CITY OF DELRAY BEACH

INTRACOASTAL WATERWAY WATER LEVEL & INFRASTRUCTURE VULNERABILITY STUDY

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February 12, 2019
City of Delray Beach

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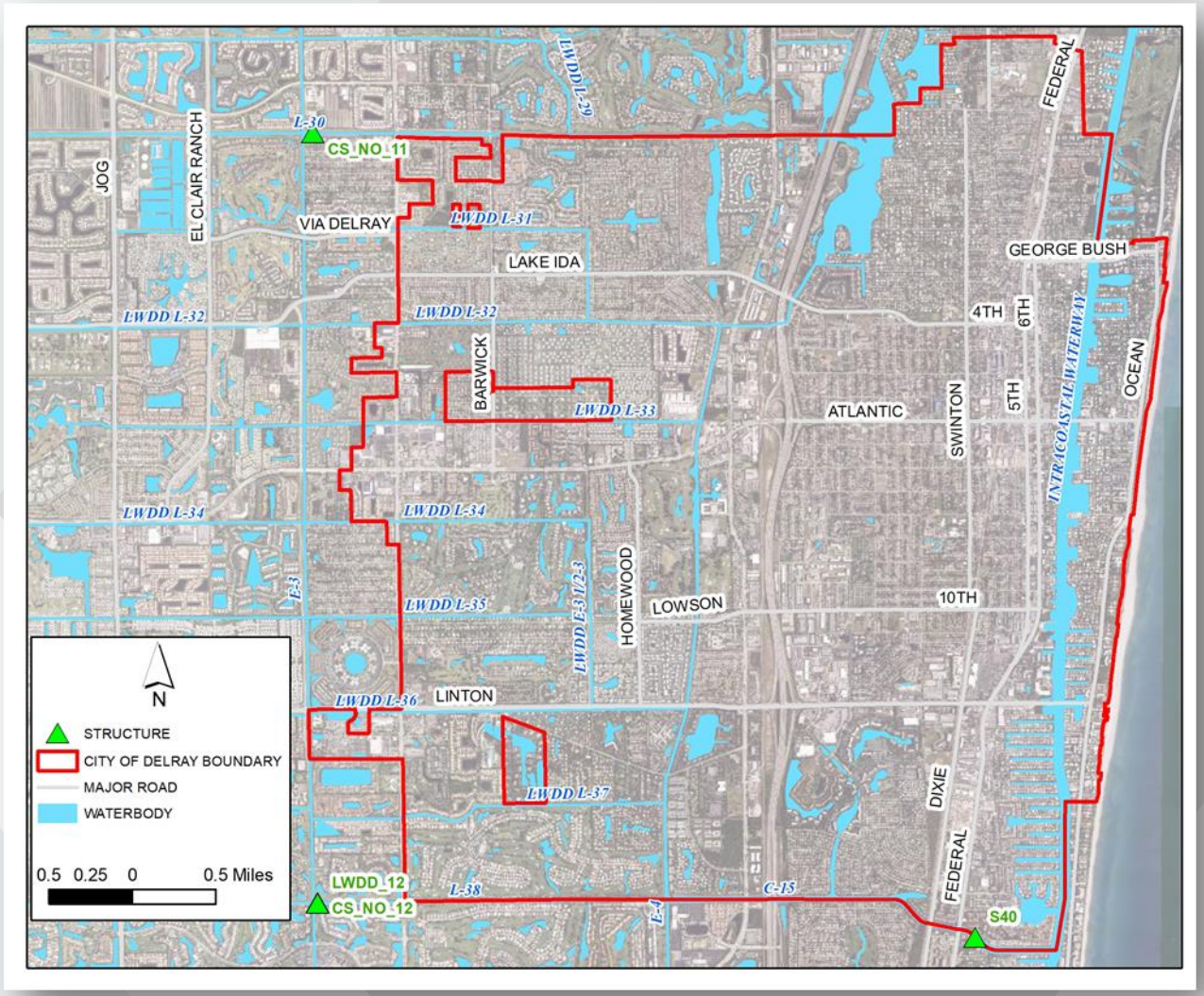
City of Delray Beach

4 Miles of Intracoastal Waterway

Under 1 Mile of Public Seawall

Over 20 miles of Private Seawalls

City Limits (16 Square Miles)



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TIDAL FLOODING











TOPICS

Seawall Vulnerability Analysis

- Interim Solutions
  - Seawall Repairs and Backflow Preventers

Stormwater Master Plan Update

- Long Term Solutions
  - Increase Size and Number of Stormwater Pump Stations
  - Raise Roads, Increase Pipe Sizes

Commission Direction

- Funding Priorities
- CRS Rating
- Sawall Ordinance Discussion

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GOALS & OBJECTIVES

Assess Future Seasonal Flooding along IntraCoastal Waterway (ICW)

- Develop water level predictions for 30 and 75 year planning horizons
- Inventory current conditions - seawalls and stormwater connections

