Design, Engineering and Construction of a Wave Wall for the Northwestern University

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SMITHGROUP

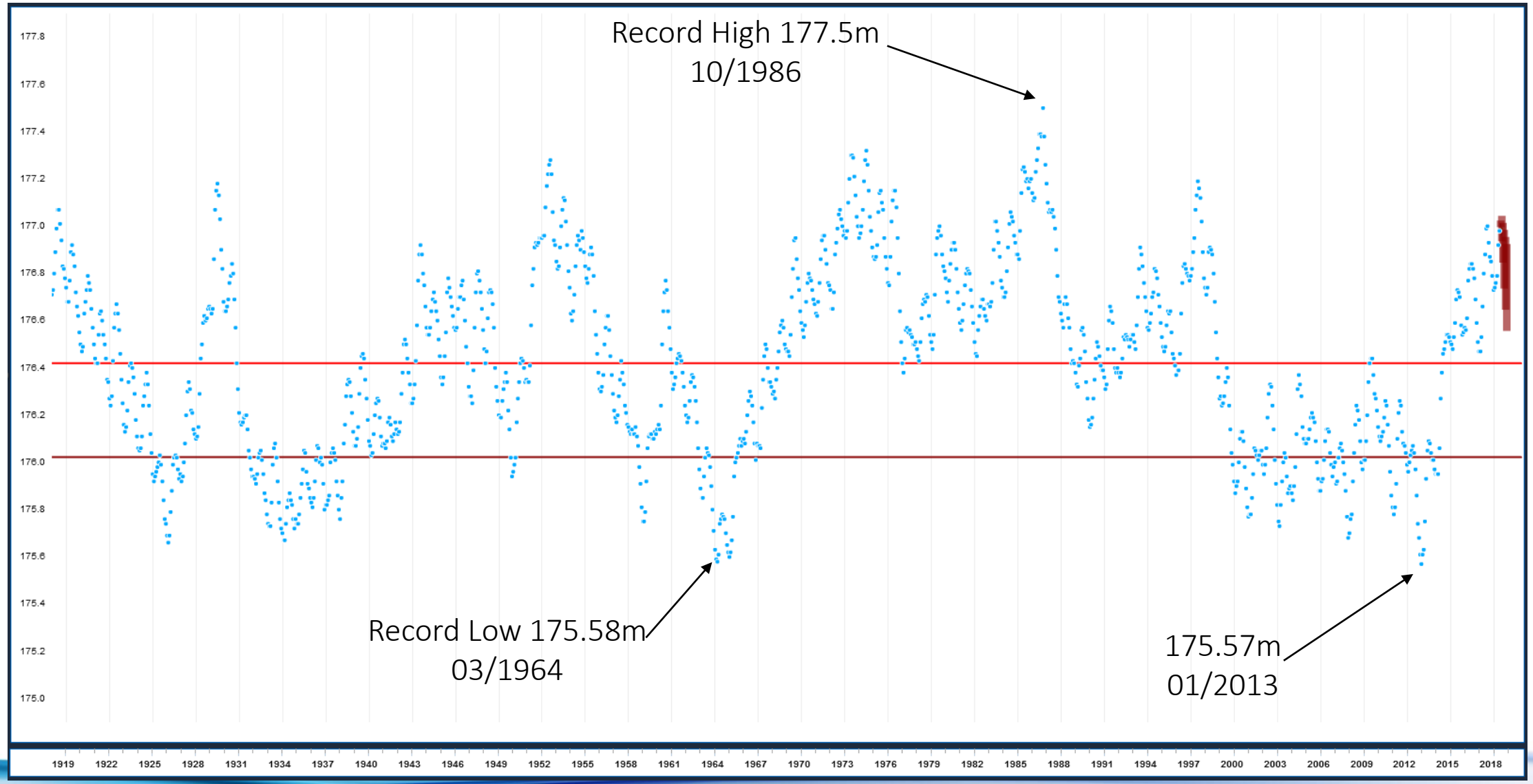
ICCE 2018

Introduction

Northwestern University sits on prime Lake Michigan real estate in Evanston, Illinois, north of Chicago.

Needing to make the most out of their landlocked urban campus, they planned to build a new athletics center on coastal land extending onto a sandy beach.


WILDCATS


Lake Michigan Surface Water Elevation (m)
177.8
177.6
177.4
177.2
177.0
176.8
176.6
176.4
176.2
176.0
175.8
175.6
175.4
175.2
175.0
1919
1922
1925
1928
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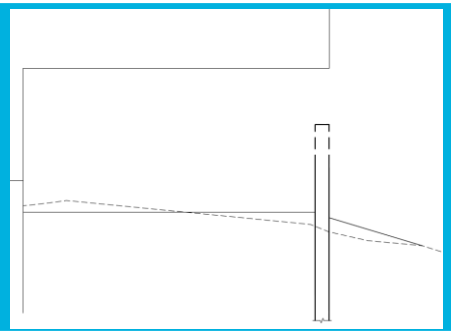
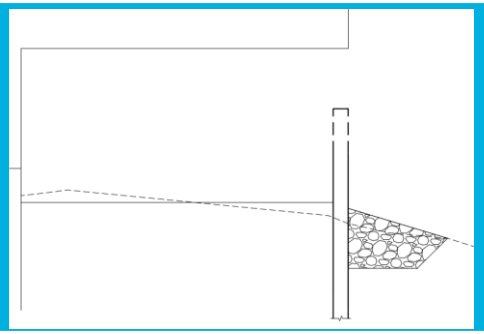
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
Record High 177.5m
10/1986
Record Low 175.58m
03/1964
175.57m
01/2013

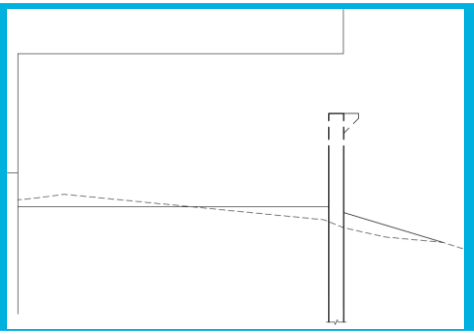
PRELIMINARY CONCEPTS



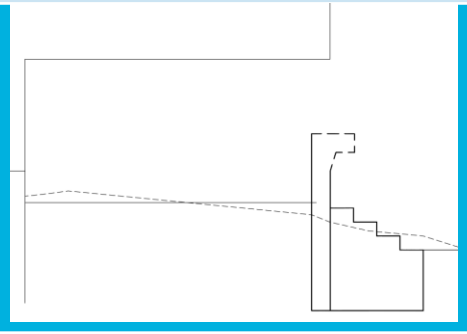
STRAIGHT VERTICAL SEAWALL



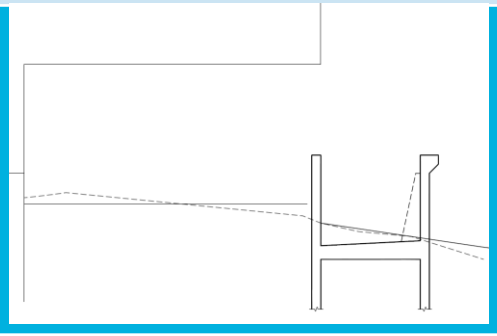
SEAWALL WITH SCOUR PROTECTION



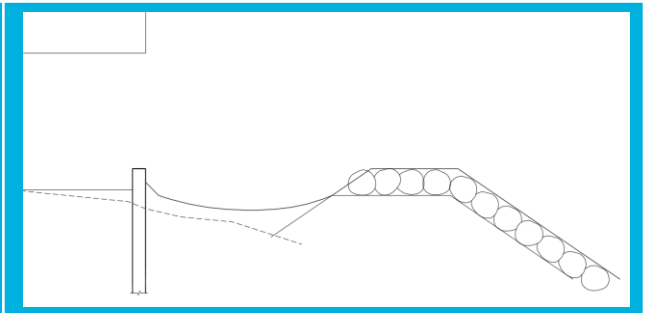
SEAWALL WITH RECURVED PARAPET



RECURVED PARAPET WITH STEPPED TOE



DOUBLE SEAWALL WITH RECURVED PARAPET



WAVE ABSORBING REVETMENT

NOTE: FINISHED LOWER FLOOR ELEVATION IS +10 FT ECD,
FINISHED FIRE LANE ELEVATION IS +7 FT ECD,
CLEARANCE ELEVATION FOR THE MAIN FLOOR
BUILDING OVERHANG IS ELEVATION + 22 FT

