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The State of the Art and Science of Coastal Engineering

PRELIMINARY ENGINEERING OF A SEAWALL TO MITIGATE TYPHOON-INDUCED WAVE OVERTOPPING ALONG ROXAS BOULEVARD, MANILA

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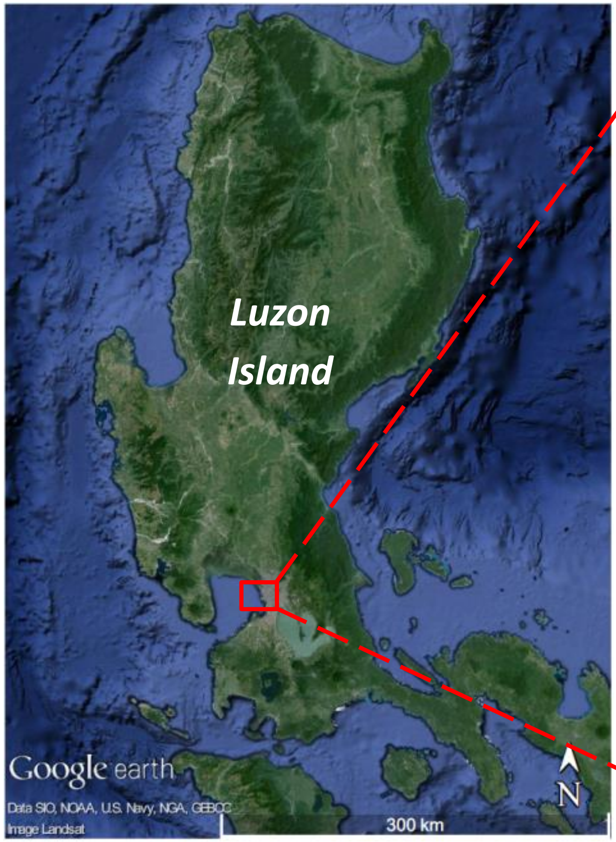
August 3, 2018

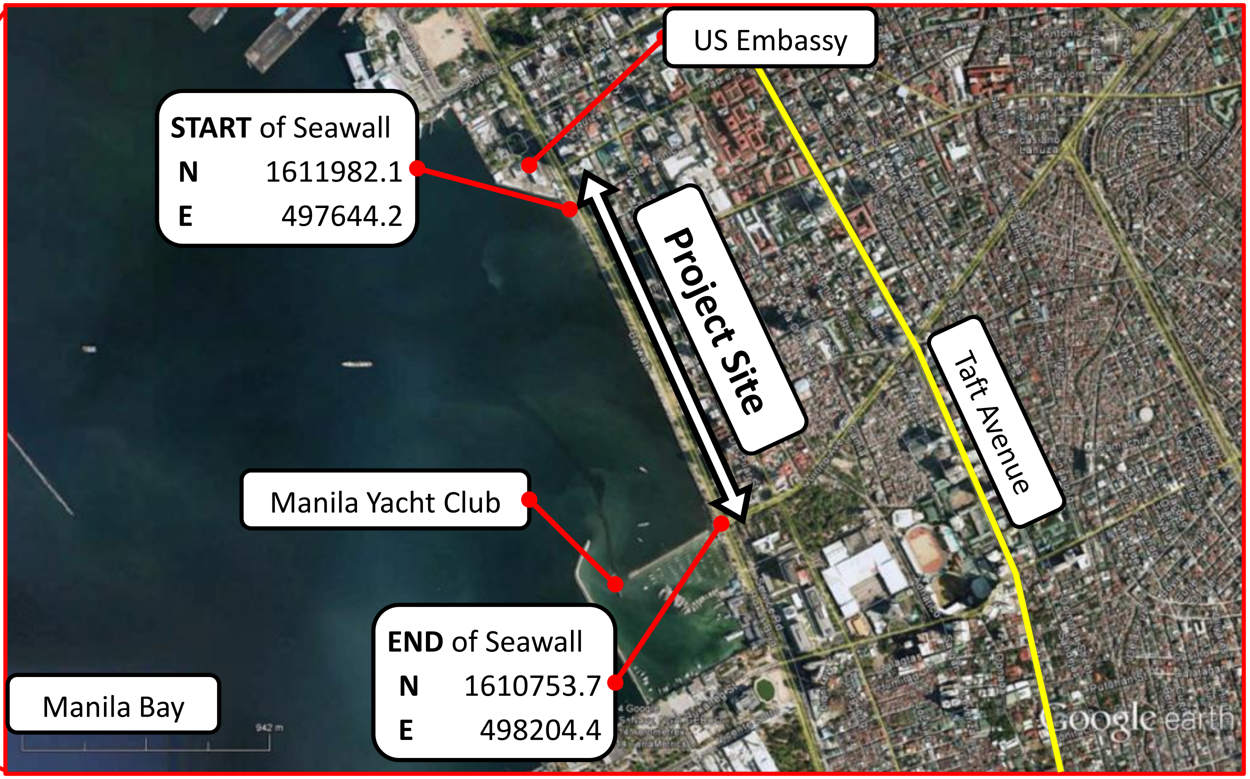
Outline

1. Introduction
2. Methodology
3. Project Area Data
4. Analysis of Historical Typhoons
5. Coastal Engineering
6. Preliminary Engineering
7. Conclusions

INTRODUCTION

Project Location





INTRODUCTION

(video)

Notes

- Observed water level nearly at level with seawall crest
- Nearly constant wave overtopping

https://www.youtube.com/watch?v=F_IkbxHawIw

INTRODUCTION

Project Background

http://www.demokrathaber.net/images/album

INTRODUCTION

Project Background

2011

- Typhoon Nesat/Pedring caused overtopping which led to the seawall collapse; rehabilitation of the seawall was immediately undertaken

2012

- High waves induced by Typhoon Saola/Gener overtopped the recently rehabilitated seawall but the seawall was not damaged extensively.

2013

- National Public Works Agency (DPWH) – commissioned a study to understand the typhoon hazards and recommend mitigating measures.

http://www.fashionpulis.com/2011/09/pedring-fierce-storm.html

INTRODUCTION

Design Considerations

1. Technical Considerations
   - Hazards, such as typhoons and earthquakes
     - ➢ Storm Tides and Waves
     - ➢ Liquefaction and Lateral Spreading

