

36th International Conference on  
Coastal Engineering 2018

# COASTAL RESILIENCY: MULTI- TIER PROTECTION SYSTEM & RISK MANAGEMENT STRATEGY

NEVIS, WEST INDIES

Robert Sloop, PE  
Jackie Brower, PhD  
Matt Trowbridge, PE SE



# WHERE'S NEVIS?



# NEVIS – WHATS IT LIKE?



# FOUR SEASONS RESORT – ORIENTATION



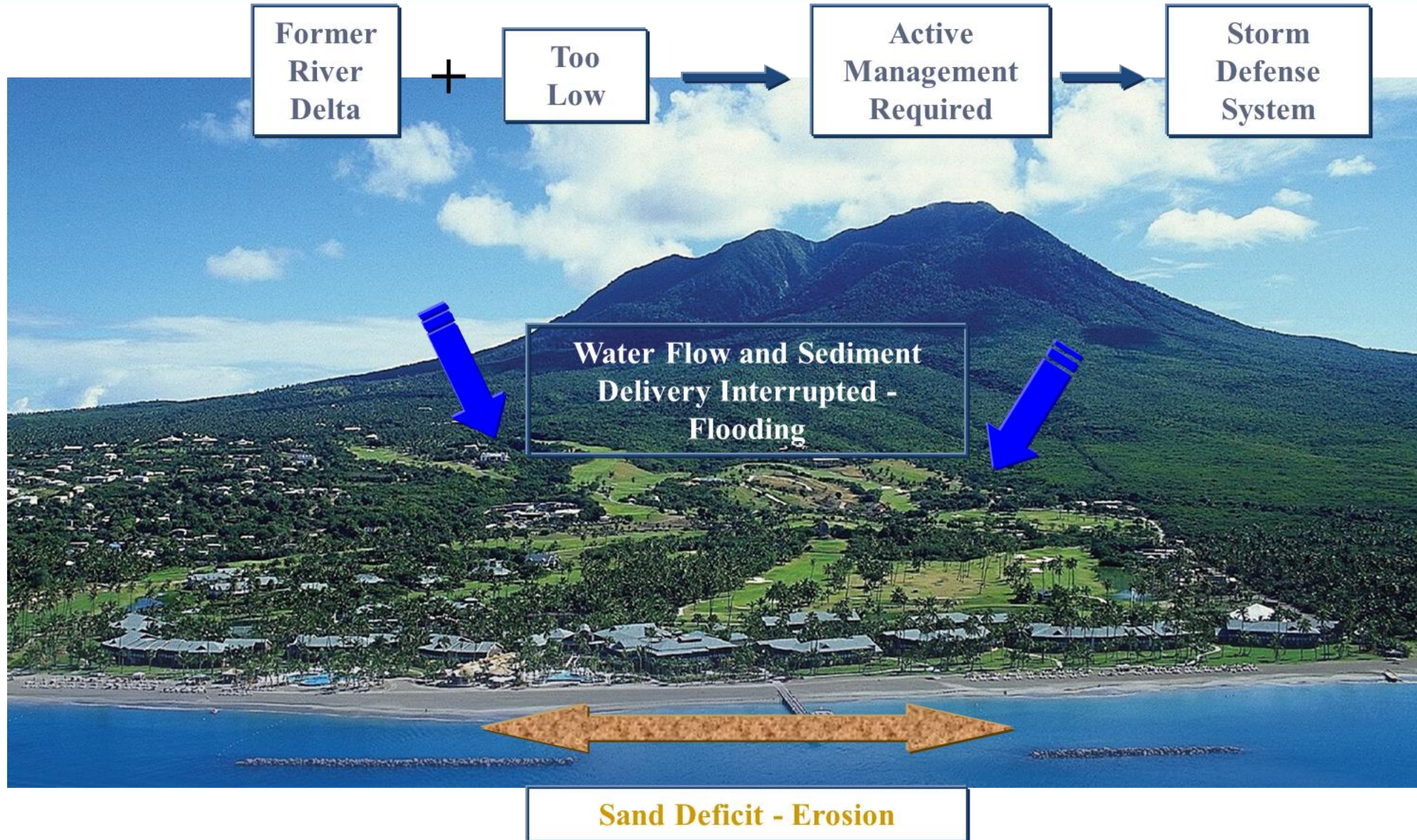
# NOT TOO SHABBY!



