Farnsworth House

Plano, IL

Investigation of Buoyant Amphibious Foundation System to Mitigate Flood Damage

Prepared for The National Trust for Historic Preservation

Prepared by
Silman
111 Devonshire Street
Boston, MA 02109

March 11, 2015

EXECUTIVE SUMMARY

Following is a table that summarizes the items that were investigated in this report, comparing the performance of the Hydraulic Lift System with the Buoyant Amphibious System.

Item No.	Criteria	Hydraulically Actuated System (HAS)	Buoyant Amphibious System
1	Able to lift structure above highest flood water	Yes	Yes
2	Able to resist rising in minor floods (*without additional enhancements to the basic system)	Yes	No*
3	Able to lift structure on command for maintenance	Yes	No
4	Able to test system prior to a flood occurring	Yes	No
5	Known precision for return of structure to exact required position	Yes	TBD
6	Able to control accelerations	Yes	No
7	Proven performance using substantially similar components	Yes	No
8	Profile exposed to wind and water currents / difficulty to resist	Small	Large
9	Able to remove debris and mud prior to lowering	Yes	No
10	Depth of excavation	Medium	Very deep
11	Failure modes	Benign	Significant
12	Effect and impact on visitor experience (* without enhancements to the basic system)	Nil	Some*
13	Relative cost	High	Moderate

INTRODUCTION

Silman was retained by The National Trust for Historic Preservation (NTHB) to conduct a preliminary study of a scheme that would rely on natural buoyancy to lift the Farnsworth House above flood waters during a flooding event. This report responds to that request.

There are generically two types of buoyant foundations. One is the floating foundation where the structure being supported on the buoyancy system simply floats on top of the water, much like a houseboat. It is always in the water and it depends on having a permanent body of water in which to reside. The other is the amphibious foundation that is comfortable both on dry land and in the water. For purposes of comparison with the Farnsworth House, we will report only on the latter system.

The description of the Farnsworth House and the problems associated with flooding of the Fox River appear in the Introduction section of the Robert Silman Associates (RSA) report on the house dated April 2014. That report concentrated on Option C, a solution that employed a hydraulically actuated system (HAS) to both temporarily raise the house above the highest water that might occur during a flooding event and then lower it after the flood had subsided and all debris had been cleaned out below the house.

During presentations of that report, a number of questions were raised about using a natural buoyant amphibious system (BAS), much like a floating dock in a lake that slides up and down using connections to pipes driven into the lake bottom. Several people cited precedents for such systems and the NTHP decided to conduct a more in-depth analysis of that system.

NTHP required that all potential options would be completely concealed when not in use and have no impact on the visitor experience. Thus, in conceiving of a buoyant system, this restriction was considered to be paramount along with maintaining the safety of the house at all times.

A buoyant amphibious system seems compelling since it appears to be simple and passive, responding to a flood by rising with the water. Conceptually the system would automatically actuate during a flood, keeping the house above the highest level of the rising waters at all times. In fact, during a presentation by Silman to Landmarks Illinois, one of their board members constructed a simple buoyancy model and demonstrated how elegantly it would work by pouring a pitcher of water into a container filled with empty water bottles, atop which sat a platform holding a model of Farnsworth. Up it went to a hearty round of applause. To be scientific if not flippant, one could say that this demonstrated conclusively that empty water bottles float in water.

RSA envisaged a BAS system by starting out similarly to the HAS described in their report of April 2014. First the house would be temporarily moved to a safe location above the flood plain on the site for the duration of construction. Then an excavation would be made directly under the original location of the house and a concrete pit installed. In this pit buoyancy tanks or blocks (in the following report reference will be made to buoyancy tanks only, with the understanding that this is meant to describe any other buoyancy system as well, including Styrofoam blocks, etc.) would be placed, connected with some sort of steel lattice work and bracing. Preliminary calculations show that the volume of buoyancy required to lift the structure and the earth tray would require the buoyancy tanks to be between seven and eight feet deep if they were exactly the same dimension as the footprint of the house and they were fitted tightly together with no spaces between them. A guidance system that disappeared into the ground when not in use would be designed, perhaps using telescoping steel tubes or some other retractable or collapsible set of tracks into which trusses might slide up to restrain and brace the house when deployed. A cover of either metal deck or concrete slab would fit snugly over the pit in the inactive period and this would contain the finished earth similar to the system described in the HAS report. The cover would rest on the steel latticework below that was interconnected to the buoyancy tanks or if sufficiently strong in itself, span across the pit unaided. When the house was moved back onto this cover, the original columns would look exactly as they always have, disappearing into the earth; they would be anchored to the structure below that covered the pit, again similar to the HAS solution. Thus, when inactive, the house would look no different than it does today.