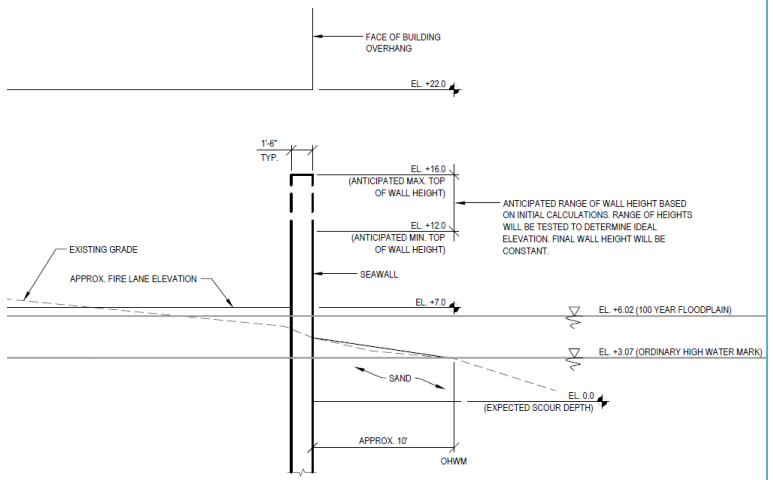
- 1% JOINT PROBABILITY OF OCCURRENCE P(A,B) = P(A)*P(B) = 0.01 = FEMA STANDARD

ALL COMBINATIONS OF WATER LEVEL AND STORM INTENSITY CONSIDERED HAVE EQUAL PROBABILITY OF OCCURRING

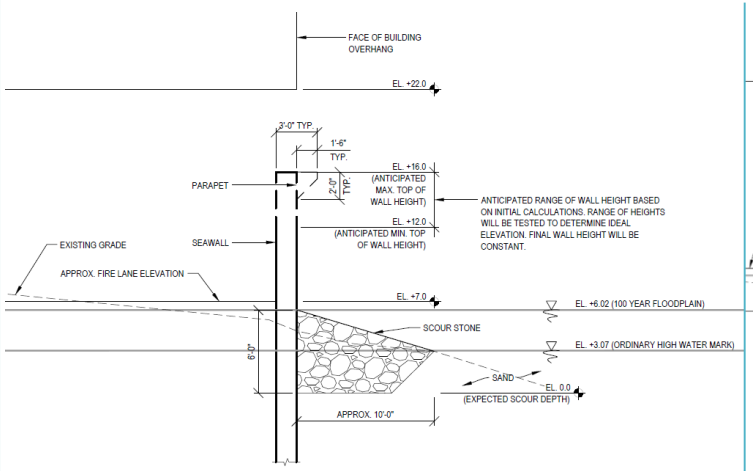
Conditions 160 ft offshore (Dominant NE Waves)

Joint Return Period Combinations	Significant Wave Height, Hs (ft)	Peak Wave Period, Tp (sec)	Water Level, Ref ECD (ft)
1 yr WL / 100 yr Storm	5.2	10.5	3.37
5 yr WL / 20 yr Storm	5.6	10.5	3.97
10 yr WL / 10 yr Storm	5.8	10.5	4.17
20 yr WL / 5 yr Storm	5.9	10.0	4.47
50 yr WL / 2 yr Storm	6.0	10.0	4.77
100 yr WL / 1 yr Storm	6.0	9.4	5.07

