

THE ECONOMIC ARGUMENT FOR AMPHIBIOUS RETROFIT CONSTRUCTION



Elizabeth C. English
Ph.D., A.M. ASCE

Associate Professor
School of Architecture
University of Waterloo

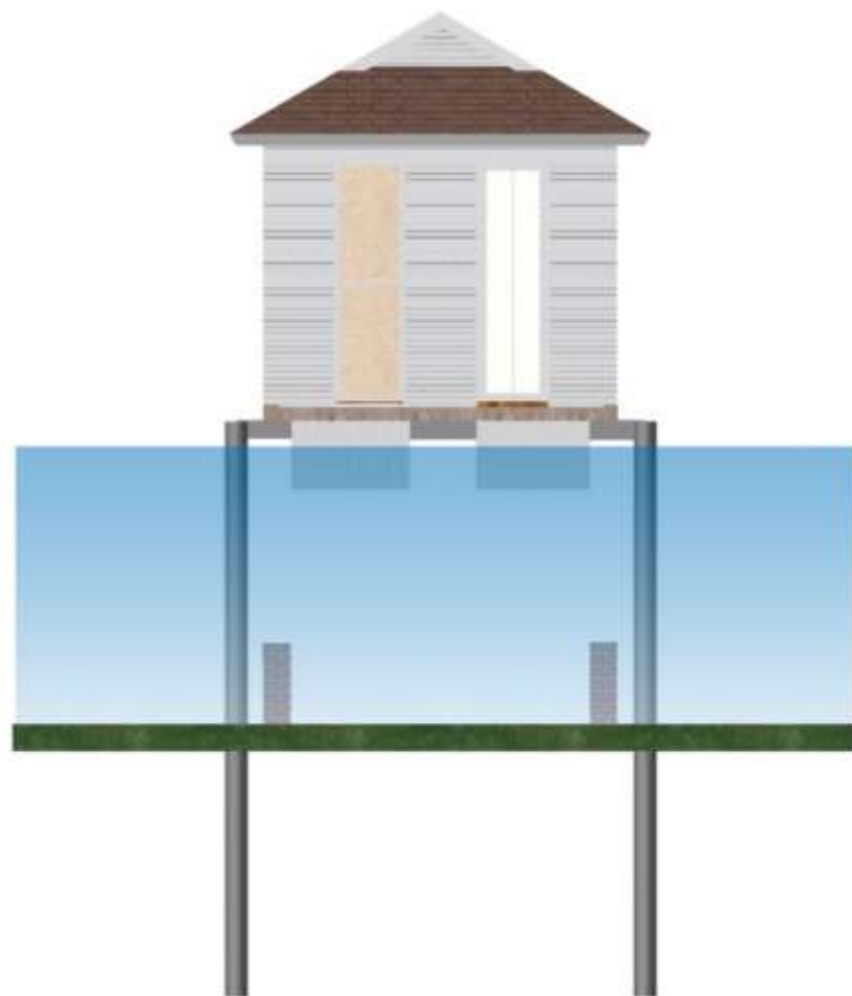


WHAT IS AMPHIBIOUS ARCHITECTURE?

- **Amphibious architecture refers to buildings that sit on dry land like ordinary buildings, except when there is a flood, in which case they are capable of rising and floating on the surface until the floodwater recedes.**
- **A buoyancy system beneath the house displaces water to provide flotation as needed, and a vertical guidance system prevents the rising and falling house from moving anywhere except straight up and down, returning it to exactly its original position upon descent.**

WHAT IS AMPHIBIOUS ARCHITECTURE?

- **This is a proven strategy that has already been applied successfully in the Netherlands since 2005 and in rural Louisiana for about forty years.**
- **Amphibious construction is an adaptive flood risk reduction strategy that works in synchrony with a flood-prone region's natural cycles of flooding, rather than attempting to obstruct them.**





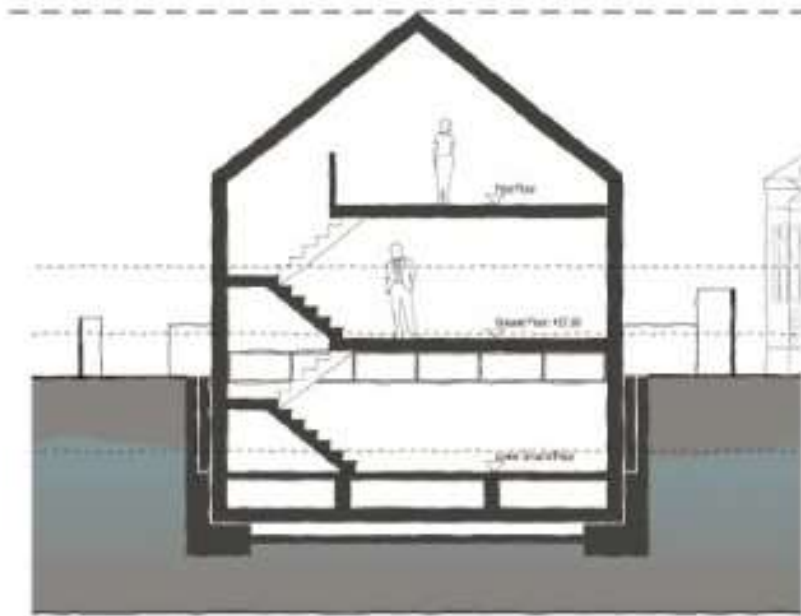
**Maasbommel,
Netherlands**



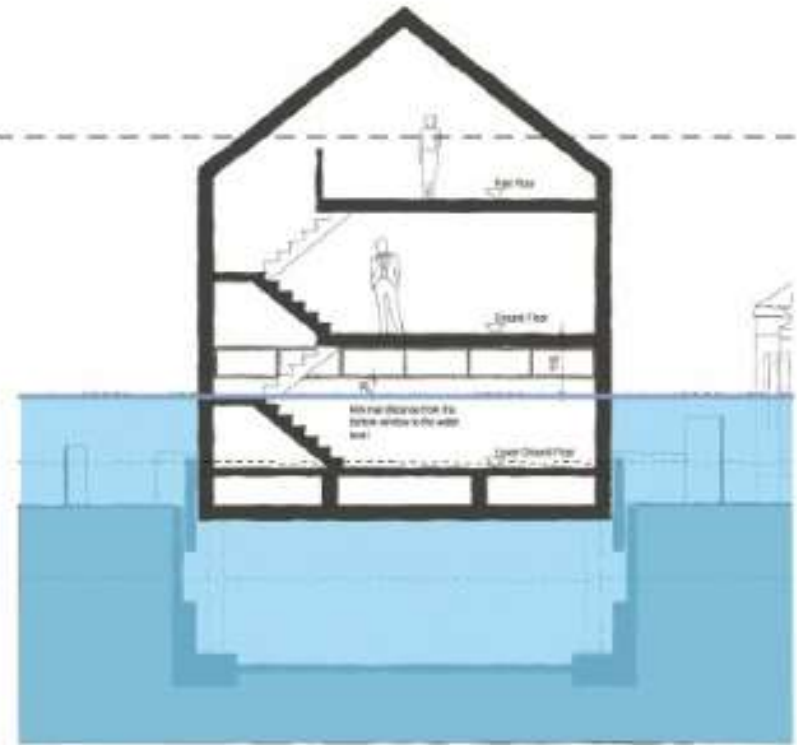
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Netherlands**



Amphibious House, BACA Architects, UK



Before a Flood



During a Flood

Amphibious House, BACA Architects, UK

LOUISIANA

For about 40 years, amphibious houses at Old River Landing in rural Louisiana have been rising and falling reliably with the level of flooding of the Mississippi River.