1990 Luzon Earthquake – resulted in wide-scale liquefaction on the island of Luzon

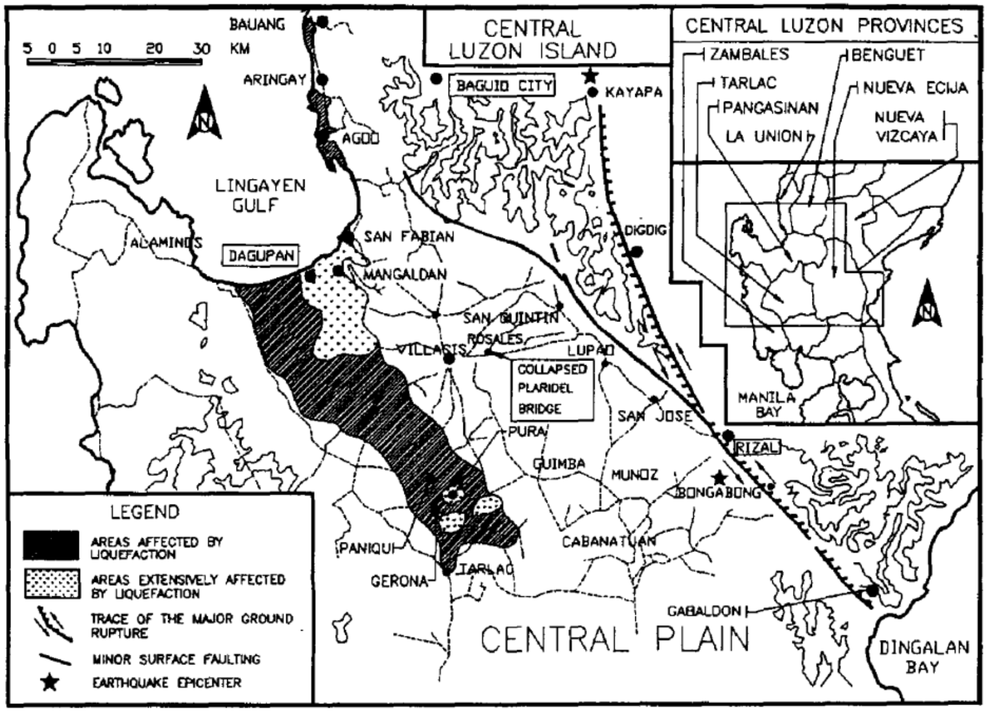
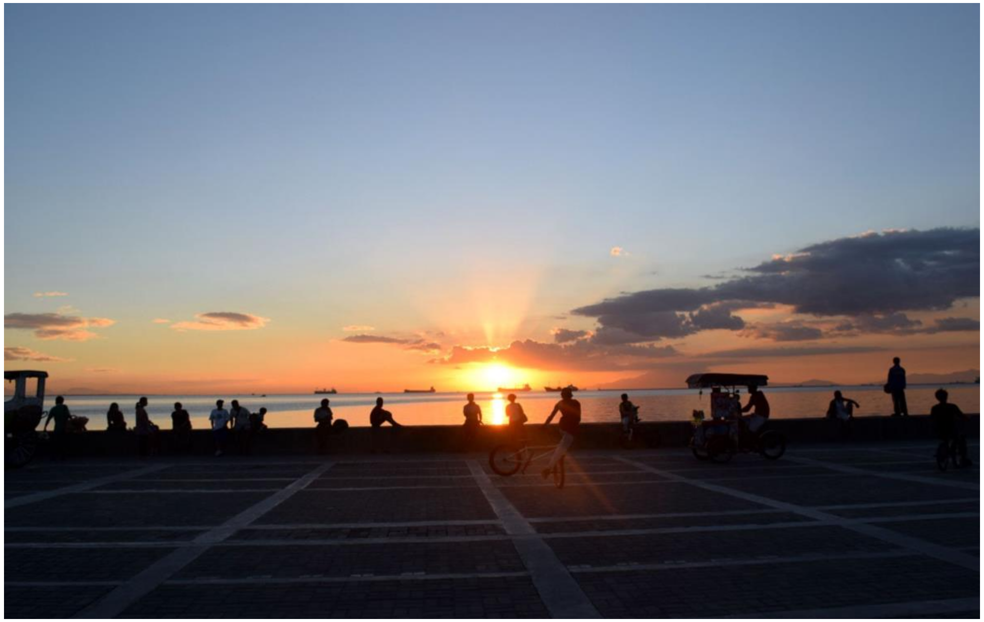


Photo on the left: thepoc.net
Extent of Liquefaction map from Punongbayan and Umbal (1990)

INTRODUCTION

2. Non-Technical Considerations
   - Preservation of the sunset view on Manila Bay
   - Existing adjacent structures
   - Cost-effective design

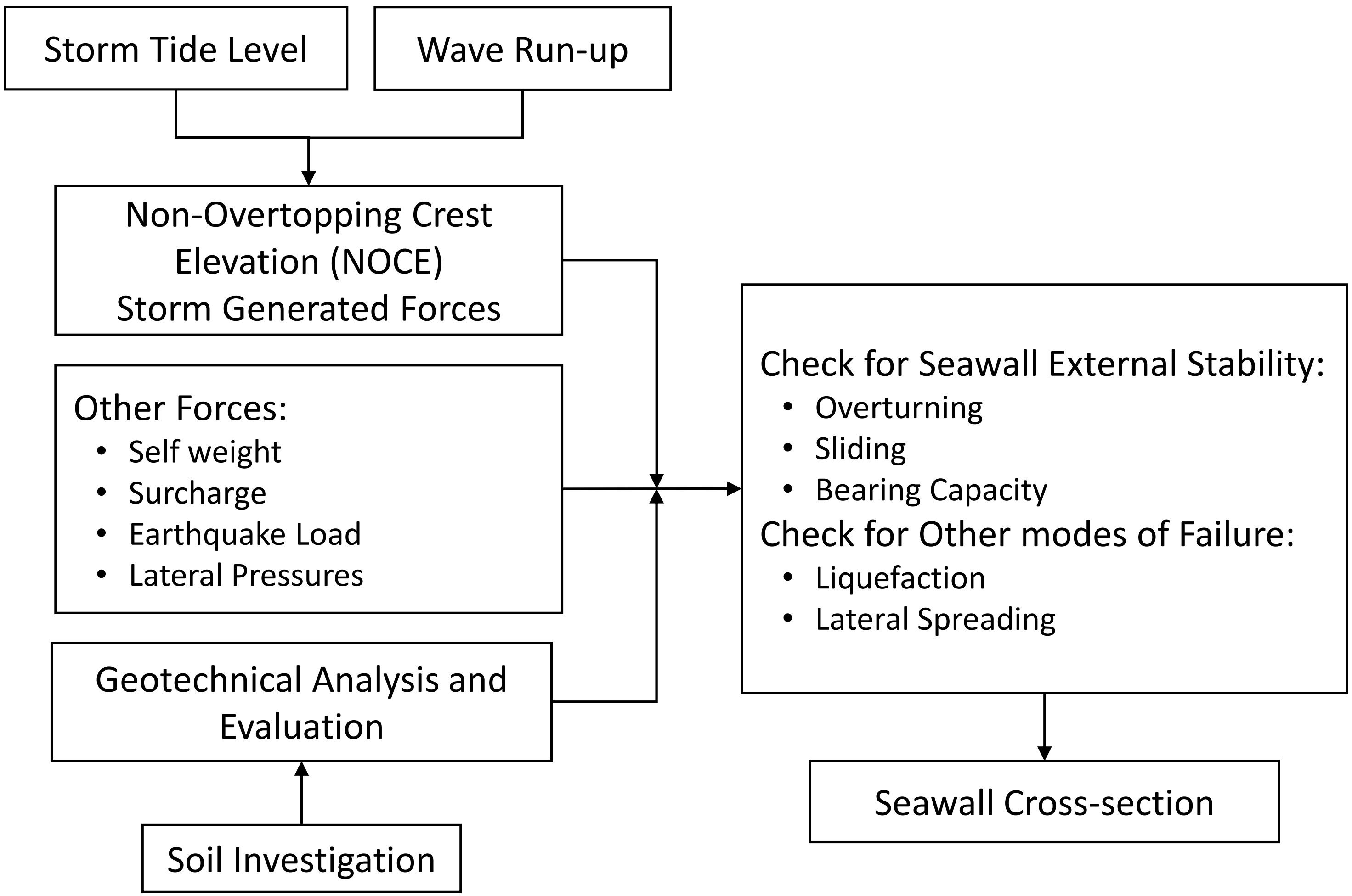


http://faq.ph/wp-content/uploads/2015/11/201.jpg
http://2.bp.blogspot.com/_a8b7S0mN5bM/TVJ2dCDlmZI/AAAAAAAAAi4/qAdIASWYpyo/s1600/roxas%2Bblvd.JPG