Silman investigated a number of criteria for each system to see if they performed as required:

1. Able to lift structure above highest flood waters
2. Able to resist rising in minor floods
3. Able to lift structure on command for maintenance
4. Able to test system prior to a flood occurring
5. Known precision for return of structure to exact required position
6. Able to control accelerations
7. Proven performance of system using substantially similar components
8. Profile exposed to wind and water currents and difficulty in resisting these
9. Able to remove debris and mud from beneath building prior to lowering
10. Depth of excavation
11. Failure modes
12. Effect and impact on visitor experience
13. Relative costs

For each of these criteria, the BAS was compared to the HAS.

Finally, Silman conducted a search to discover similar applications of buoyant foundation systems. These are described in Appendix A.

1.0 ABLE TO LIFT STRUCTURE ABOVE THE HIGHEST FLOOD WATERS

The BAS clearly would be able to lift the house by eight or nine feet so that it would be safe above the 500 year return period design flood. As long as sufficient buoyancy was provided, the house would rise up and float such that the underside of the first floor was clear of the design flood elevation by several feet (to allow for free board and small debris to float underneath it). The best analogy for this is to compare it to a system of floating docks in a lake where empty 55-gallon drums or Styrofoam blocks are fixed to the bottom of the dock. The HAS also possesses this ability to lift the structure.

2.0 ABLE TO RESIST RISING IN MINOR FLOODS

Inasmuch as the BAS has a permanently installed buoyancy system, as soon as the water level reaches the top of the tanks the house will begin to rise. This is not desirable in a case of very high ground water say just below the surface of the ground or even in a ‘minor’ flood. A significant issue to consider is how to prevent the house from lifting in a minor flood. The BAS will require special design considerations to prevent the house from lifting during minor flood events and even in conditions of high ground water. In the event of a failure of these systems (e.g., failure of the perimeter seal of the pit cover or of the sump pump in the pit or of the flood water intake system) the house might rise unexpectedly making guest visitation out of the question. The HAS will only raise on command regardless of the water level.

SSK-01, SSK-02, SSK-03, and SSK-04 present four cases in which the BAS might be evaluated.

Case 1 is the at-rest situation where the ground water table is at its stable condition approximately six or seven feet below grade as determined by the geotechnical report by GEI Consultants, Inc. dated 2/18/2014. In this situation neither the BAS nor the HAS would be activated. It is assumed that the concrete pit would be watertight, with a sump to pump out any minimal water that might intrude.

Case 2 shows a situation where the ground water table rises to within one foot of the ground surface. At this point one must postulate how the BAS becomes activated. How is water introduced into the pit? If one assumes that the seal between the top of the pit wall and the underside of the tray that holds the soil is not fully waterproof and is , in fact, designed to let flood waters enter, then that is the elevation at which water would begin to enter the pit. In that scenario, the house would begin to rise because the full buoyancy would be engaged, with the water rising above the top of the tanks. In this scenario, the details that allow flood water ingress but generally keep out downward percolating ground water seepage are very difficult to achieve. It would be preferable to design some other method to allow water to be introduced into the pit.

It is conceivable to think of another way that the BAS might be activated. If the seal between the top of the wall and underside of the tray could be counted on to be watertight (note that this is a single point failure location), then some sort of above-grade inlet valve or inlet scoop could be located some distance from the house so it was not visible, with a pipe that would allow water to flow into the pit when it reached the elevation of the scoop invert. Then the house would not begin to rise until the water reached that invert elevation. This scenario has complications and maintenance requirements to insure that both the inlet scoop and pipe remain unobstructed both before and during a flood event (these are single point failure zones). It is very likely that a flood could occur during a spring thaw when there were ice floes in the river. If ice accumulated at the floodwater inlet, it could clog it and render the system inoperable. Other floating debris such as trees and branches and mud are also a potential source of obstruction.

Additionally this raised invert system would introduce water into the pit when the flood elevation was already above the top of the buoyancy tanks. It is easy to visualize that the seal between the pit cover and the pit wall would have to break and at that moment the house might actually “shoot up” as water rushed in all around the tanks and pit cover with a strong possibility of uneven forces causing the house to pitch and yaw until it reached equilibrium.