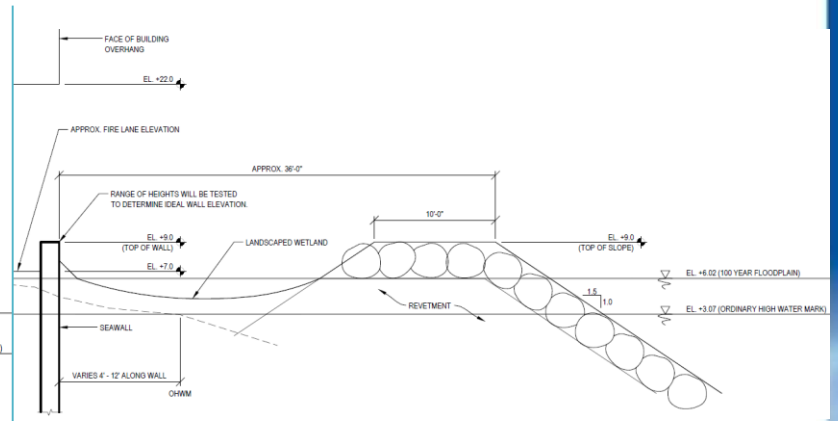
Tested Protection Concepts



STRAIGHT VERTICAL SEAWALL



SEAWALL WITH RECURVED PARAPET



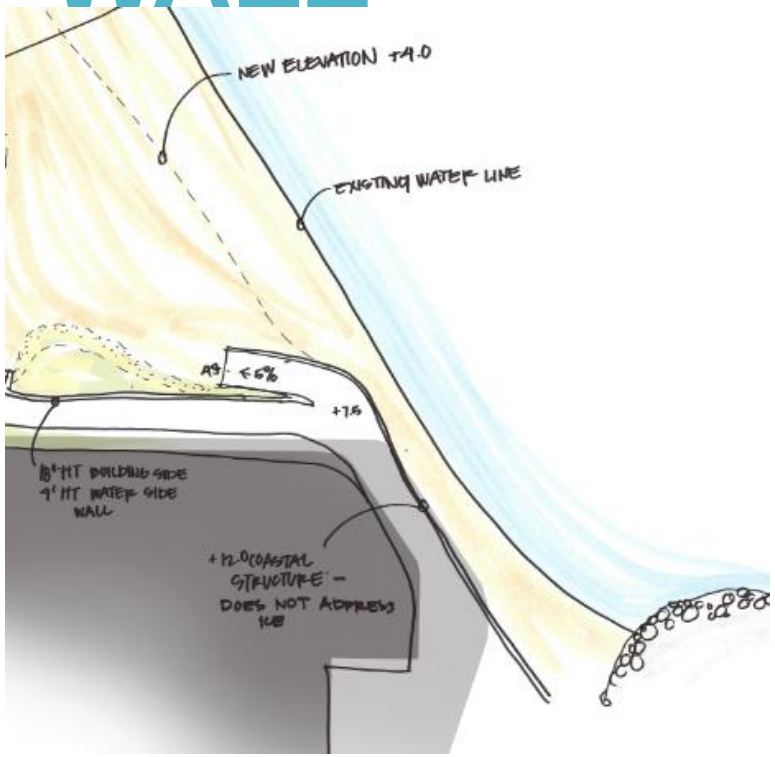
WAVE ABSORBING REVETMENT

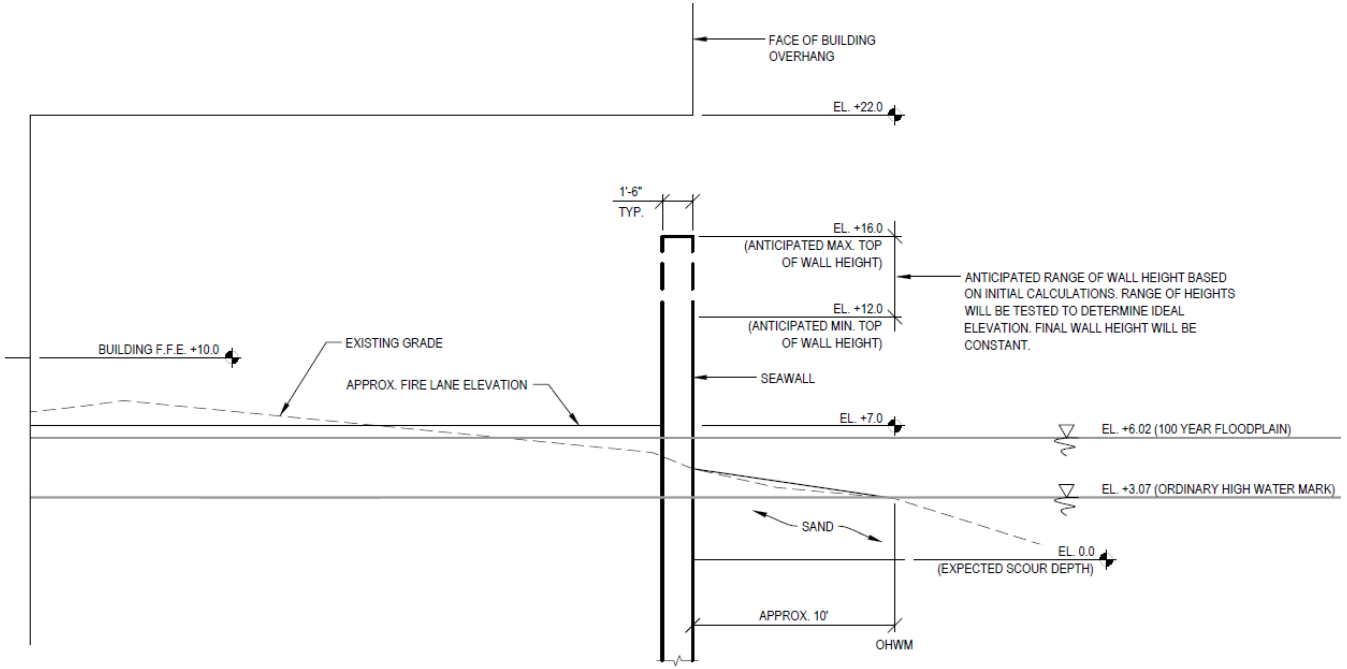
Model Construction

PLACING SAND BEACH

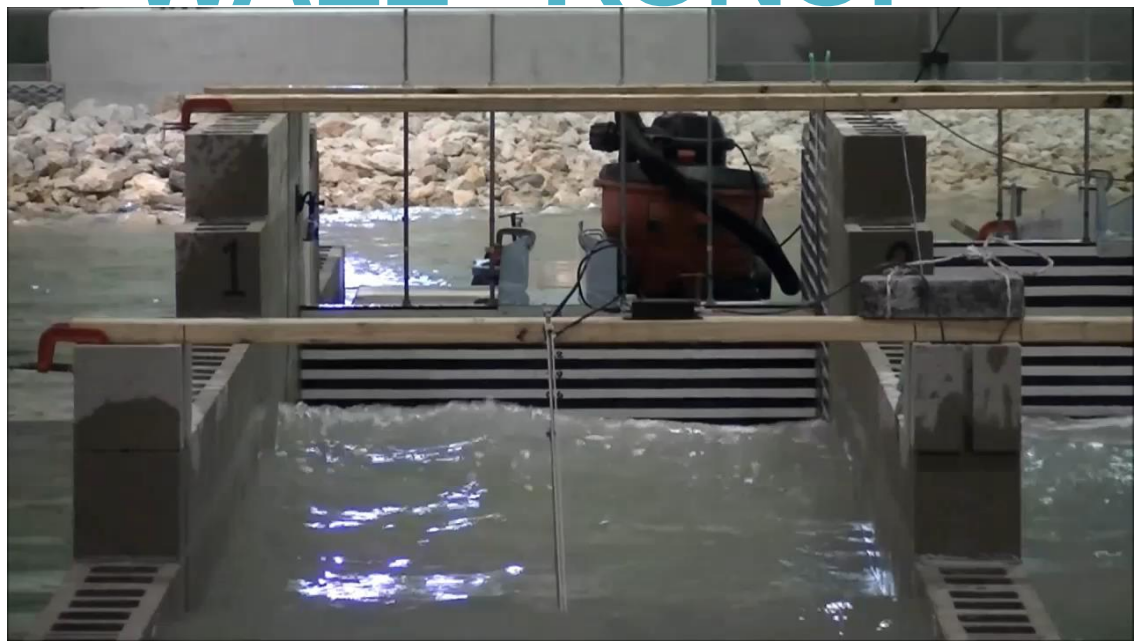
PLACING CONCRETE COVER

STRAIGHT VERTICAL WALL

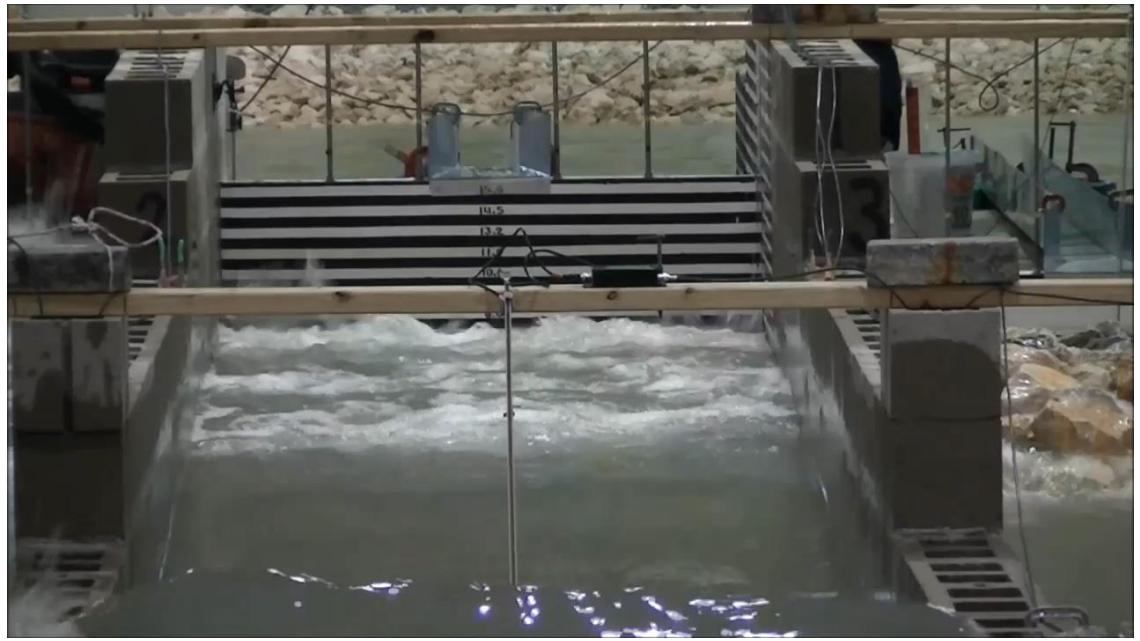




STRAIGHT VERTICAL WALL - RUNUP



ELEVATION + 12 FT ECD (5.0 FT WALL ABOVE ROAD)



