Protection of the Havana seafront from wave action . Alternatives and Laboratory Testing

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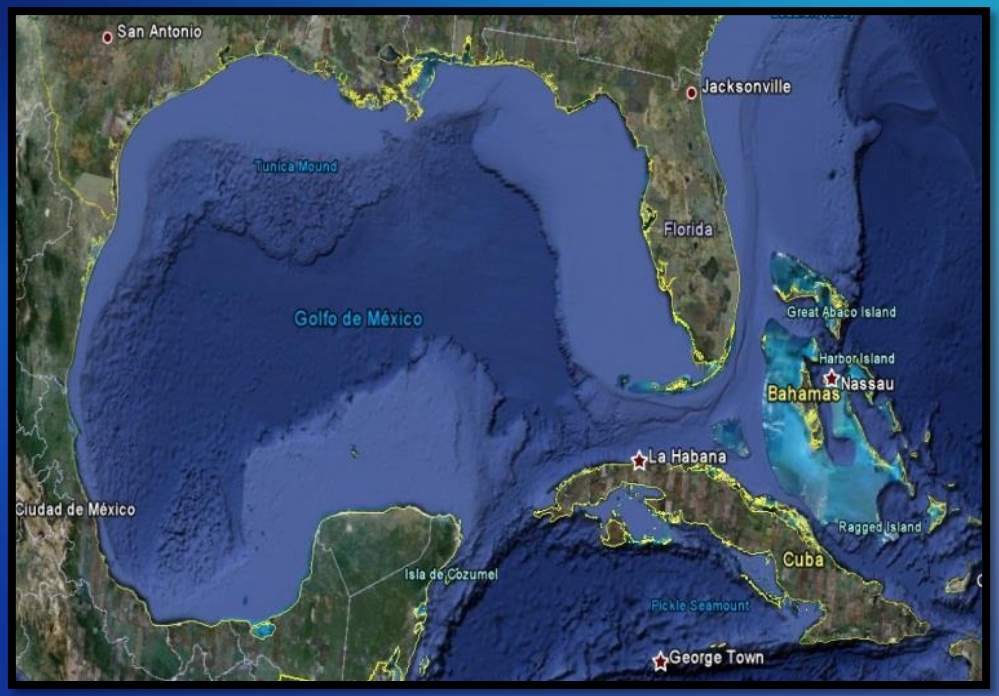
Cuba

- 1,250 km (780 mi) long.
- Land area (104,556 km^2)
- Largest island in the Caribbean.
- People (11,241,161)
- Capital (Havana)
- Coast line length (5,746 km)



Cuba is located in the northern Caribbean Sea at the confluence with the Gulf of Mexico and the Atlantic Ocean. There is an area where almost every year originate and moving hurricanes which together with the presence of cold fronts and extratropical storm make coastal areas highly vulnerable to flooding due to penetrations of the sea.

Havana

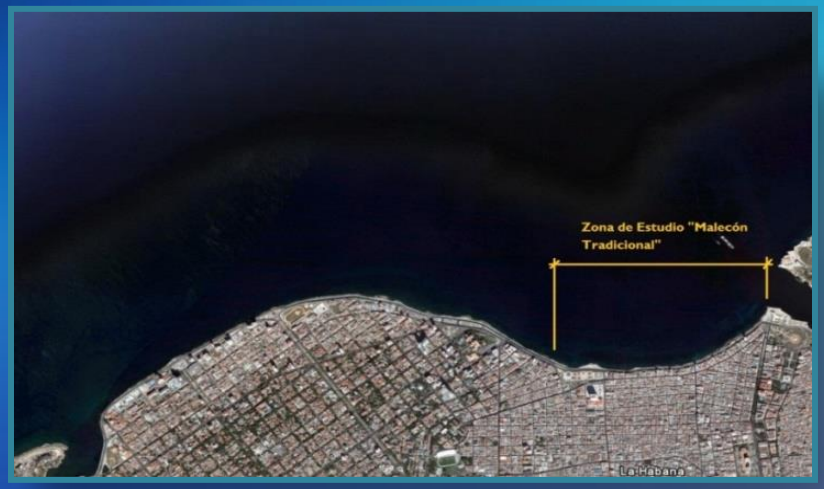
- Land area (728.26 km^2)
- People (2,1 millions)
- Capital city of the country
- Third largest metropolitan area in the Caribbean region.

Havana is constantly evolving because it is the capital of the country, besides it represents a great interest for tourism. One of the areas in which more work is being done is on the Malecon in Havana and in the bay.

“Malecón de la Habana”

It has three main functions.