METHODOLOGY

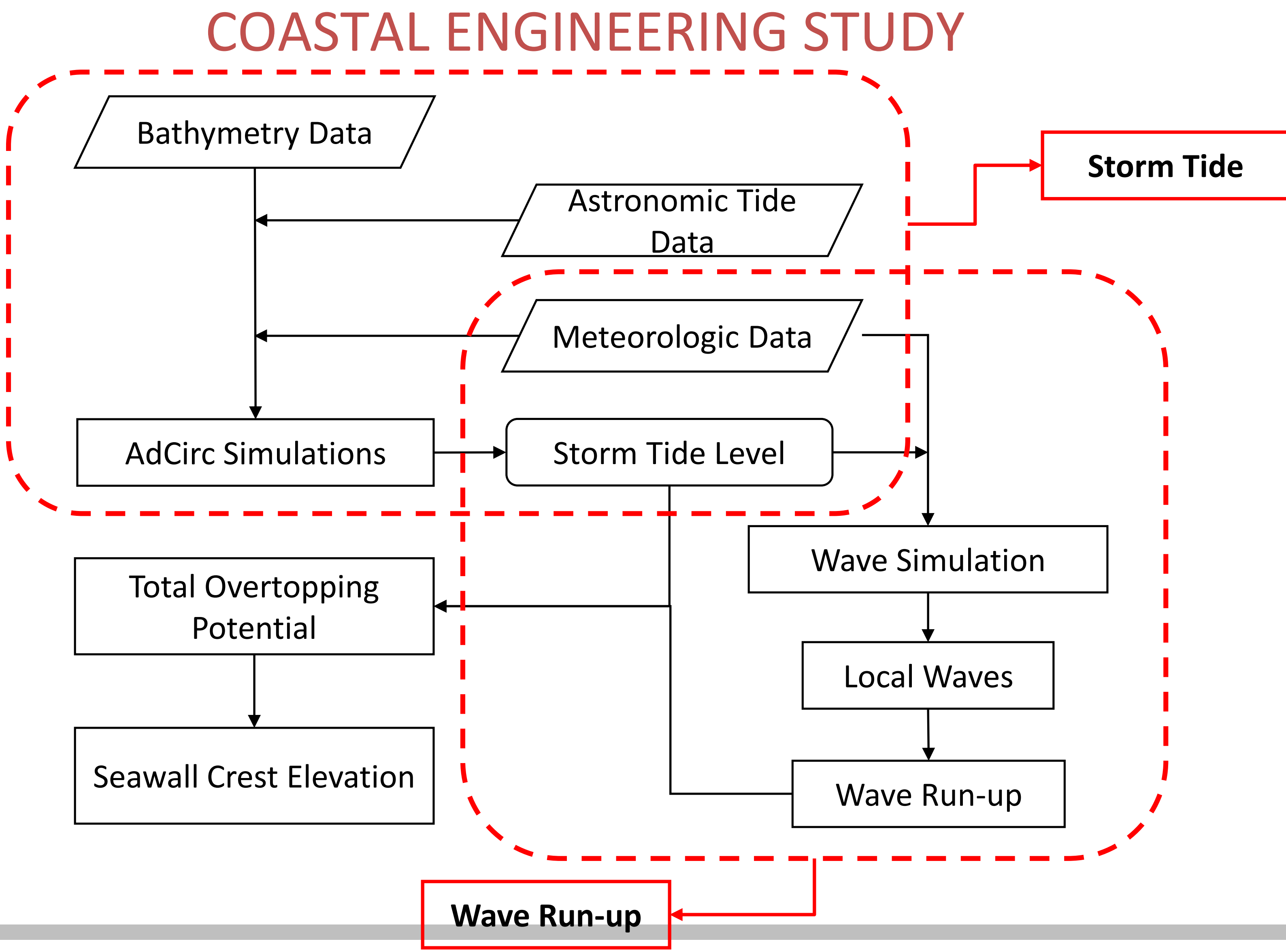
Conceptual Framework

PRELIMINARY ENGINEERING DESIGN



METHODOLOGY

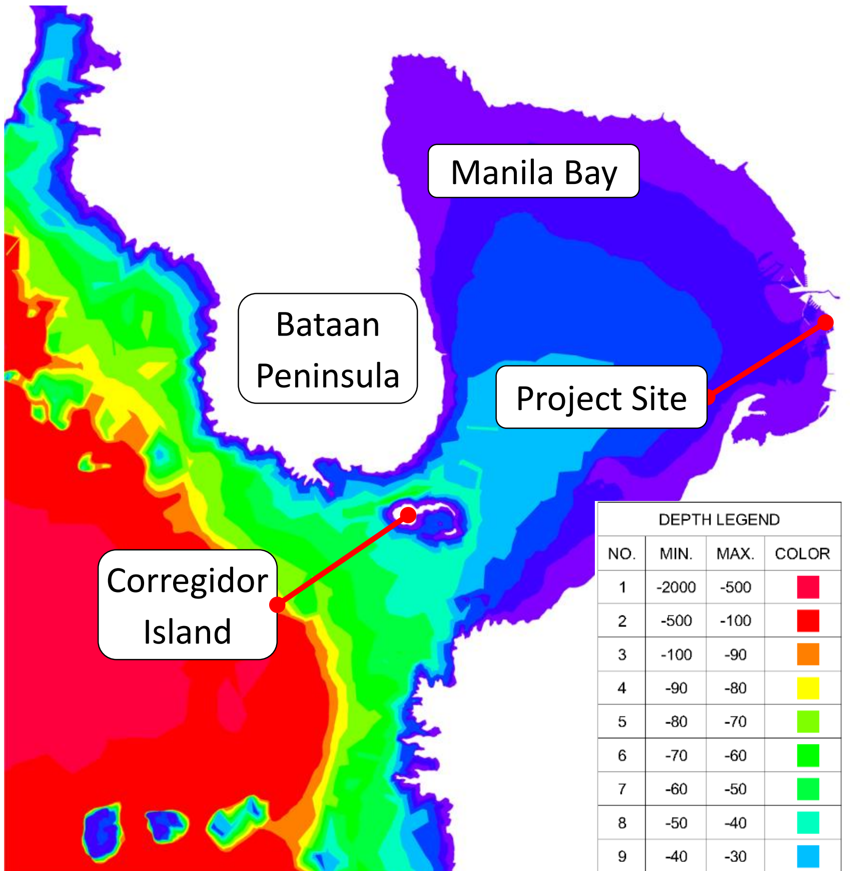
Conceptual Framework



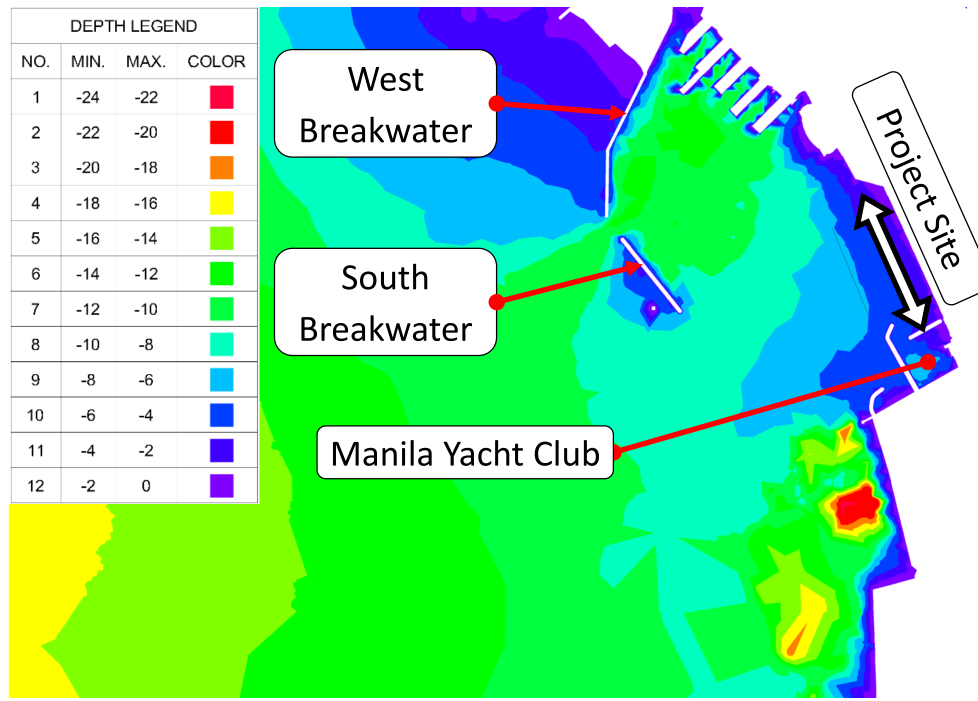
PROJECT AREA DATA

Site Bathymetry

- Consolidation of bathymetric data from available nautical maps and commissioned bathymetric survey



DEPTH LEGEND			
NO.	MIN.	MAX.	COLOR
1	-2000	-500	
2	-500	-100	
3	-100	-90	
4	-90	-80	
5	-80	-70	
6	-70	-60	
7	-60	-50	
8	-50	-40	
9	-40	-30	
10	-30	-20	
11	-20	-10	
12	-10	0	