Case 3 shows the flood water at a ‘minimal’ level, say one foot above grade, that does not threaten the house. The NTHP may choose to establish a policy that they would not want to take any action concerning raising the house for a ‘minimal’ flood. Since the bottom of the first floor stands some four feet clear of the ground, the NTHP might elect to do nothing and simply wait for such a minimal flood to subside. The house would suffer no damage under these conditions. The BAS system can be calibrated to respond to this decision. In the scenario of an above-grade inlet scoop used to provide flood water ingress into the pit, the height of the fixed invert would be the height of water at which the BAS became activated in an unfolding flood event. If the inlet passage could be guaranteed to remain open and unblocked, then this seems like a good resolution to this issue of a minimal flood.

Of course in the HAS, the house would rise only on command, by activating the system. Such activation could be at any water level; it would not be one fixed elevation as in the BAS.

Case 4 illustrates the maximum 500 year design flood. In this situation, everything discussed in this report, both before and after this section, would apply. This is not a minor flood event.

3.0 ABLE TO LIFT STRUCTURE ON COMMAND FOR MAINTENANCE

The BAS in its simplest passive form would have no means to lift the structure on command for periodic maintenance and inspection. In fact it would not be possible to ascertain whether the BAS had even been properly designed until the initial major flood occurred, possibly several years after commissioning. The HAS has this capability built in. Since the BAS relies completely on a flooding situation to lift the building, it would only rise in response to a high water event. So the system could never be properly inspected nor could it ever be ascertained if maintenance was required since the buoyancy elements would be permanently contained within the pit or submerged below water. Maintenance of the pit cover seal and the sump pump would be similarly inhibited. Of course the pit could be enlarged or deepened to allow for service catwalks around the tanks, but this would require viewing in a very confined space and maintenance, were it required, almost impossible to achieve. Also, for reasons of site landscape, it is desirable to limit the pit to the size of the footprint of the house above.

It is possible to think of a modified BAS where there would be an auxiliary active hydraulic system that could allow such a testing and inspection to occur on command. See the section, 5.0 Known Precision of Return of Structure to Required Position, for a discussion of this type of a hybrid system.

4.0 ABLE TO LIFT STRUCTURE PRIOR TO A FLOOD OCCURRING

The BAS in its simplest form would have no means to lift the structure on command prior to a flood occurring to see whether in fact it would work. Indeed the exact balancing of the buoyancy tanks required to compensate for the uneven distribution of the load imposed from the house, the soil and the pit cover could never be accomplished except during a flood event. It would seem obvious that this is not possible to achieve. If the BAS remained dormant for a number of years, it is conceivable that components might become difficult to operate or even become totally inoperable due to corrosion, silting, misalignment, etc.

The HAS can be operated on command and raised to any height for testing purposes. During a flood alert it could even be raised before the flood waters arrive in order to give certainty to its functionality.

5.0 KNOWN PRECISION OF RETURN OF STRUCTURE TO EXACT REQUIRED POSITION

One of most important requirements of any system that is proposed to lift the house, be it a BAS or a HAS, is that when it is at rest and not in use, it be totally invisible to the visitor. Satisfying this criterion requires the house to return to an exact position after deployment. Satisfying this criterion requires the house to return to an exact position after deployment. Silman envisages that a thin stainless steel 'curb' would be fixed to the sides of the pit all around extending up to just below the ground surface in order to contain the soil as the house is lifted. A similar thin stainless steel curb would be fixed to the edge of the tray containing the soil, the two plates mating closely together in the at-rest position. When it is in this at-rest position, a thin cover of soil can be raked over the plate curbs to make them disappear. There is no grass directly under the footprint of the house and this is the proposed location of the thin curbs.

When the house is returned to its at-rest positon after a flood, it is crucial that it fit tightly and precisely into the hole that is formed by the stainless steel curb that is fixed to and projecting up from the concrete pit wall. In the HAS this is readily achievable. Concerning the BAS system Silman was unable to discover amphibious structures that could hold the tolerances required for the Farnsworth application. That precision is simply not required in the buoyancy applications that are in current use. Additionally for the BAS Silman was unable to discover or even conceive of a flood-driven guidance system that would be stiff enough to maintain the house in perfect alignment so that it would return exactly and precisely into the hole from which it emerged. Tight tolerances in the BAS may cause binding and result in a failure to lift or raise properly (see Sect. 11, Failure Modes). Loose tolerances may allow the house to settle off-center and not properly seat within the design envelope. The house would be lowered by the receding water with no control over where it landed, other than the guidance system that would have to allow a certain amount of lateral movement and drift in order for it to function as a dynamic system without binding. To make it infinitely stiff would be to prevent it from working at all.