- Social enjoyment
- Roadway
- Wall for coastal defense

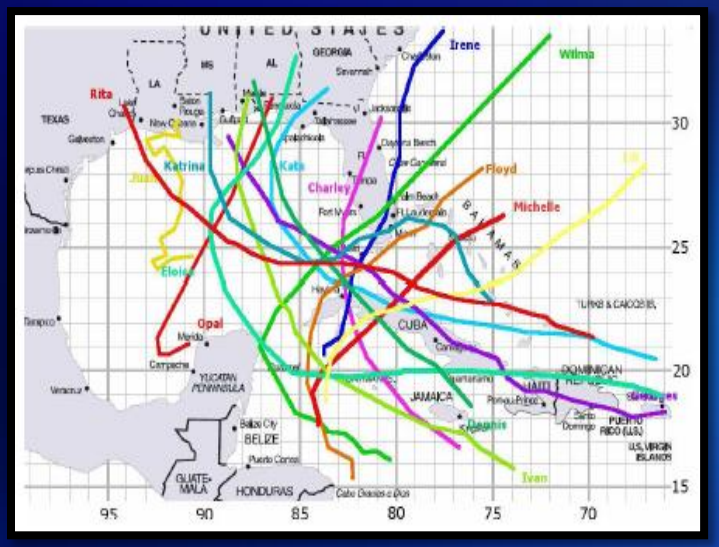


Malecón Traditional

- Social enjoyment

- Roadway

- Wall for coastal defense



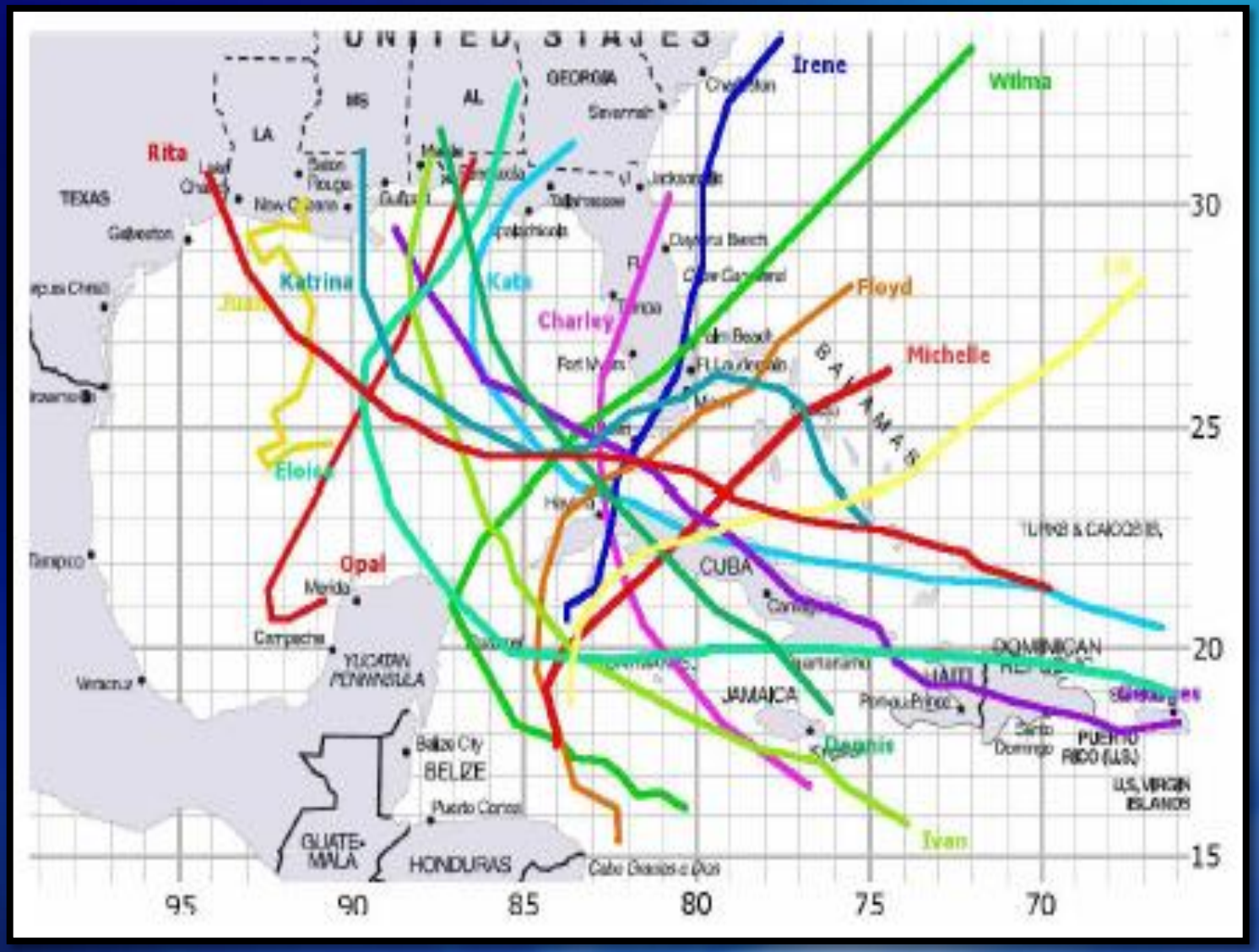
Different hurricanes trajectories have attacked Havana

Problem situation

- Global Climate Change increase frequency and intensity of hurricanes and tropical storms.
- Great amount of water overtopping the seawall due to:

Height of the waves combined with storm surge

Necessity to make work projects to defense coastal zones against severe waves attacks



Different hurricanes trajectories have attacked Havana

Problems to be solved by protection works

- ✓ Avoid the ingress of sea water for the storm drains that discharges to malecon.

- ✓ Avoid or reduce wave overtopping on Malecón seawall.

Problems to be solved by protection works

Entrance of the sea water thought storm drains during the attack of Wilma hurricane.

Problems to be solved by protection works

Wave overtopping during
the attack of storms

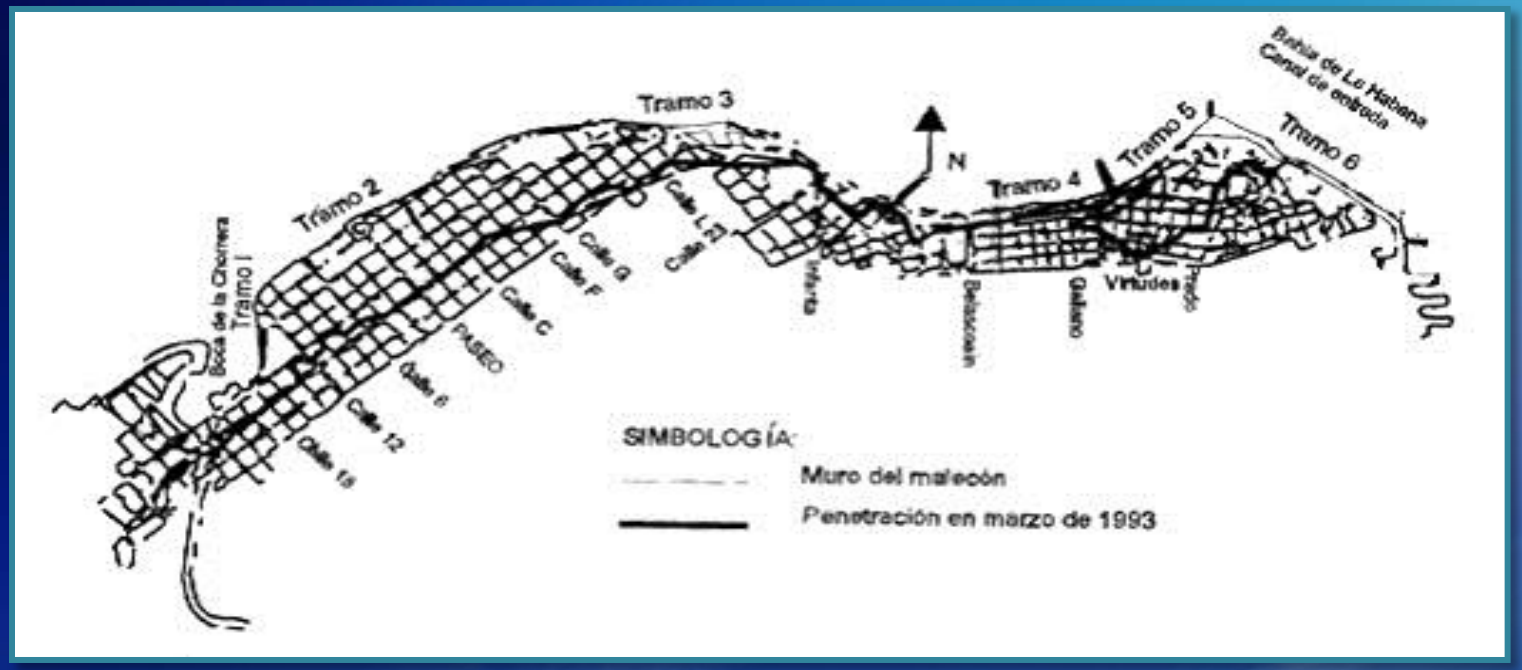
Hydraulic Research Center of ISPJAE joined to Malecon Protection studies since the end of 80th and with greater intensity since the beginning of 90th .

Facilities where the physical modeling studies are done at CIH - CUJAE

Wave flume
90 meters of length
1,5 meters of width
2,0 meters of depth
Regular waves generation

Wave pool
25 meters of length
25 meters of width
1,0 meters of depth
Regular waves generation

Expert group after the attack of “Tormenta del siglo” extratropical storm. (1993)



At that time was studied section 2

The actual section corresponds to section 4 and 5

Avoid the ingress of sea water for the storm drains that discharges to malecon.

Alternatives studied

Outfall. Length 100 meters. Frontal out and resting on the bottom.

Outfall. Length 25 feet. Two sides outlets.

Outfall. Length 25 meters. Frontal out.

Punta de lanza with side at 90 degrees.

Punta de lanza proposed by researchers in CIH.