ELEVATION + 16 FT ECD (9.0 FT WALL ABOVE ROAD)

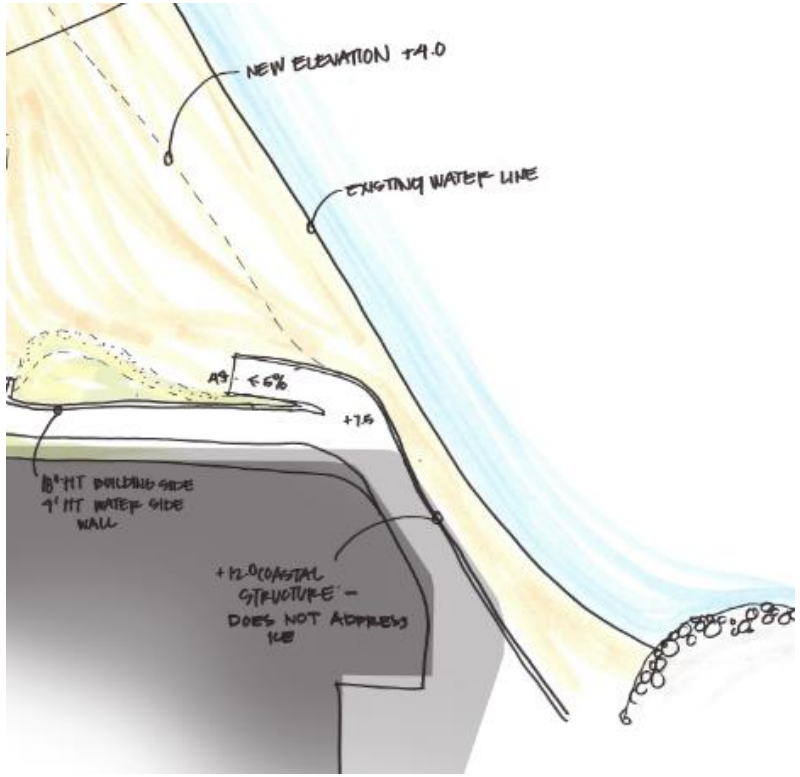
STRAIGHT VERTICAL WALL - OVERTOPPING

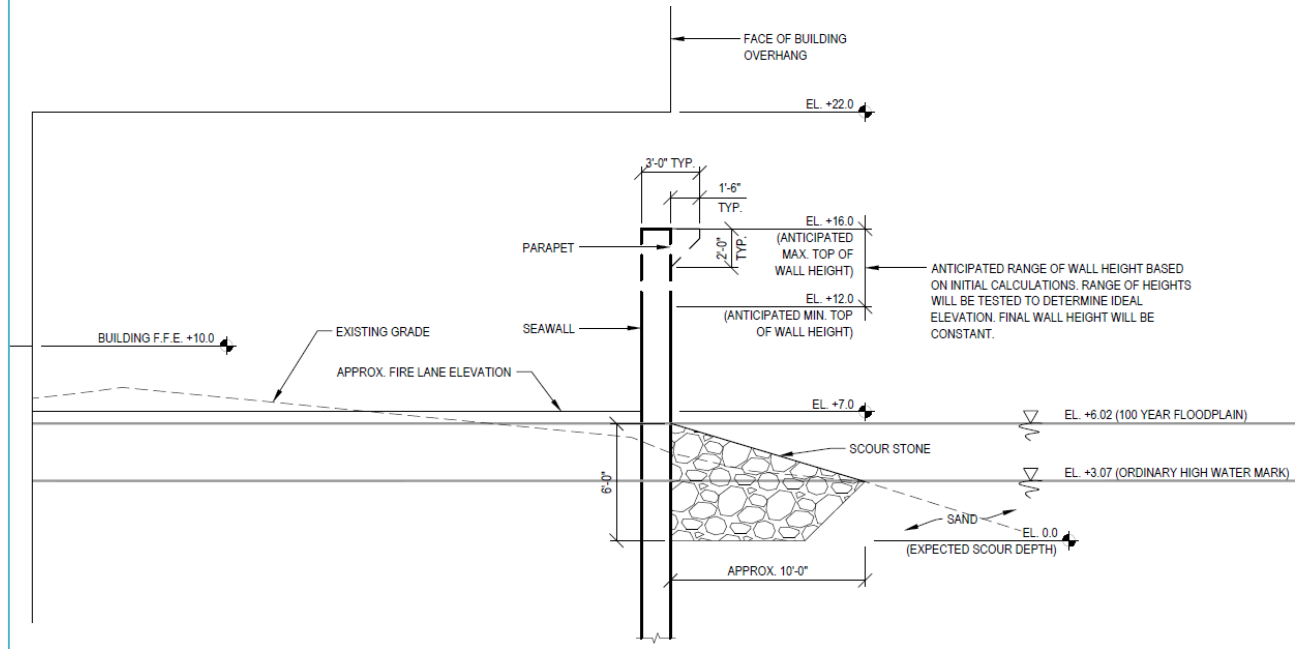
ELEVATION +16 FT ECD (9.0 FT WALL ABOVE ROAD)

ELEVATION + 12 ECD (5.0 FT WALL ABOVE ROAD)