Silman has had discussions about this (and other) potential problems of the BAS with experts in this field. The only reliable answer to this issue would be to install a supplementary hydraulically actuated lift system that would allow the house to be guided into the necessary alignment to its return position. This could also answer the objections to the inability to maintain and inspect the buoyancy elements as well as everything else in the concrete pit below grade. The capacity of the hydraulic jacks would be the same as for the HAS because they would have to carry the same weight. The pit would likely have to be deeper for the BAS. However, once these hydraulically actuated elements are introduced, then why even consider a BAS at all? Its passive simplicity is now gone. There are no advantages remaining.

The HAS will be designed with close tolerance pivot connections thus enabling the house to return to the original design location with a good degree of precision. With this configuration, the operational motion envelope is repeatable and can be very closely predicted. The type of linkage and bearings proposed are well understood and manufactured to very close tolerances with similar configurations in everyday use. That is, it will always end up in the same place within a small fraction of an inch. This ability is demonstrated every day by large movable structures that use similar components, (e.g. movable road bridges). Tolerances for the BAS will be several orders of magnitude higher than the few thousandths of an inch required by HAS.

6.0 ABLE TO CONTROL ACCELERATIONS

It is vitally important for the protection of the house that there be no sudden or unwanted accelerations during the raising or lowering of the house. In Section 2.0 above under Case 2, a possible case of the house "shooting" up from a stationary position to a buoyant one was described. In addition, it is conceivable that during a situation with rising flood waters that there could be hydraulic surges upon which the BAS would be floating and to which the house would have to respond. Even more so during the receding flood waters there could be situations where debris temporarily impaired the downward movement of the house but once the debris was swept clear, the house would suddenly drop. Any of these situations would be tremendously detrimental to the intact survival of this historic structure.

As described above, the HAS maintains rigid control of the position of the house at all times during the cycle, no matter what the flood waters are doing or where debris is collecting.

7.0 PROVEN PERFORMANCE OF SYSTEM USING SUBSTANTIALLY SIMILAR COMPONENTS

A major consideration of any lifting system is reliability. How do we know it will work? As in any design, the surest proof is to point to similar installations using similar equipment under similar circumstances. If these have performed satisfactorily, then there is every reason to believe that they will do so in the proposed new design. For the HAS, this was fully discussed in the April 2014 report. All of the components were off the shelf items that had been used in like conditions and situations.

Although Silman reviewed several types of buoyant amphibious structures that have been successfully deployed, we were unable to discover any that satisfied the operational criteria necessary to guarantee the safety of the Farnsworth House. In discussion with experts in BAS, no precedents could be found for applications requiring this degree of precision and certainty. Most of the BAS applications were not for buildings as sensitive as the Farnsworth House and therefore the tolerances were much more relaxed. In some of the more primitive applications of the guidance systems, permanent poles or piles were driven into the ground and left projecting above the ground to a height sufficient to restrain the structures in a flood. In more sophisticated applications, either the structures were high enough to contain the poles within the building itself or the poles telescoped into the ground. The utilities were designed to either break away and to be replaced after the event or to have the capability to be flexible enough to go up and down with the structure. The weight of these simple wood frame houses was considerably less than the steel and concrete Farnsworth House and therefore the amount of buoyancy was also much less.

The HAS was designed to be invulnerable to a single point failure as discussed in the earlier report. Silman could not find an example of or conceive of a design using BAS that could achieve this important criterion.

8.0 PROFILE EXPOSED TO WIND AND WATER CURRENTS AND ABILITY TO RESIST THESE

One of the difficulties the BAS encounters is that, like an iceberg, a very substantial portion of the structure remains submerged and must fight against the flood waters. Even a slow current will generate tremendous forces that must be resisted solely by the guide system. If these are telescoping poles or even hydraulic cylinders, these will be subjected to bending as cantilevers. Two difficulties with this approach are that manufacturers of hydraulic cylinders may not guarantee their products for this use and the diameter of the pipes could get quite large in order that they are proportioned to be strong enough and stiff enough. If the pipes are simply one nested inside the next larger diameter with no seal, then there is real concern about debris or corrosion product impairing future upward movement, particularly if years elapse between flood events and no testing takes place during this interval. (See Section 11.0, Failure Modes.) If there is a seal, it will require a very large movement capability.

In addition for the simplified BAS, it is difficult to compensate for uneven load conditions thus permitting the house to pitch. Adjustments can be made by varying the ballast but these adjustments cannot compensate for water currents and wind forces that may cause the house to bob and bounce around when fully raised.

In comparison, the HAS incorporates a robust pantograph type linkage that can easily resist uneven load distribution or water currents. This type of linkage will ensure that the house maintains a level attitude regardless of uneven loading, flood water conditions and wind loads, wherever in the raise/lower cycle it may be. Additionally, this design will maintain the house rigid and stationary once it has reached the fully raised position.