Avoid or reduce wave overtopping on Malecón seawall

Study of different alternatives for protection against wave overtopping by physical model in the 90th

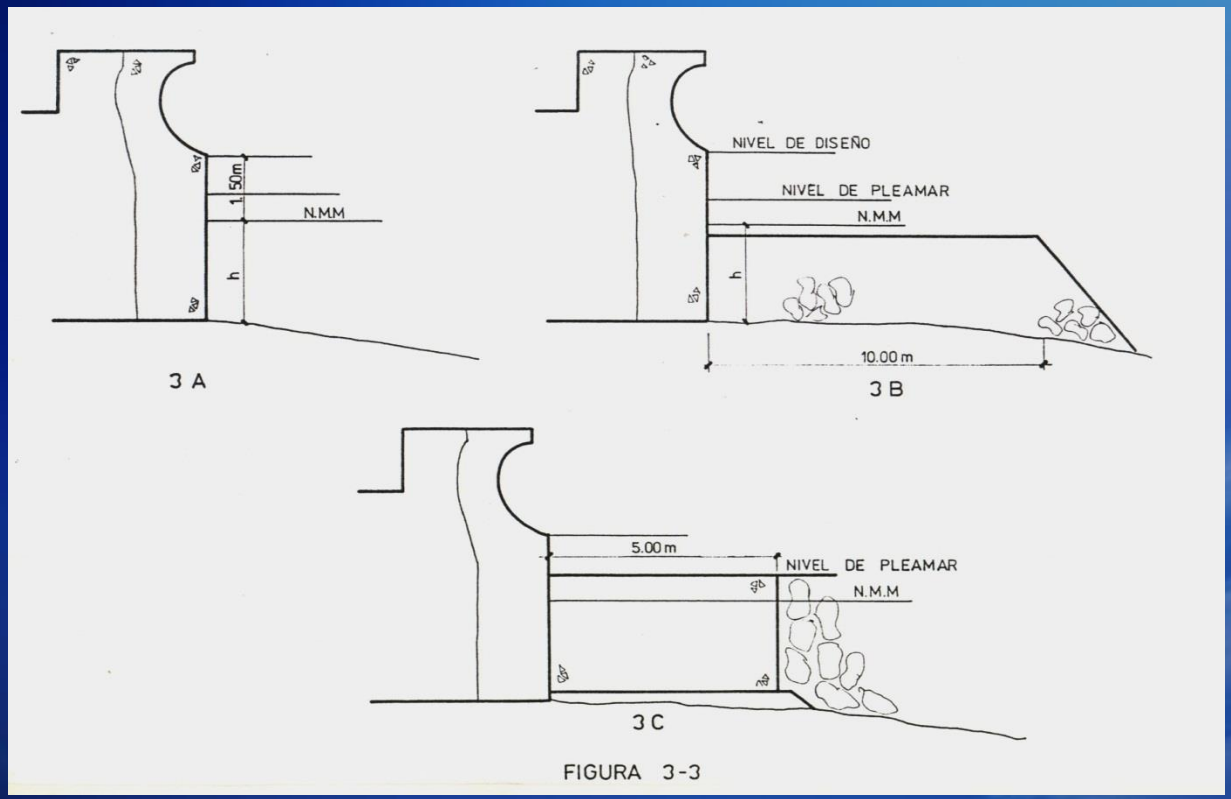
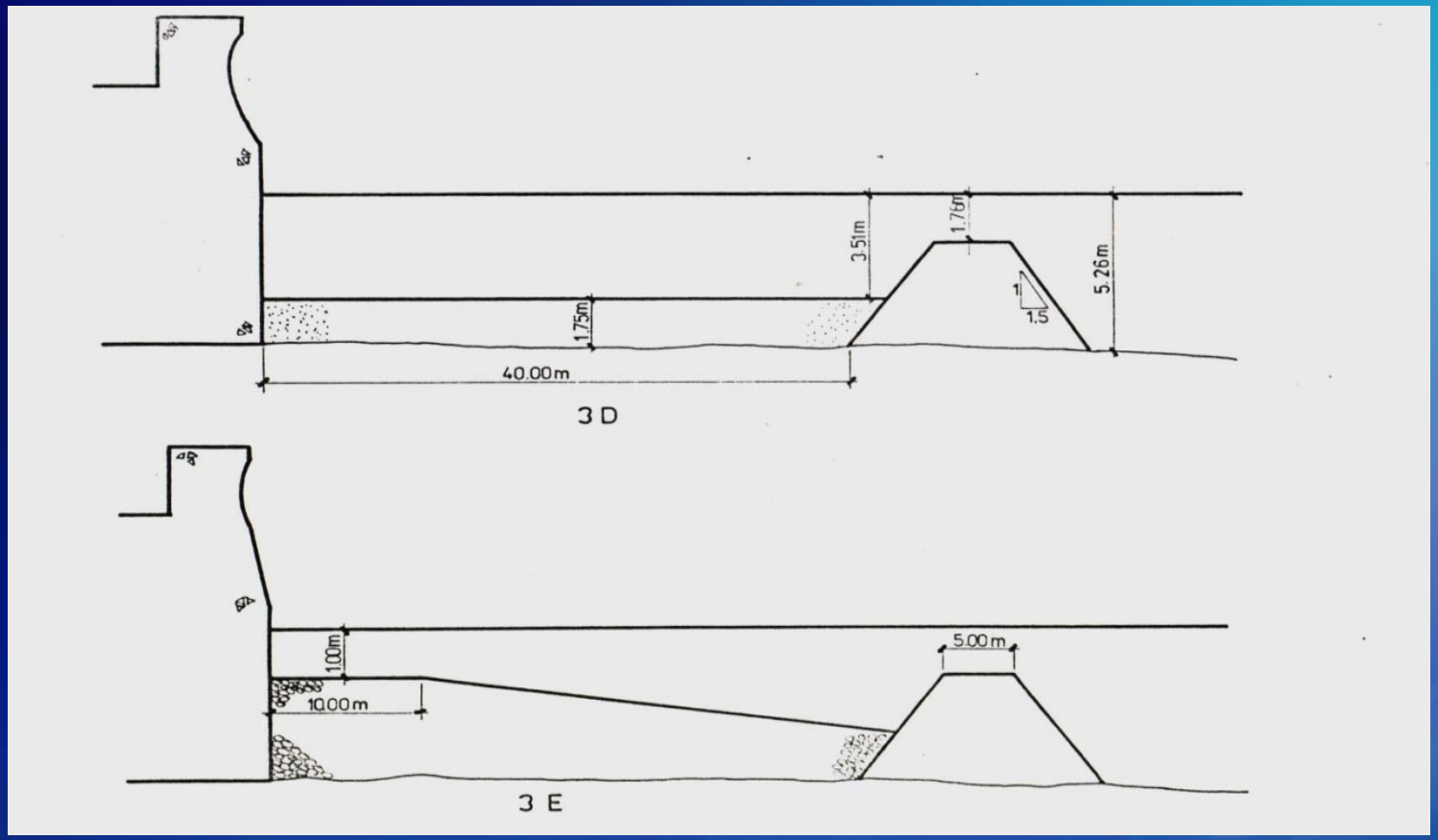