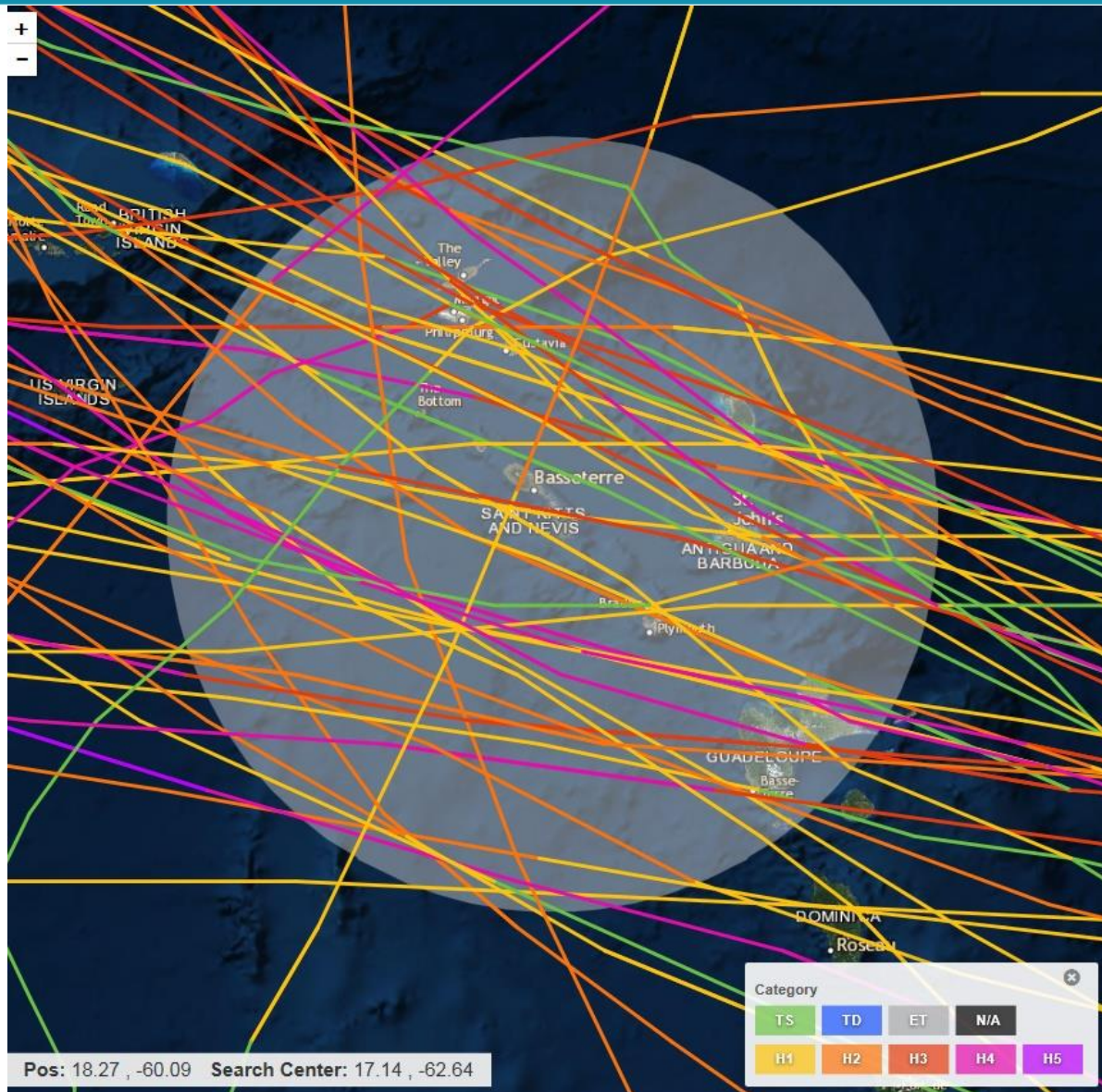
# I WILL BE HERE IN TWO WEEKS



# WHAT COULD GO WORNG?



# HURRICANE TRACKS AND DAMAGE





# HURRICANE LENNY

1999



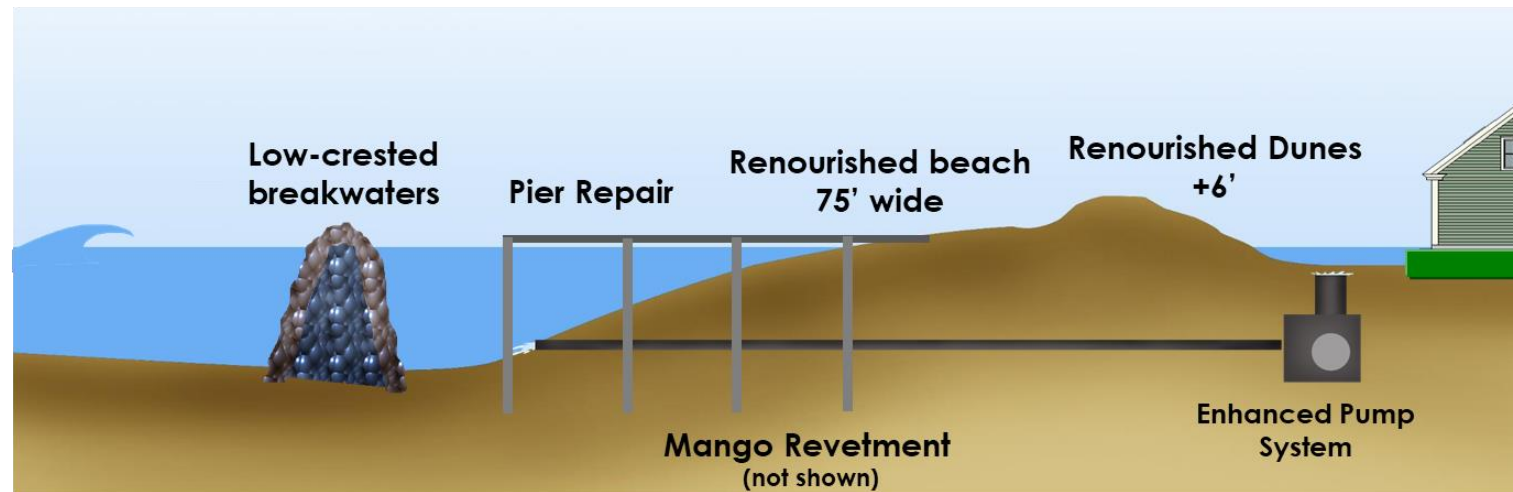
Hurricane Lenny (1 year lost operations)