The HAS does not have to fight the flood currents. It simply raises the house above them with a mostly open structure below the surface. When fully raised, wind and water currents can flow freely under the house and there is no bending in the hydraulic cylinders. In the BAS the actual exposure to wind and current is much greater than in the HAS because the vertical sides of the buoyancy tanks will be solid surfaces against which wind and water will act. Additionally, the HAS will be immune to current and waves that can cause bobbing and bouncing around with a floating structure.

Thus in the BAS, it is likely that a simple telescoping pole system will have to be modified to include stiffening trusses or **X** bracing between the poles. This would take some or most of the bending out of the poles but would seriously complicate the guidance system.

9.0 ABLE TO REMOVE DEBRIS AND MUD FROM PIT BENEATH BUILDING PRIOR TO LOWERING

It seems certain that debris and mud will be carried along by the flood waters. Some of it is bound to settle to the bottom of the pit, necessitating a method for cleaning prior to lowering the building. In addition, the interface between the top of the pit walls and the underside of the tray of earth holding the soil must be cleaned to insure that the waterproof seal will be as effective as possible once the house is lowered.

In the HAS this is no problem, as the command to lower the house will not be issued until all of this cleaning has been completed. In its simplest passive form, these tasks cannot be accomplished in the BAS system because the house will simply lower itself back down as the water recedes until it finally comes to rest on the top of the pit walls. Presumably any water remaining in the pit could be pumped out, similar to what would be necessary in the HAS. But debris and mud removal as well as cleaning of the seal at the top of the pit wall is not possible. This is one more reason why a supplementary active hydraulic cylinder support system (as proposed in Sections 3.0 and 4.0 above) would be required – to delay lowering the house until after the flood recedes. (See Section 11.0, Failure Modes.)

10.0 DEPTH OF EXCAVATION

As outlined in the April 2014 report, the house must be raised by at least 7.0 or 7.5 feet above its present height to be above the 500 year flood level. This includes allowances for freeboard and water waves. To achieve that using BAS, the amount of buoyancy would be somewhere in the neighborhood of seven to eight feet high if its area was exactly the same area as the footprint of the house. Ideally the footprint of the buoyancy tanks would want to be somewhat smaller than the house so that there would be room for the surrounding steel latticework as well as perhaps an inspection catwalk. Making the footprint smaller would make the tanks deeper.

If the soil cover is 1.0 foot, the slab cover or steel latticework is 2.0 feet, the tanks 7.5 feet, the steel latticework under the tanks 1.5 feet, and the pit slab 2.0 feet, then the total depth of the pit would be 14.0 feet below existing grade. This places the pit slab directly on top of the rock and creates an uplift head due to normal ground water of 8.0 feet. If the area of the footprint of the buoyancy tanks is restricted to something smaller, it would push the pit bottom lower and it might require removing rock using blasting. The uplift would also increase.

The pit for the HAS system described in Option C of the original report, could be two levels with the deeper part only in the center and going down about 10.0 or 11.0 feet. Because the hydraulic actuators in the HAS can telescope together, thereby reducing their length, the depth of the pit can be limited. In the buoyancy scheme, there is no flexibility regarding the depth of the pit because the size of the tanks is fixed.

11.0 FAILURE MODES

When engineers design systems that interface with high value properties or people (i.e., life safety critical systems) they perform a Failure Mode and Effects Analysis (FMEA). In a FMEA the engineer will postulate **every possible** type of failure and analyze what sort of outcome will precipitate from such a failure. The goal is to provide a Single Point Failure Proof (SPFP) or Fail Safe design. That is a design where any single component can suffer a catastrophic failure without resulting in damage to the property or injury to a person.

There are many life safety critical applications where SPFP design is impossible or impractical. For example a ski lift rope. There is only one rope. In these instances engineers do several other things to insure safety. First, they design it well within understood stress limits. Secondly, they specify test and inspection procedures to discover any fatigue or defects that may be developing and thirdly, they specify a life duration after which the component must be changed out.

At this stage, the designs for both systems are conceptual. That having been said, from prior experience Silman has a high degree of confidence that a SPFP design will be created for the HAS whereby, if the failure of any valve, hose, link, actuator, etc. occurs, the failure mode is benign. That is, motion simply ceases. The failure will not propagate or cascade to additional failure such as breakage of glass or brittle stone floor finishes.

In the passive BAS several failure modes are postulated that could impart damaging stresses into the house. Additionally, it will be difficult or impossible to establish tests to discover latent deficiencies in components during their service life.