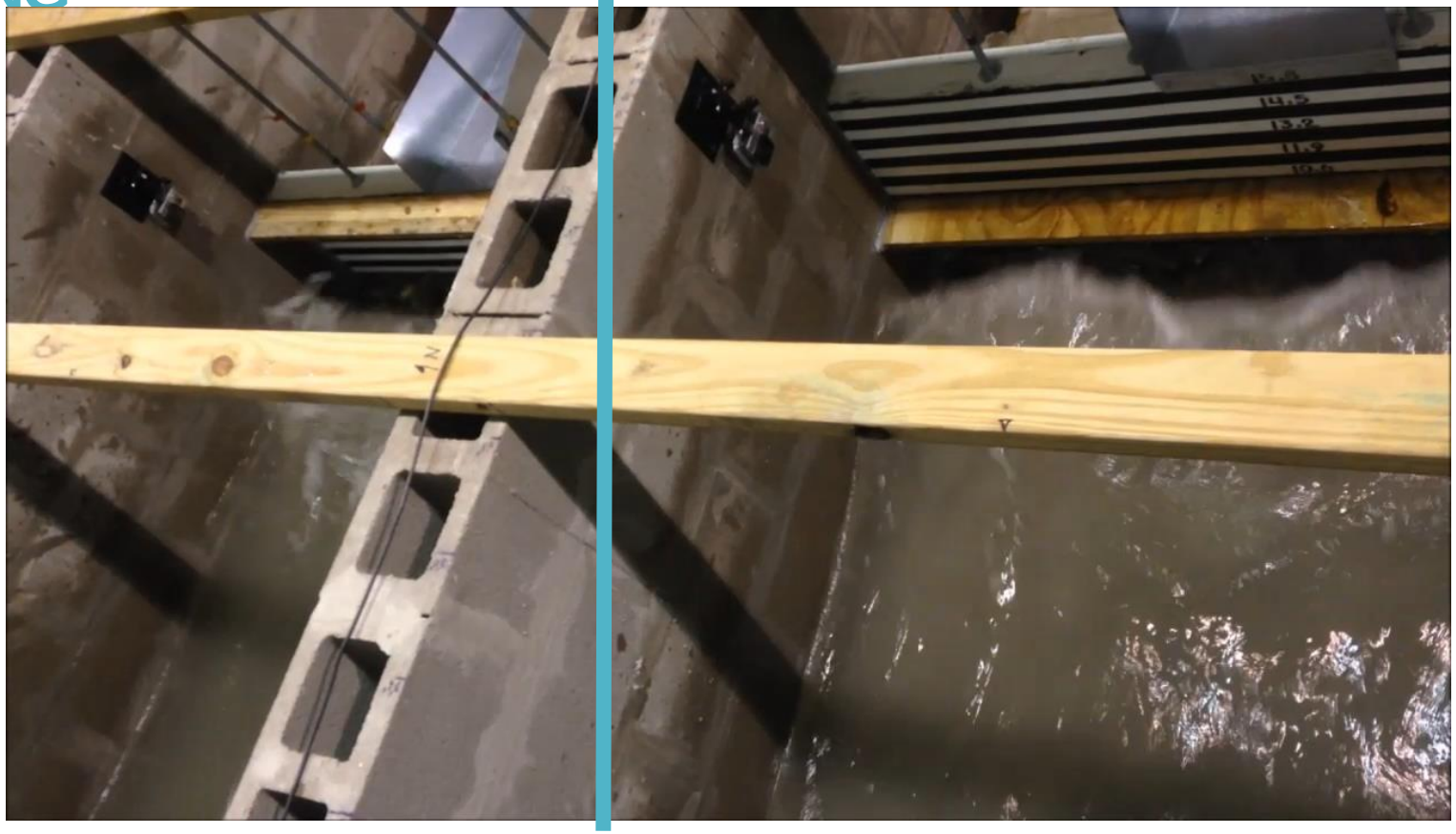
NOTE OVERTOPPING OCCURS AT BOTH WALL HEIGHTS

SEAWALL WITH RECURVED PARAPET





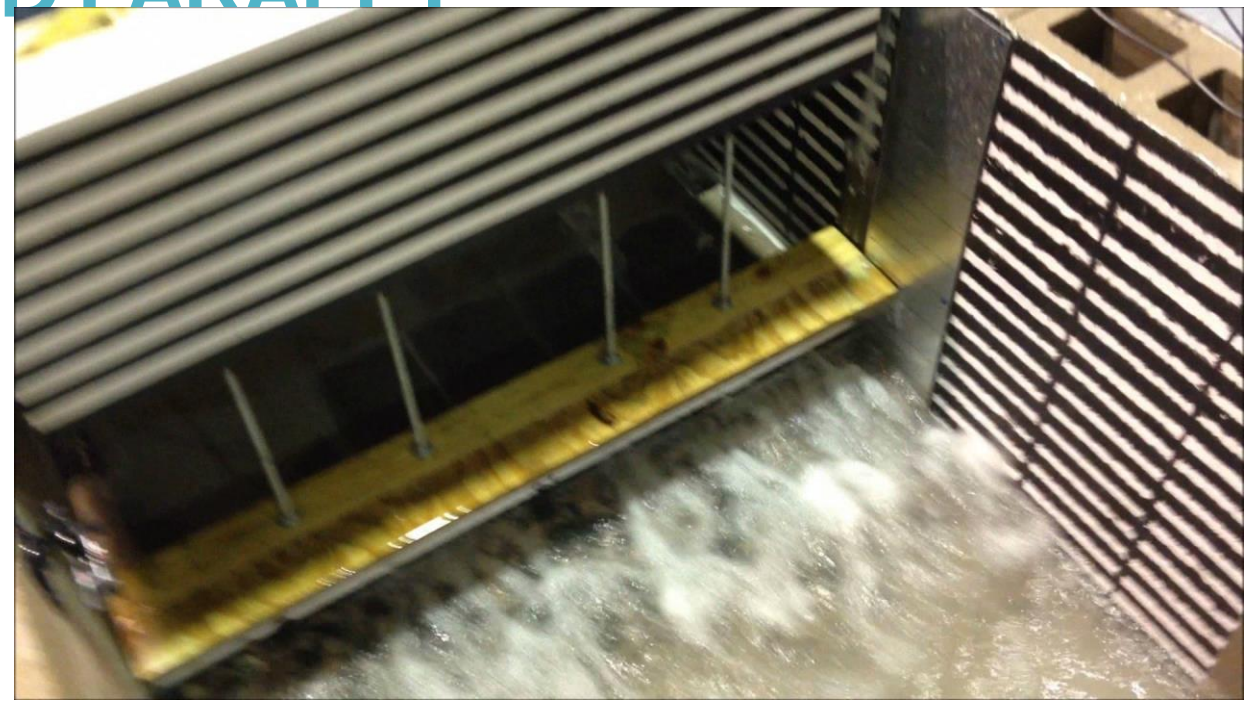
SEAWALL WITH RECURVED PARAPET – RUNUP AND OVERTOPPING



ELEVATION + 10.3 FT ECD
(5.0 FT ABOVE ROAD)

ELEVATION + 9.3 FT ECD
(2.3 FT ABOVE ROAD)

REVISED CONCEPT – SEAWALL WITH RECURVED PARAPET

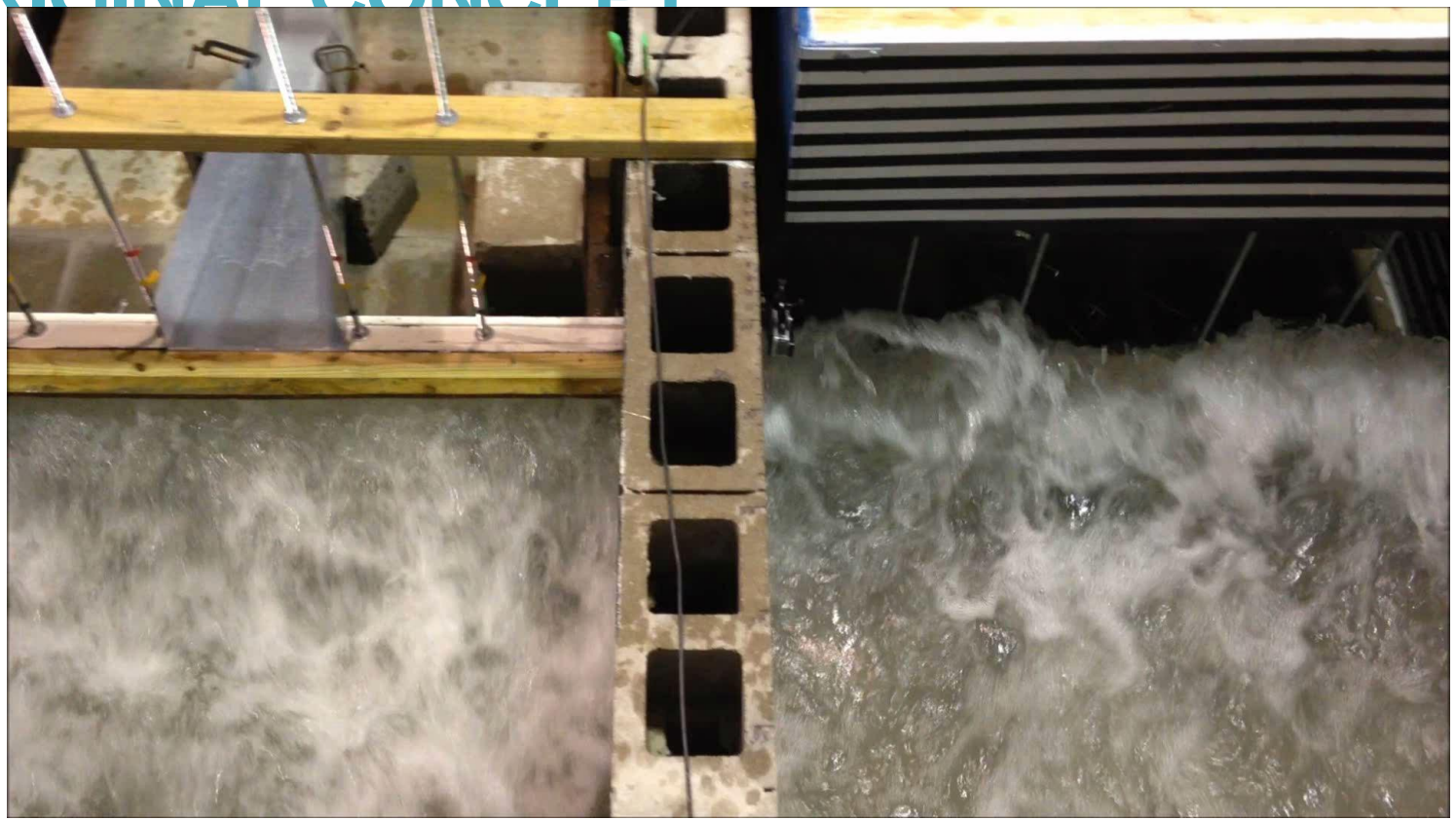


ELEVATION +10.3 FT ECD (3.3 FT WALL ABOVE ROAD)