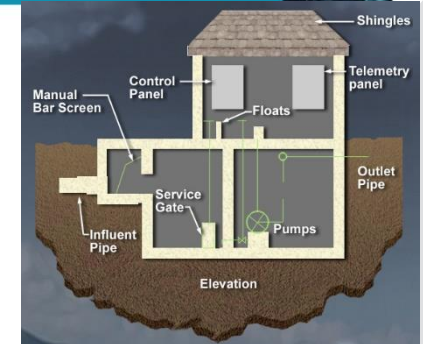
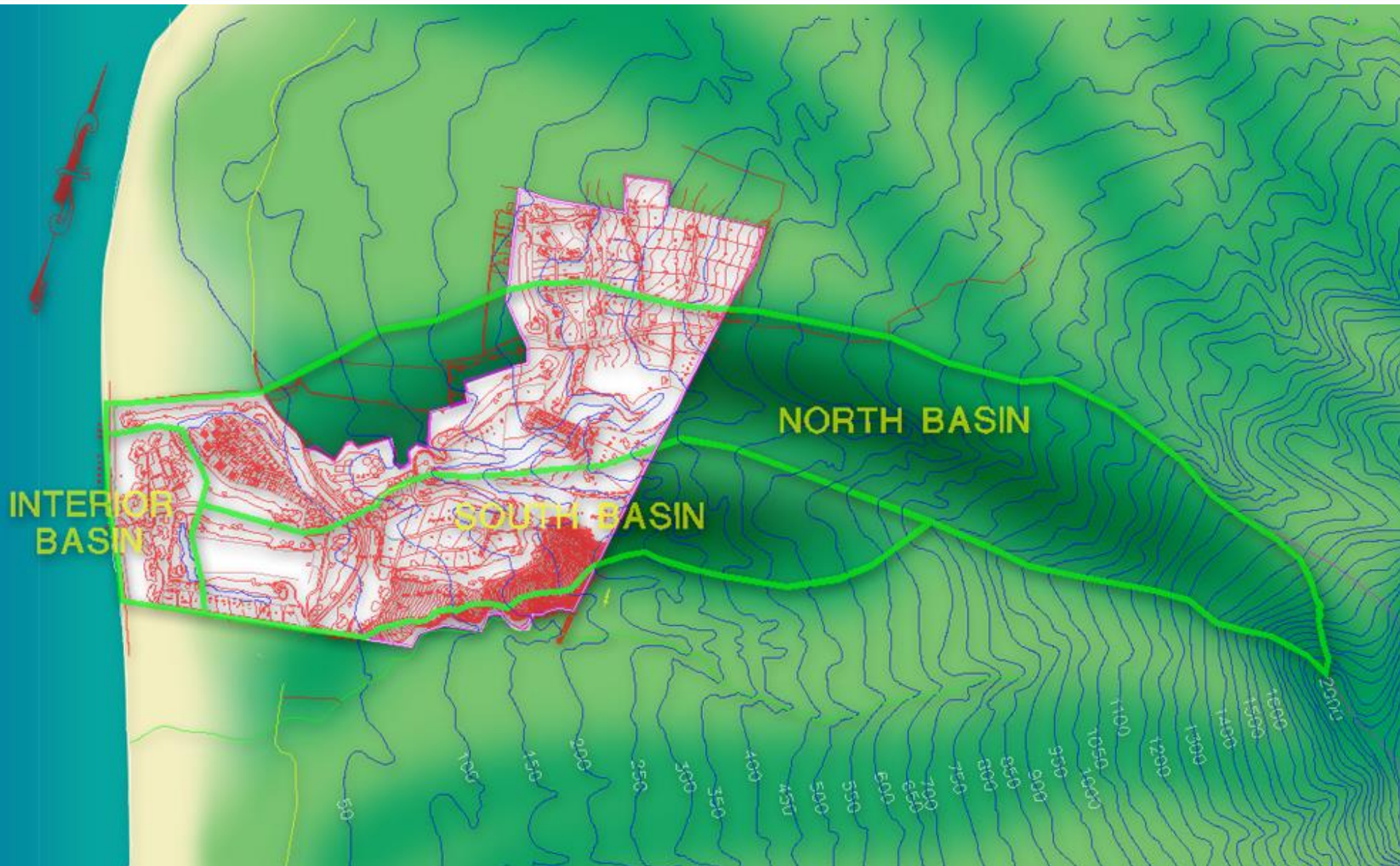
Approved Coastal Recovery Work	2000 (Hurricane Lenny, 1999)
Beach Re-nourishment	Beach Re-nourishment 100,000 CY
Dune Re-nourishment	Dune Re-nourishment +6' MSL
Existing Infrastructure Enhancements	Southern Pier & Outfall Construction Pier Reconstruction
Breakwaters	Four (4) Breakwaters 1,200 LF
Revetments	Mango Revetment Construction

## Impacts

- Loss of Beach
- Eroded Dune System
- Flooding in Rooms
- Damage to Coastal Infrastructure
  - Arrivals Pier
  - Mangos Restaurant
  - Southern Outfall



# STORMWATER MANAGEMENT SYSTEM



# HOW DO YOU KNOW ITS GOING TO WORK?



# THE ORIGINAL CONUNDRUM

DUNE HEIGHT LIMITED BY  
LOUNGE CHAIR-LEVEL VIEW

PUMP CAPACITY – 25,000 GPM –  
LIMITED BY \$\$

LETS ROLL THE DICE (Uh-Oh)

Dune Elevation (FT MSL)	GPM South	GPM North	Total
5.0	206,400	282,800	490,200
5.5	89,600	123,200	212,800
6.0	38,400	52,800	91,200
6.5	6,800	23,100	39,900
7.0	7,200	9,900	17,100
8.0	1,600	2,200	3,800
8.3	800	1,100	1,900

# HURRICANE OMAR – NOT AGAIN!?



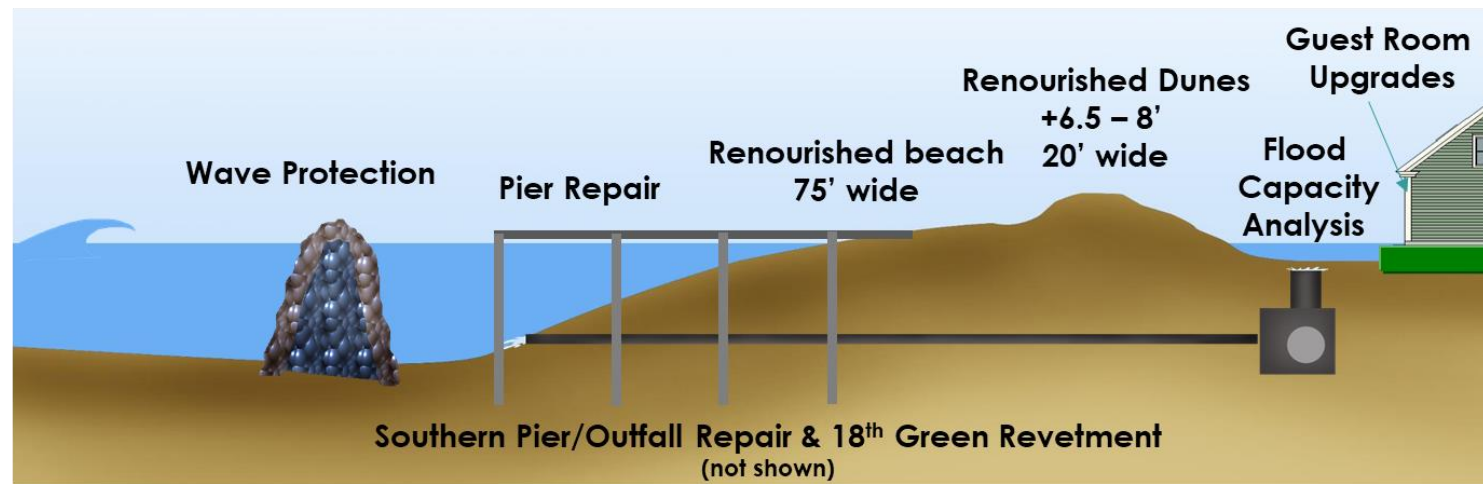
Hurricane Omar (2 years lost operations)



Approved Coastal Recovery Work	2010 (Hurricane Omar, 2008)
Beach Re-nourishment	Beach Re-nourishment 85,000 CY
Dune Re-nourishment	Dune Re-nourishment +6.5' to +8' MSL
Existing Infrastructure Enhancements	Southern Pier & Outfall Extension Pier Repair
Breakwaters	Breakwater Repair
Revetments	Revetment Repair & Addition at 18 <sup>th</sup> Green
Flooding Protection	Guest Room Window & Door Upgrades