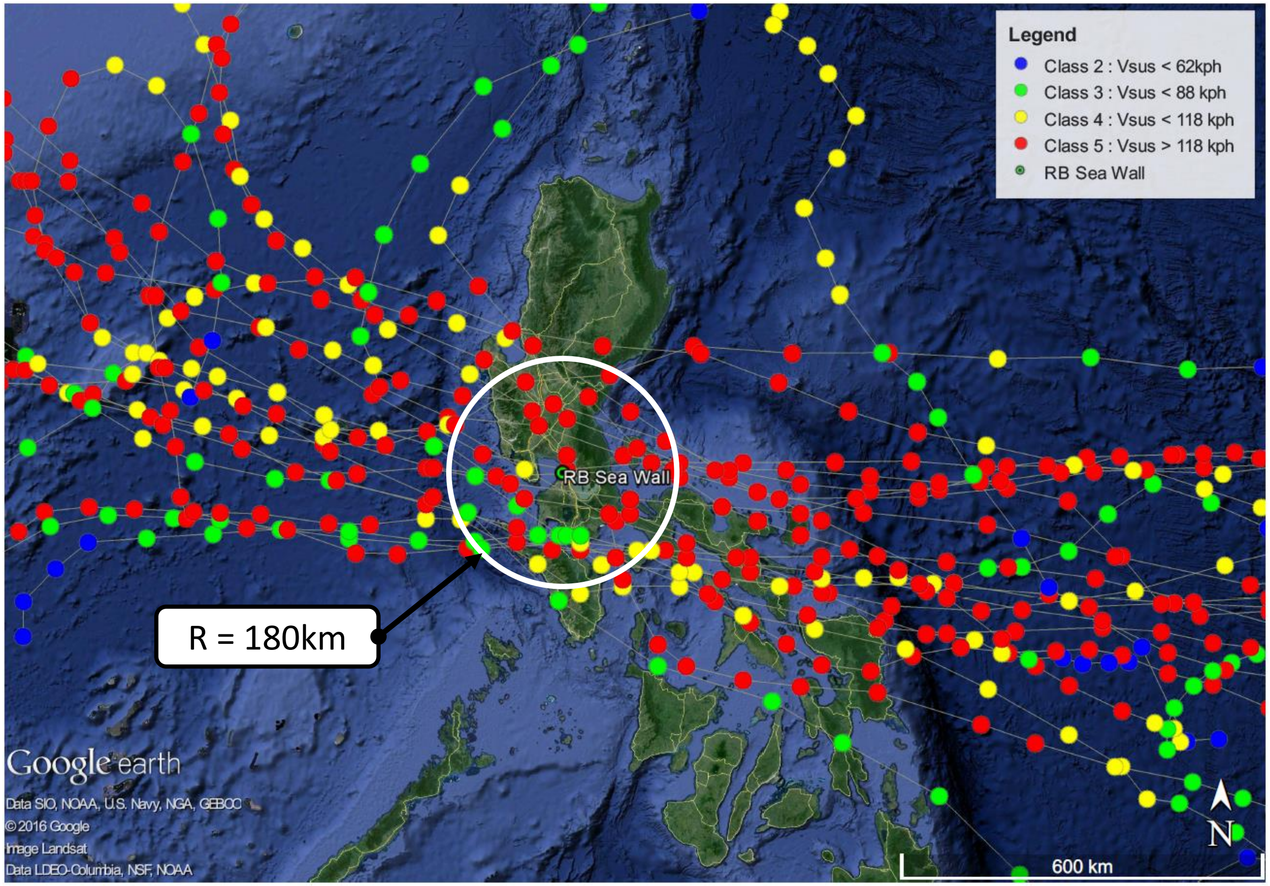


DEPTH LEGEND			
NO.	MIN.	MAX.	COLOR
1	-24	-22	
2	-22	-20	
3	-20	-18	
4	-18	-16	
5	-16	-14	
6	-14	-12	
7	-12	-10	
8	-10	-8	
9	-8	-6	
10	-6	-4	
11	-4	-2	
12	-2	0	

TYPHOON ANALYSIS

Historical Typhoons

- Typhoon Tracks of 30 historical typhoons



- Summary of Meteorological Data of Historical Typhoons

Year	Name Int'l/ Local	Vmax (kph)	Rmax (km)	Pc (hPa)	Relative Track	Distance to site (km)
1977	Kim/ Unding	205	230	920	N	60
1978	Rita/ Kading	220	230	880	N	80
1979	Mac/ Pepang	100	60	985	S	40
1980	Forrest / Gloring	100	90	992	N	120
1981	Irma / Klaring	205	280	905	N	140
1982	Winona / Emang	95	0	985	N	140
1983	Vera / Bebeng	140	130	965	S	8
1984	Betty / Konsing	95	0	985	N	170
1985	Dot / Saling	220	330	895	N	90
1986	Georgia / Ruping	85	0	985	S	160
1987	Betty/ Herming	205	190	890	S	100
1988	Ruby / Unsang	140	280	950	N	100
1989	Hunt / Unsing	140	150	960	N	120
1990	Nathan / Akang	100	220	980	N	95
1991	Wilda / Warling	85	0	992	S	50

