STANDARDIZED TESTING PROTOCOL FOR EVALUATION OF EXPEDIENT FLOODFIGHT STRUCTURES[1]

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1.0 Introduction

The primary purpose for developing this protocol is to test and evaluate the effectiveness of various types of expedient flood-fighting devices. Vendors of a wide range of commercial expedient structures are competing for U.S. Army Corps of Engineers emergency flood-fighting funds. These structures vary widely in form and function. For the most part, the only technical literature available on the products comes from the vendors themselves. Few vendors have tested their products at established laboratories; the majority bases their performance expectations on results of their own testing. Some vendors promote products that are conceptual or in prototype development stage only. Financial decision-makers within Federal, State, and Local government agencies responsible for flood fighting are the primary targets-of-opportunity for these vendors. The fundamental problem faced by these decision-makers is that they have no basis for substantiation of the claims made by these vendors. A Standardized Testing Protocol (STP) developed, administered, and executed by the US Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC) laboratories is a logical and necessary tool for providing unbiased, objective technical performance data. In order to participate in the testing program, the vendors of the various products will supply funding, materials, equipment and labor to assemble their systems in accordance with the STP, and in accordance with a Testing Services Agreement (TSA) to be executed between each vendor and ERDC.

The STP focuses on configuring expedient structures as a wall or impoundment within one of the Coastal and Hydraulics Laboratory's (CHL) Wave Basins (Attachment 1). Several key performance factors will be evaluated using STP guidelines. Structures will

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be subjected to hydrostatic loads, wave-induced dynamic loads, impact loads and overtopping, with the response of the structure to each test mode evaluated. Using this STP, a variety of expedient structures may be tested under the same set of controlled conditions. The results of the tests will allow the end user to determine applicability, benefits, and product performance for various situations.

In addition to performance factors, several operational factors will be measured and recorded. Included in the operational factors are man-hours required to construct and remove the test structure, special equipment or tools required, fill materials (if any), structure footprint, and suitability for construction by untrained labor. Suitability of the structure for use on uneven or sloping ground, different types of substrate, and with bends or curves will be considered.

2.0 Classes of Expedient Structures

The range and diversity of products used or intended for expedient flood-fighting is quite large. Products can be classified several ways. We have chosen to categorize these products into three major types:

A) Permanent: the structure remains in place at all times.

B) Semi-permanent: mounting brackets and fixtures may be permantently mounted but walls or other sections are removable between floods

C) Temporary: erected when a flood situation is imminent and removed when the danger has passed.

This STP is intended for testing of Temporary flood fighting structures.

3.0 Standardized Testing Protocol

The STP utilizes a physical model testing facility to subject the expedient flood-fighting structures to loading similar to that found in a real flood situation. One important facet of the STP is to establish a baseline of performance for comparing the effectiveness of the new products. The integrity of the new products will be evaluated against the performance of a sandbag levee built according to typical USACE guidelines. The STP will include documentation of construction requirements, material costs, labor, hydraulic

performance, environmentally acceptable materials, and structural integrity of the baseline case as well as each product tested.

The following elements form the basis of the STP:

- The base (floor) for the Expedient Flood-Fighting (EFF) structure to be tested will be constructed in the area shown in Attachment 1. Each EFF structure will be configured as an approximately 80 ft-long levee configured as a modified "U" shape. The area to be protected by the structure is flanked by two 10-ft-long wingwalls, 30-ft apart. The EFF structure will start at one wingwall, extend a minimum of 20 ft perpendicularly out from the wingwall, turn 90 degrees and extend parallel to the wing walls for 20 ft, then angle back to the second wingwall. The EFF structure will be constructed to between two and 3.75 foot high.
- The EFF structure base should fit within the 10-ft-wide construction base area. Additional membranes used for seepage reduction and an occasional sandbags used as membrane hold-downs may be used in the pool area simulating the floodwater side of the EFF structure. No EFF structure parts, sandbags or membranes will be allowed inside the "off-limit" area shown in Attachment 1. If parts of the EFF structure extend beyond the construction area into the pool area, a notation will be made that the structure may be unsuitable for use on levees with narrow crest widths.
- Structures will be subjected to hydrostatic loads from incrementally increasing floodwater head, or depth.
- Structures will be subjected to hydrodynamic loads by applying waves of incrementally increasing height.
- Structures will be subjected to steady-state overtopping with a depth of flow over the structure of one inch.
- Structures will be subjected to a prototypical impact log test.
- Measurements of seepage and movement of EFF structure will be made during all phases of the testing.
- Observations of movement of EFF structure, fatigue or structural deterioration will be made during all phases of the testing.