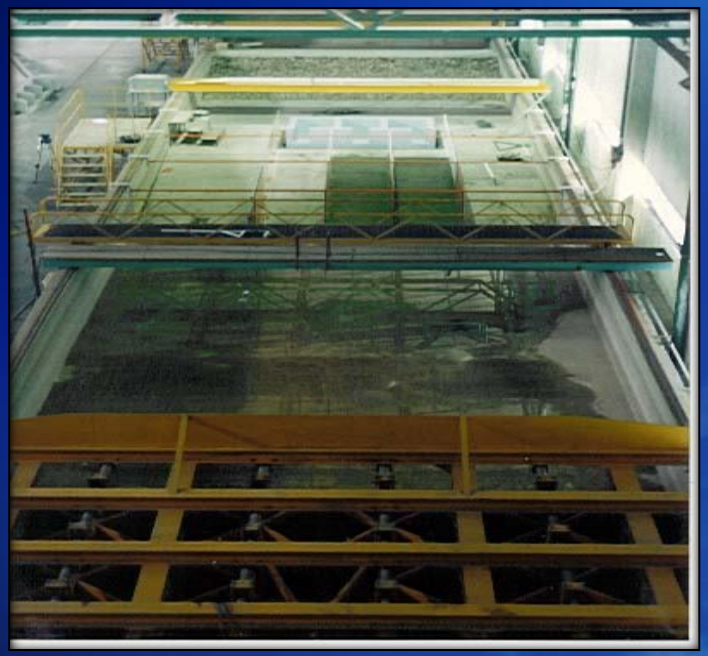
FIGURA 3-3



Offshore Breakwater with change of the profile

Studies of coastal protection alternatives by physical modeling in irregular wave tank. CEPYC. 1995. Spain. Section # 2

In 1995, for a period of three months a group of Cuban specialists in conjunction with Spanish specialists conducted a significant number of physical model tests in irregular wave tank facilities of the Center for Ports and Coasts in Madrid, Spain.



Structures testing

Curve wall with berm

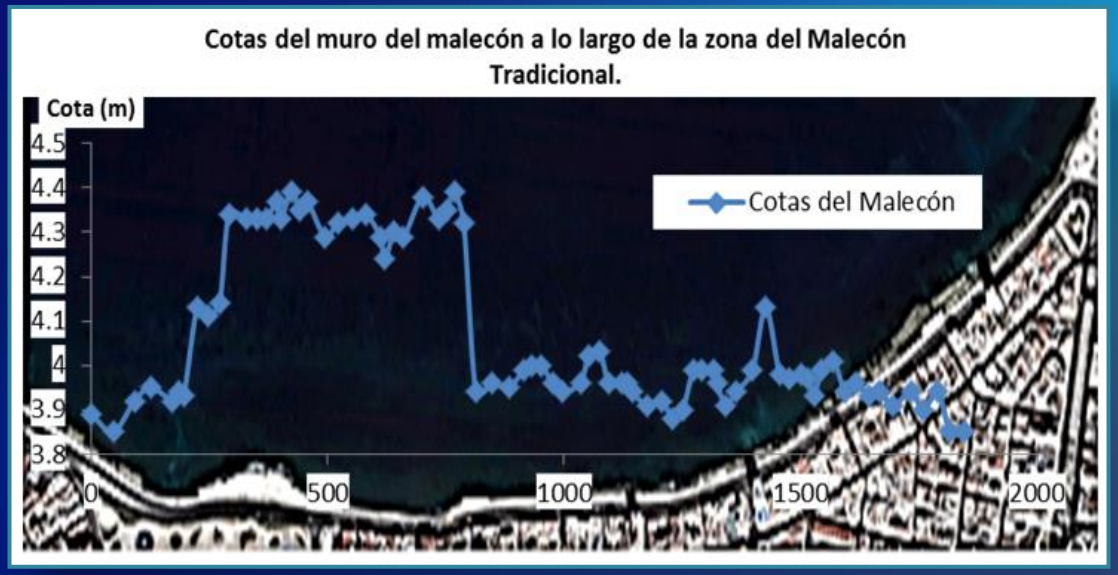
Curve wall without berm

PROPOSED COASTAL DEFENCE WORKS TO GIVE SOLUTION TO THE PENETRATION OF THE SEA IN TRADITIONAL MALECÓN AREA OF THE CITY OF HAVANA

Objetives

- Study of Climate, bathymetry and topography for the section to study.
- Study of wave propagation through the application of mathematical modeling
- Characterization of the study area based on the propagated waves and in bathymetric and topographic features.
- Dimensioning of the defense elements, say coast protection and defense of storm drains that discharge into the study area. Preliminary study of the performance of the proposed solutions.

Seawall characteristics



Subsections	Average height of the wall**(m)**	Average height of the wall over the sidewalk **(m)**	Minimal height of the wall**(m)**	Maximal height of the wall**(m)**	Subsection length**(m)**
1	3.978	0.898	3.85	4.14	245.56
2	4.332	1.182	4.24	4.39	516.03
3	3.956	0.717	3.85	4.13	1053.84

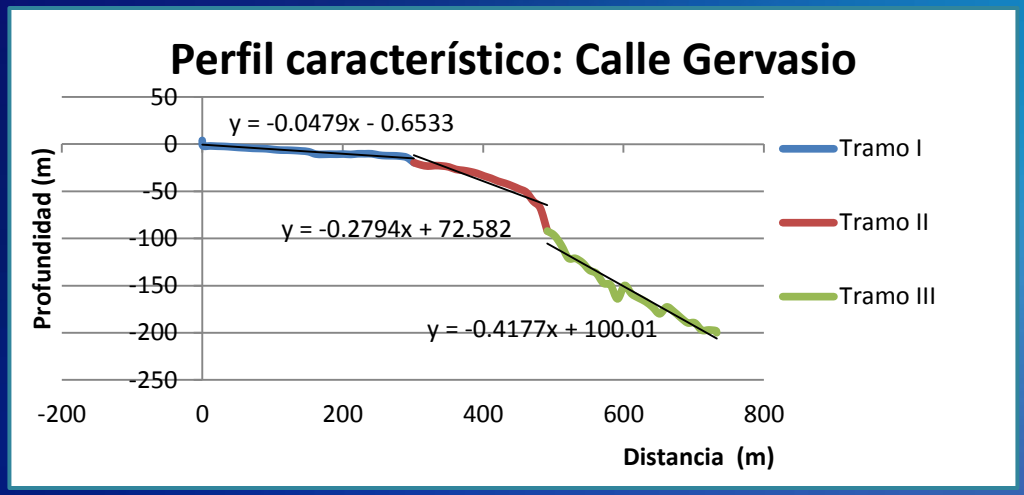
Scenarios	Hs (m)	Tp (s)	Surge (m)	high tide (m)	climate change (m)	total sea level (m)
Return period 50 years	9.2	10.6	1.06*	0.40*	0.27	1.73
Rita hurricane	3.7	11.09	1.31	0.40*	0.27	1.98
Wilma hurricane	5.8	11.34	1.53	0.48	0.27	2.28

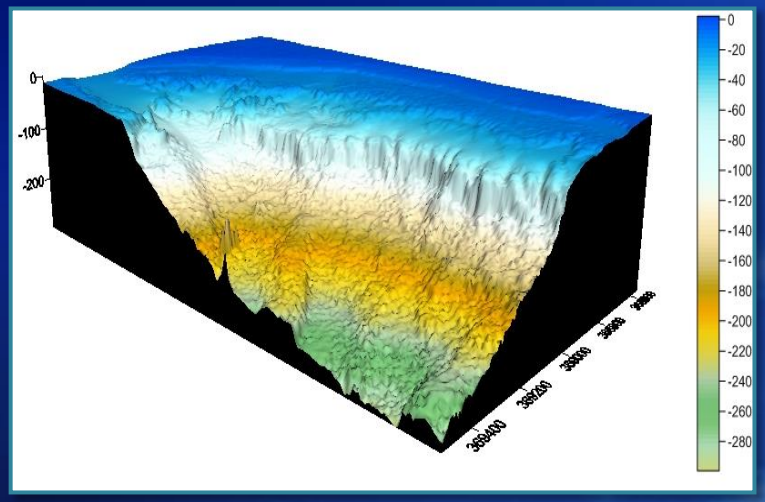
The value of surge for Return Period scenario 1/50 years has been taken from the final report "general hydrometeorological characteristics of the coastal zone for the Malecón Habanero", by Dr. Ida Mitrani (1994). The same applies to the freeboard due to the influence of the wind "wind setup".