TYPHOON ANALYSIS

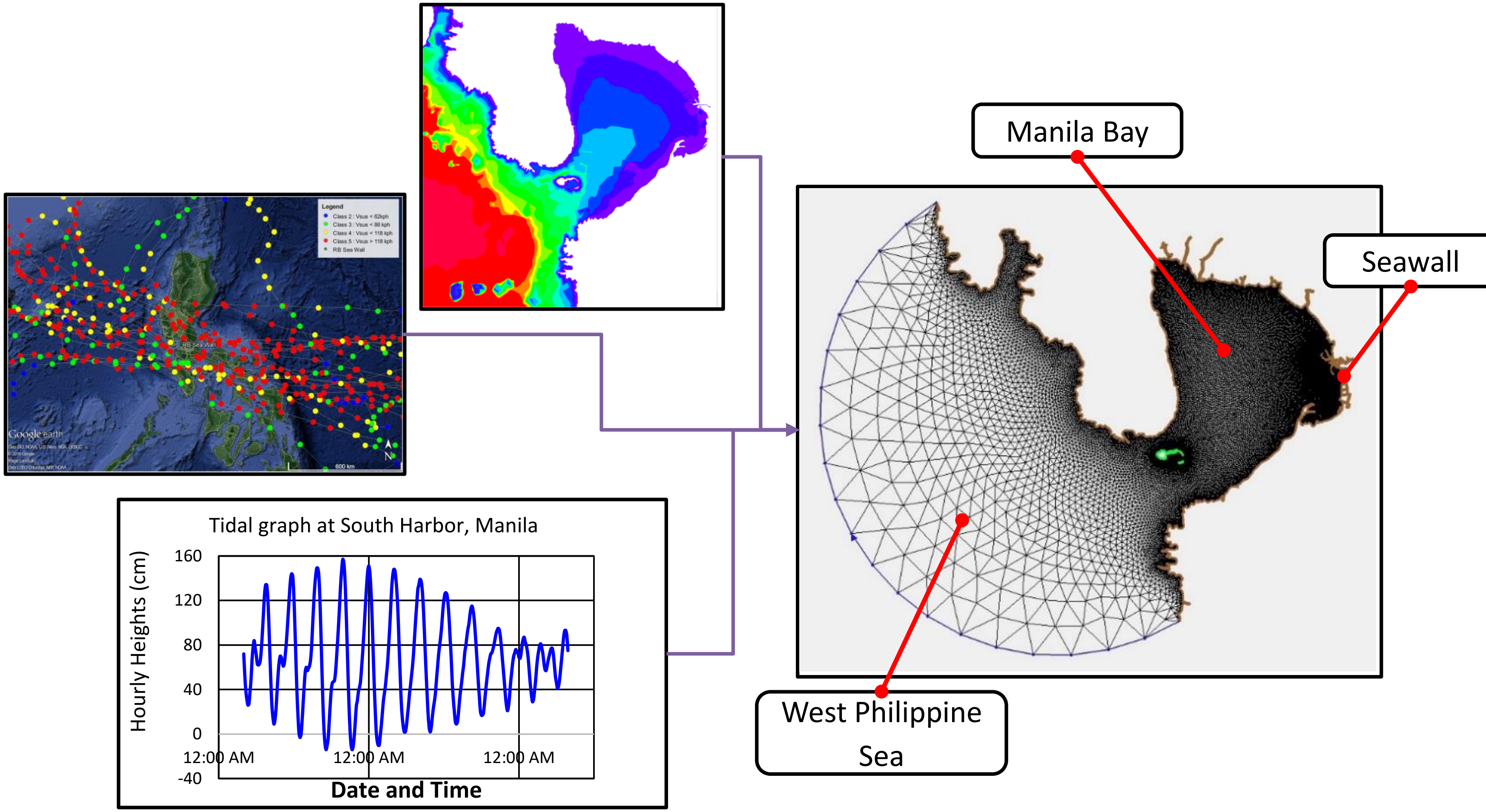
Historical Typhoons

- Summary of Meteorological Data of Historical Typhoons

Year	Name Int'l/ Local	Vmax (kph)	Rmax (km)	Pc (hPa)	Relative Track	Distance to site (km)
1992	Eli / Konsing	130	150	965	N	160
1993	Lola / Monang	150	190	955	S	90
1994	Teresa / Katring	150	150	955	S	40
1995	Sibyl / Mameng	95	0	985	N,E	15
1996	Ernie / Toyang	75	0	992	N	260
1997	Mort / Pining	85	0	992	N	180
1998	Babs / Loleng	160	260	940	N	110
1999	Eve / Rening	85	0	990	N	25
2000	Xangsane/ Reming	140	150	960	S	10
2001	Cimaron/ Crising	95	0	985	E	180
2006	Xangsane/ Milenyo	160	120	940	S	25
2008	Fengshen/ Frank	165	90	945	E, N	20
2011	Nesat/ Pedring	150	220	950	N	200
2012	Saola/ Gener	130	110	960	E	505
2014	Rammasun / Glenda	165	130	935	S	45

TYPHOON ANALYSIS

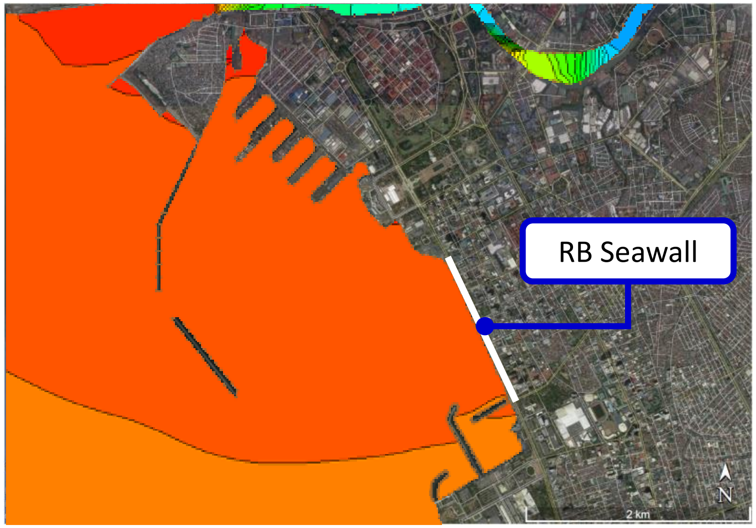
- Advance Circulation (AdCirc) Numerical Model



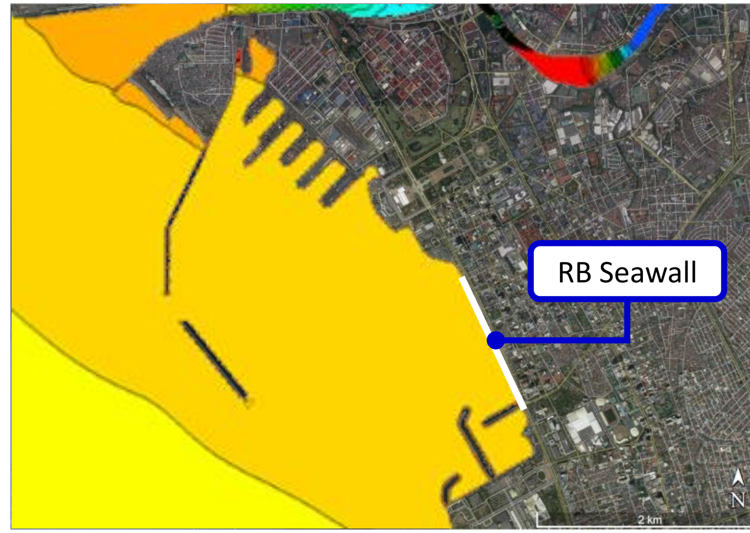
TYPHOON ANALYSIS

Storm Tides

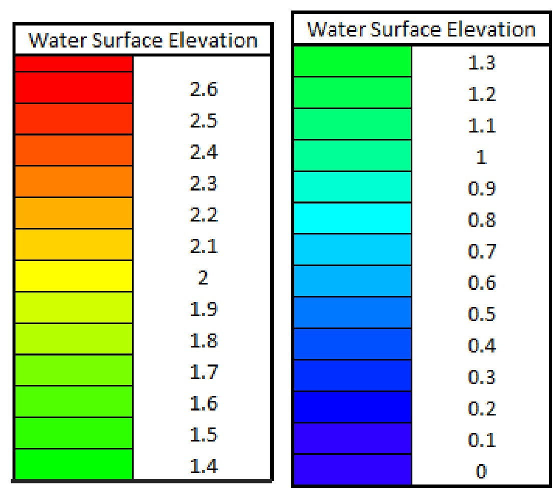
Results - Rammasun / Glenda (2014)



Results – Xangsane / Milenyo (2006)



Results Fengshen / Frank (2008)



TYPHOON ANALYSIS

- Highest 6 Storm Tide Levels

Typhoon / Local name	Astronomic Tide (m)	Storm Tide Level (m)	Max. Storm Surge (m)	Time of Occurrence of Max STL
Rammasun / Glenda 2014	1.125	**2.358**	1.233	7/16 10:41 AM
Xangsane / Milenyo 2006	0.473	**2.088**	1.614	9/28 2:43 PM
Fengshen / Frank 2008	1.244	**1.763**	0.519	6/21 11:13 AM
Dot / Saling 1985	1.283	**1.714**	0.431	10/19 1:10 AM
Vera / Bebeng 1983	1.232	**1.607**	0.375	7/15 12:06 PM
Betty / Herming 1987	1.246	**1.515**	0.269	8/11 11:09 AM

TYPHOON ANALYSIS

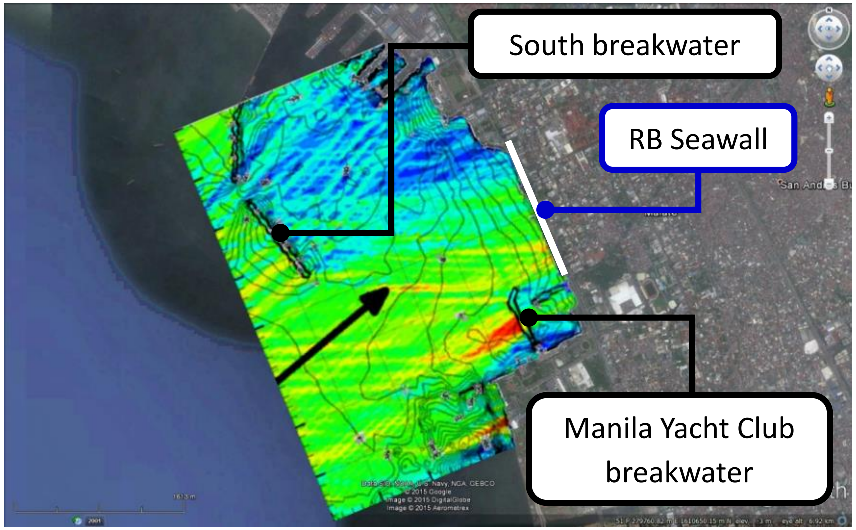
- Offshore storm wave conditions at time of highest STL

Typhoon / Local name	Offshore significant waves		
	Wave Height (m)	Wave Period (s)	Wave direction
Ramassun / Glenda 2014	3.6	10.93	SW-5^o
Xangsane / Milenyo 2006	4.45	11.20	SW-10^o
Fengshen / Frank 2008	4.2	12.52	WNW