NOTE OCCASIONAL OVERTOPPING OF PARAPET WALL

NOTE: HORIZONTAL FORCES MEASURED AGAINST SEAWALL ≈ 20 KIPS/FT

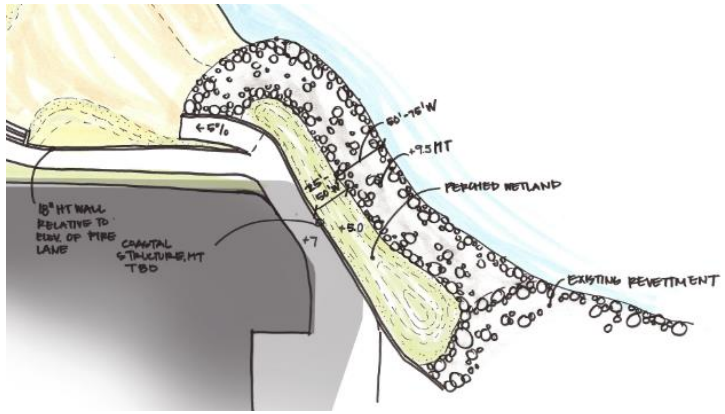
COMPARISON: REVISED CONCEPT VERSUS ORIGINAL CONCEPT

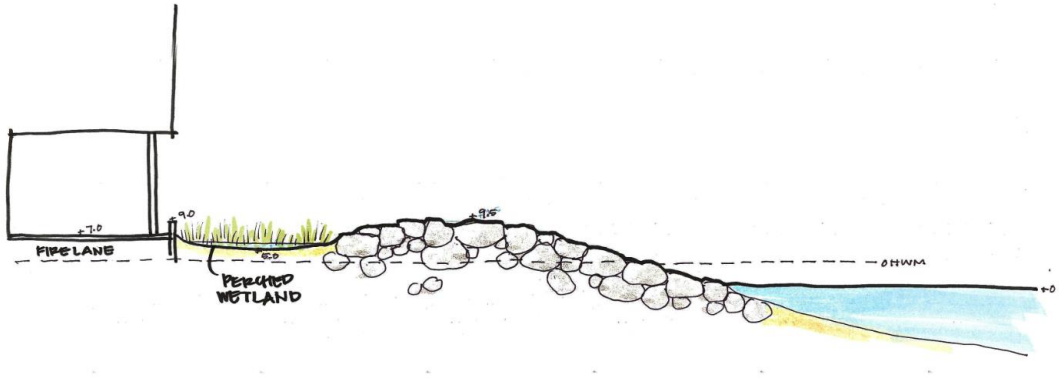


REVISED CONCEPT ELEVATION +12 FT ECD (5.0 FT WALL ABOVE ROAD)

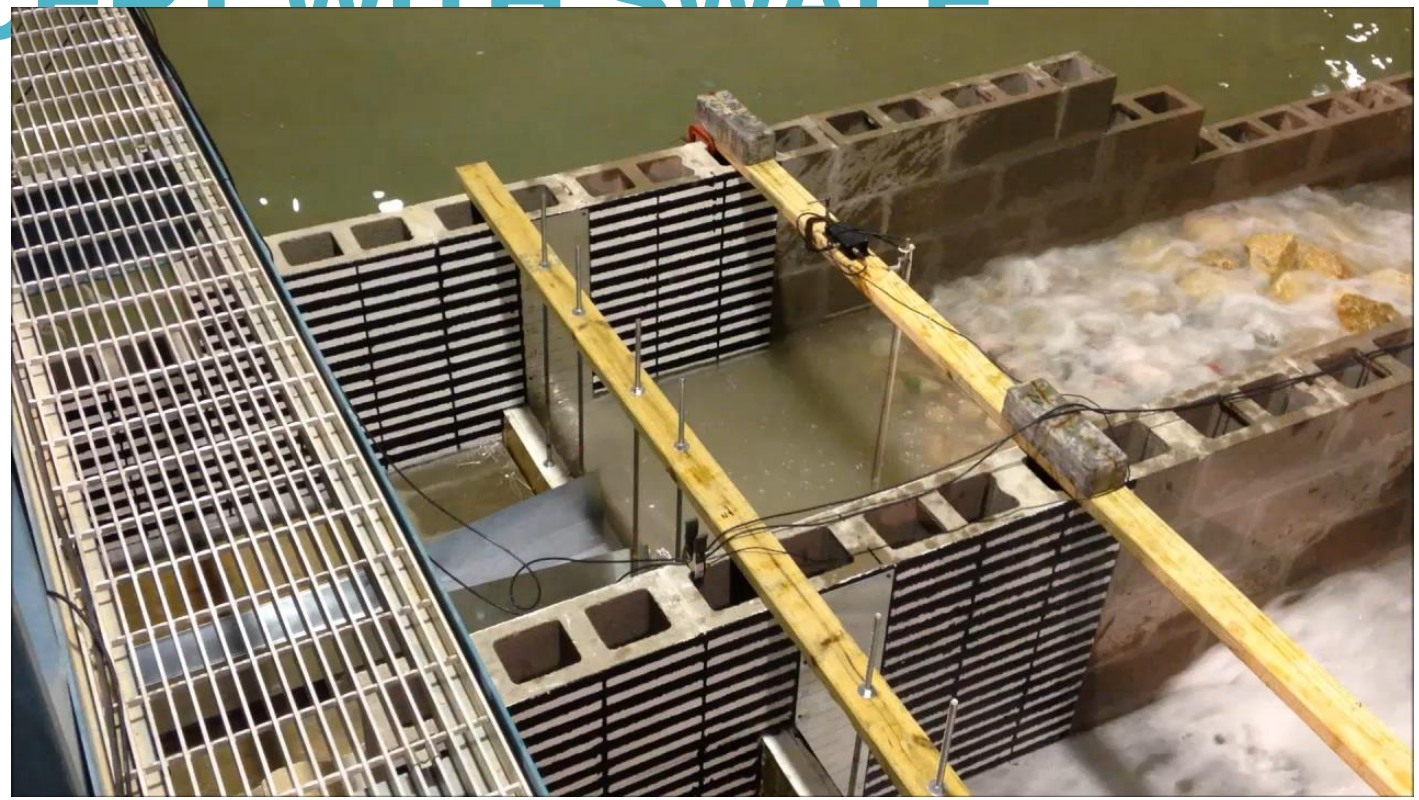
ORIGINAL CONCEPT ELEVATION +9.3 ECD (2.3 WALL FT ABOVE ROAD)