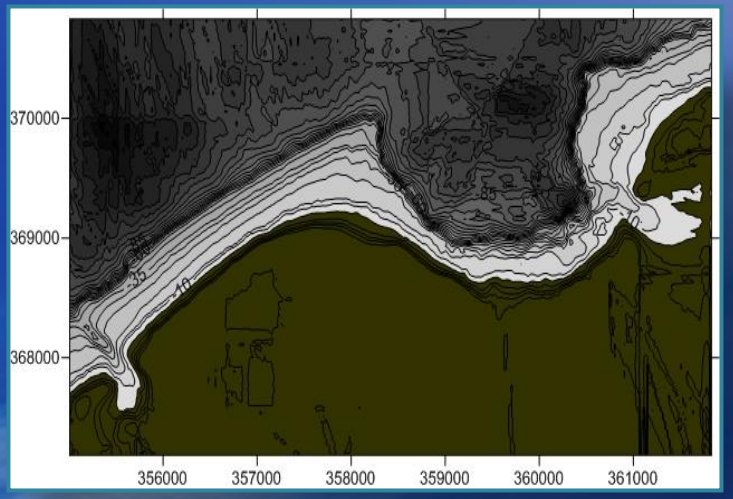
Main restrictions

- Maximal height of the seawall looking from the street: 1.26 m
- Maximal overtopping: 50 l/s/m

Bathymetric characteristic of the study area



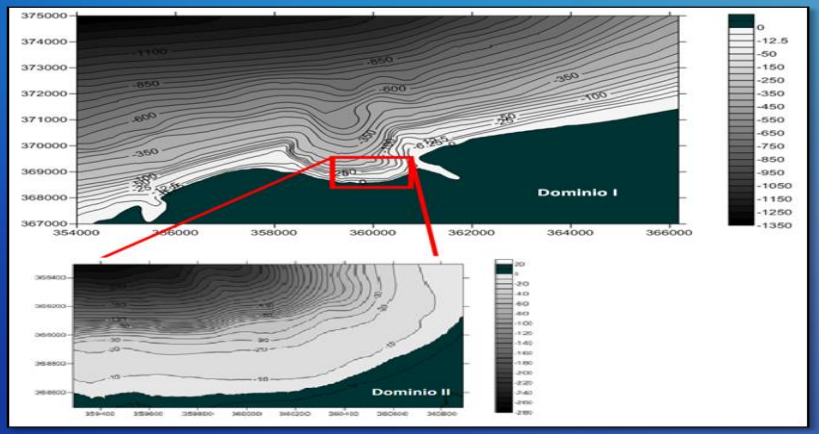


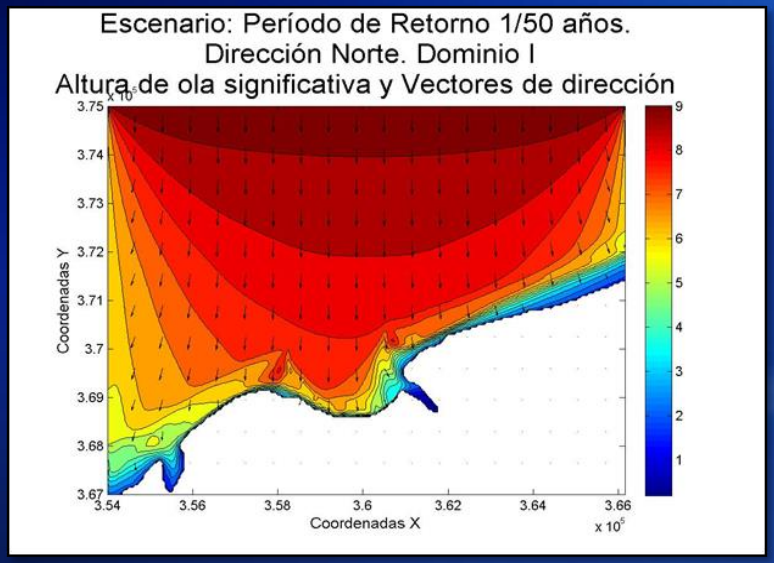


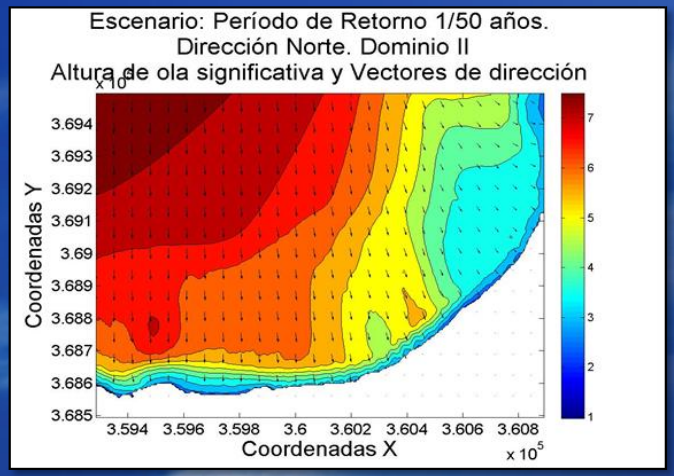
Study of wave propagation to the coast

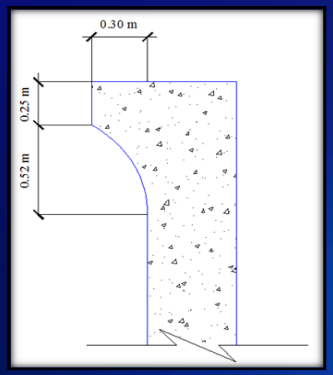
The process of wave transformation from deep water to the coast line, is done by mathematical modeling.

The mathematical model used is SWAN: A model of wave generation and propagation of third generation, with which we obtain wave parameters in coastal areas.