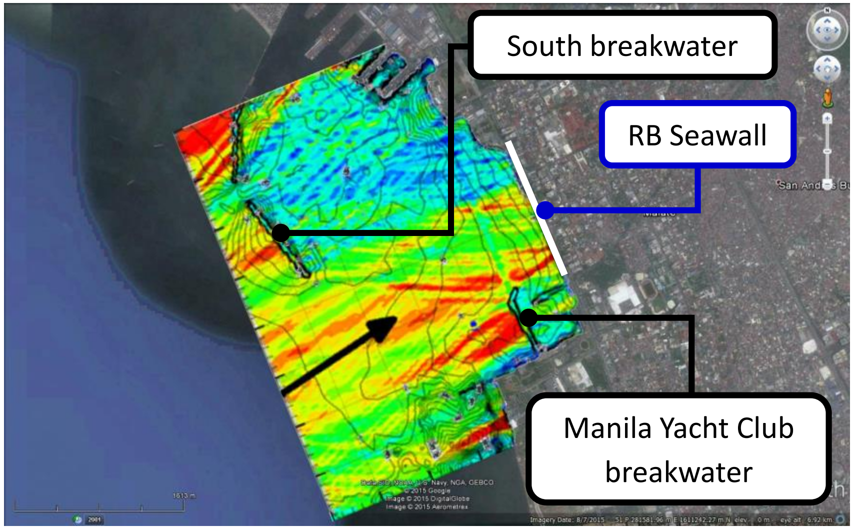
TYPHOON ANALYSIS

Wave Runup

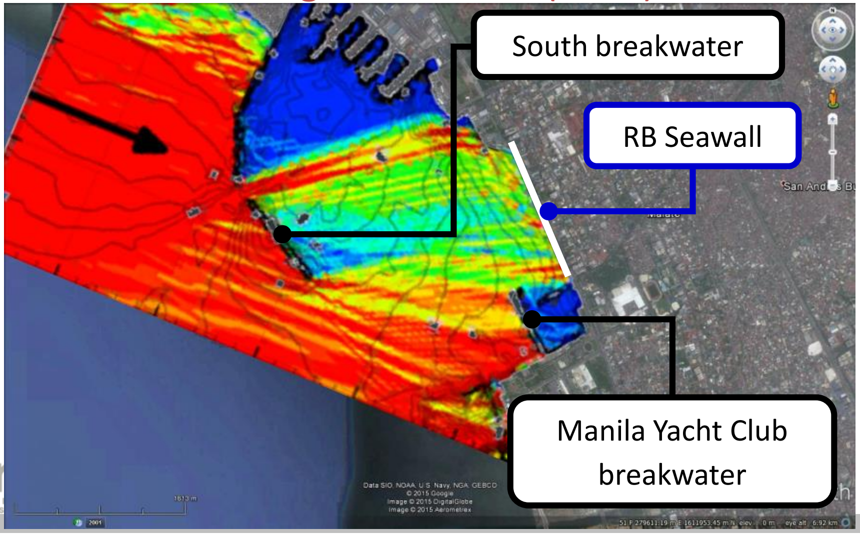
Results - Rammasun / Glenda (2014)

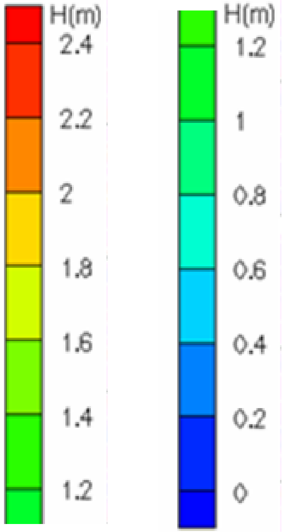


Results – Xangsane / Milenyo (2006)

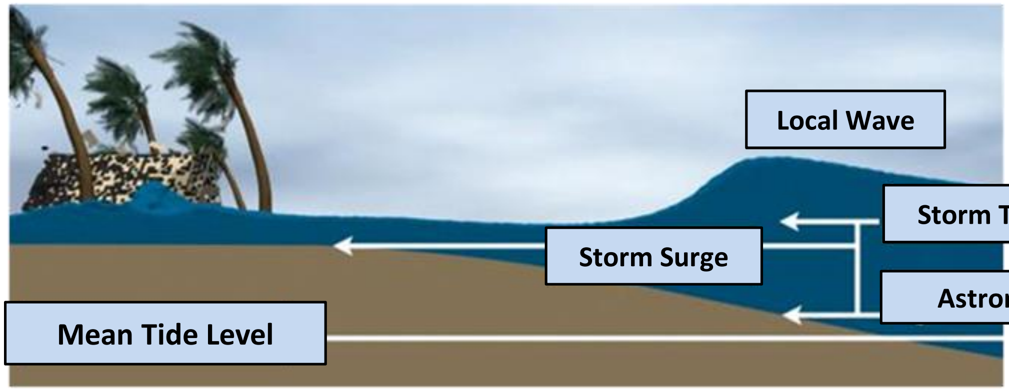


Results Fengshen / Frank (2008)





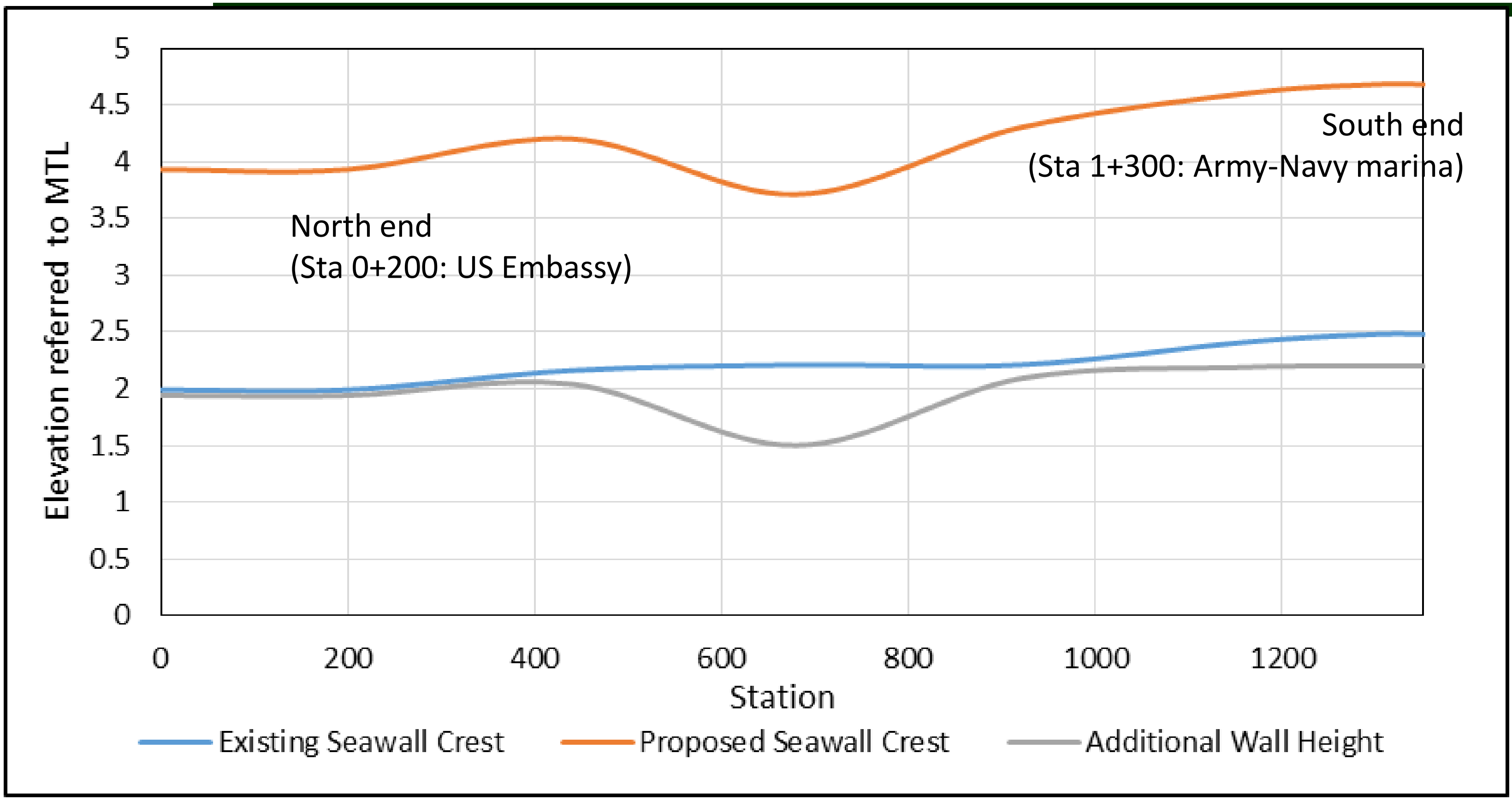
- Results of the analysis were compared to the crest elevation of the existing seawall.