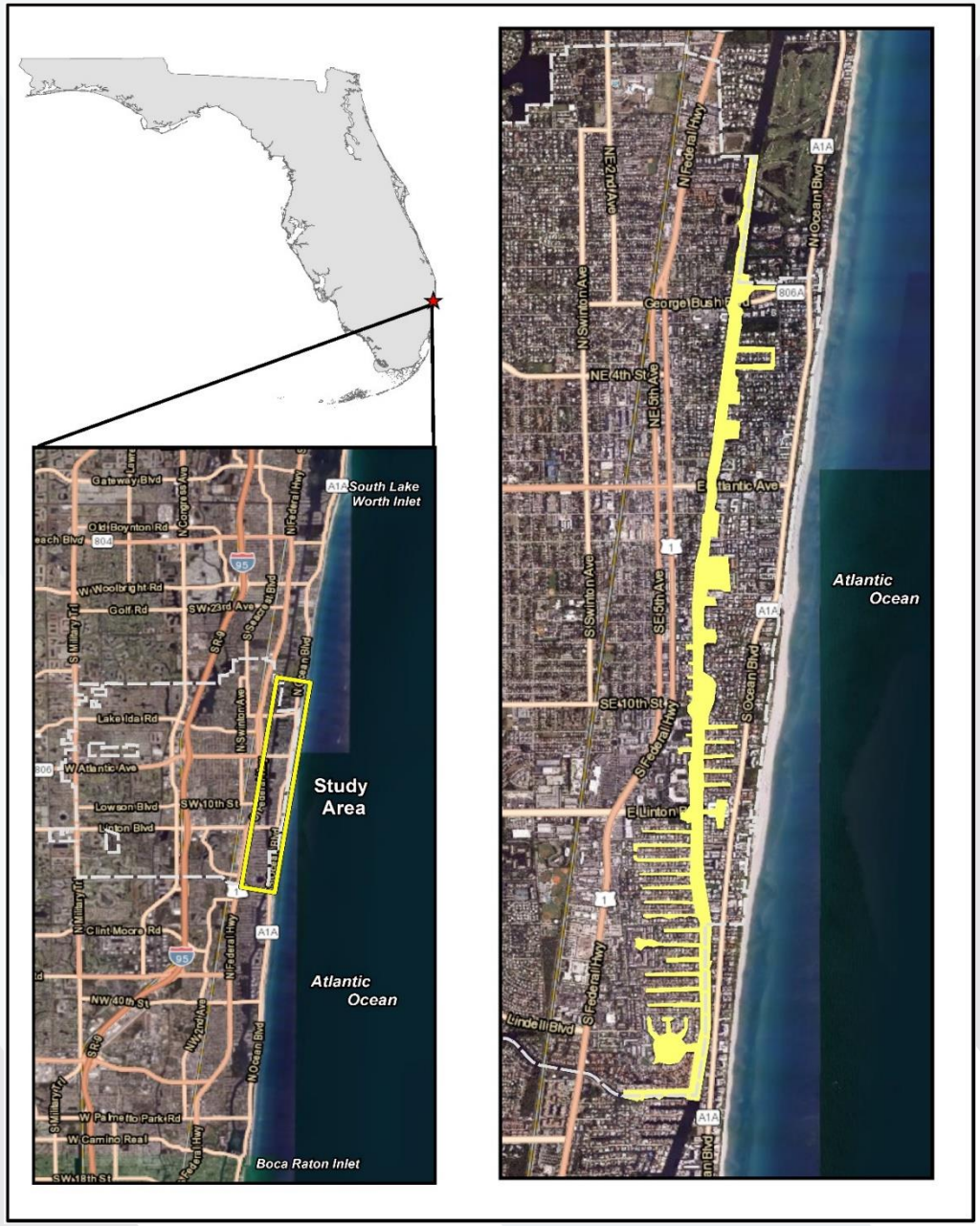
Identify Options to Protect Infrastructure and Property

- Assess current conditions given water level predictions
- Prioritize improvement projects

Address Stormwater System Infrastructure Needs into the Future

- Implementation Strategies
- Funding Strategies
- Commission Actions required

COMPONENTS OF THE TOTAL WATER LEVEL



- Astronomical Tides
- Ocean Storm Surge
- Stormwater Discharge from Inland Rain
- Sea Level Rise

SFWMD S40-T (DELRAY BEACH ICW)
TOP 10 RECORDED WATER LEVELS

Rank	Date	Feet NAVD88	Associated Storm Event
1	9/10/2017	3.14	Hurricane Irma
2	11/16/1996	3.10	
3	10/13/1996	2.98	
4	10/28/2012	2.97	Hurricane Sandy
5	9/25/2004	2.84	Hurricane Jeane
6	9/29/2015	2.66	Hurricane Joaquin
7	9/4/2004	2.64	Hurricane Frances
8	10/17/2016	2.61	
9	10/5/2017	2.60	
10	10/15/1999	2.59	Hurricane Irene

SEA LEVEL RISE

South Florida Regional Compact on Climate Change guidance references :

- Intergovernmental Panel on Climate Change (IPCC) AR5 Medium Rate
- U.S. Army Corps of Engineers (USACE) High Rate (NRC Curve III)

Year	Increase in MSL Relative to 2018			
	USACE High Curve		IPCC Curve	
	Inches	Feet	Inches	Feet
2048	12.5	1.1	7.1	0.6
2093	48.9	4.1	24.0	2.0

30-YEAR PLANNING ELEVATION

3.9 to 4.4 ft. NAVD

Freeboard	0.5 ft.
5-year Return Period Event	1.8 ft.
30 years of SLR	0.6-1.1 ft.
Average Daily Maximum Water Level 2017	1.0 ft.