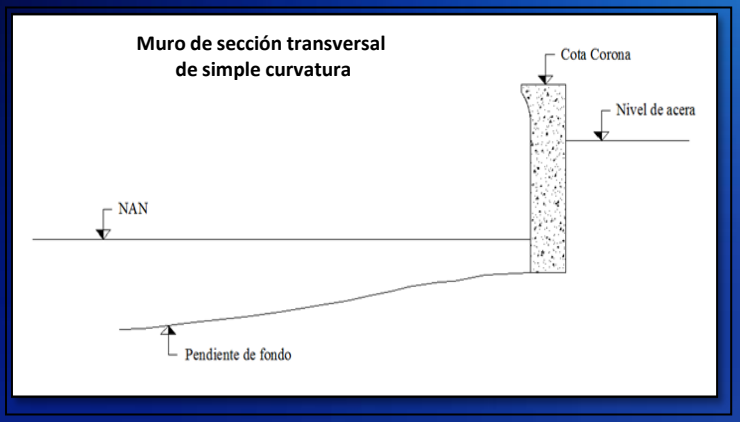


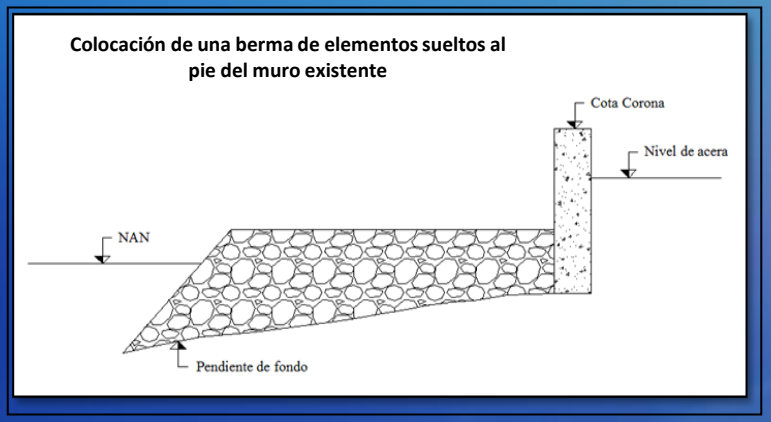


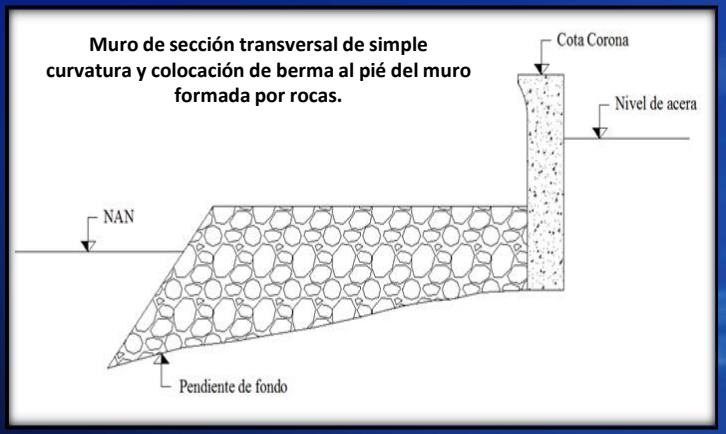
Typologies

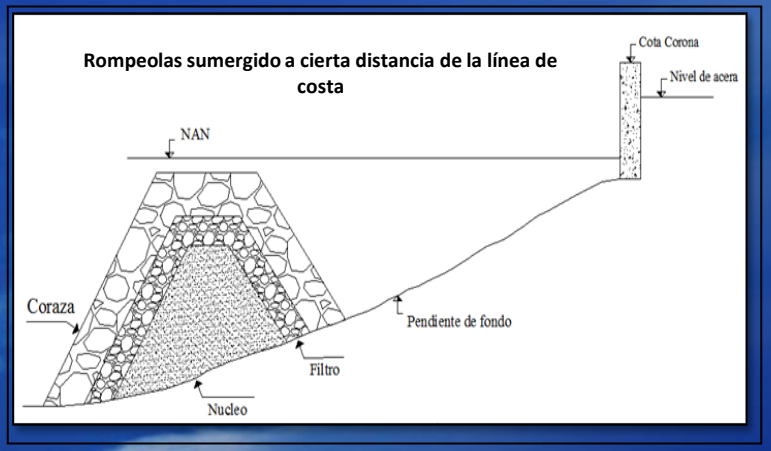
Alternatives are classified into two groups:

- Group One: those developed on shallow water or at coast line
- Group Two: the solutions at sea