AMPHIBIOUS FOUNDATIONS ARE NOT NEW!



Dry in September . . . The same house . . . Floating in February

LOUISIANA

**Cost of buoyancy system
is typically \$5,000 or less.**



Dry in September . . . The same house . . . Floating in February



**Old River
Landing,
Pointe
Coupee
Parish, LA**



**Old River Landing,
Pointe Coupee Parish, LA**





**Old River Landing,
Pointe Coupee
Parish, LA**



**Old River Landing,
Pointe Coupee
Parish, LA**





MAY 11 2011









After the spring 2011 flood. Amphibious house on left is undamaged. Note waterline on elevated house on right.





Undamaged amphibious home on left. Elevated house on right is extensively damaged.



Extensive damage to elevated home on left. Undamaged amphibious home on right.



Extensive damage to home on left. Undamaged amphibious home on right.

WHAT IS THE BUOYANT FOUNDATION PROJECT?

A Buoyant Foundation is a particular type of amphibious foundation that is specifically designed to be **retrofitted to an existing house that is already slightly elevated off the ground and supported on short piers.**



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A Buoyant Foundation is a particular type of amphibious foundation that is specifically designed to be **retrofitted** to an existing house that is already slightly elevated off the ground and supported on short piers.

The system consists of three basic elements: **buoyancy blocks** underneath the house that provide flotation, **vertical guidance posts** that prevent the house from going anywhere except straight up and down, and a **structural sub-frame** that ties everything together.

WHAT IS THE BUOYANT FOUNDATION PROJECT?

Caveat: Buoyant Foundations as currently designed are not intended for coastal regions subject to storm-surge inundation that includes wave action, or for high velocity flows.

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They are best suited to large, flat floodplain areas, to regions that are protected by levees where flooding is due to overtopping, to coastal regions well-protected by barrier islands or peninsulas, and to similar flood situations where the water is primarily rising rather than fast-flowing.

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IT'S NOT A ONE-SIZE-FITS-ALL SOLUTION!

BUOYANT FOUNDATIONS

CREATE HOMES THAT FLOAT IN A FLOOD

Advantages

- **Temporarily elevates house to exactly the height required to stay above water**
- **House otherwise remains close to the ground**

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- **House looks essentially the same as before**
- **Preserves traditional architecture**
- **Neighborhood retains original character**

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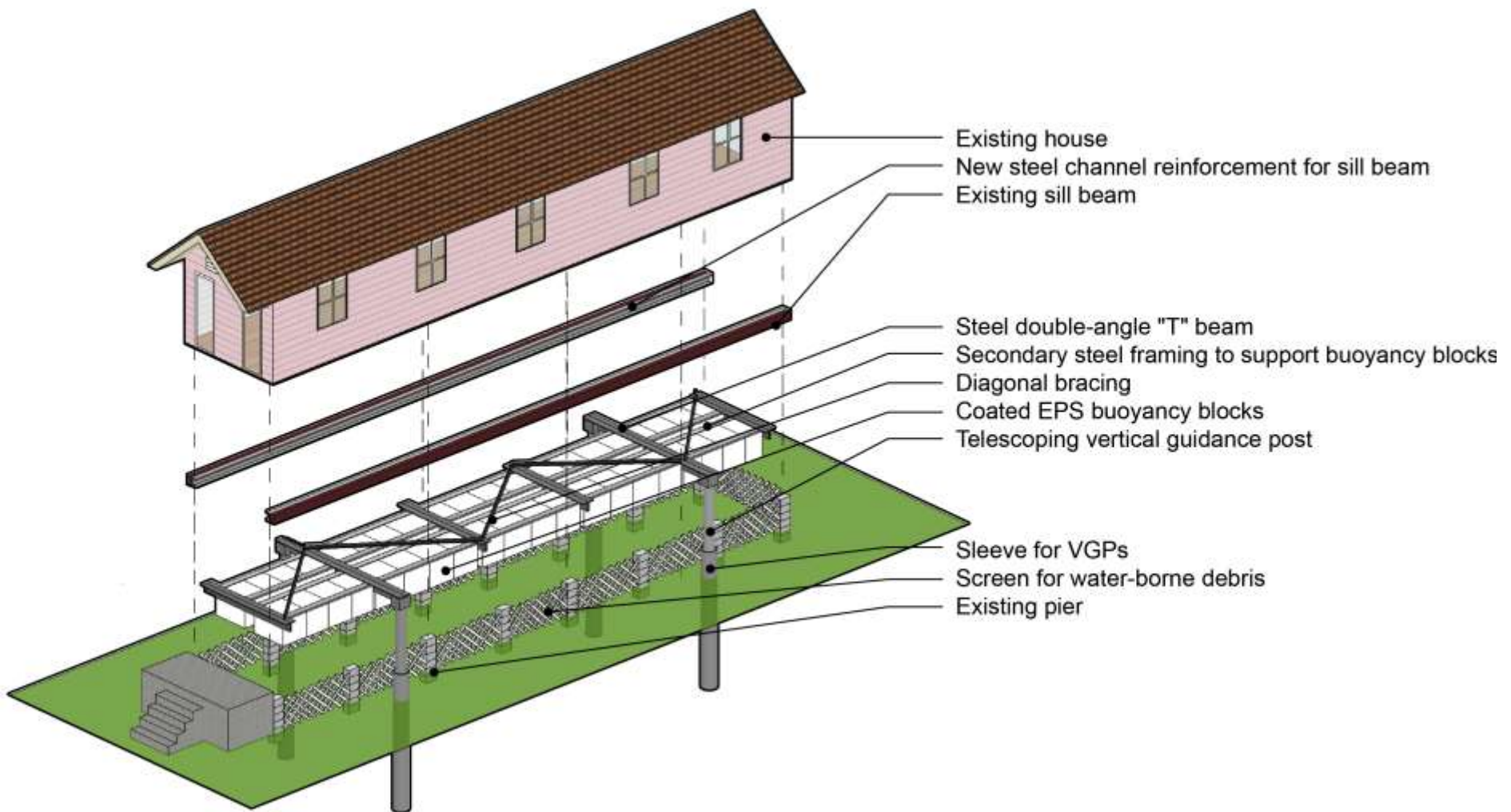
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- **Half the cost** (or less) of permanent static elevation