2018 Veteran's Park Seawall Improvement





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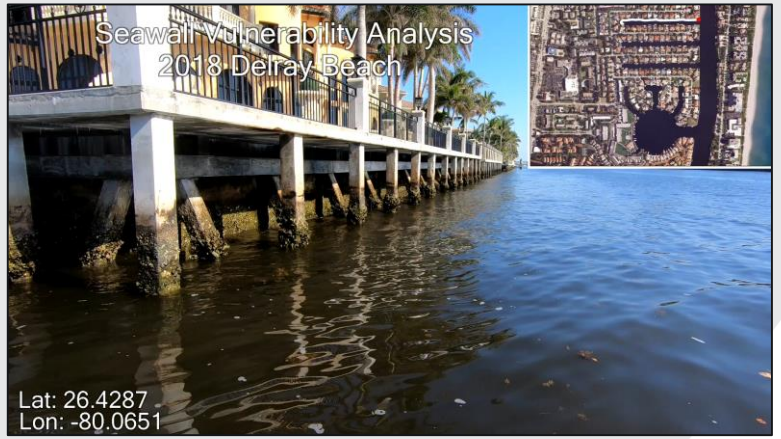
CURRENT CONDITION SURVEYS

Public & Private Seawalls

- Seawall Elevations

- Seawall Structural Assessments
  - Public top-side inspections
  - Private rapid structural assessments
  - Video inventory





CURRENT CONDITION SURVEYS

Stormwater System

- Stormwater Inlet & Outfall Elevations
- Stormwater Outfall Inspections
- Backflow Prevention Device Inventory













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Stages of Stormwater Infrastructure Failure due to Sea Level Rise

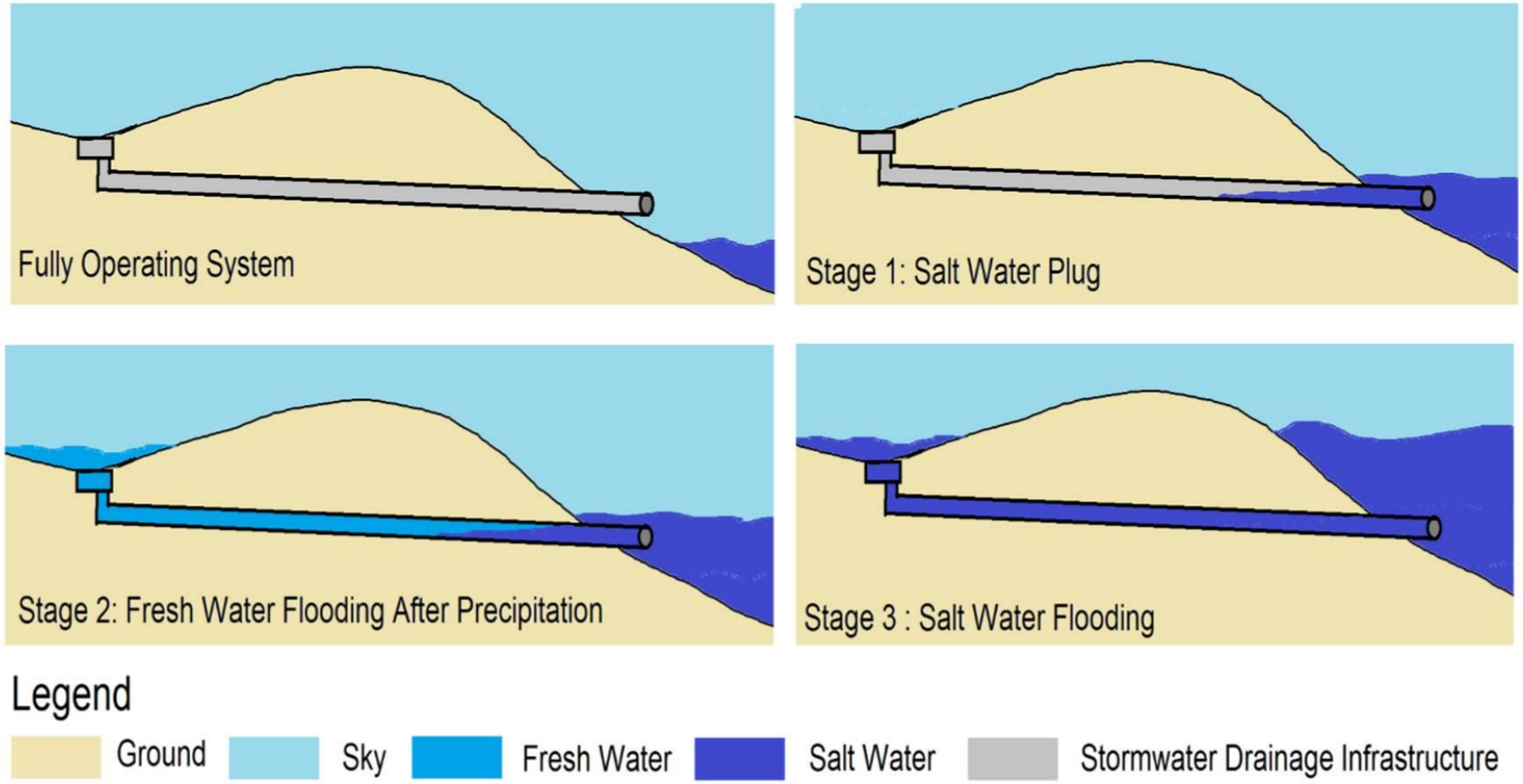
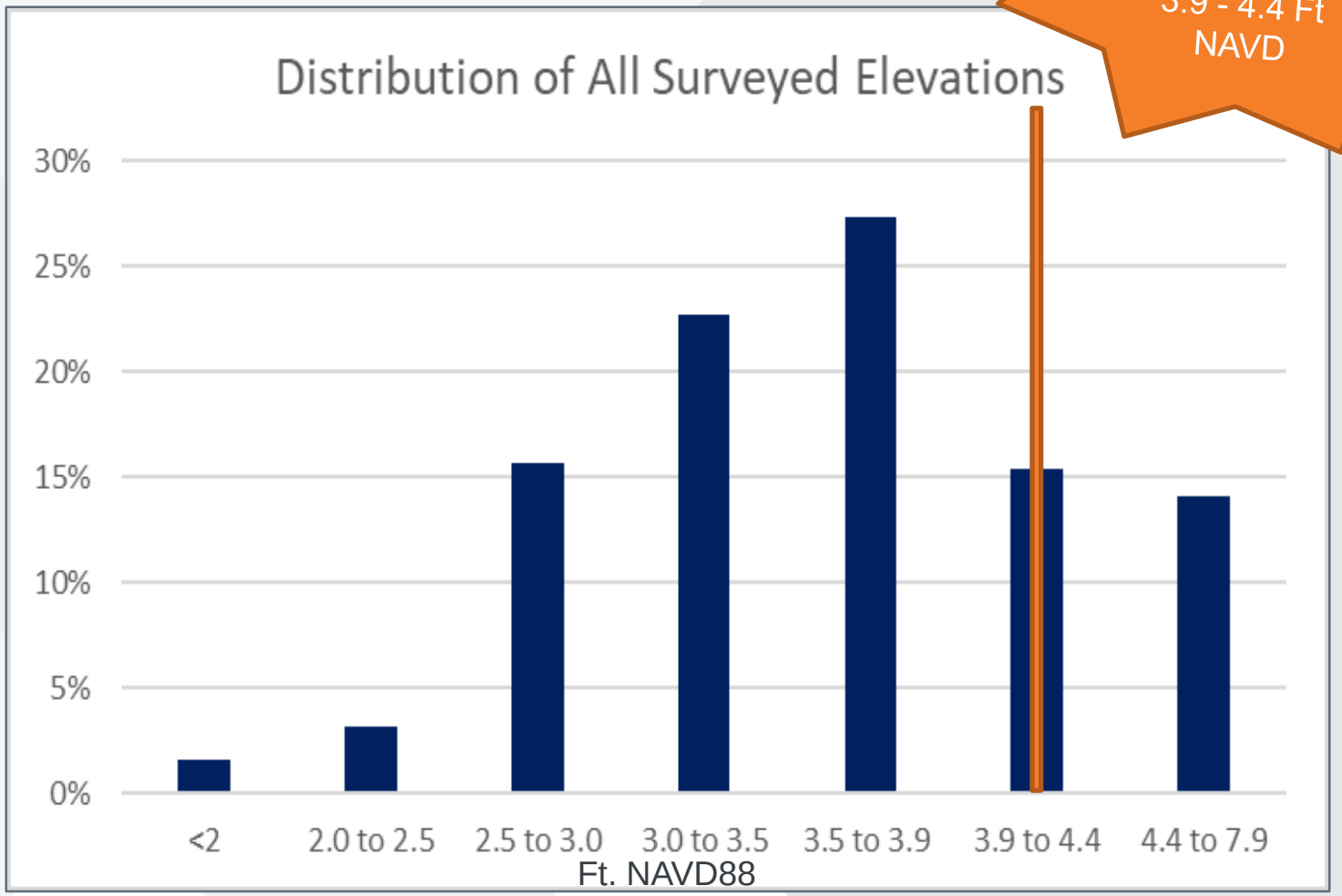