One example of a postulated failure for both systems is the following scenario:
A tree of some size floats downstream and lodges under the house. With the HAS the house remains raised after the flood waters recede and a clean-up crew comes in with chain saws and removes the tree. Once the debris is clear the house is safely lowered.

With the passive BAS, as the waters recede, the house lowers down on top of the tree. Imagine that it encounters a large branch of the tree which begins supporting some of the weight of the house. As the waters recede more of the buoyancy structure is held further above the water line increasing stresses in the tree branch. Eventually the buoyancy level is held several feet above the water level. At this point the increased load causes the branch to break, dropping the house several feet and resulting in a damaging impact with the water or concrete pit structure.

Other potential failure modes in BAS would result from silt causing guides to bind and operate imperfectly causing sudden accelerations or from imperfect initial ballast calculations or from an accumulation of mud in the pit as the house is being lowered.

12.0 EFFECT AND IMPACT ON VISITOR EXPERIENCE

There will be no difference between the BAS and HAS on the visitor experience. Both will be fully retracted and invisible in their at-rest position in the pit. That is, provided that the yet to be conceived mechanisms can permit BAS to meet the tight return tolerances. Neither will permit visitation during high river water.

13.0 RELATIVE COST

In theory a simplified passive BAS would be considerably less costly than the HAS. However because of all of the objections listed above, there seemed little point in performing a cost estimate. If the passive BAS is modified to include hydraulically actuated cylinders, then all of the same equipment and controls specified in the HAS would be required. The retractable trusses in the HAS would have their equivalent in the trusses that braced the guidance system. Thus Silman sees little cost difference between the two systems.

CONCLUSION

Silman concludes from an examination of the twelve items that the BAS does not sufficiently meet the required criteria for the project. The following are some of the major shortcomings of the BAS:

- Difficult to control in minor floods
- Control of water inlet into the pit
- Performance of maintenance
- Lifting prior to a flood
- Tolerances and return of structure to original position
- Consequences of pit cover seal failure
- Accurate prediction of performance prior to first flood
- Single point failure locations
- Vulnerability to wind and water currents
- Controlled raising and lowering to prevent accelerations
- Allowance for cleaning pit prior to lowering
- Deeper pit requiring greater resistance to water uplift and possible rock excavation

Only if the passive system is abandoned and an active hydraulic system is paired with the buoyancy scheme will the latter work satisfactorily. Once the additional hydraulic components are added, there seems little sense in having the passive BAS. The HAS overall is more reliable, more secure and more easily controlled than the BAS which relies on nature.

APPENDIX A. RESEARCH FINDINGS ON BUOYANT AND AMPHIBIOUS FOUNDATION SYSTEMS

A search of the Internet has revealed that a number of people are working on designing buoyant and amphibious foundation systems. They often champion their cause with slogans such as, "Why fight floodwater when you can float on it."

In the United States, the preeminent group working on this is the Buoyant Foundation Project founded in 2006 in New Orleans as a response to the devastation of Hurricane Katrina. The founder and guiding spirit of the project is Prof. Elizabeth English, then a research professor at Louisiana State University and now at the University of Waterloo in Ontario. Prof. English has promoted a very simple and elegant passive buoyancy system for the typical "shotgun" houses to be found in the Lower Ninth Ward that was severely ravaged in Katrina.

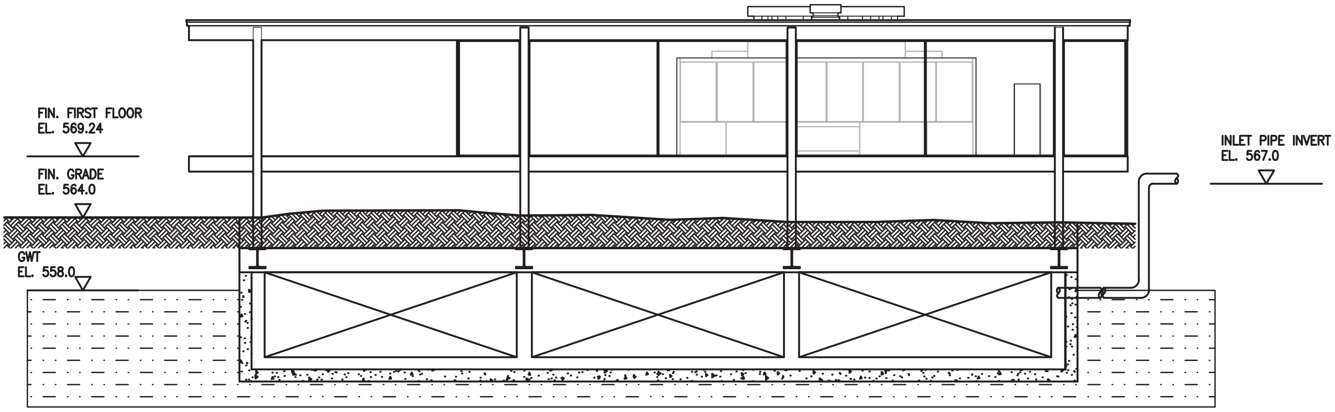
The Buoyant Foundation Project has tested a full scale prototype of a buoyant foundation using coated Styrofoam blocks connected to a light steel frame. Testing was conducted by building a small swimming pool enclosure around the foundation and flooding it with water. The house is connected to four telescoping steel poles sunk into the ground that act as a guidance system when the house rises in a flood. They maintain the alignment of the house so that when a flood occurs, the house will return to its original position when the waters recede. Details can be found at: http://www.buoyantfoundation.org/pdfs/ECEnglish_ParisUFMpaper_nov2009.pdf