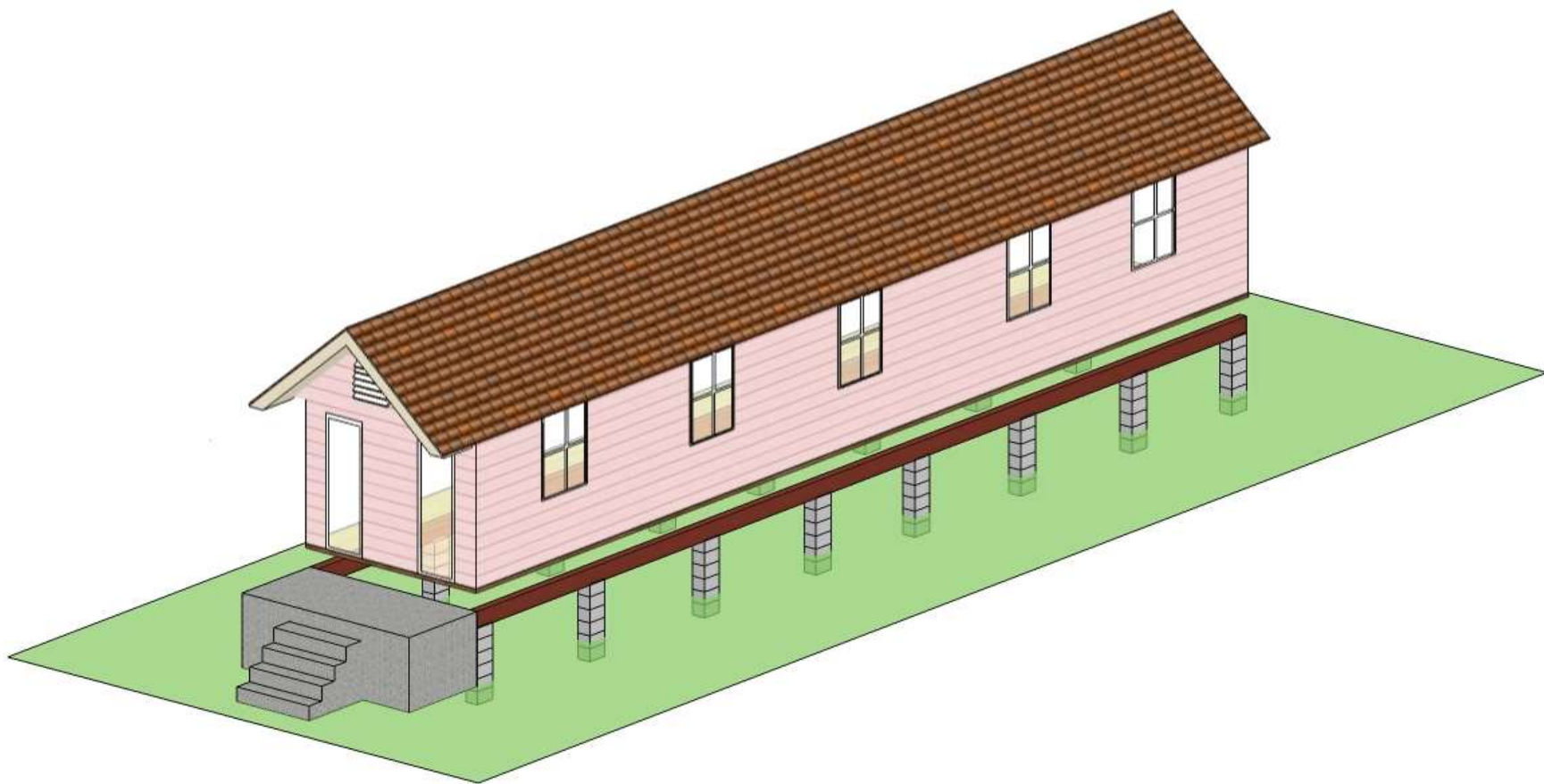
TESTING THE PROTOTYPE AT LSU

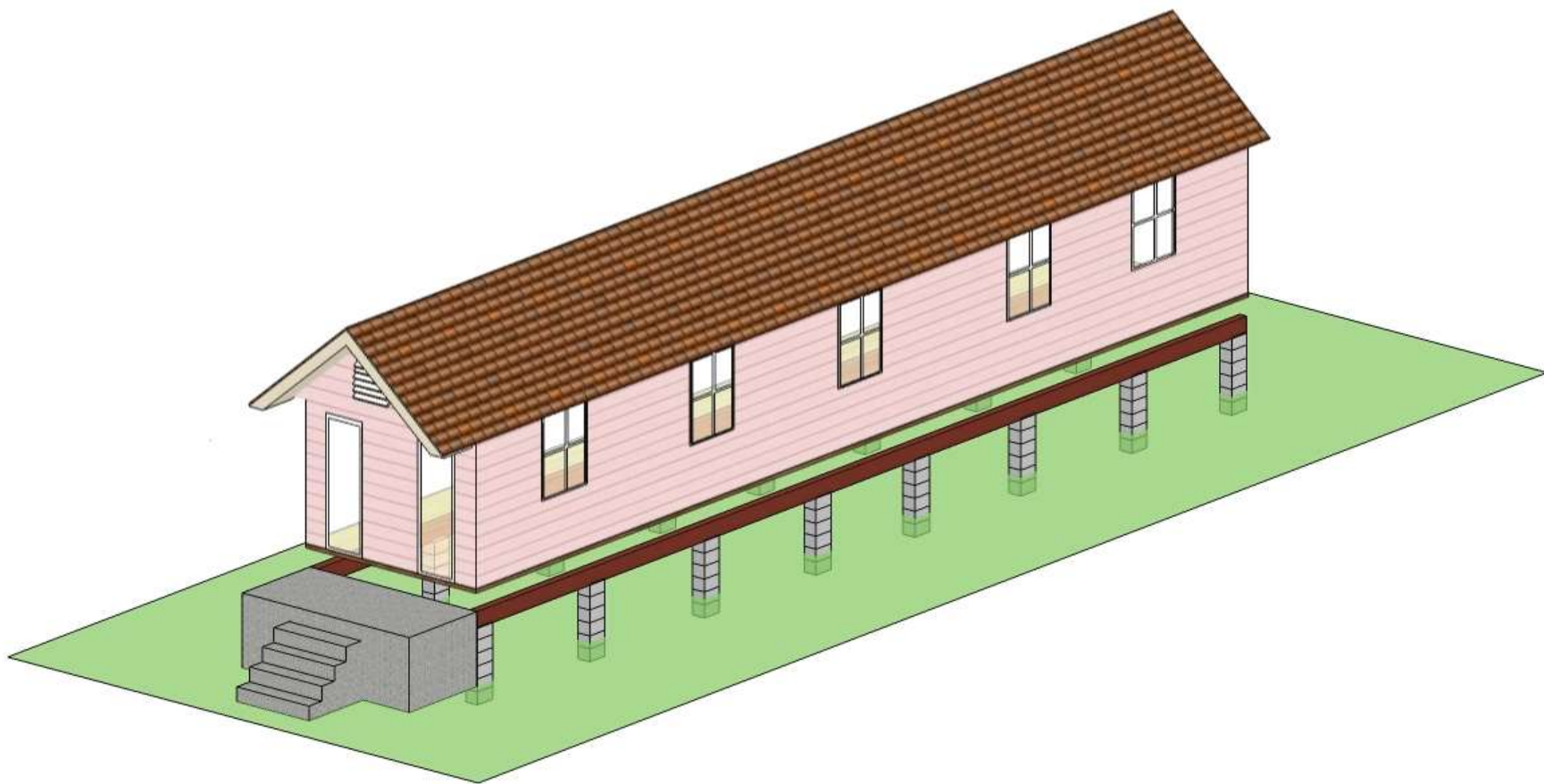












SO WHY FIGHT FLOODWATER
WHEN YOU CAN FLOAT ON IT?