Figure by Emily Niederman, Stetson University (Class of 2017)

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SEAWALL ELEVATION ANALYSIS

30-Yr Planning Elevation Range = 3.9 - 4.4 Ft NAVD



SEAWALL STRUCTURAL ANALYSIS

- Seawall Structural Assessments
  - Public top-side inspections
  - Private rapid structural assessments
  - Video inventory

	Good	Satisfactory	Fair	Poor	Serious	Critical
Public	1	16	9	3	0	0
Private	48	170	450	152	41	7
Total %	4%	19%	53%	18%	5%	1%

PUBLIC SEAWALL ANALYSIS

- Top-side structural assessments of 29 public seawalls
- Observation reports developed
- Ranked based on condition and need for repair/replacement

Highest	SF	Structural Seawall Failures
	LK	Water and Soil Leaks
	SD	Structural Seawall Decay and Repairs
	CE	Cap Elevation Issues
Lowest	NA	No Action

NE 1st Court



Beach Drive



STORMWATER SYSTEM ANALYSIS

- Surveyed 103 inlets and their associated outfalls along ICW
- 86 inlets below 4.4 ft.
- 28 protected by current or planned back flow prevention devices
  - Some are in need of maintenance
- 58 remain unprotected and below 4.4 ft.
- Ranked based on inlet elevation for prioritizing future backflow prevention installations
- Potential to provide protection within 10 years by installing ~6 backflow prevention devices per year



Spanish Trail E 1.
Oysters prevent closure of the duckbill.