- Up to three relatively small-scale repairs of documented damage are allowed during a test series.

4.0 Constructability Evaluation

Vendors may construct and install their own product at the ERDC test facility in Vicksburg, MS. Alternatively, a construction crew will be provided by CHL and the Vendor may send a trainer/supervisor to instruct the crew in the construction of the structure and supervise their efforts. The construction process will be recorded using one or more video cameras. The first evaluation of the STP deals with issues of construction. Documentation and evaluation will be made of specific constructability issues. These issues include:

a) Manpower requirements
b) Foundation requirements
c) Material and equipment required
d) Ease of construction
e) Construction duration
f) Special construction considerations.
g) Application limitations
h) Damage during construction

The vendor will arrive on-site with all supplies and materials (except fill) loaded in one or more trucks, similar to transporting the product to a remote levee site. Fill material may be stockpiled at a designated location outside the test facility. No materials will be unloaded from the trucks until initiation of the testing protocol. A waterproof gate to the test basin will be open and small front end loaders or similar equipment may be used to aid in construction of the EFF structure. When construction is complete, the gate to the test basin will be closed and no further access to the EFF structure with mechanized equipment will be possible until after the overtopping test is completed.

At the completion of the tests, the vendor will disassemble the EFF structure and return it to the truck(s) for removal. Suitability of the EFF structure for reuse will be considered.

5.0 Hydrostatic Testing Protocol

The initial and most basic component of the STP is to evaluate the structural and hydraulic response of each EFF structure to quasi-static, slowly rising hydrostatic head. The testing protocol for the hydrostatic head test will consist of flooding the basin on the river-side (or "wet" side) of the barrier or wall to the desired water level. Three water levels will be used for testing: 1 ft, 2 ft, and 95% of the design height of the structure, also shown in Attachment 2. At each increment, the water level will be held at constant stage for a minimum of 22 hours. Continuous measurements will be made of seepages through the interface and the body of EFF structure. Any observable movement of the EFF structure will be documented and recorded on video. The wall will be measured for any lateral deflection at up to six different locations in order to determine whether it is sound under increasing static loading. Measurements in terms of average volumetric quantity per unit of time will be used to calculate amounts of water flowing under or through the barrier. This will allow the engineer to determine how much water may become impounded, for a given duration, behind the wall.

6.0 Wave-induced Hydrodynamic Load Testing Protocol

The purpose of wave-induced dynamic load testing is to observe the structural response of the EFF structure under hydrodynamic loading conditions. Typical hydrodynamic failures of temporary structures include material failure or fatigue, fill loss, wall sliding or overturning, and deformation. The protocol specifies that packets of monochromatic waves with a wave period of $T = 2.0$ seconds be generated to impinge against the barrier. The wave tests will be conducted at two different calm water depths: 66.7% x h and 80% x h , where h is design water depth for the structure or 3.5 ft, whichever is lower. At 66.7% x h waves of approximately 2 to 3 in. height (measured from trough to crest) will be generated continuously for a period of 7 hrs. The following day waves ranging from 7 in. to 9 in. (measured from trough to crest) will be allowed to impact the structure for three ten minute increments, for a total wave impact time of 30 min. Between each 10-min increment, the basin will be allowed to still to prevent the buildup of reflected wave energy in the basin. Afterwards, waves ranging in height from 10 in. to 13 in. will be

allowed to impact the structure for one ten-minute increment. At the end of each ten minute increment of wave testing (excluding the 7 hrs of 2-3 in. waves), the basin will be stilled for up to 45 minutes to allow the waves to dissipate.

The water will then be brought to a level of 80% x *h* and the above tests will be repeated (Attachment 2) *except that* the 2-3 in. waves may be run for a minimum of 1 hr instead of 7 hrs. The 2-3 in. wave may be run for up to the entire 7 hrs if it is deemed necessary by the CHL engineer. The reason for wave testing at the higher still water level is to insure that there is some overtopping of the larger waves so that the response of the structure to wave overtopping may be observed.