WAVE ABSORBING REVETMENT





ORIGINAL REVETMENT CONCEPT WITH SWALE

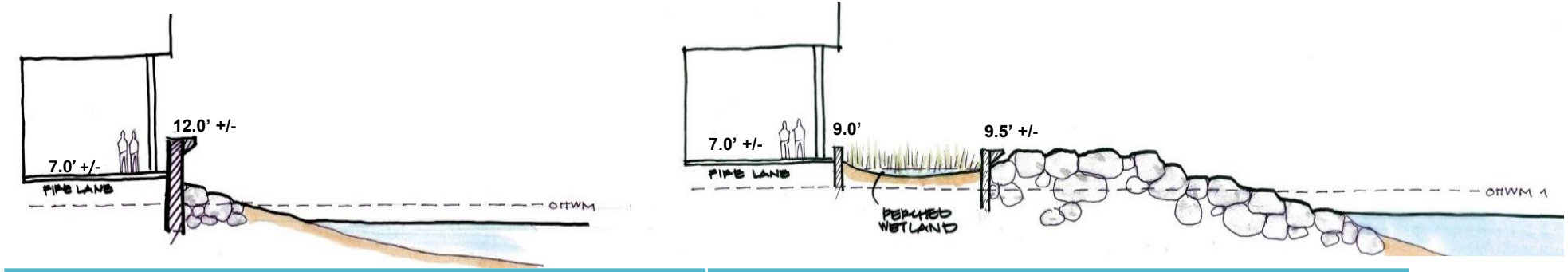


REVISED REVETMENT WITH SWALE & CUT-OFF WALL

REVETMENT & CUTOFF WALL ELEVATION + 9.5 FT ECD, REAR WALL ELEVATION + 9.3 FT ECD (2.3 FT ABOVE ROAD)

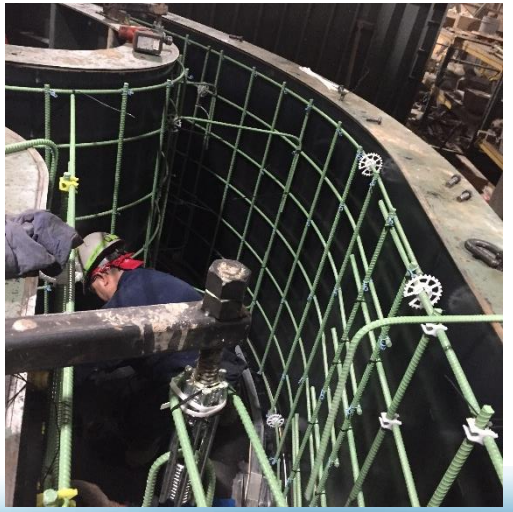
NOTE LACK OF PONDING CONTROLLED BY CUTOFF WALL AND DRAINAGE MANAGEMENT

Discussion



SEAWALL WITH RECURVED PARAPET		WAVE ABSORBING REVETMENT	
Pro	Con	Pro	Con
1. Structure stays within OHWM limit 2. Reduced public involvement in the permit process 3. Effective in minimizing direct spray and overtopping at EL + 12 ECD (5.0ft above road).	1. Exceedingly high & sharp wave loads 2. High cost of wall 3. Risk in icing events 4. Increased risk of splash and building icing for seawalls < +12 ft 5. Toe scour protection will extend outside OHWM; Scours down 6 ft+ without protection	1. Effective at all water levels 2. Effective against ice 3. Minimal splash/spray 4. Provides a "green" design solution 5. Retains a larger open view to the lake	1. Involves lake fill 2. May be more challenging to permit with greater public exposure required 3. Will require more demonstration of non-impact to adjacent properties

Construction

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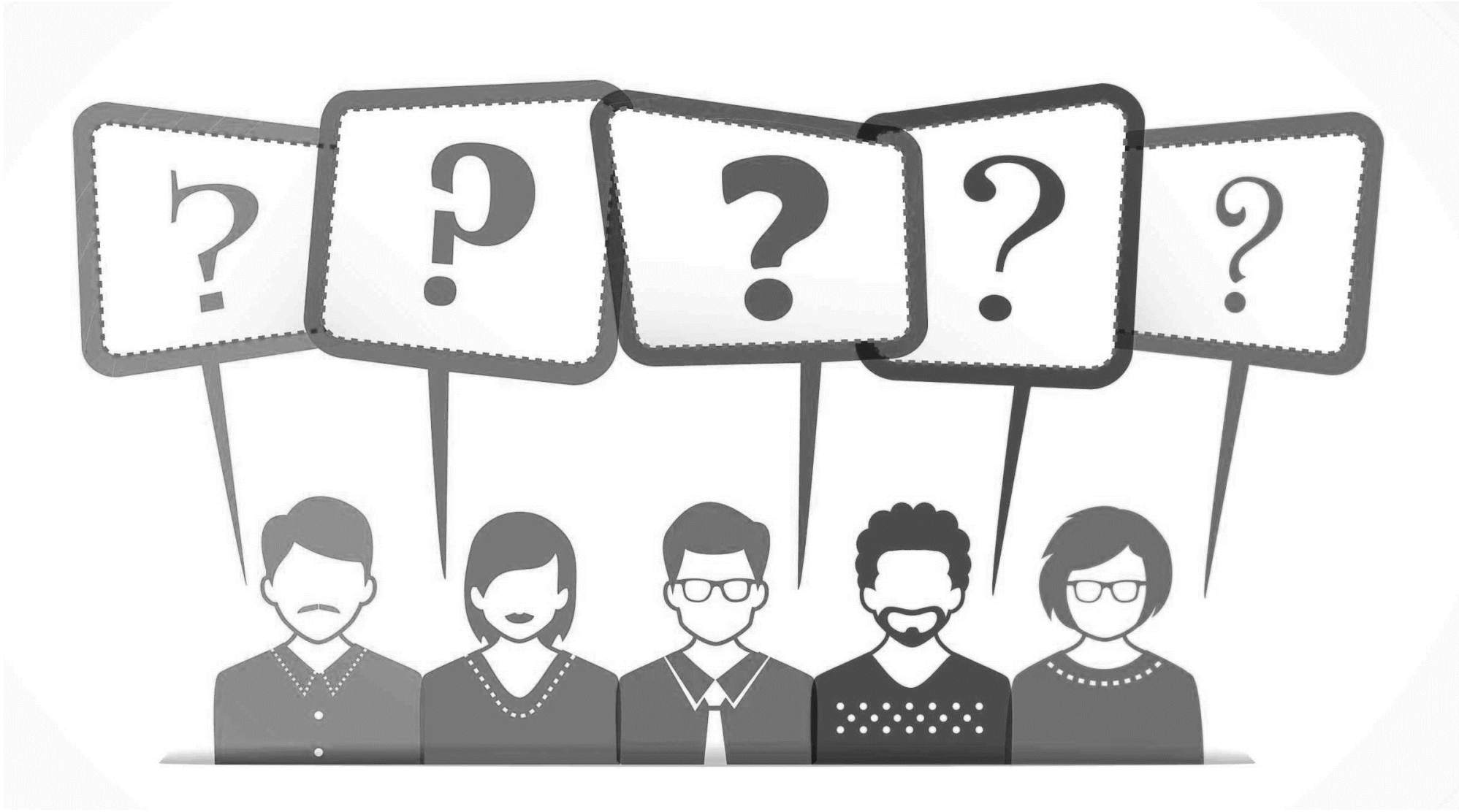
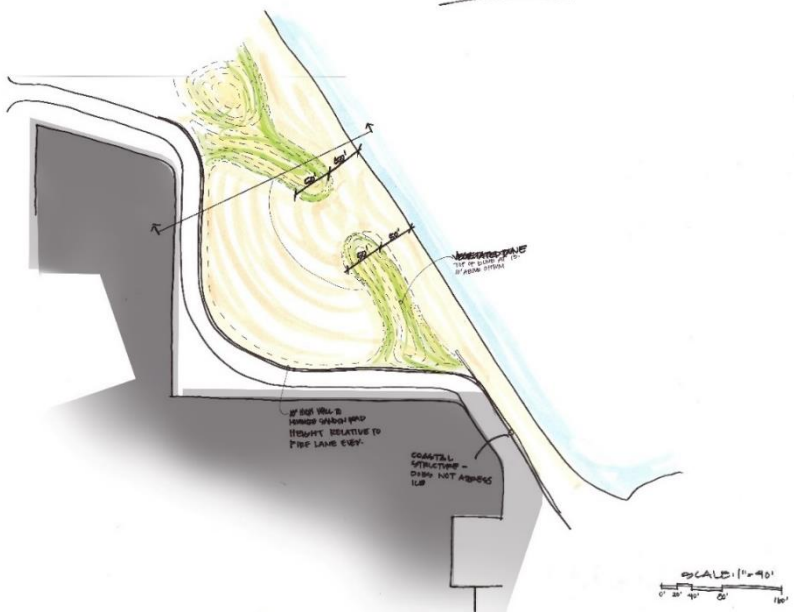
ATHLETIC CENTER WAVE WALL EVANSTON,IL