Waterway Lane

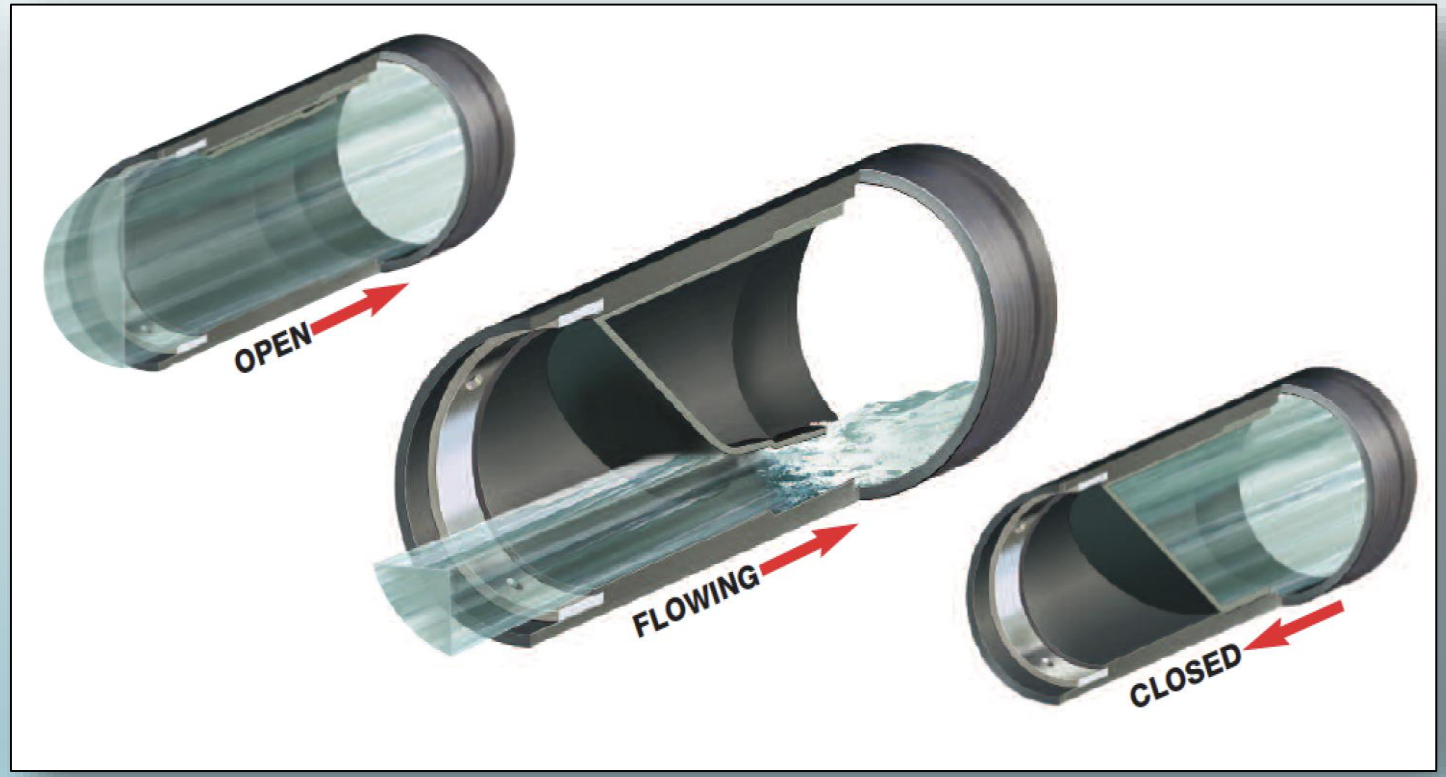


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Capital Improvement Projects (TM5) – Cont.

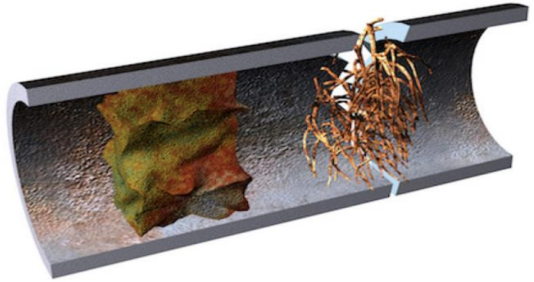
- **Backflow preventers (In-line Valves)**



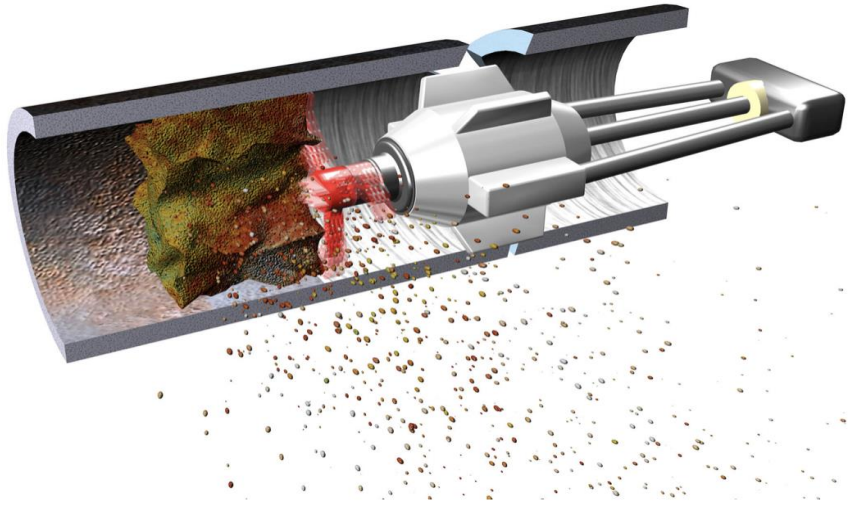


Capital Improvement Projects (TM5) – Cont.