## Impacts

- Loss of Beach
- Eroded Dune System
- Flooding in Rooms
- Damage to Coastal Infrastructure
  - Arrivals Pier
  - Mangos Revetment
  - 18<sup>th</sup> Green
  - Southern Outfall



# LETS TRY THIS MATH AGAIN

Dune Elevation (FT MSL)	GPM South	GPM North	Total
5.0	206,400	282,800	490,200
5.5	89,600	123,200	212,800
<b>6.0</b>	<b>38,400</b>	<b>52,800</b>	<b>91,200</b>
6.5	6,800	23,100	39,900
7.0	7,200	9,900	17,100
8.0	1,600	2,200	3,800
8.3	800	1,100	1,900

PUMP CAPACITY – **25,000 GPM**

RAISE DUNE to +8.0 \$300,000

ADD SEAT WALLS \$250,000

HARDENING \$150,000

TOTAL \$700,000

INCREASE PUMP CAPACITY \$2,200,000

HOW ABOUT WE AVERAGE THE DUNE HEIGHT AND MAKE VIEW CORRIDORS? (Huh?)

# HURRICANES OTTO, EARL, MATTHEW – SERIOUSLY?



Hurricane Otto (2010)

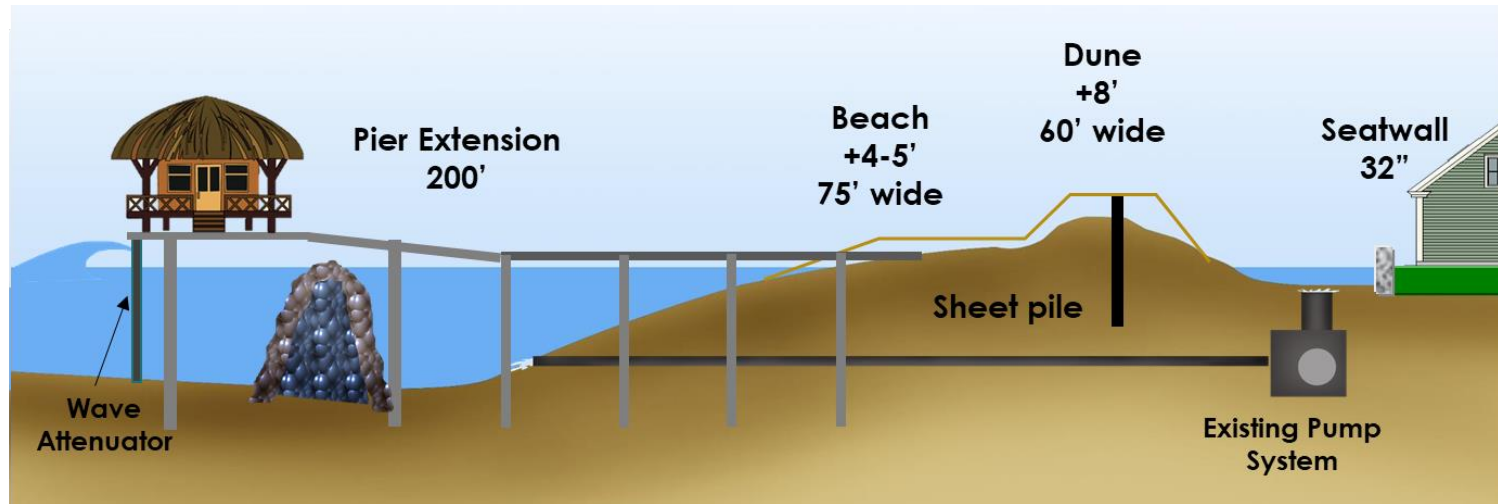


Hurricane Matthew (2016)



Approved Coastal Recovery Work	2017 (Hurricane Matthew, 2016)
Beach Re-nourishment	Beach Re-nourishment 50,000 CY
Dune Re-nourishment	Dune Re-nourishment +8-9' MSL
Pier Extension & Wave Attenuator	200' Extension & Elevate Wave Attenuator
Seawall Installation	32" Seawall for flood capacity
Stoplogs/ Flood protection	Greathouse flood protection

Hurricane Earl (2010)



# BEACH NOURISHMENT – THE BIG DITCH





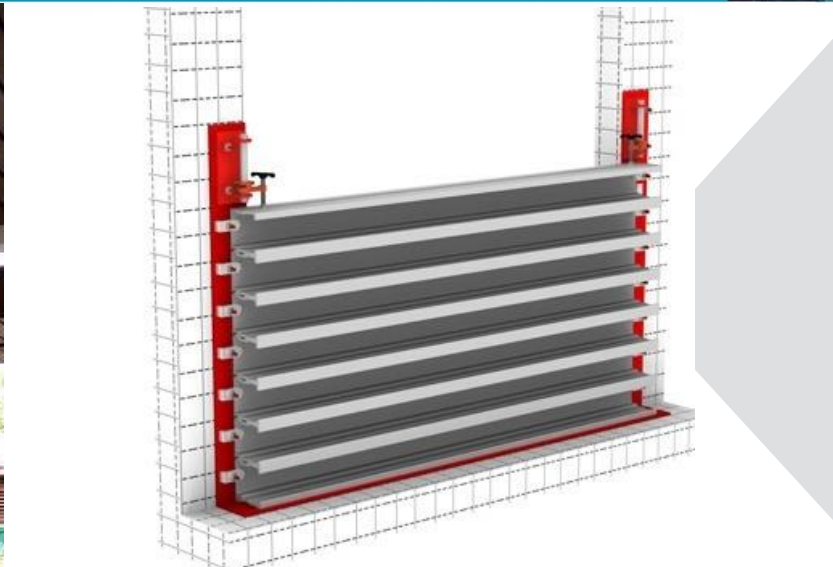
# PIER CONSTRUCTION – THIS IS COOL



# SEAWALL AND FLOODGATE



# STOPLOGS AND HURRICANE DOORS



# RESILIENCY LAYERS and BENEFITS

## STORM WATER PROTECTION

- Berms, Basins, Lakes
- Diversion
- Pumping Systems
- Inlet Grates and Cages

## SHORELINE PROTECTION

- Breakwaters – Segmented, low crested
- Wave Wall – Integrated in to new pier
- Revetments – Exposed and Buried
- Beach – Wide and Superelevated
- Dune – Elevated and Planted

## LOCAL HARDENING

- Hurricane Doors and Windows
- Shutters
- Seat Walls - Flood Gates
- Stoplogs
- Diversion
- Pumping Systems

## SECONDARY BENEFITS

- Habitat Creation
- Recreational Space
- Event Space – Beach and Pier
- Dune Cabanas
- Private Garden Space
- Safer Arrival Experience

# OGRES, ONIONS AND FLOOD PROTECTION

Ogres are like onions. Ogres have layers. Onions have layers.  
You get it? We both have layers.