Typhoon	Vertical Siting for STL and Waves (m above MTL)			
	Maximum wave runup	Minimum Deficit	Maximum Deficit	**Required Vertical Siting**
Rammasun 2014	2.23	1.50	2.18	**4.59**
Xangsane 2006	2.51	1.41	2.19	**4.60**
Frank 2008	2.92	0.05	2.20	**4.68**

COASTAL ENGINEERING

Vertical Siting

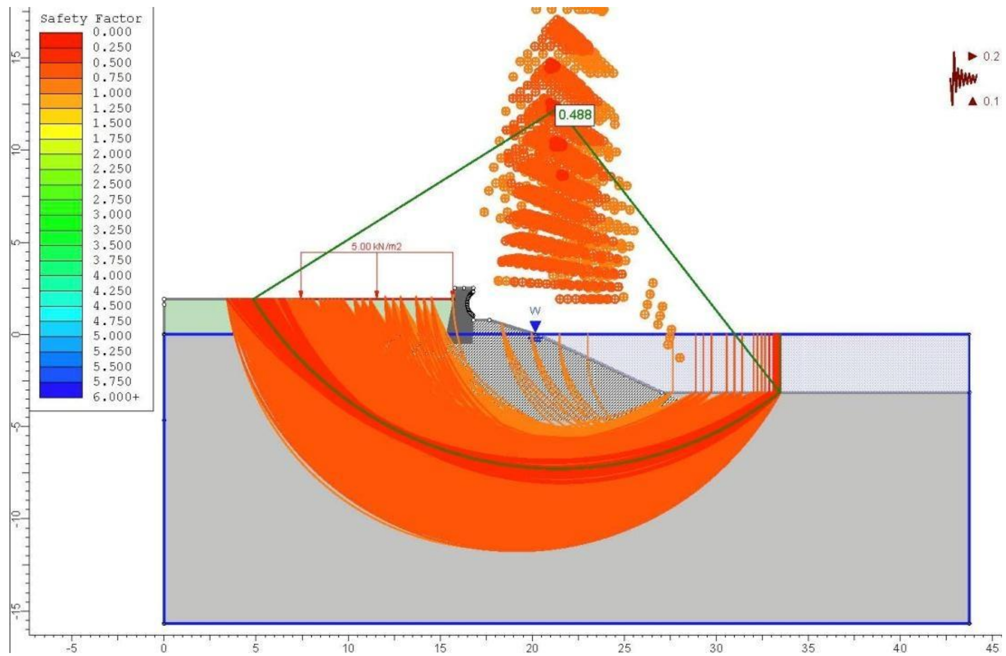


	Seawall Stationing					
Seawall Stationing	0+200	0+440	0+680	0+920	1+160	1+300
Seawall Crest Elev.	1.99	2.16	2.21	2.21	2.41	2.48
Vertical Siting (= STL + Wave runp)	3.93	4.20	3.71	4.30	4.60	4.68
Additional wall height (m)	1.94	2.04	1.50	2.09	2.19	2.20

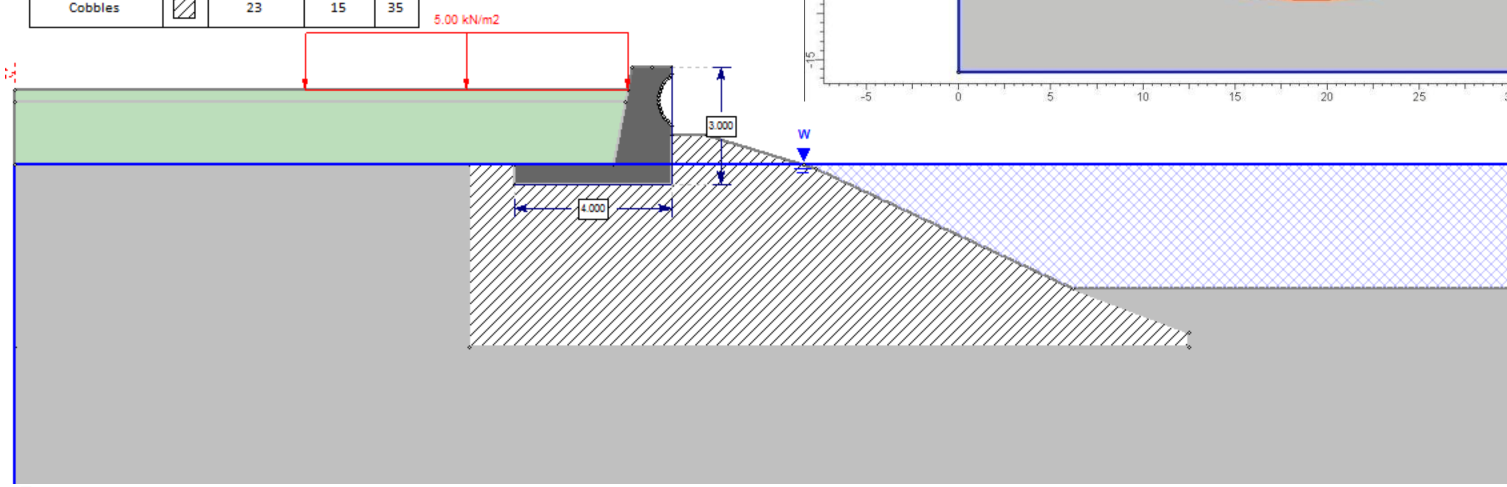
GEOTECHNICAL ENGINEERING

Geotechnical Investigation

- Stability Analysis under Earthquake Condition considering the reduction in soil strength due to liquefaction using Slide™



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Concrete		24	200	35
Compacted Sand		18	1	30
Loose Sand		16	1	14
Cobbles		23	15	35



- Considering the presence of the boulder layer, the utilization of **shallow foundation** is feasible.

- Cost comparison between the use of shallow foundation and pile foundation is provided below for reference.

Foundation System	Indicative Costs per linear meter	Remarks
Shallow Foundation	~ PhP 120,000.00 ~ USD 2,300.00	This includes the rehabilitation of the seawall should liquefaction occur.
Deep Foundation	~ PhP 360,000.00 ~ USD 6,800.00	This includes bored pile construction only.

PRELIMINARY ENGINEERING

Preliminary Engineering

- Vertical Siting (foregoing)
- Seawall Stability Analysis
- Seawall Cross Section

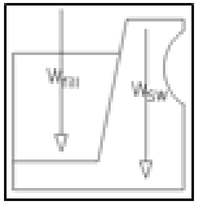
Design Cases:

1. Storm Conditions
2. Non-Storm Condition

Loads and Load Combinations:

- Philippine Ports Authority (PPA) Design Guidelines
- National Structural Code of the Philippines (NSCP)
- Coastal Engineering Manual

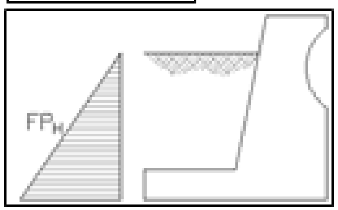
Case 1: Storm Condition



Dead Load – Dead weight of the concrete seawall structure and fill within the seawall footing.