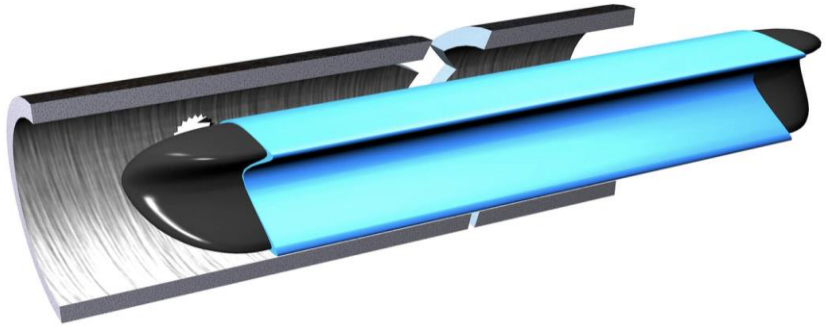
➢ Pipe lining (Slip Lining):



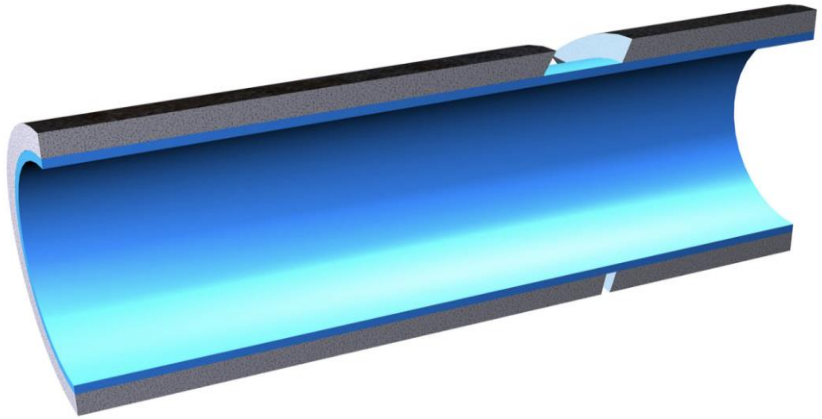
First, a SPT sewer camera reveals the waste buildup, breach, or possible root intrusion.



Then, a pneumatic cleaning tool cleans the pipe internally.



Next, a CIPP liner is pulled into place and the bladder is inflated.



After curing, the CIPP lining product is a structural "pipe within the original pipe."

City of Delray Beach

STORMWATER MANAGEMENT MASTER PLAN UPDATE

City Commission Workshop

February 12, 2019

A·D·A ENGINEERING

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Stormwater Master Plan Update Purpose and Benefits

1. Provide the City with a 5-year stormwater Capital Improvement Plan to implement high priority projects in a systematic, objective and cost-effective manner

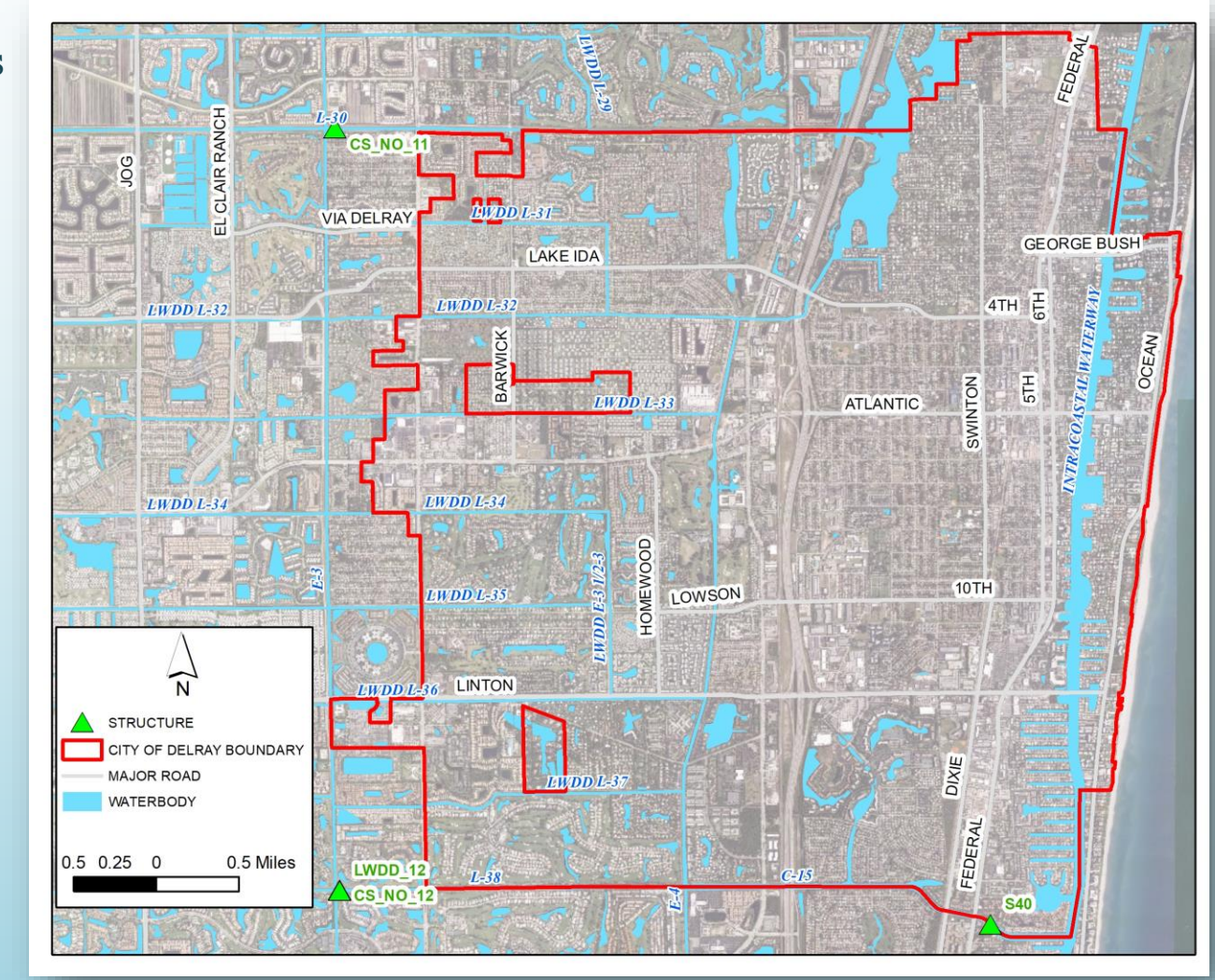
2. Assist the City in developing and Adaptive Management Plan for Climate Change, and mitigating projected sea-level and groundwater rise