Conclusions

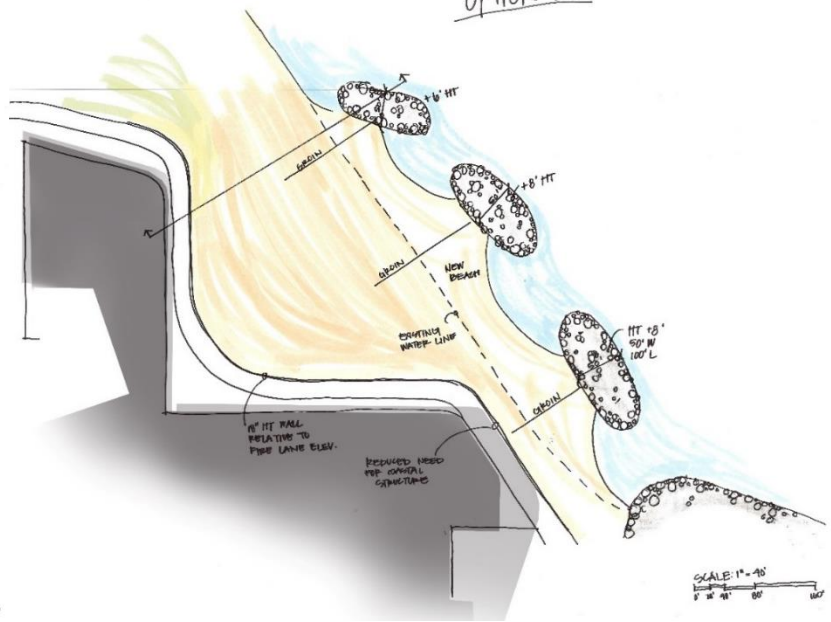
- A full site analysis was performed to determine the lake conditions at various water levels using offshore and nearshore numerical models.
- Wave climate, longshore currents, and cross-shore stability were modeled to gain an understanding of the dynamic nature of the existing beach.
- Based on the information collected, a physical model was built and beach run-up and overtopping were determined for different mitigation alternatives.
- Based on the results the seawall with recurved parapet was chosen and designed to achieve a high level of performance while minimizing regulatory process.
- A 90-degree return was incorporated into the wall's design to limit water overtopping as well as aerated spray against the building.
- The curvilinear wall was designed to blend into its surroundings while expressing itself as an architectural feature.



OPTION 1



OPTION 2



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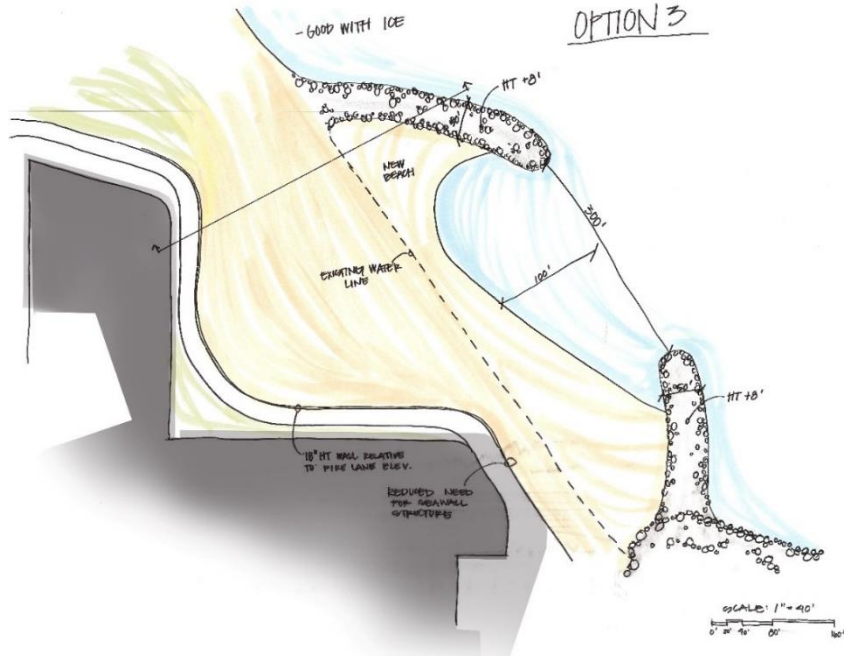

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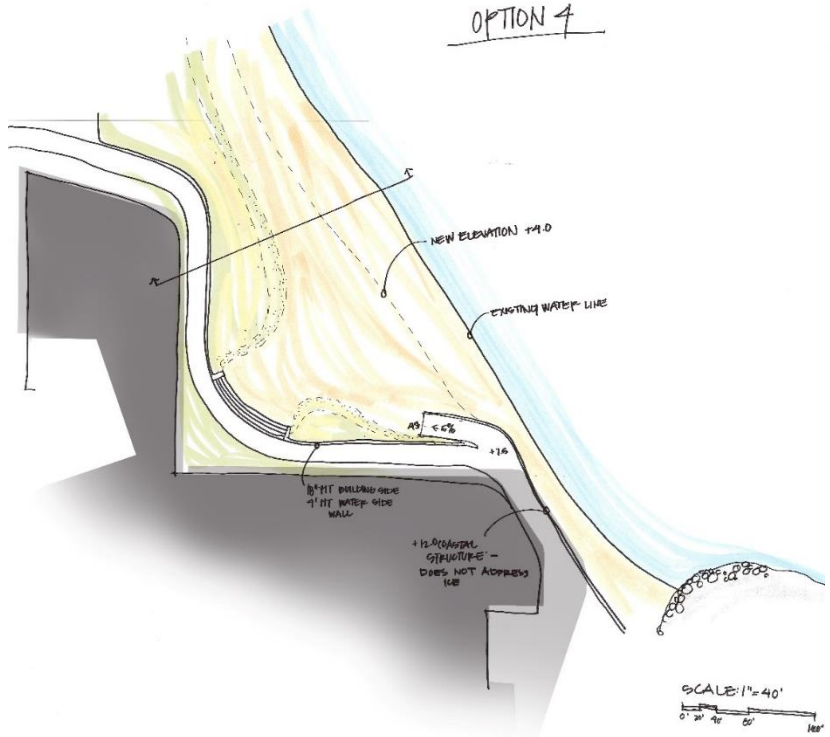

OPTION 5