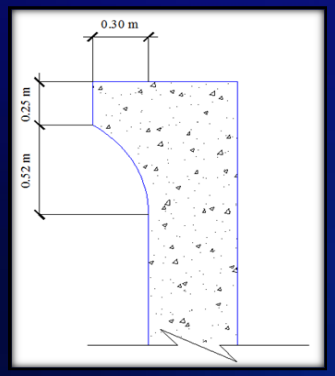


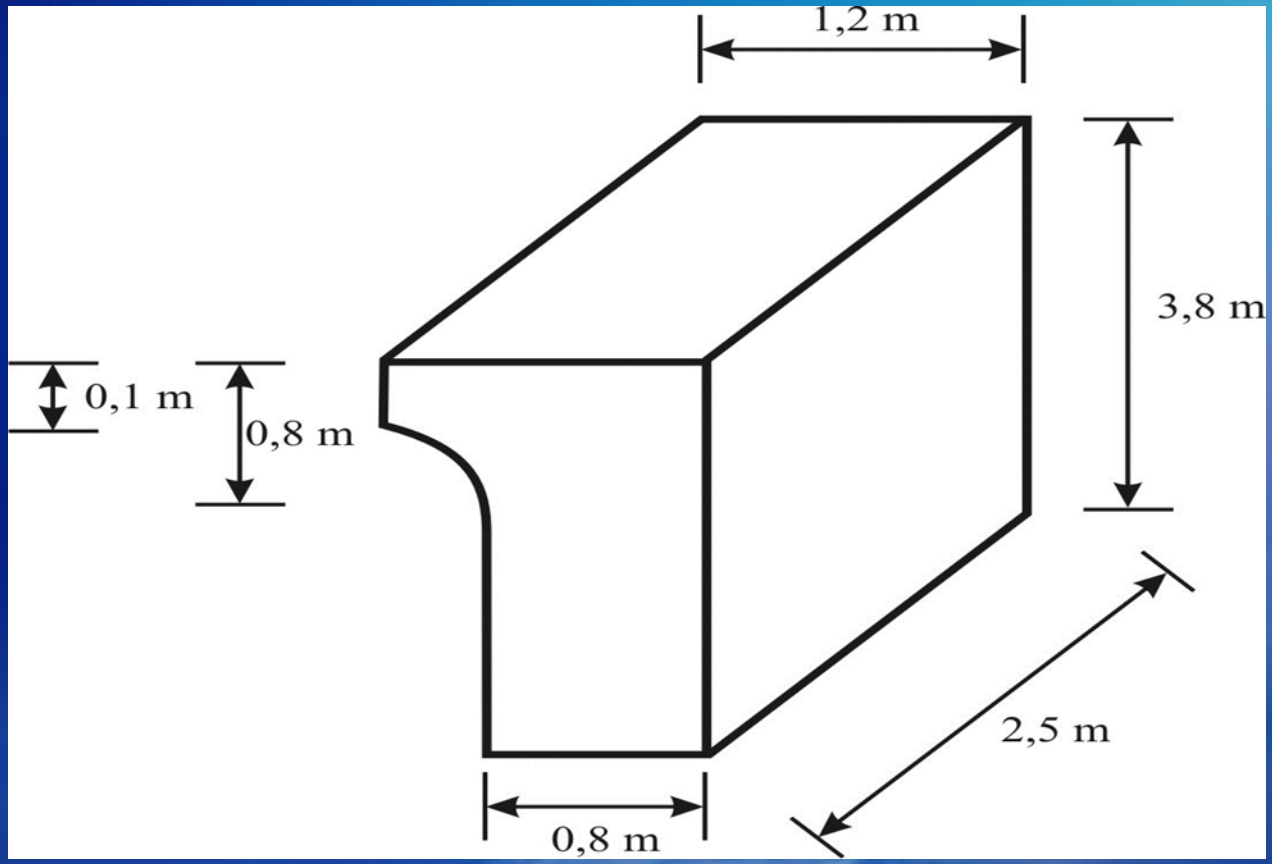




Physical model studies

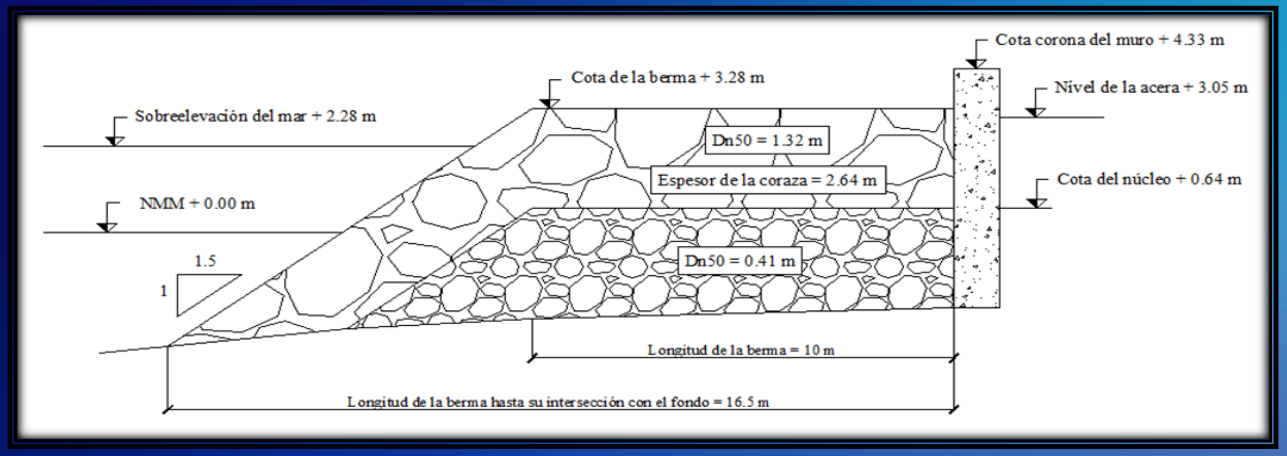
Different structures to study in the laboratory