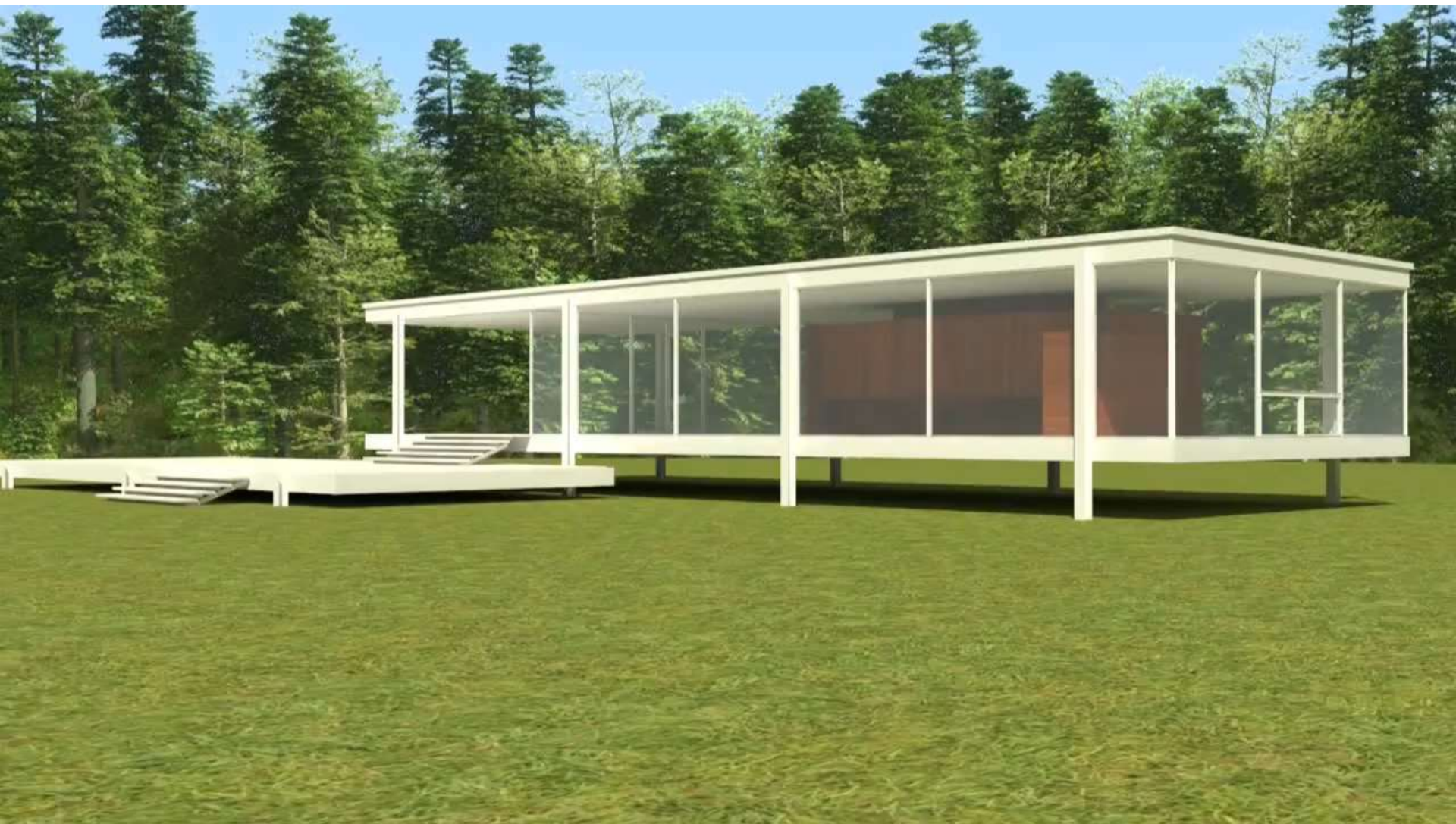


**BFP applied to
a New Orleans
shotgun house**



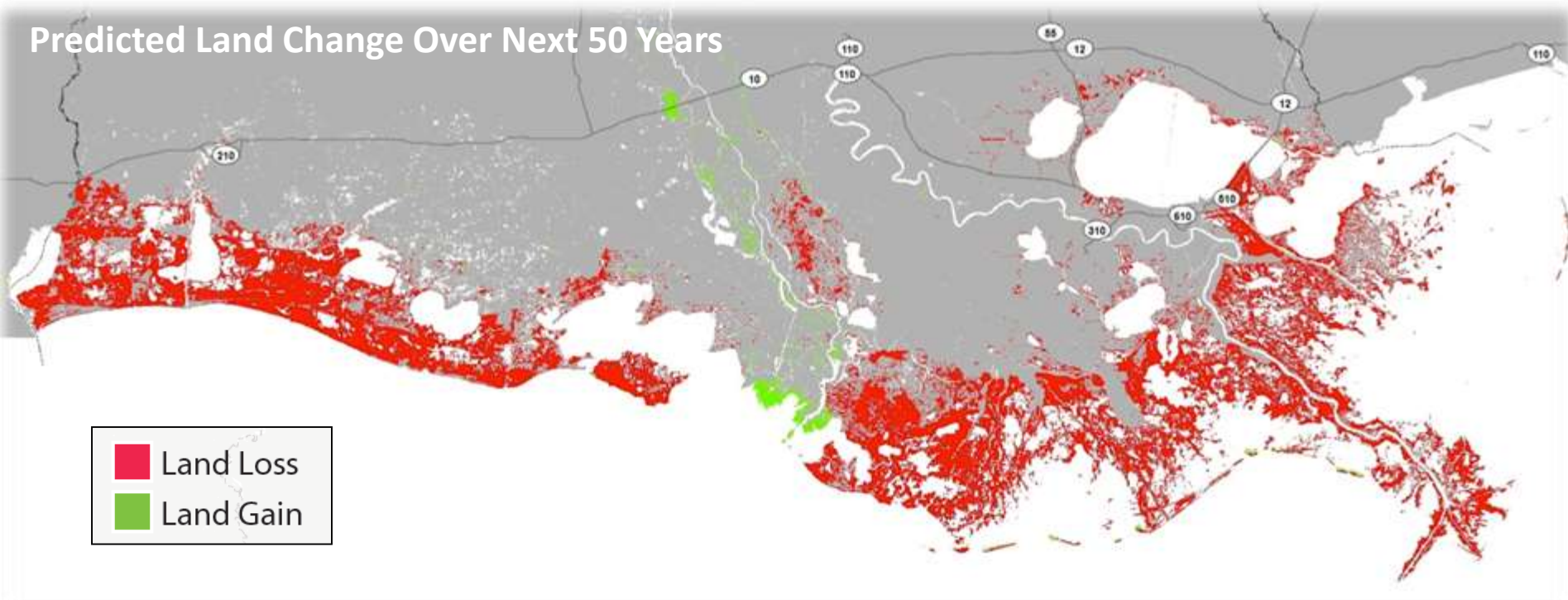






LOUISIANA IS EXPERIENCING A COASTAL CRISIS

Predicted Land Change Over Next 50 Years



Potential to lose an additional 800 – 1,750 square miles of land over the next 50 years

ONGOING LAND LOSS

FLOATING HOPE : PRESERVING AN INDIGENOUS COMMUNITY

5

“ 1883 sq. miles of land have been lost in the last 80 years. 1756 sq. miles of additional land are at risk of being lost in the next 50 years. ”

COASTAL PROTECTION AND RESTORATION AUTHORITY

The ongoing catastrophe of land loss.