Prof. English has asked her students to look at the flooding issues at Farnsworth and they have produced a short video titled 'Phibious Farnsworth or 'Fibious Farnsworth: http://architizer.com/projects/fibious-farnsworth/media/765798/

A fully completed buoyant foundation-supported house (the FLOAT house designed by Morphosis) was constructed by Brad Pitt's Make It Right foundation in New Orleans using concrete coated Styrofoam blocks and two internal vertical guides. Utilities are designed to be either flexible, able to rise and fall with the movement of the house, or breakaway, to be replaced after the flood event. The FLOAT house has never been put to the test since there has been no flooding in New Orleans since it was constructed. Details can be found at: http://www.dezeen.com/2009/10/20/float-house-by-morphosis-for-make-it-right/

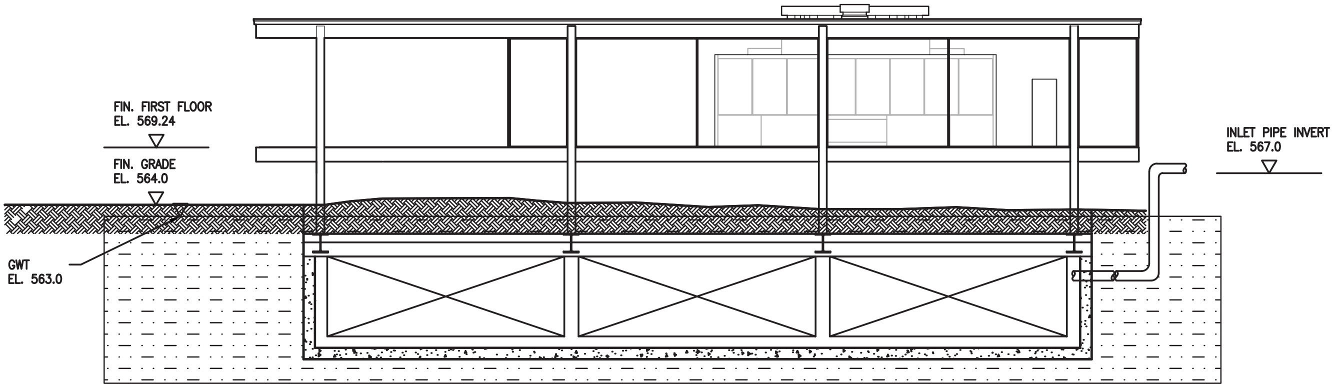
In the Netherlands city of Maasbommel in 2005, a group of 32 buoyant amphibious houses were built along the flood-prone River Maas. They employed prefabricated concrete hulls that were then dropped into site cast concrete pile-supported docks. The houses were connected in pairs, with each pair sharing two mooring pylons. Each house was constructed on top of a concrete hull. In this situation the concrete hull weighed 70 tons, the dead load of the superstructure 27 tons and the live load only 4 tons. Thus the center of gravity was kept desirably very low in the system. In January 2011 the river flooded and the houses reportedly all functioned exactly as designed. Details can be found at: http://ftp.cs.ru.nl/toinesmits/course%20material%20IWM%202011/project%20review%20Maasbommel%202011.pdf When compared to conditions at the Farnsworth House, these amphibious houses had much simpler foundation conditions with potentially much more forgiving tolerances. In addition, the guides were permanent concrete piers above grade located within the houses and not visible. At Farnsworth, the house is elevated and the foundation and guidance conditions are much more complex.