Donkey: Oh, you both have layers. Oh.  
You know, not everybody like onions.

Shrek (2001)

# DISAPPEARING BREAKWATERS



# BREAKWATER HABITAT



# EVENT SPACE AND RECREATION

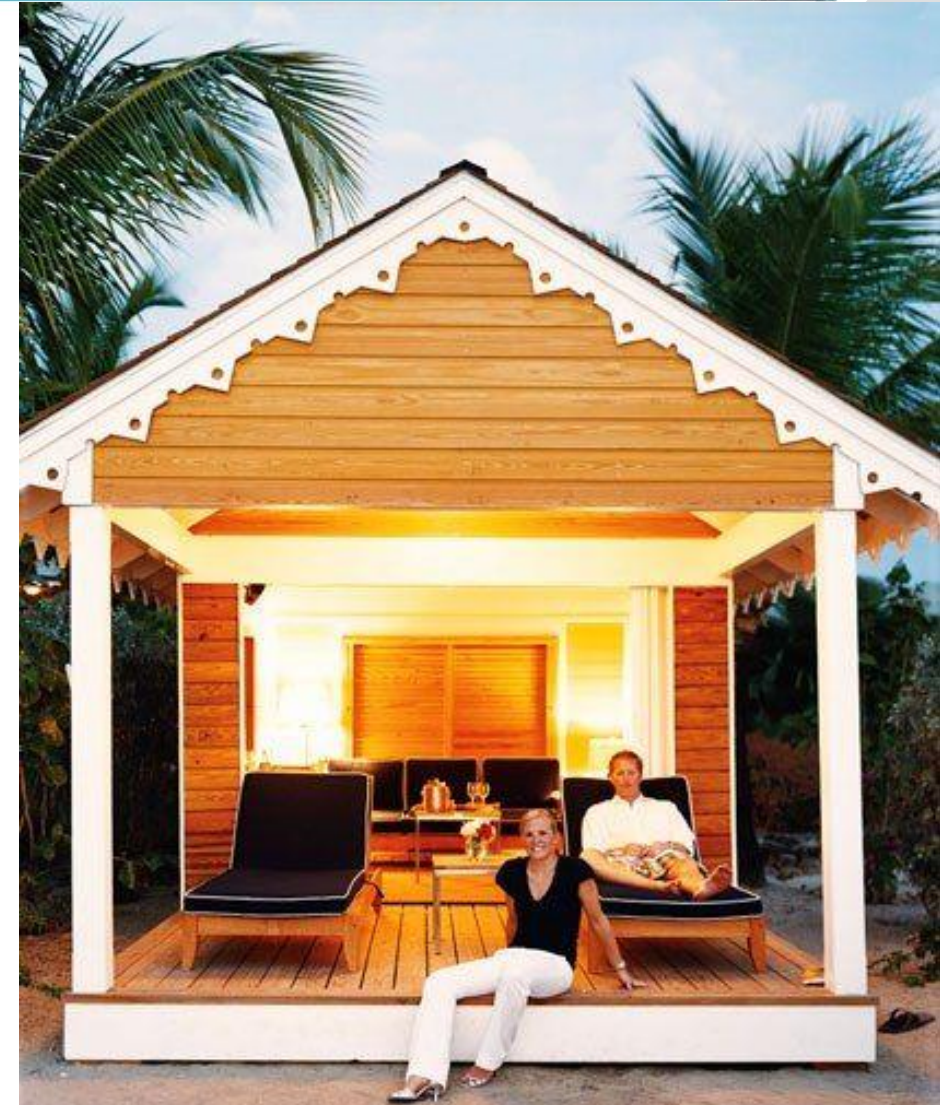




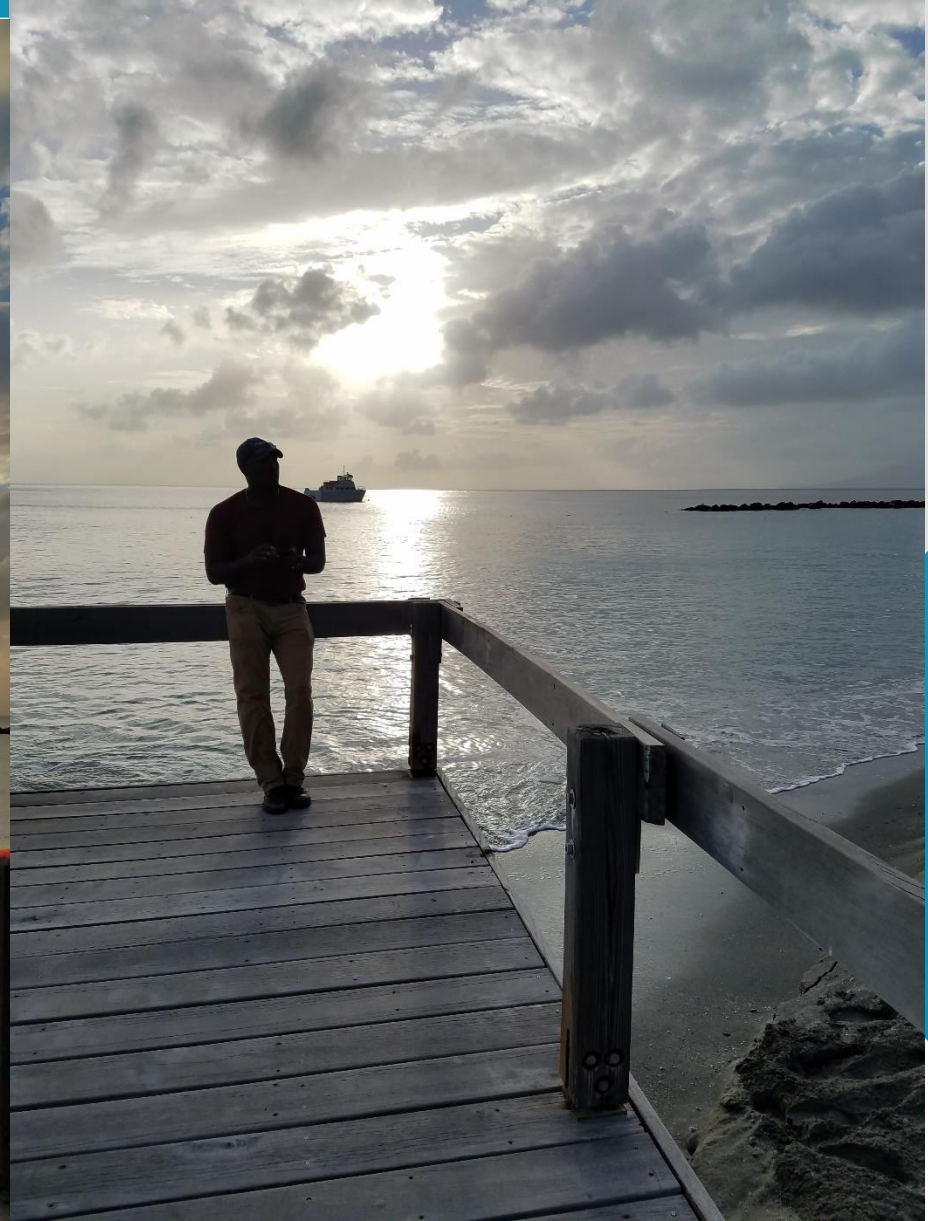
# PROTECTED ARRIVAL OPERATIONS AND NEW EVENT SPACE



# CABANAS ON THE DUNE



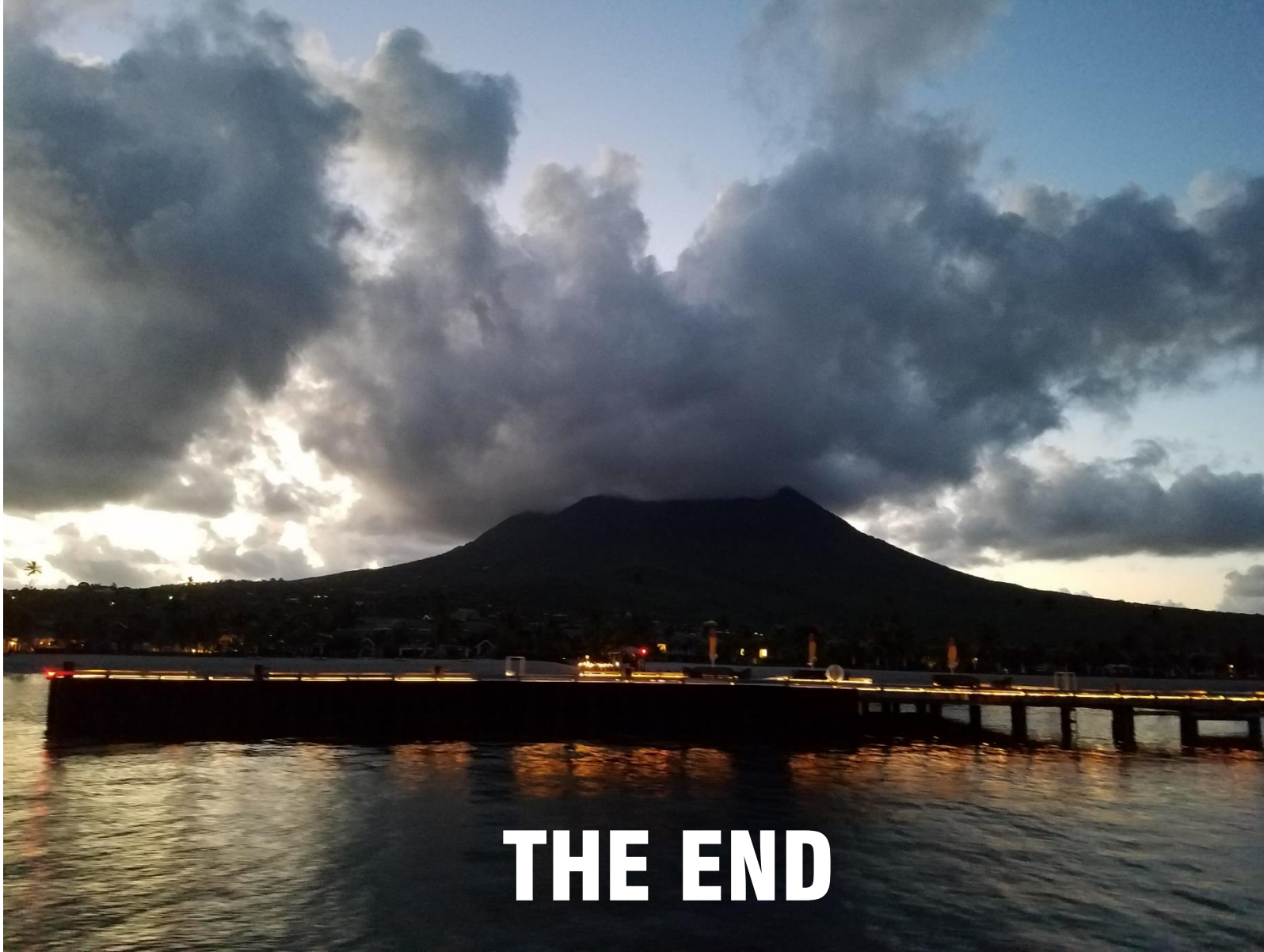