The seepage observations and displacement measurement as described in Section 5.0 will also be done during hydrodynamic testing. As waves grow in height, a portion of the wave may spill over the EFF structure, depending on frontal geometry, porosity, and roughness. This quantity of water can have a significant impact on the volume of impoundment.

7.0 Additional Observations and Measurements of Failing Structures During Static and Dynamic Tests

Observations and measurements of any structural damage, such as material breakage, fatigue, component failure, and an estimated fill loss will be made. Three repairs of the EFF structure will be allowed during the test series as will be described in Section 10. This allows an evaluation of the expediency of the repair, method used, and integrity of the repair.

8.0 Overtopping

Water level on the flood (wet) side of the EFF structure will be slowly raised until the height of the structure is exceeded and depth of flow over the structure is one inch (depth of water several feet out from the structure will be approximately two inches greater than structure height). Pumps on the dry side of the EFF structure will return the water to the basin to maintain a constant head in the basin and to keep the water level on the dry side

of the EFF structure as low as practical. This overtopping test will proceed for one hour after steady state conditions are achieved or until failure occurs. If the structure floats up the water will be raised to the appropriate elevation and the pumping will begin even though no overtopping occurs. The performance of EFF structure during overtopping includes recording the movement of the structure, and observation from one or more video cameras.

9.0 Debris Impact Test

Following the overtopping test, the vendor will have the opportunity, if desired, to remove all of the water from the basin and to rebuild the EFF structure to its original condition before the static, dynamic, and overtopping tests. The reconstruction procedure should be the same as the construction before static loading tests. The water level will be filled to a height of 66-2/3 % of the design height of the EFF structure, and the debris impact test will be performed (Attachment 3). The purpose of this test is to evaluate the structural response of the EFF structure to a simulated debris load. The EFF structure will be struck with two different floating logs. A log will be pulled into the EFF structure using an electric winch system to provide an impact with a velocity of 7 feet per second, or about 5 miles per hour. The trajectory angle between the log and the levee will be about 75 degrees. Twelve in. and 17 in. diameter logs, each 12 feet long, will be used. The smaller log will be used first, followed by the bigger one. The movement and damage to the EFF structure, if any, from the smaller log impact test will be observed before continuing to the larger log impact test. If the EFF structure is leaking profusely or has experienced more than 6” permanent movement after the smaller impact log test, the bigger impact log test may not be performed. ERDC personnel will determine if it is safe to continue with the next impact log tests.

The vendor may choose to reverse the order of the debris impact test and the overtopping test, that is, conduct the debris impact first followed by the overtopping. This may be advisable for a structure that is likely to be damaged by the overtopping but unlikely to be damaged by the debris impact test, thus potentially saving the need for a rebuild of the structure. However, a rebuild after the debris impact test and before the overtopping test

is not allowed.

10.0 Repairs to Innovative Flood-Fight Structures

Up to a total of three minor repairs to a vendor's EFF structure will be allowed during the three major tests (hydrostatic, hydrodynamic, and overtopping). This does not mean three repairs during each test. A minor repair is hereby defined as "a repair requiring a maximum of 30 minutes using a maximum of four men, using only materials available on site". There will be seven opportunities to make repairs, and the vendor can only make three repair attempts. The vendor must understand the STP completely before deciding the condition under which these three minor repairs will take place. The testing will not be halted during a particular test phase to make a repair. The repairs must all be made after the test or tests at one level is/are complete; this becomes more important during the dynamic testing, which is discussed below. The three types of repairs are described as follows:

10.1 Static Test/Repair Description:

During a static test, the water elevation will be raised to three different levels: 1 ft, 2 ft, and 95% x *h* , and each level is maintained for a minimum of 22 hours while seepage, displacement, and material loss are recorded (Attachment 2). If the need for a minor repair develops at 1 ft or 2 ft, the vendor may choose whether or not to perform the minor repairs before the tests proceed to the next level. If the vendor wants to make a repair after the 95% x *h* depth, safety dictates that they must wait until the water level is dropped to the 66.7% x *h* level and prior to the dynamic test to make this repair.

