interior baffles but then stabilized. Much of wall "B" had scoured to the height of the interior baffles, but then stabilized.

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Figure 43. Water flowing over the structure during the overtopping test.

Additional Tests

At request of the vendor, waves were added to the basin while water was still overtopping the structure. Small waves with a 2 in. wave height were run for 3 min, then 6- to 8-in. waves were run for 1 min, and 10-in. wave were run for 15 sec (Figure 44). The diesel pumps could not keep up with the overtopping when the large waves were added, so the waves were stopped after only 15 sec, but the barrier was not endangered. The barrier was not noticeably affected by the waves and remained stable.

Figure 44. Large waves added to the overtopping test.

The drain was then opened to empty the basin. However, while the water was still overtopping the structure one of the bags in wall "B" was sliced open along the inner walll to test the ability of the barrier to withstand being damaged. The overtopping water quickly washed the sand out of the damaged bag. The walls of the adjacent bags bulged inward along the centerline of the barrier making a smaller opening where the cut bag had been, while the fabric held and the damage did not spread to other bags (Figure 45). The outer wall of the damaged bag was pushed inward by the water pressure. The top of the outer wall where it was pushed into the damaged bag was 18 in. below the top of the other bags. A pile of sandbags placed in front of the damaged RIBS bag would have stopped much of the flow through the damaged bag. In Figure 45, movement of the bag adjacent to the one that was cut when it bulged over into the opening left by the cut bag is apparent from the lasers and the circles where the lasers had been pointing.

Figure 45. One bag cut open with water still overtopping structure.

Disassembly

Tear down of the structure required less time than any structure tested to date. A two man crew removed the entire barrier in 1:08 hours, including removing the sand and placing it in a stockpile.

Disassembly started with one man inside the barrier and one man on the outside slicing open each bag vertically with a box-cutter knife (Figure 46). One of the men then got on the skid-steer which was set with the front-end bucket. The bucket was used to roll over the bags in the barrier, ripping the fabric along the bottom of the barrier and spilling the sand from the baskets (Figure 47).

Figure 46. For removal, a box cutter is used to slice open the bags on both the inside and outside.

Figure 47. A skid-steer loader is used to roll the bags over, dumping out the sand.

One extension fork was fastened to the front of the bucket. The fork picked the fabric up out of the sand pile, ripping it free as necessary (Figure 48). The fabric was shaken if necessary to dislodge the sand, then the man on the ground took the fabric to a refuse pile. Thirty minutes after the start of disassembly all the fabric was removed leaving just a pile of sand.

Figure 48. One extension fork is fastened to the front of the bucket to remove the bag material from the sand.

At this point, the man on the ground was no longer needed but his time is still included in the recorded man-hours because disassembly used a 2-man crew. Removal of the sand was completed with the skid-steer in 32 min.

Six minutes later, all equipment and discarded bags were removed from the basin and the test was over. All of the sand was removed from the barrier and placed in a stockpile within the basin. Total time from start was 1 hr 8 min, for a total of less than 2.3 man-hrs.

Equipment used in the disassembly were a skid-steer loader with bucket and one extension fork, and two box-cutter knives.

The bags are not considered reusable and were destroyed in the disassembly.

A Cat 916 front-end loader later removed the sand from the stockpile in the basin to an external stockpile.

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3 Summary

A 76-ft 1-in long barrier 32-in.-high was constructed by a 3-man crew in 5.8 hrs (17.5 man-hrs), or 0.23 man-hrs/ft. No heavy equipment was used in the construction. Other than hand tools, the only equipment used were a special deployment trailer and a small skid-steer (Bobcat™) loader.

The Standardized Test Protocol required that the structure be built in a skewed "U" shape including sealing two ends to wingwalls. Straight-line placement of the barrier, such as typical placement on a levee, is much faster. Constructing the straight section of wall "B" took only 0.11 man-hrs/ft (52 min for 24 ft). For a straight section of barrier, a 3-man crew (including the skid-steer operator) should be able to construct a 100-ft length of wall in 3.6 hrs.