LOUISIANA 1932

ISLE DE JEAN CHARLES

LOUISIANA 2014
EXTENSIVE LAND LOSS ALONG COAST

ISLE DE JEAN CHARLES

ISLE DE JEAN CHARLES

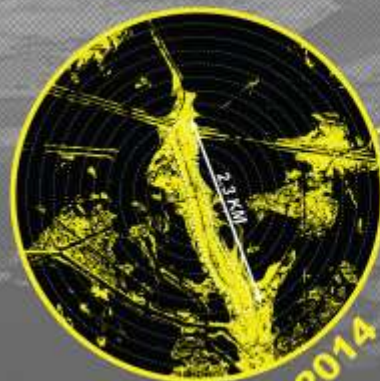
LAND LOSS OVER TIME



1963



1993



2014



1978



2008

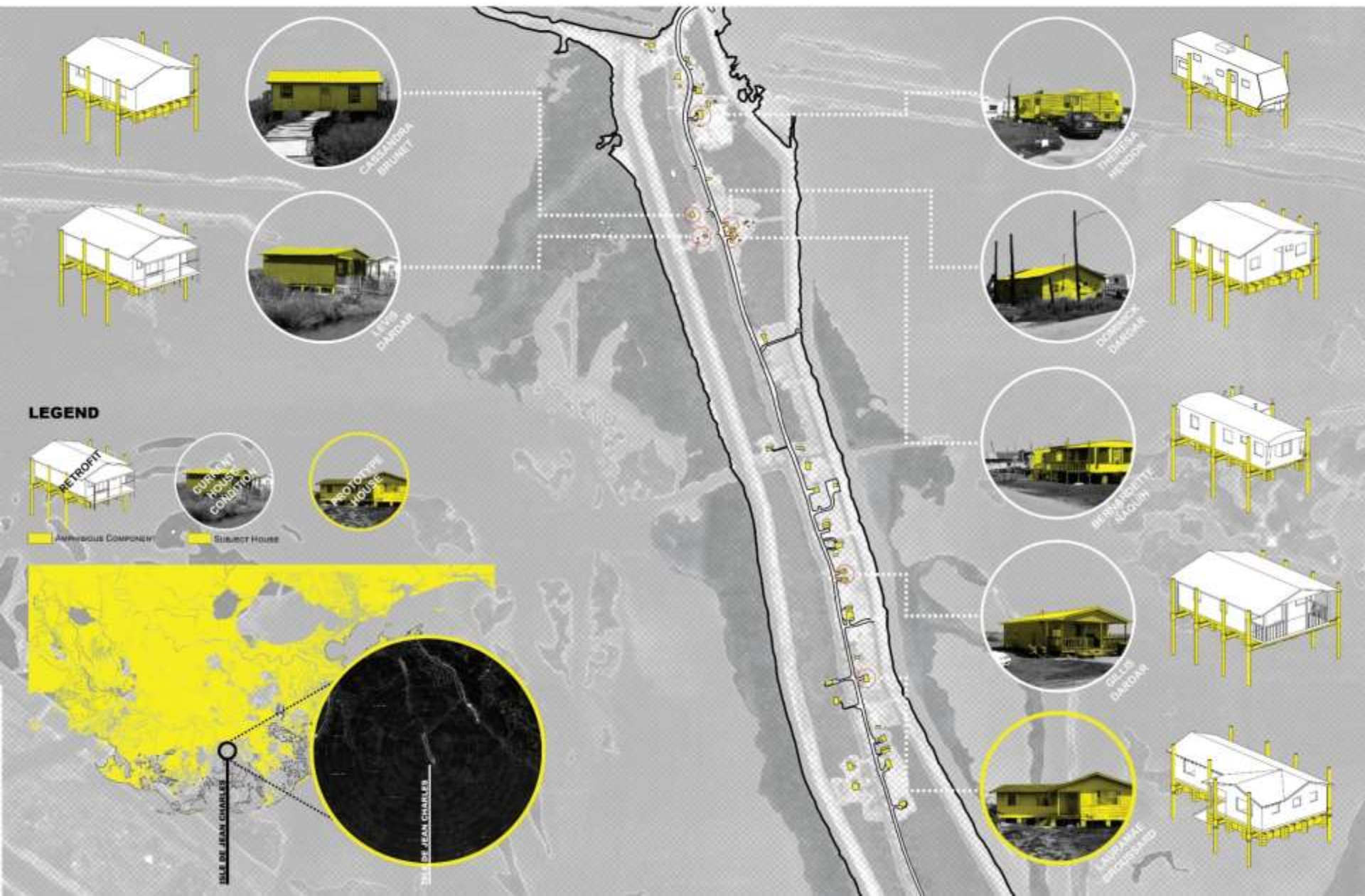


“The people who live on the island want to stay on the island.
My plan is to get the community back together. We want a
community where we can all live and intermarry and
continue on with our community and culture.”