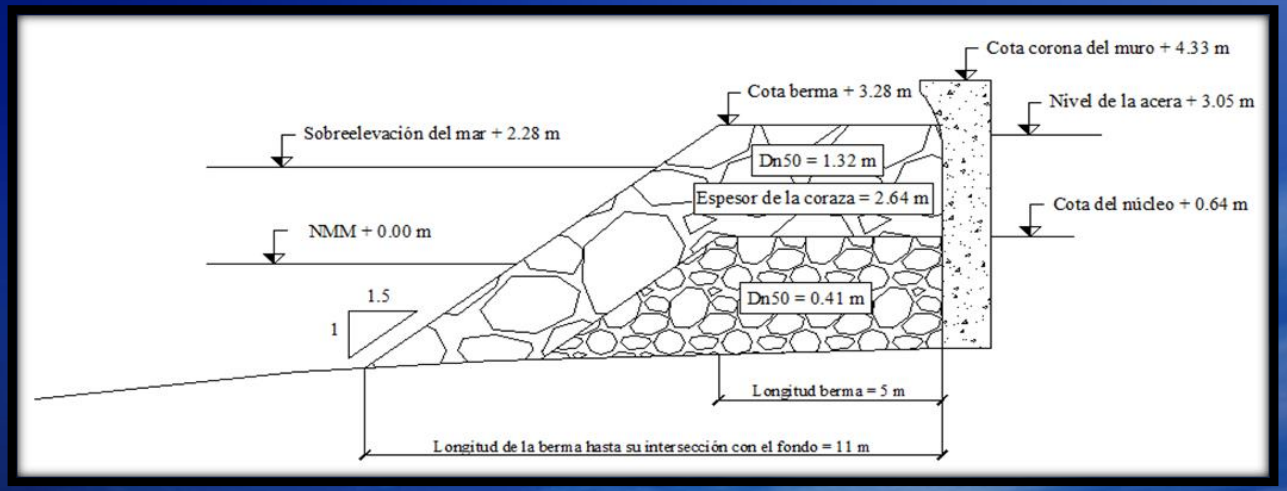


Curve seawall

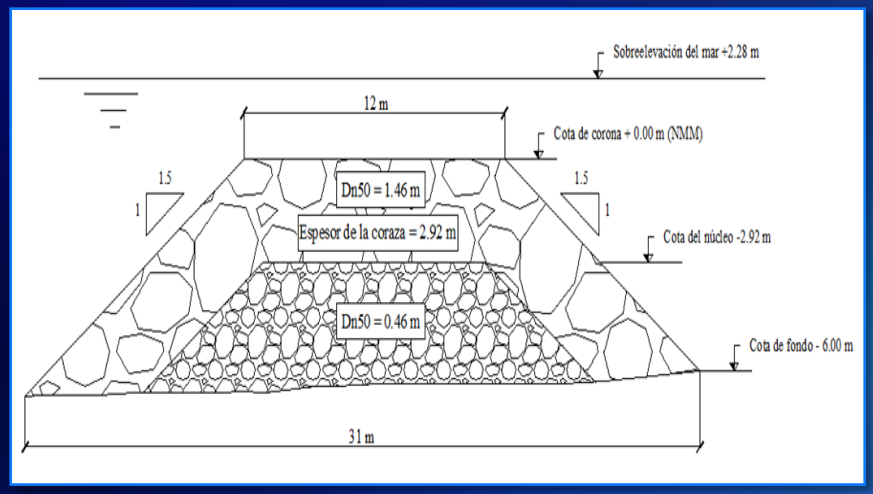
Alternatives



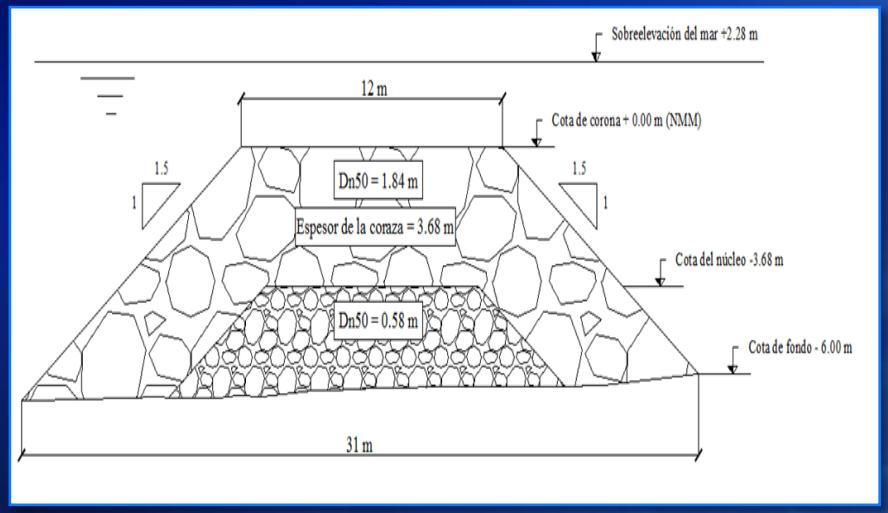
Rock berm in front of the current wall



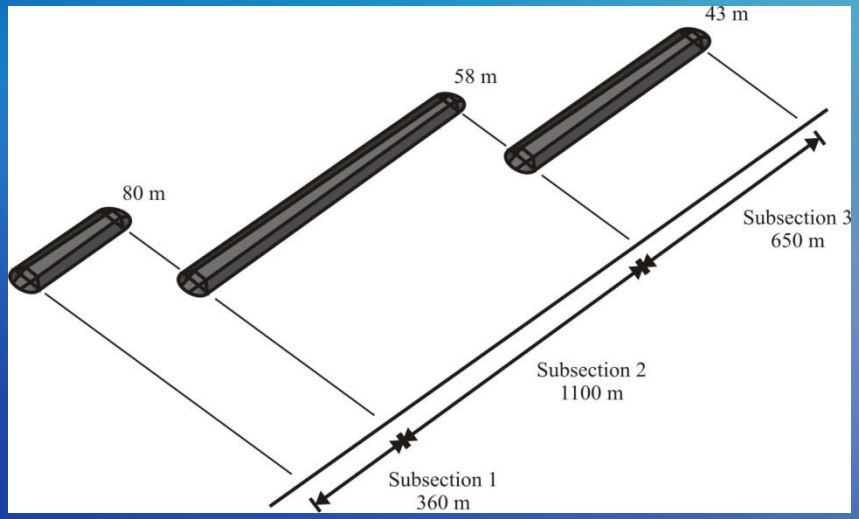
Rock berm in front of the curve wall



Trunk section



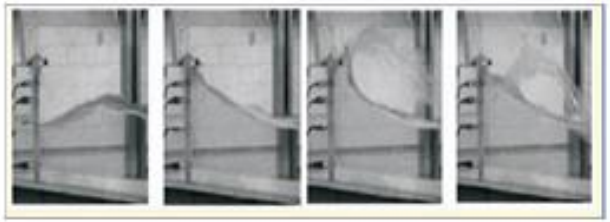
Head section



Necessity of the physical model studies

- The equations used for the design of the alternatives are empiric and they don't represent the situation totally.

Fallo estructural del muro actual durante el huracán Wilma (octubre 2005)



Main tests

1. Wave overtopping.

2. Stability of the elements that compose the berms and the breakwater.

3. Mensuration of the pressures on the seawall.

Taken Eurotop manual 2007

Objectives and scope of the Study in physical model.

- **The studies in physical model would be two-dimensional scale 1:30, it would be directed to:**

1. *To evaluate the reduction percent of the wave overtopping and number of wave overtopping for different scenarios, keeping in mind the climatic change.*

2. *Optimization the curve Wall to reduce wave overtopping.*

3. *In the case of the application of berms , the stability of the elements should be studied to avoid excessive damages that it puts in danger its stability and later operation.*

4. *Determination of the pressures, fundamentally in the case of the curve wall, so that an appropriate design can be carried out from the structural point of view, and to avoid breaks of the bend, that which bears to the disqualification of its operation.*

Process of construction of the model.

Scale of the model = 1:30

Process of construction of the model.

Process of construction of the model.

Process of construction of the model.

Reproduction of the profile

Reproduction of the profile

Process of wave calibration

Scenarios

4 steps of waves (4m; 6 m; 8m and 10 m)

2 steps of wave period pick (10 s. and 12 s.)

2 steps water level

+1.73 about msl

+2.28 about msl

TOTAL = 16

Process of wave calibration.
Placement of the level sensors

Process of wave calibration.
Making waves !!!!

Future studies

Determination with more precision the wave and storm surge

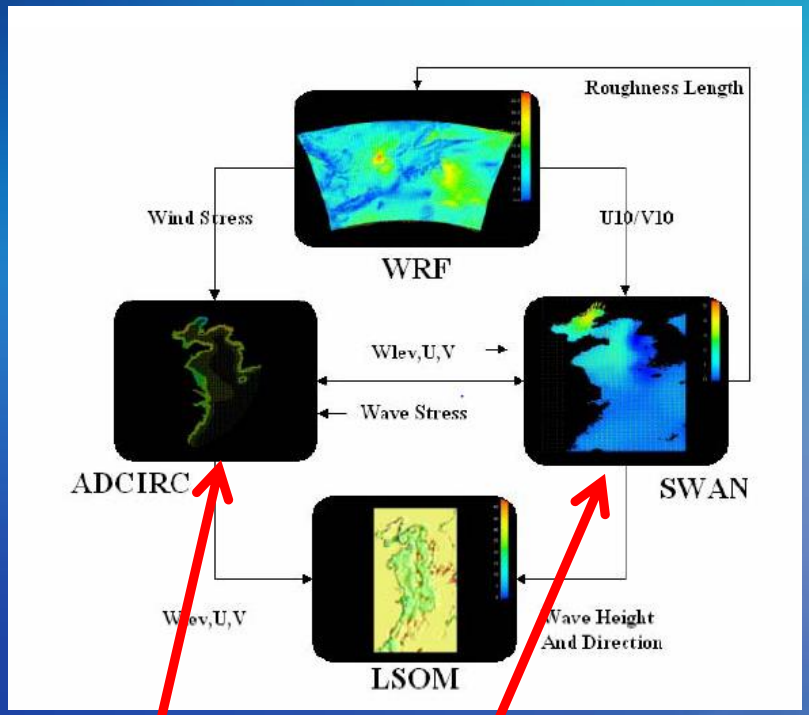
Carrying out studies of simulation of the storm surge by means of the combination of:

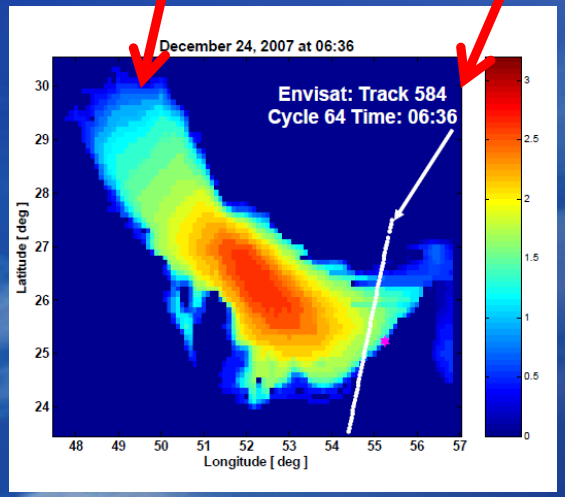
1. Hydrodinamic mathematical models

2. Mensurations of tides buoys

3. Altimetry satellite

4. Modeling hurricane waves and storm surge using integrally-coupled, models





SATELLITE ALTIMETER CALIBRATION OF A WAVE MODEL IN THE ARABIAN GULF

Alanoud N. Al-Ragum ,Claudia Giarrusso, Eugenio Pugliese Carratelli CUGRI and University of Salerno

Muchas Gracias
Grazie mille
Thank you very much