Initial seepage rates were relatively high until some of the major leaks on the seams were plugged, reducing the seepage by more than a third.

The barrier appeared to be completely stable and was not significantly affected by the hydrostatic forces, wave action, overtopping, or debris impact.

Disassembly required the fewest man-hrs of all flood-fighting structure tested to date. A two man team took down the entire wall in 1 hr 8 min, or 2.3 man-hrs, using just a small skid-steer loader.

A summary of construction/disassembly times and seepage rates are given in Table 2.

Table 2. Summary of Tests with RIBS flood fighting barrier.

Test	Measurements
Construction/Repairs/Disassembly	
Construction (man-hrs)	17.5
Repairs (man-hrs)	4.8
Disassembly (man-hrs)	2.3

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Hydrostatic Seepage Rates (gpm/lft)	
1 ft Head	0.31
1 ft Head after Repair	0.20
2 ft Head	0.40
0.95H Head (2.53 ft)	0.50

Other Factors

Constructability and Re-usability

No heavy equipment was used in the assembly or disassembly, demonstrating that the barrier can be erected and removed in areas that are inaccessible to heavy equipment. A special deployment trailer was used, which requires that the surface on which the barrier is constructed be accessible to a wheeled trailer. A portable frame was used to bridge a gap in the barrier (between walls "B" and "C") which could also be used to bridge a short section that is inaccessible to the wheeled trailer.

The barrier is not considered re-usable and was destroyed on removal.

Environmental

The material used in the RIBS is non-toxic and may be disposed of in a common landfill. The sand may retain contaminants from the flood waters and require special disposal, but otherwise is fully re-usable. Because the bags are waterproofed, seepage through the bags is minimal and the sand is not subjected to large amounts of flood waters unless there is overtopping by waves or water level, therefore contamination of the sand should be minimal.

Other materials used were the expanding foam sealant and the concrete crack repair material. The cured expanding foam sealant may be disposed of in a landfill, but the concrete crack repair material may require special handling.

Cost

According to Landmark Earth Solutions, a 24-ft-long RIBS 3 ft high costs $420. A 1,000-ft-long barrier would require 420 units (1,008 ft total) for a cost of $17,640, or $17.64/ft.

Other sizes of RIBS available are a 4-ft-high barrier fro $498 and a 6-ft-high barrier for $1,080.

Use of the custom deployment trailer is free with the purchase of a minimum of 2,640 feet of RIBS (one-half mile). Rental of the trailer is $1,500/week for shorter purchases.

These rates were provided by the manufacturer in April 2011.

Comparison to Sandbags Baseline Data

Table 3 compares measured parameters from the RIBS flood fighting barrier tests reported herein to baseline data collected in 2004 with a sandbag barrier following the same protocol.

Table 3. Comparison of RIBS Flood Protection Barrier to sandbag baseline data.

	RIBS	Sandbags
Install/Remove	**Man-hrs**	
Construction	17.5	205.1
Repair 1	4.8	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	0.31	0.05
1.0 (after repair)	0.20	
2.0	0.40	0.23
2.53	0.50	
2.85		0.53

4 Conclusions

The Rapid Installment Barrier System (RIBS) by Landmark Earth Solutions is an expedient and cost-effective solution for a temporary flood-fighting barrier. Using the same testing protocol, the RIBS barrier was constructed in about one-twelfth the time it took to build a similar sandbag barrier, and removal of the barrier took about one-fourth the time required to remove the sandbag barrier. No heavy equipment was required for the RIBS barrier, and the only mechanized equipment used was a small skid-steer loader.

Seepage rates with the RIBS were reasonable but higher at low water levels (one ft and two ft depths) than with sandbags, and similar to sandbags are greater depths.

The RIBS barrier withstood tests with waves, overtopping, and debris impact without failure. Some sand was washed out of the bags during wave overtopping and overtopping due to high water level, but the integrity and stability of the bags were not lost.

At $17.64/ft for the 3-ft-high bags, the RIBS system is a cost-effective alternative to sandbags.

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