3. Help the City secure grants for flood protection, sea-level and groundwater rise, and water quality improvement projects

4. Help improve the City's FEMA Community Rating Score (CRS) that will help reduce resident flood insurance rates

5. Allow evaluation of existing Stormwater Utility Rates based on projected needed improvements and costs

City Limits (16 Square Miles)



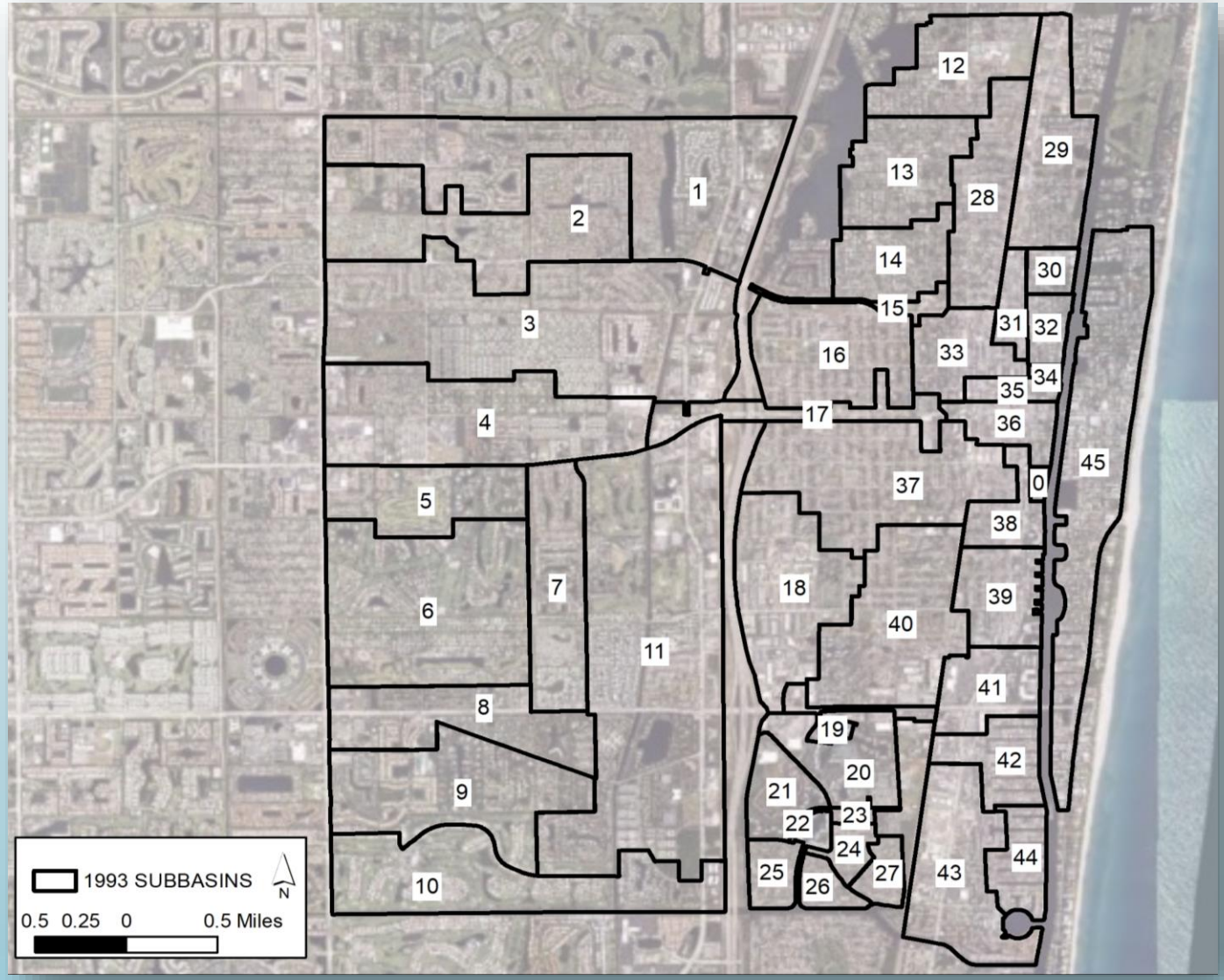
Stormwater Master Plan Update Scope of Work