10.2 Dynamic Test/Repair Description:

During a dynamic test, the water level will be raised to an elevation corresponding to either 66.7% x *h* or 80% x *h*. For each water elevation, three different wave magnitudes (2 to 3 in, 7 in to 9 in, and 10 in to 13 in) will be allowed to impact the structure. The first wave height will run for seven hours, followed by the second wave height for 30 min (three 10 minute packets), followed by the third wave height for 10 minutes (one 10 minute packets) (See Attachment 2). Repairs will only be allowed after first wave height

is completed and after the third wave height is completed for the elevation being tested.

10.3 Over topping Test/Repairs:

Repairs conducted after the overtopping test is completed are not counted as a minor repair because the levee may be repaired to its original condition preceding the log impact test. A maximum of 8 hours will be allowed for this repair with no limit on the number of personnel. This repair will be the responsibility of the product vendor. The method of construction should be consistent with the original method without any modification.

10.4 Review of the three repairs allowed and when they may be performed:

In summary, three minor repairs are allowed and can be performed out of 7 different times of opportunity as shown in Table 1. After the overtopping test, vendor may need to do repair or rebuild if necessary for debris impact test. All of the repair materials must be on site to make the needed repairs in and at the times specified. Repairs must be made from like materials or repair kits for the structure.

11.0 Environmental Evaluation

Material that will be used for the construction of protective barriers will be required to have an Material Safety Data Sheet (MSDS) attached if it is required by the properties of the material. The MSDS will provide information as to the chemical make-up and physical properties of the material. The MSDS will be reviewed to determine if the material will pose any environmental risk when place on or in the protective barrier. The EFF structure, its fill (if any), anchoring system (if any) or any other aspects of the system will be evaluated to determine any environmental effects that might occur if it comes in contact with certain such items as sewage, oil, debris, etc, and if special handling or disposal procedures are needed after prolonged contact with contaminated waters.