Silman could not find any references for the use of a buoyant amphibious system for significant historic structures such as the Farnsworth House or for a building that weighed nearly as much as Farnsworth or for a situation where the buoyancy system was required to be completely below grade and out of sight. Also, considering that Farnsworth is a retrofit, there was nothing comparable to be found on the internet. Most futuristic solutions to the problems of flooding and rising sea level due to climate change do not utilize amphibious systems but rather floating systems which are possible since these locations are immediately adjacent to water.



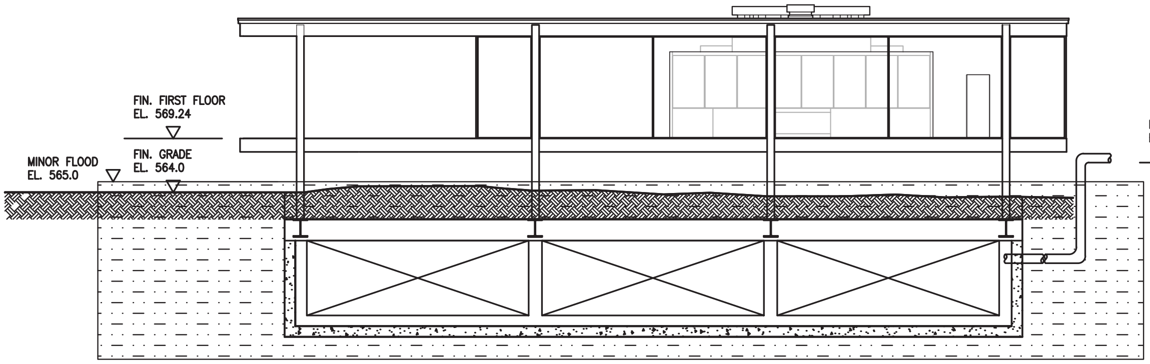
CASE 1 – AT REST, NO FLOOD, GWT AT EL. 558.0, –6'–0'

SSK-01



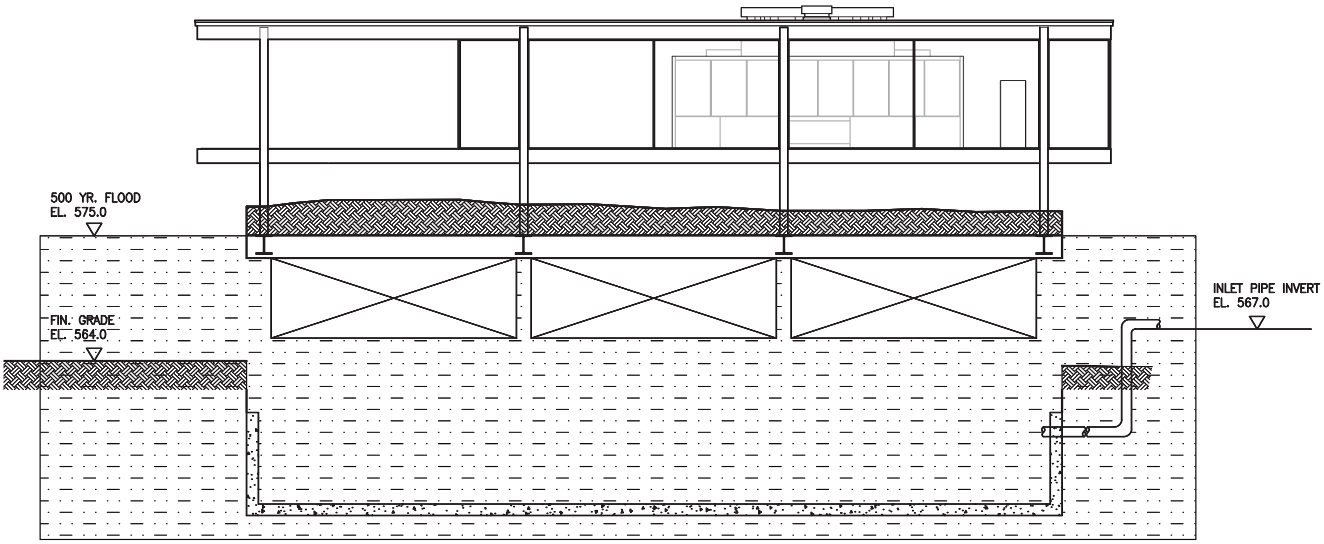
CASE 2 – GWT ELEVATED AT EL. 563.0, –1.0' BELOW GRADE

SSK-02



CASE 3 – FLOOD AT EL. 565.0. +1.0' ABOVE GRADE

SSK-03



CASE 4 – 500 YEAR FLOOD AT EL. 575.0 +11.0' ABOVE GRADE

SSK-04