# SHOUTHERN OUTFALL – SHORT PIER



# BEAUTIFUL MARKETING MATERIAL

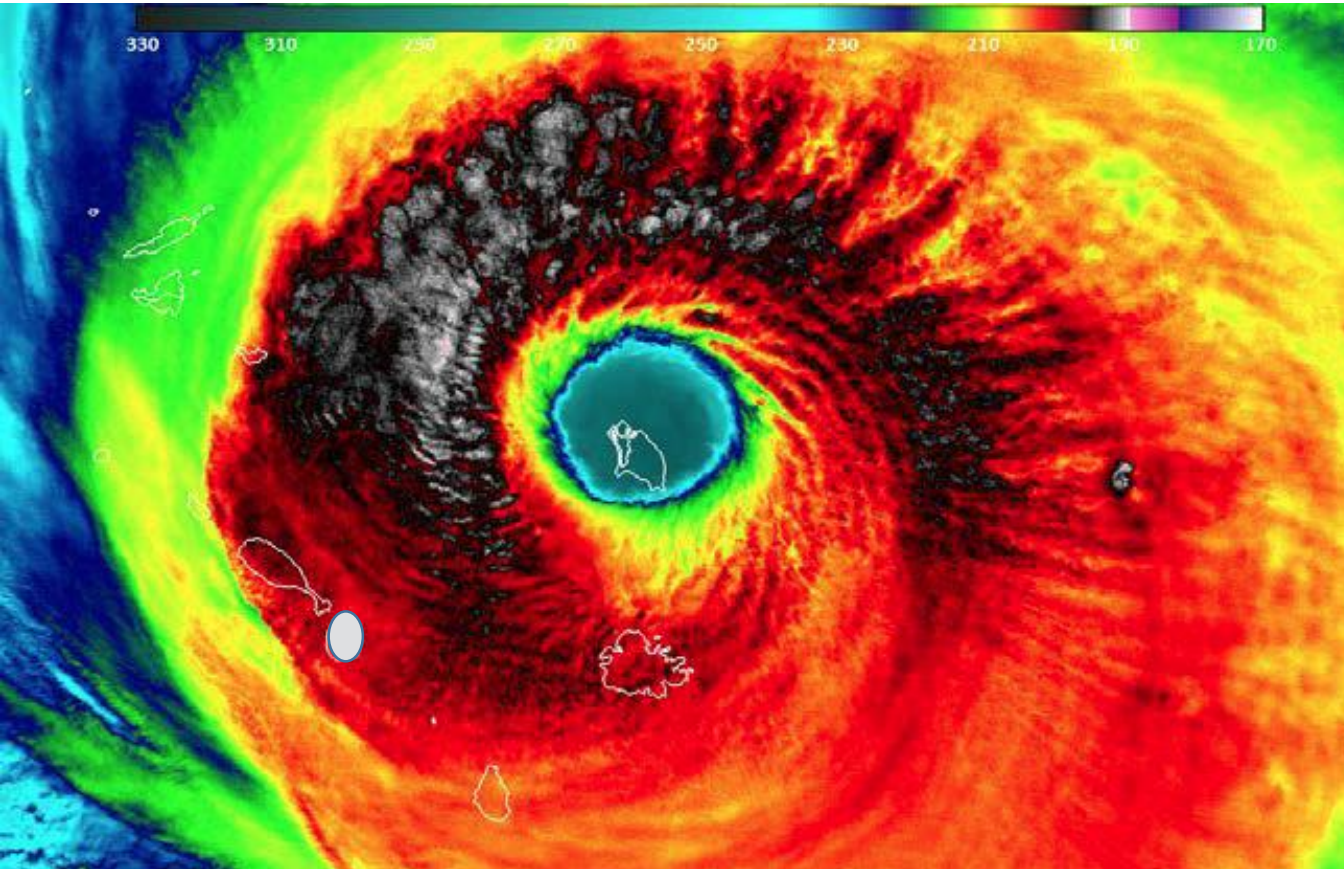


# OBLIGATORY FINAL MOOD SHOT

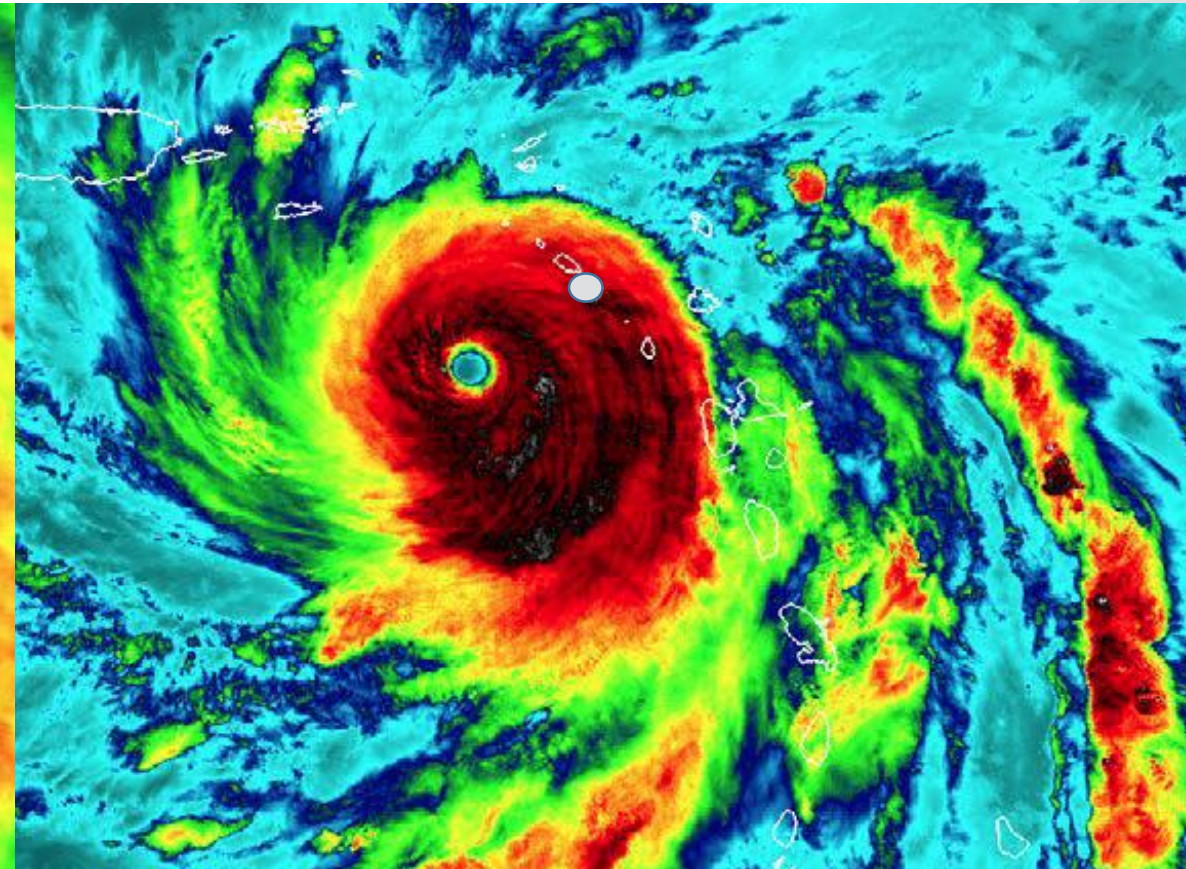


**THE END**

# Cat 5 STRIKES – 13 DAYS APART



IRMA – SEPTEMBER 6, 2017

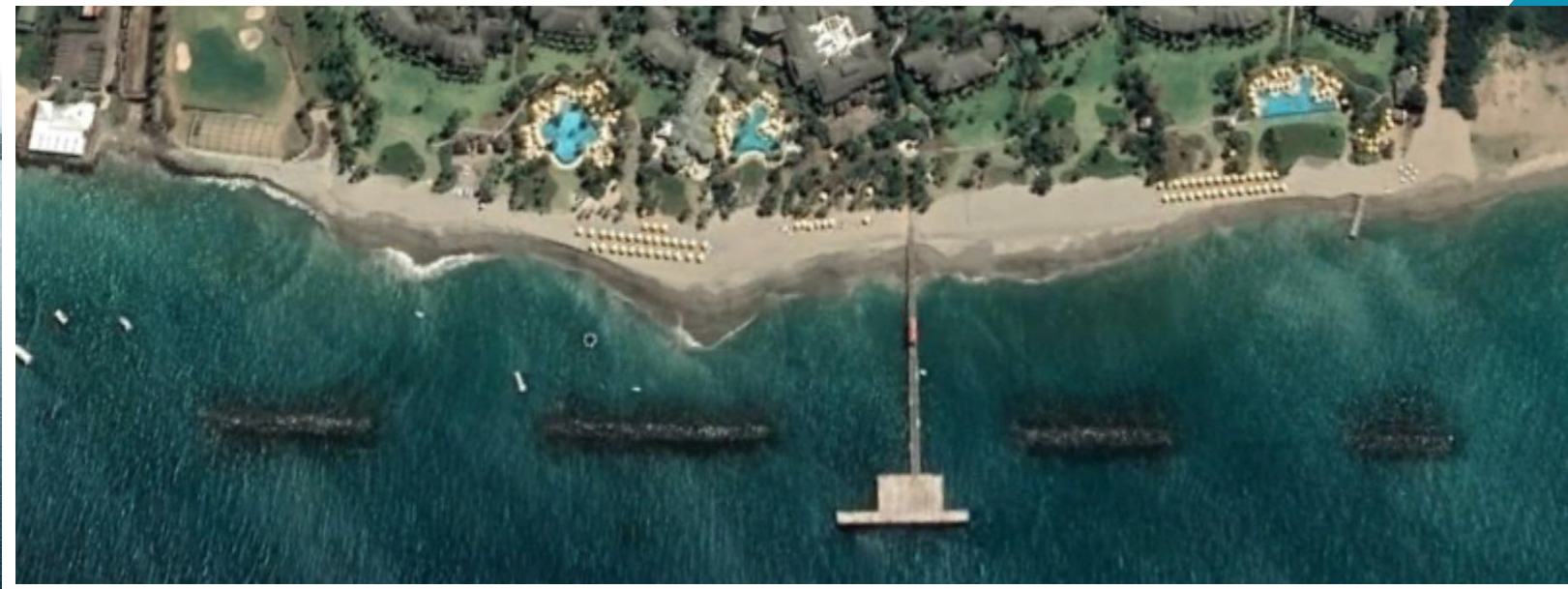
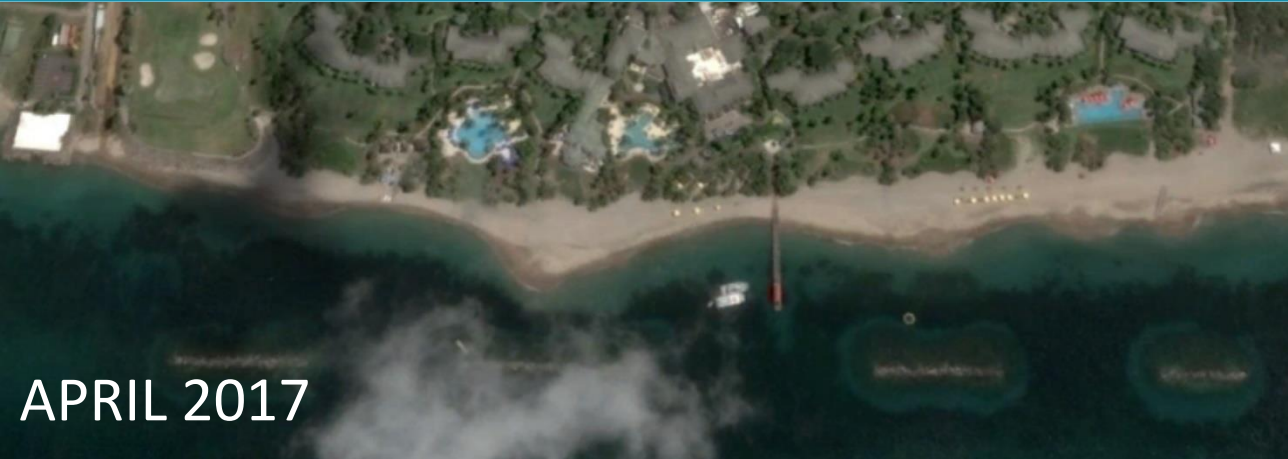


MARIA – SEPTEMBER 19, 2017