- Chief Albert Naquin

SUBJECT HOUSES

FLOATING HOPE : PRESERVING AN INDIGENOUS COMMUNITY



PUTTING IT TOGETHER

FLOATING HOPE : PRESERVING AN INDIGENOUS COMMUNITY

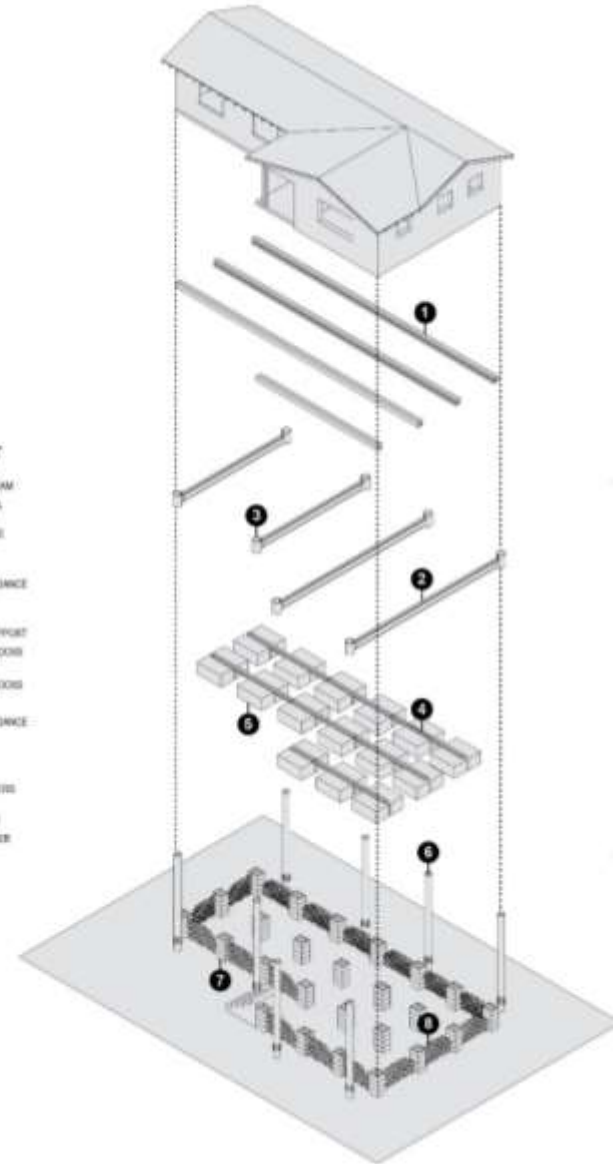
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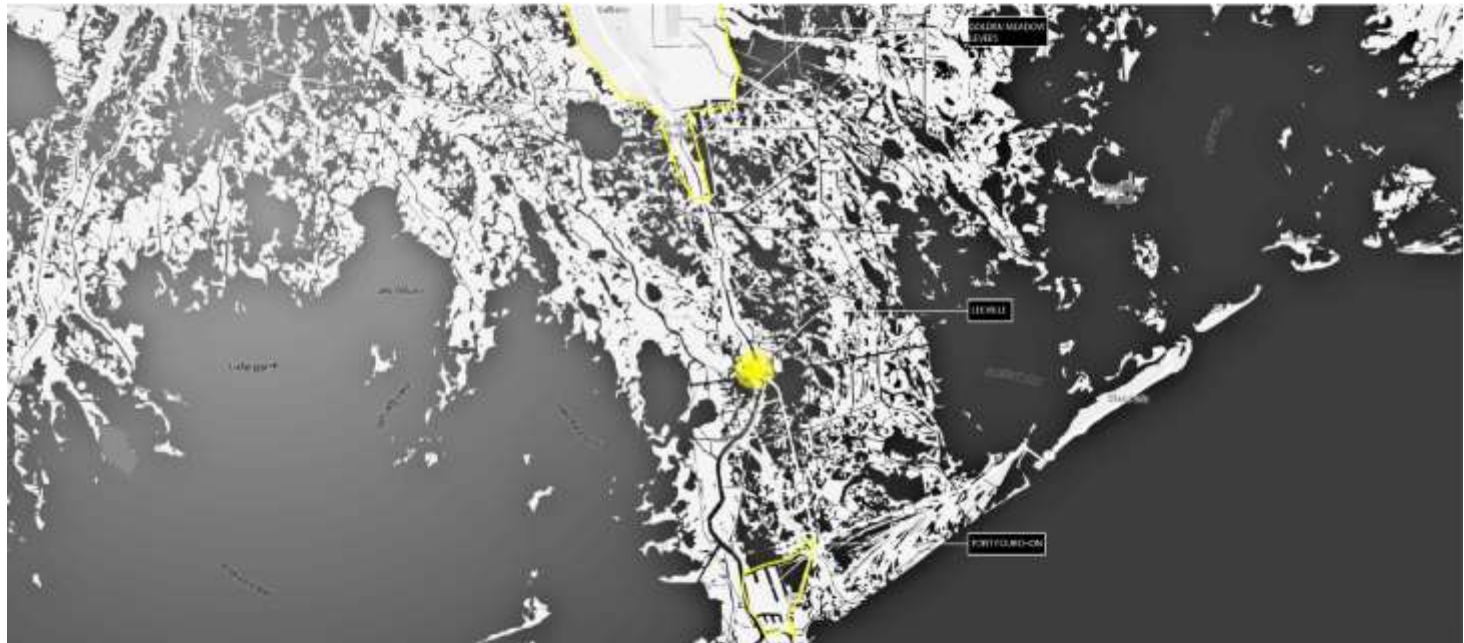


LAURAMAE BROUSSARD

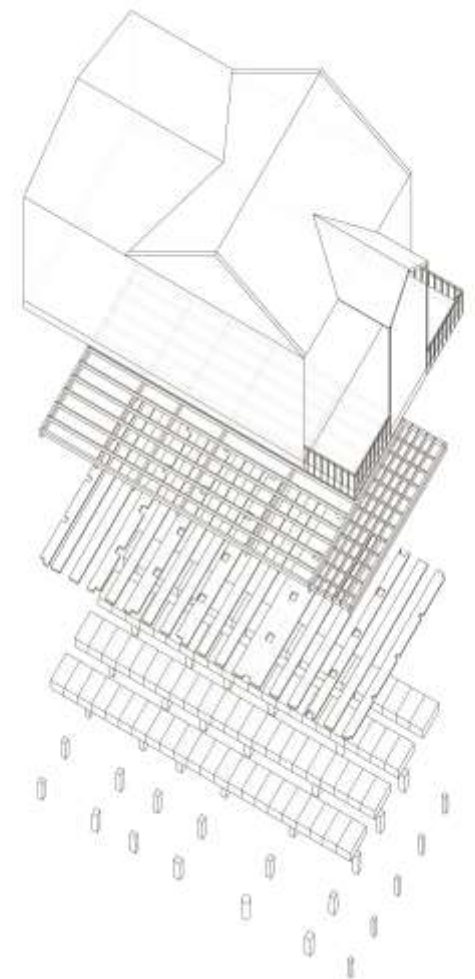
PARTS LIST

- 1 WOOD BELL BEAM
w/ C-CHANNEL
- 2 DOUBLE ANGLE
1" BEAM
- 3 VERTICAL GUIDANCE
SLEEVE
- 4 FRAME TO SUPPORT
RAILWAY SLODS
- 5 RAILWAY SLODS
- 6 VERTICAL GUIDANCE
POST
- 7 EXISTING
MASONRY PIER
- 8 WATER BOMB
CORK SAWTEE









THREE CATEGORIES OF LOSSES AVOIDED

The LAS (Loss Avoidance Study) looks at three categories of losses that can be avoided if the house were to be retrofitted with a buoyant foundation:

- Building Repair Costs

The Building Repair Costs are determined using a **Building Replacement Value**, which is the monetary value to replace the house. This includes the replacement value for any structural, electrical, mechanical, drywall, flooring and roofing damages. The Building Replacement Value for this case study house is **\$70,000**.

- Contents Damage Costs

The Contents Damage Costs are determined using the **Contents Value**, which is the value of all the contents in the house such as furniture, appliances, electronic equipment, clothing, tools and machinery. The Contents Value is estimated to be 30% of the Building Replacement Value. The Contents Value for this case study house is **\$21,000**.

- Displacement Costs

The Displacement Costs are determined by the **number of days a household is relocated** due to the flooding of their home and the cost of living while being displaced from their home. From 2010 Census data, the cost of living per average household of 2.5 people is **\$220.30/day**. This value will be used as the Displacement cost per day.

MITIGATION COSTS

The costs of installing a buoyant foundation for this house might be as follows:

Vertical Guidance Posts = \$8,600

Dock floats = \$14/sq.ft

Marine Plywood = \$5.5/sq.ft

Hurricane ties and fasteners = \$0.5/sq.ft

(costs include installation labor)

So, the cost of retrofitting this house with a Buoyant Foundation might be

\$30,280

LOSSES AVOIDED RATIO

The Losses Avoided Ratio is the ratio of the calculated Losses Avoided to the calculated Mitigation Cost.