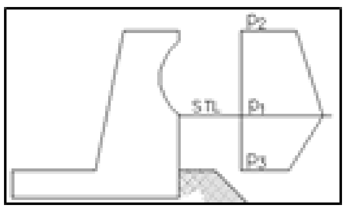
W_{sw} = 100.67 kN/m

W_{fill} = 95.59 kN/m



Passive Earth Pressure – Stabilizing Passive Force due to the backfill on the leeward side of the seawall.

FP_H = 305.03 kN/m

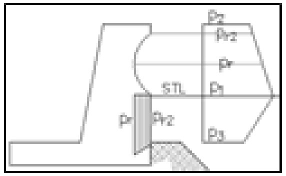


Wave Force – Force Generated by wave hitting the seawall, solved by using the Goda Formula from the Coastal Engineering Manual.

p_1 = 33.03 kN/m²

p_2 = 15.54 kN/m²

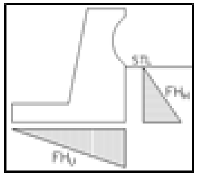
p_3 = 32.98 kN/m²



Upward Force due to Seawall Geometry – Wave force that was added because of the geometry of the re-entrant, based on the calculated wave forces.

p_r = 21.95 kN/m²

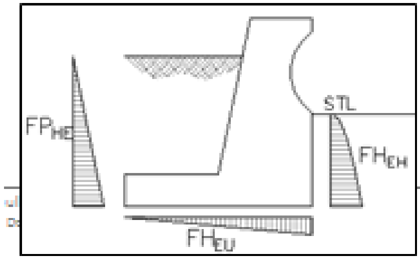
p_{r2} = 17.04 kN/m²



Hydrostatic Force – Hydrostatic forces composed of Horizontal component and Uplift due to seepage.

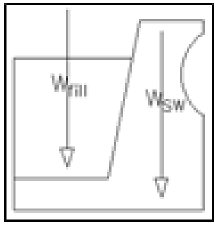
FH_H = 2.2 kN/m

FH_U = 13.33 kN/m



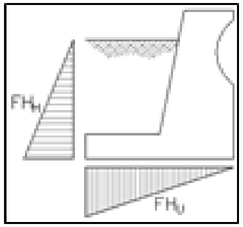
Earthquake Forces – Earthquake forces from soil and hydrostatic forces determined by multiplying seismic coefficient and obtained formula from PPA.

Case 2:
Non-storm Conditions



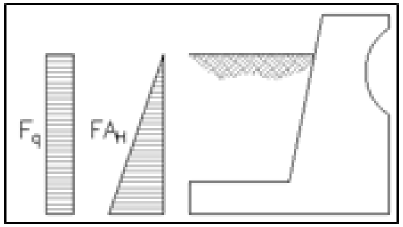
Dead Load – Dead weight of the concrete seawall structure and fill within the seawall footing.

W_{SW} ~~= 100.66~~ kN/m
W_{fill} = 95.59 kN/m



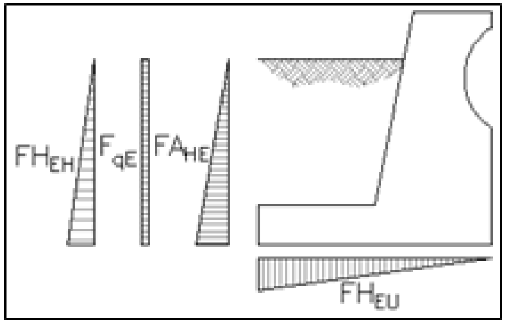
Hydrostatic Force – Hydrostatic forces composed of Horizontal component and Uplift due to seepage.

FH_H = 29.09 kN/m
FH_U = 48.48 kN/m



Active Earth Pressure – Overturning Active Force due to the backfill on the leeward side of the seawall and estimated surcharge based from NSCP.

FA_H = 33.82 kN/m
F_q = 3.33 kN/m

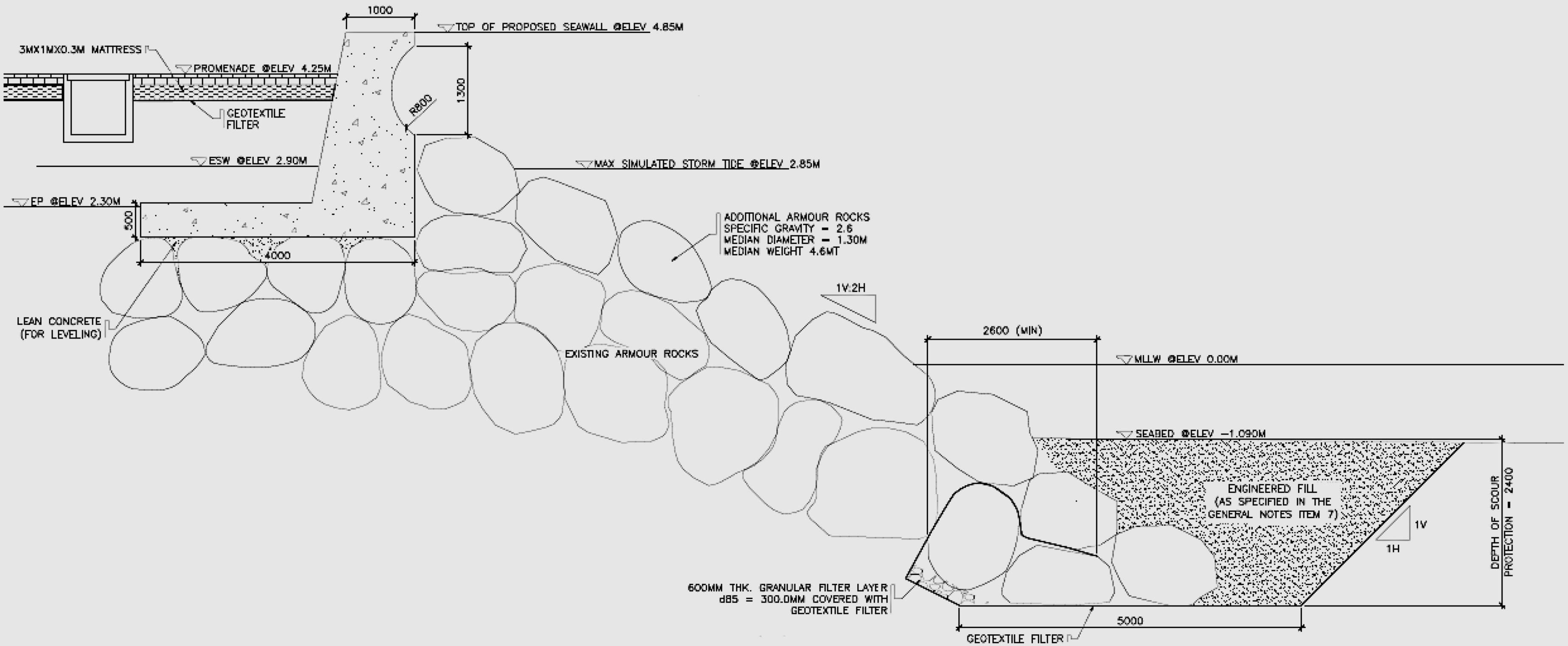


Earthquake Forces – Earthquake forces from soil and hydrostatic forces determined by multiplying seismic coefficient and obtained formula from PPA.

FA_{HE} = 25.12 kN/m
F_{qE} = 2.47 kN/m
FH_{EH} = 6.55 kN/m
FH_{EU} = 5.45 kN/m

PRELIMINARY ENGINEERING

Seawall Cross-section



PRELIMINARY ENGINEERING

- ✓ Seawall Promenade is raised to maintain view of Manila Bay sunset from land
- ✓ Interior drainage to allow overtopping water to flow back to sea or detained temporarily

CONCLUSIONS

- Historical typhoons tracking within the project seawall are analyzed to obtain historical storm tide levels and wave runup
- The non-overtopping crest elevation (MTL +4.68 m) is used as basis of the crest elevation of the rehabilitated seawall.
- A geotechnical investigation and analysis established that a shallow foundation is best for the seawall site considering safety and economy.
- Preliminary engineering is completed by carrying out external stability analyses to obtain seawall geometry and cross-section
- The access to the sunset view of the bay is considered in the site development concept.

THANK YOU for your attention.