# 2017 HURRICANE STATISTICS

<b>Forecast Parameter</b>	<b>Observed 2017 Atlantic TC Activity</b>	<b>Atlantic Full Season 1981- 2010 Median</b>	<b>2017 as Percentage of Full Season Median</b>
<b>Named Storms (NS)</b>	<b>17</b>	<b>12.0</b>	<b>142%</b>
<b>Named Storm Days (NSD)</b>	<b>89</b>	<b>60.1</b>	<b>148%</b>
<b>Hurricanes (H)</b>	<b>10</b>	<b>6.5</b>	<b>154%</b>
<b>Hurricane Days (HD)</b>	<b>51.25</b>	<b>21.3</b>	<b>241%</b>
<b>Major Hurricanes (MH)</b>	<b>6</b>	<b>2.0</b>	<b>300%</b>
<b>Major Hurricane Days (MHD)</b>	<b>19.25</b>	<b>3.9</b>	<b>494%</b>
<b>Accumulated Cyclone Energy (ACE)</b>	<b>224</b>	<b>92</b>	<b>243%</b>

# FOUR SEASONS





# LESSONS LEARNED



PLEASE  
DO NOT WASH SANDY FEET  
OR  
CHILDREN IN SINK!

- **BASIN OF DESIGN DECISIONS ARE CRITICAL**
- **LAYERS ARE GOOD**
- **SECONDARY BENEFITS ARE IMPORTANT**