Losses Avoided = Costs of building repair + contents damage + displacement

Losses Avoided Ratio = Losses Avoided / Mitigation Cost

The losses avoided ratio for a pre-mitigation flood depth of **0.5m**
= \$38,930 / \$30,280
= **1.28**

The losses avoided ratio for a pre-mitigation flood depth of **1m**
= \$62,430 / \$30,280
= **2.06**

The losses avoided ratio for a pre-mitigation flood depth of **1.5m**
= \$78,021 / \$30,280
= **2.58**

A ratio greater than one indicates that applying the mitigation strategy to the house in question is expected to be beneficial or that it has performed successfully.





Flooding on the Peguis Reservation, 2011



Assiniboine River Flooding, 2011







IMPORTANT TERMS AND VALUES

High Water Mark

A High Water Mark is the recorded elevation that flooding has reached in the past. It is measured relative to ground level. For the purpose of this Loss Avoidance Study, projected high water marks of 1.0m (3ft), 1.5m (4.5ft), 2m (6ft) and 2.5m (7.5ft) will be used.

Projected Flood Depth

This is the depth of the water levels above the finished floor of the house, before it has been retrofitted with a buoyant foundation. It can be determined by subtracting the Finished Floor Elevation (approximately 1m) from the projected High Water Marks.

This study will look at projected flood depths of 0m, 0.5m, 1m and 1.5m.

Pre Mitigation Losses

These are calculations to determine the monetary value of damage that occurs pre mitigation under the three categories of losses avoided. These calculations are aided by formulas developed by FEMA, data collected on Pinaymootang and assumptions from previous case studies.

LOSS AVOIDANCE STUDY -- \$70,000 HOUSE

The LAS looks at three categories of losses that can be avoided if the houses were to be fitted with a buoyant foundation:

- Building Repair Costs

The Building Repair Costs are determined using a Building Replacement Value, which is the monetary value to replace the house. This includes the replacement value for any structural, electrical, mechanical, drywall, flooring and roofing damages. The Building Replacement Value for this case study house is **\$70,000**. *This value is conservative as it does not account for an insulated envelope.

- Contents Damage Costs

The Contents Damage Costs are determined using the Contents Value, which is the value of all the contents in the house such as furniture, appliances, electronic equipment, clothing, tools and machinery. The Contents Value is estimated to be 30% of the Building Replacement Value. The Contents Value for this case study house is **\$21,000**.

- Displacement Costs

The Displacement Costs are determined by the number of days a household is relocated due to the flooding of their home and the cost of living while being displaced from their home. From 2011 Census data, the cost of living per average household of 3.9 people is **\$343.70/day**. This value will be used as the Displacement cost per day.

LOSS AVOIDANCE STUDY -- \$120,000 HOUSE

The LAS looks at three categories of losses that can be avoided if the houses were to be fitted with a buoyant foundation:

- Building Repair Costs

The Building Repair Costs are determined using a Building Replacement Value, which is the monetary value to replace the house. This includes the replacement value for any structural, electrical, mechanical, drywall, flooring and roofing damages. The Building Replacement Value for this case study house is **\$120,000**.

- Contents Damage Costs

The Contents Damage Costs are determined using the Contents Value, which is the value of all the contents in the house such as furniture, appliances, electronic equipment, clothing, tools and machinery. The Contents Value is estimated to be 30% of the Building Replacement Value. The Contents Value for this case study house is **\$36,000**.

- Displacement Costs

The Displacement Costs are determined by the number of days a household is relocated due to the flooding of their home and the cost of living while being displaced from their home. From 2011 Census data, the cost of living per average household of 3.9 people is **\$343.70/day**. This value will be used as the Displacement cost per day.

LOSS AVOIDANCE STUDY -- \$250,000 HOUSE

The LAS looks at three categories of losses that can be avoided if the houses were to be fitted with a buoyant foundation:

- Building Repair Costs

The Building Repair Costs are determined using a Building Replacement Value, which is the monetary value to replace the house. This includes the replacement value for any structural, electrical, mechanical, drywall, flooring and roofing damages. The Building Replacement Value for this case study house is **\$250,000**.

- Contents Damage Costs

The Contents Damage Costs are determined using the Contents Value, which is the value of all the contents in the house such as furniture, appliances, electronic equipment, clothing, tools and machinery. The Contents Value is estimated to be 30% of the Building Replacement Value. The Contents Value for this case study house is **\$75,000**.

- Displacement Costs

The Displacement Costs are determined by the number of days a household is relocated due to the flooding of their home and the cost of living while being displaced from their home. From 2011 Census data, the cost of living per average household of 3.9 people is **\$343.70/day**. This value will be used as the Displacement cost per day.

MITIGATION COSTS

The costs of installing a buoyant foundation system can range as follows:

\$10 / sq. ft \longrightarrow \$25 / sq. ft \longrightarrow \$40 / sq. ft

- Static vertical guidance posts
- Uncoated EPS (“styrofoam”) blocks
- T1-11 Plywood sub-structure
- Telescoping guidance posts
- Manufactured dock floats
- Steel frame sub-structure

So, the cost of retrofitting this house with a Buoyant Foundation could range from **\$10,000** to **\$40,000**

SUMMARY

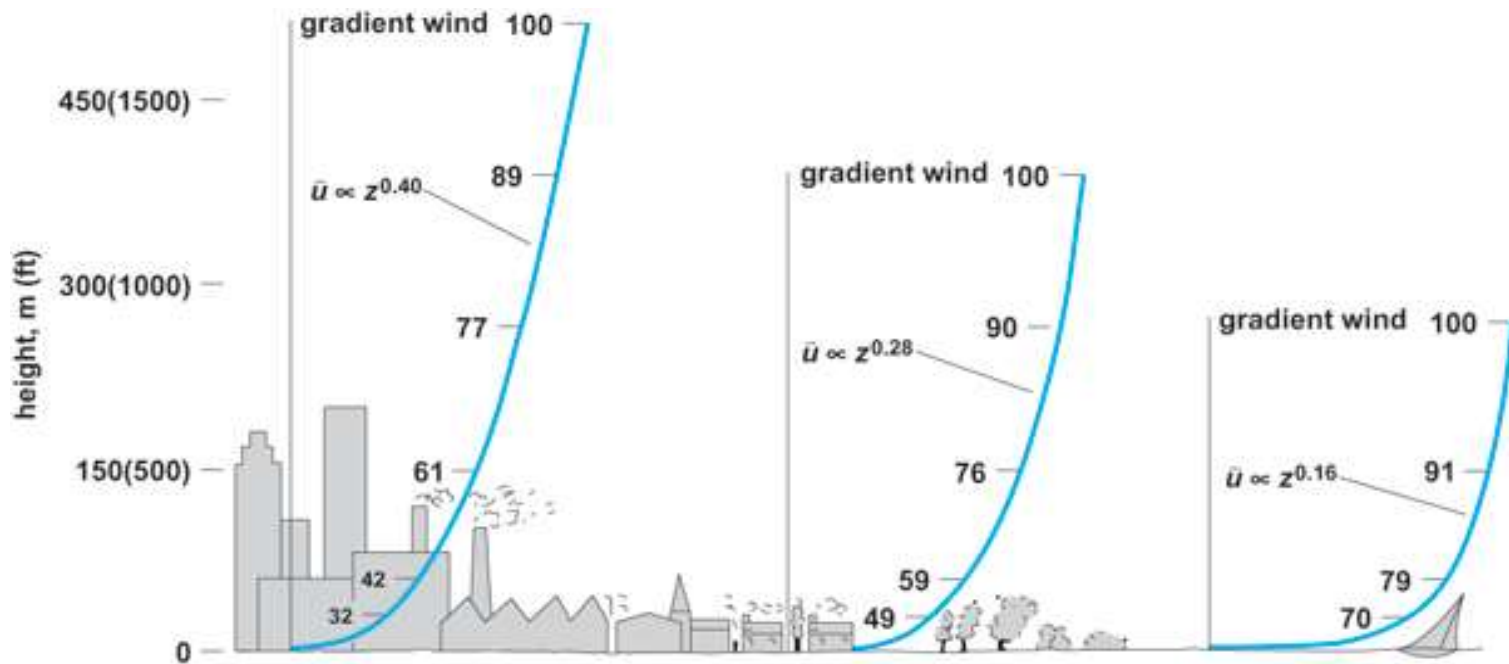
<i>Building Replacement Value</i>	<i>Flood Mitigation Cost</i>	<i>Losses Avoided Ratio for Flood Depth</i>			
		<i>0m</i>	<i>0.5m</i>	<i>1.0m</i>	<i>1.5m</i>
\$70,000	\$10,000 (\$10 / sq.ft)	1.10	3.46	7.91	10.02
	\$25,000 (\$25 / sq.ft)	0.44	1.38	3.16	4.01
	\$40,000 (\$40 / sq.ft)	0.28	0.86	1.98	2.51
\$120,000	\$10,000 (\$10 / sq.ft)	1.90	4.82	10.24	12.76
	\$25,000 (\$25 / sq.ft)	0.76	1.93	4.10	5.11
	\$40,000 (\$40 / sq.ft)	0.47	1.21	2.56	3.19
\$250,000	\$10,000 (\$10 / sq.ft)	3.96	8.37	16.32	19.90
	\$25,000 (\$25 / sq.ft)	1.58	3.35	6.53	7.96
	\$40,000 (\$40 / sq.ft)	0.99	2.09	4.08	4.97

PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY



PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

Homes may be exposed to significantly higher wind speeds when elevated.



Permanent Static Elevation for Houses

Especially after Hurricanes Katrina and Sandy, the US Federal Emergency Management Agency (FEMA) has required many homeowners in flood-prone areas to elevate their houses in order to retain their eligibility for subsidized flood insurance policies from the National Flood Insurance Program (NFIP).

NFIP is critically important in the US housing market because banks require flood insurance as a precondition for providing mortgages to homes in flood zones.



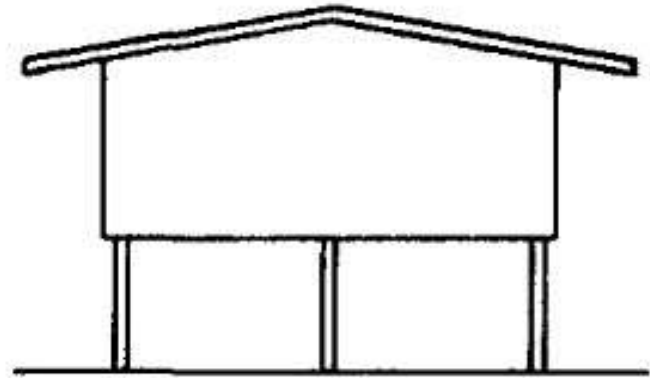
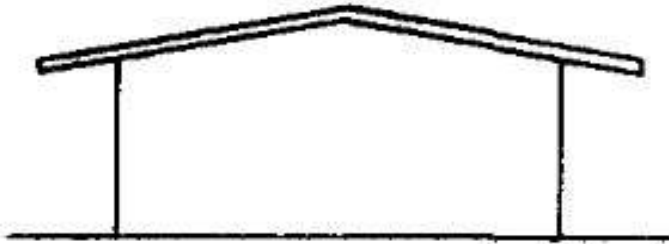
Disadvantages of Permanent Static Elevation

- Difficult access – especially for the elderly & disabled
- Expensive
- Creates gap-toothed effect in a neighborhood
- Homes lose close relationship to the street
- Loss of neighborhood character in an urban setting
- Provides insufficient protection from extreme flooding
- Increases the home's vulnerability to wind damage



PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

John Holmes, "Wind Pressures on Tropical Housing":



“The higher pressure coefficients on the elevated house are combined with a dynamic pressure based on the mean velocity at eaves height which is 20-30% higher. Thus the *pressures* occurring in the same windstorm may be expected to be *40-80% higher on the elevated building*. This may be why buildings of this type experienced considerably more damage during Cyclone ‘Tracy’ in Darwin, Australia (1974).”

[*Journal of Wind Engineering & Industrial Aerodynamics* 53.1-2 (1994): 105-23]

PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

Wind Loss – Economic Loss for Variable Roof Heights

- Based on methodology developed at LSU using Hazus-MH economic loss functions representing building, contents and loss of use.
- Loss functions for single story residential buildings are assumed to have a mean roof height (MRH) of 4 m.
- A new mean roof height loss function (L_{MRH}) is calculated from the Hazus 10-m loss function at the MRH wind speed using the power law.
- The MRH wind speed is calculated from the 10-m wind speed generated in the Monte Carlo simulation and used as input to the L_{MRH} to obtain the corresponding loss.

PERMANENT STATIC ELEVATION AND INCREASED WIND VULNERABILITY

Case Study – preliminary analysis

House with a 4 meter mean roof height elevated to a 10 meter mean roof height:

Case Study	Roof Mean Height	EAL (%)
Current scenario	4 m	2.8%
Elevated scenario	10 m	4.9%

Increase in roof height wind speed: 11%

Increase in wind pressure: 19%

Increase in expected annual loss (EAL): 75%

This effect becomes more pronounced the higher the structure is raised above the ground.







ACKNOWLEDGEMENTS

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International Development Research Centre
Centre de recherches pour le développement international



Social Sciences and Humanities
Research Council of Canada

Conseil de recherches en
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Canada

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University of Waterloo, Waterloo, ON

WWW.ICAADE.ORG




FLOAT WHEN IT FLOODS

www.buoyantfoundation.org




"We have major concerns that this type of development does not meet minimum National Flood Insurance Program (NFIP) criteria (44 CFR Part 60.3) which local governments must adopt in order to participate in the program and make flood insurance available. . . . The local floodplain management regulations must be met in order for the entity to continue to participate in the NFIP. . . . We have concerns about a concept being promoted and publicized that would jeopardize a community's good standing in the NFIP. With that in mind, I would highly recommend that LSU withholds any information to the public until the recommended concept meets all local regulatory requirements."



FEMA OKAYS BFP?

Well, not really . . .

"Depending on the type of structure, different National Flood Insurance Program (NFIP) regulations may apply as to the eligibility for flood insurance coverage for floating structures. . . . There may be circumstances where a structure that is primarily land-based, but was built on platforms to allow for sporadic flotation, could be ruled eligible for flood insurance."



**FEMA
OKAYS
BFP!**

YES!!

“This technique [amphibious construction] would be allowed under the NFIP regulations on pre-FIRM non-substantially damaged/improved structures as the NFIP regulation [cited above] only applies to new construction and . . . substantially improved structures.”