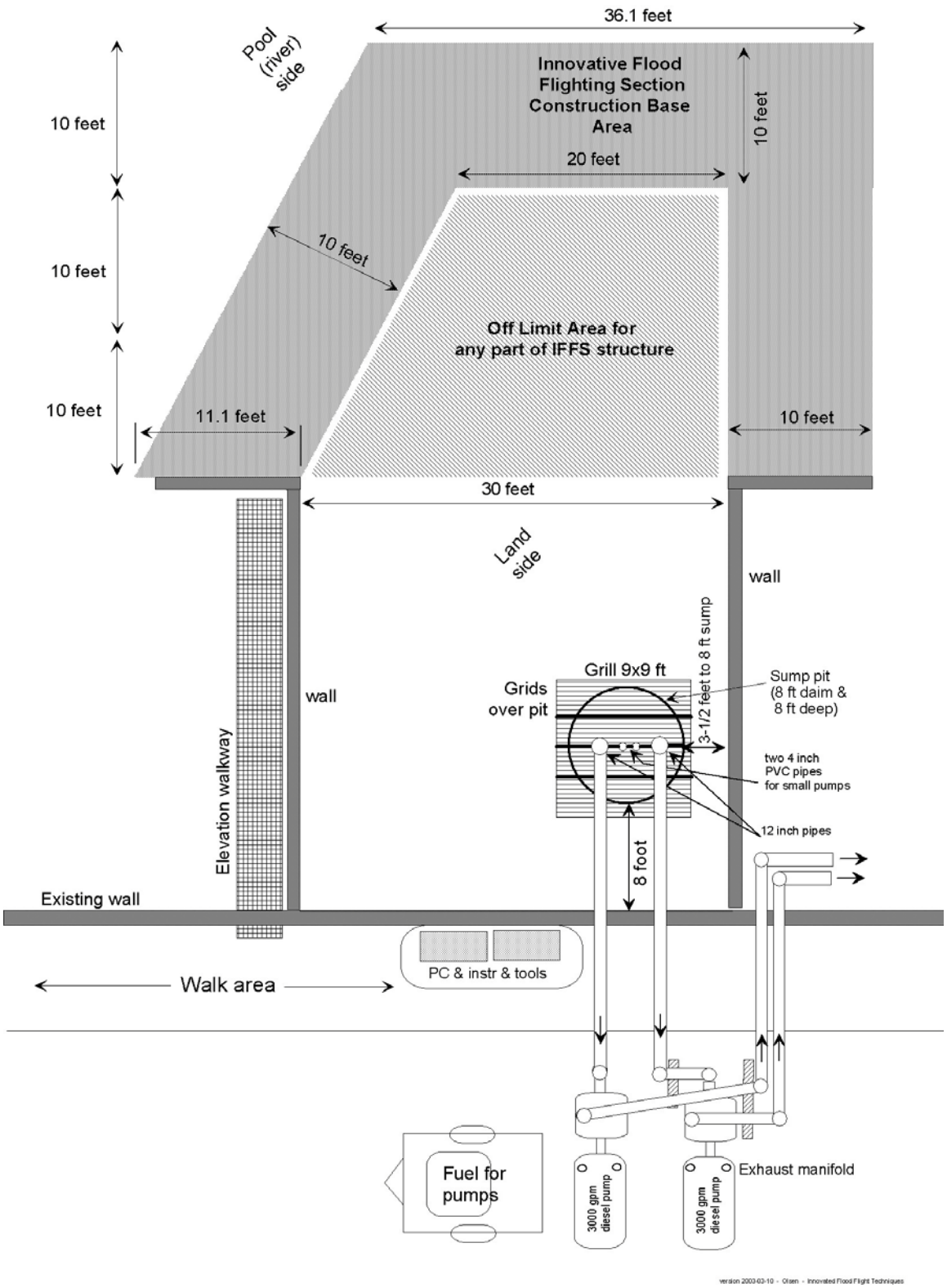
Table 1. EFF Structure Testing Matrix

Test	Condition	Repair Allowed
Hydrostatic	1 ft depth, 22 hours	After 22 hours test
	2 ft depth, 22 hours	After 22 hours test
	95 % h, 22 hours	After 22 hours test, and water level lower to 66 2/3 % h
Hydrodynamic	66.7% h, Low Wave, 7 hrs	After finish of 7 hrs
	66.7 % h, Med Wave, 3 x 10 minutes test	After finish 66.7 % h, High Wave Test
	66.7 % h, High Wave, 1 x 10 minutes test	
	80 % h, Low Wave 7 hrs	After finish of 7 hrs
	80 % h, Med Wave, 3 x 10 minutes test	After finish 80 % h, High Wave test
	80 % h, High Wave 1 x 10 minutes test	
Overtopping	1 in overflow, 1 hours	Major repair or rebuild
Debris Impact	12 in log, 5mph 17 in log, 5 mph	Removal of all material

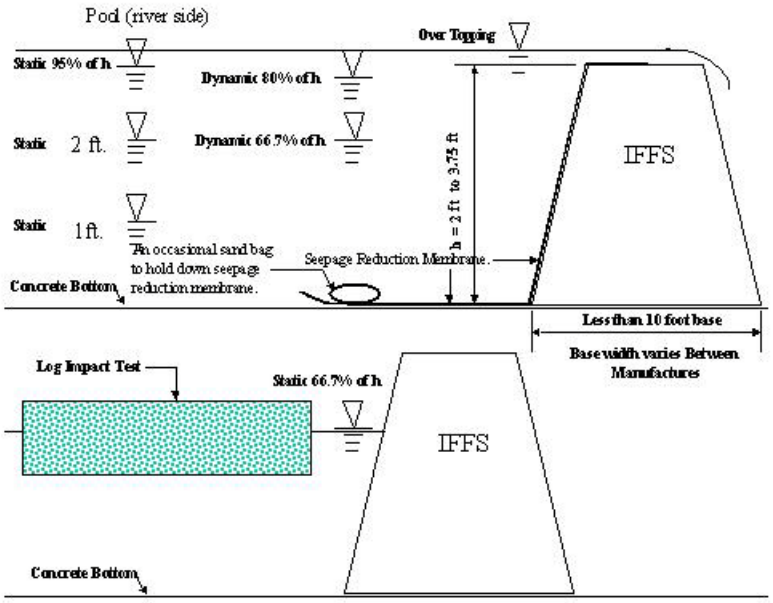
13.0 Evaluation Process

At the end of the test sequence, all measurement data will be compiled and presented in tables and charts. Photos of EFF structure during construction, during test, and after test will also be presented. Quantitative results obtained for the EFF structure will be compared to the results obtained with sand bag tests, which are intended as a baseline performance reference. For qualitative performance evaluations (constructability and repair difficulty), the sandbag levee performance will also be used as a reference baseline. The final evaluation report will include narrative, photographs, drawings, and

tables. The report will not provide a rating of the various products, rather it will assist the field engineer in making informed decisions about the application of flood fight products to a particular application.

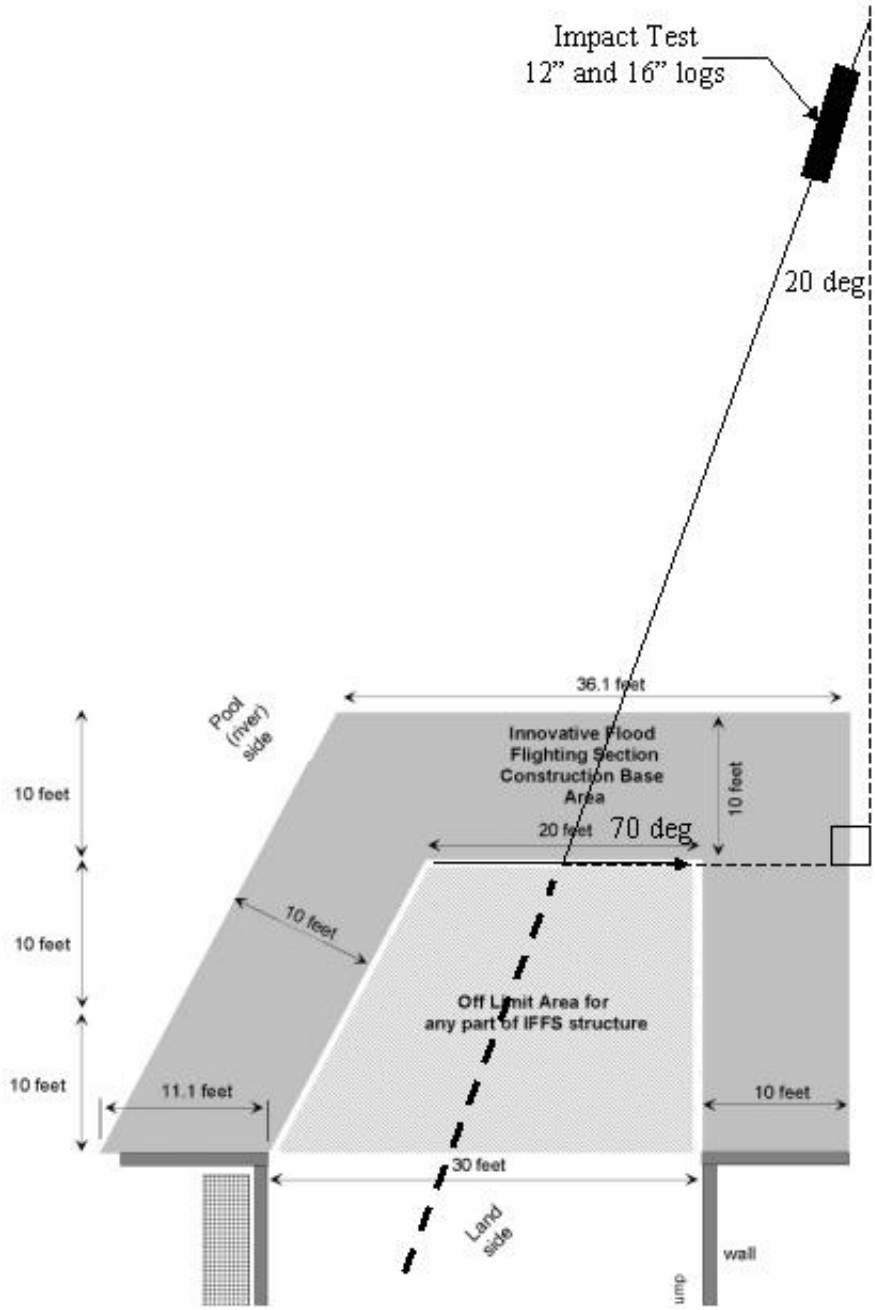


Attachment 1



Attachment 2

Impact Tests



Attachment 3