- Task 1 – Kickoff Meeting
- Task 2 – Data Acquisition and Evaluation
- Task 3 – Existing Conditions Hydrologic/Hydraulic Modeling (TM1)
- Task 4 – Existing Conditions Flood Protection Level of Service (TM2)
- Task 5 – Projected Sea Level Rise and Groundwater Rise Impacts (TM3)
- Task 6 – Water Quality Assessment (TM4)
- Task 7 – Capital Improvement Projects (TM5)
- Task 8 – Stormwater Ordinance Review – (Provided as separate deliverable)
- Task 9 – Utility Rate Structure Review Assistance (Optional Task)
- Task 10 – NPDES Review (TM6)

Task 3
Existing Conditions
Hydrologic/Hydraulic Modeling (TM1)

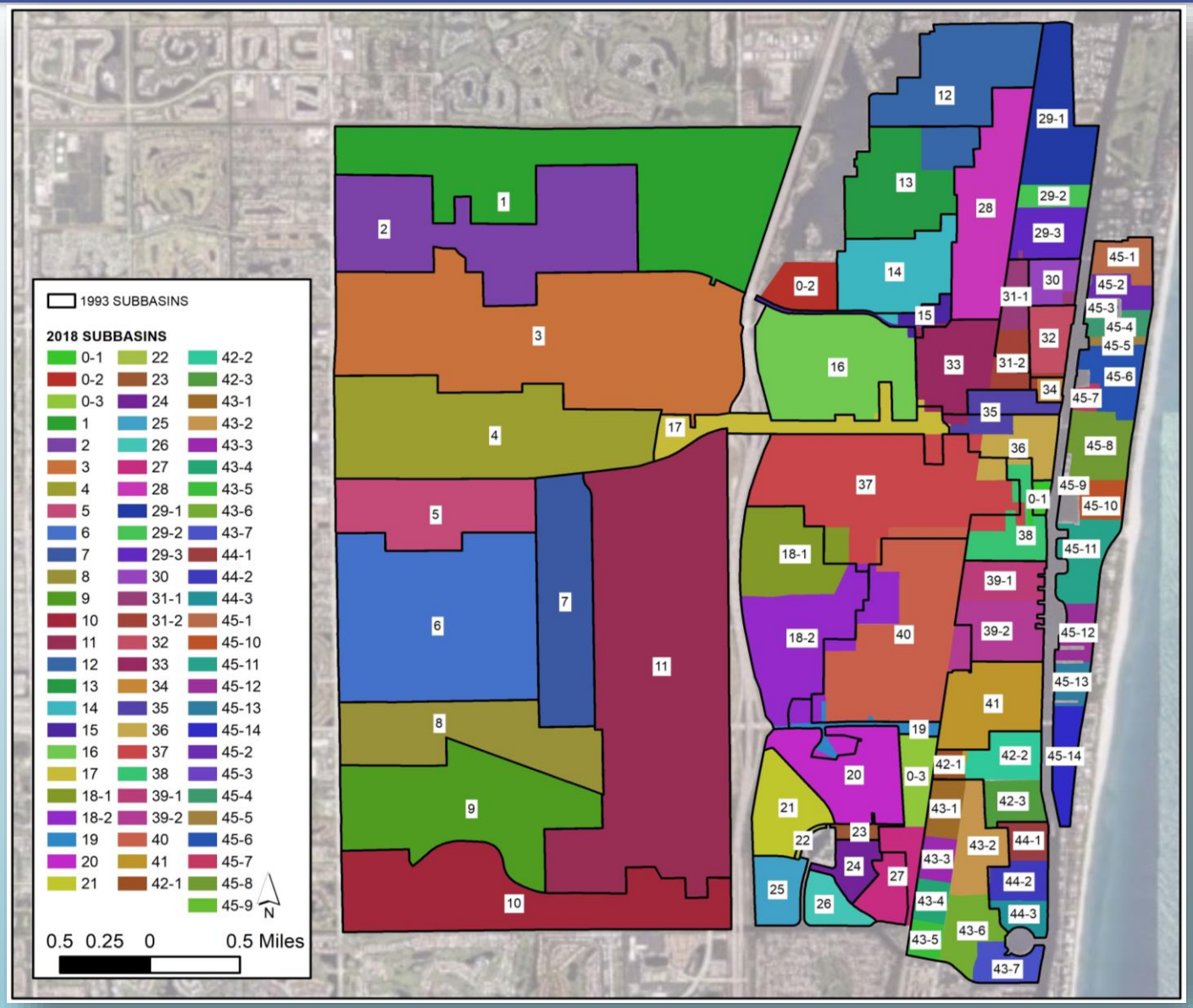
Existing Conditions Hydrologic/Hydraulic Modeling (TM1)

- **Sub-basin Delineations:**
  - 1993 Stormwater Master Plan subdivided City in to 45 sub-basins
  - Sub-basin delineations were refined based on (total of 76 sub-basins) :
    - ✓ Better available topography
    - ✓ New infrastructure information
    - ✓ Most up to date permit files

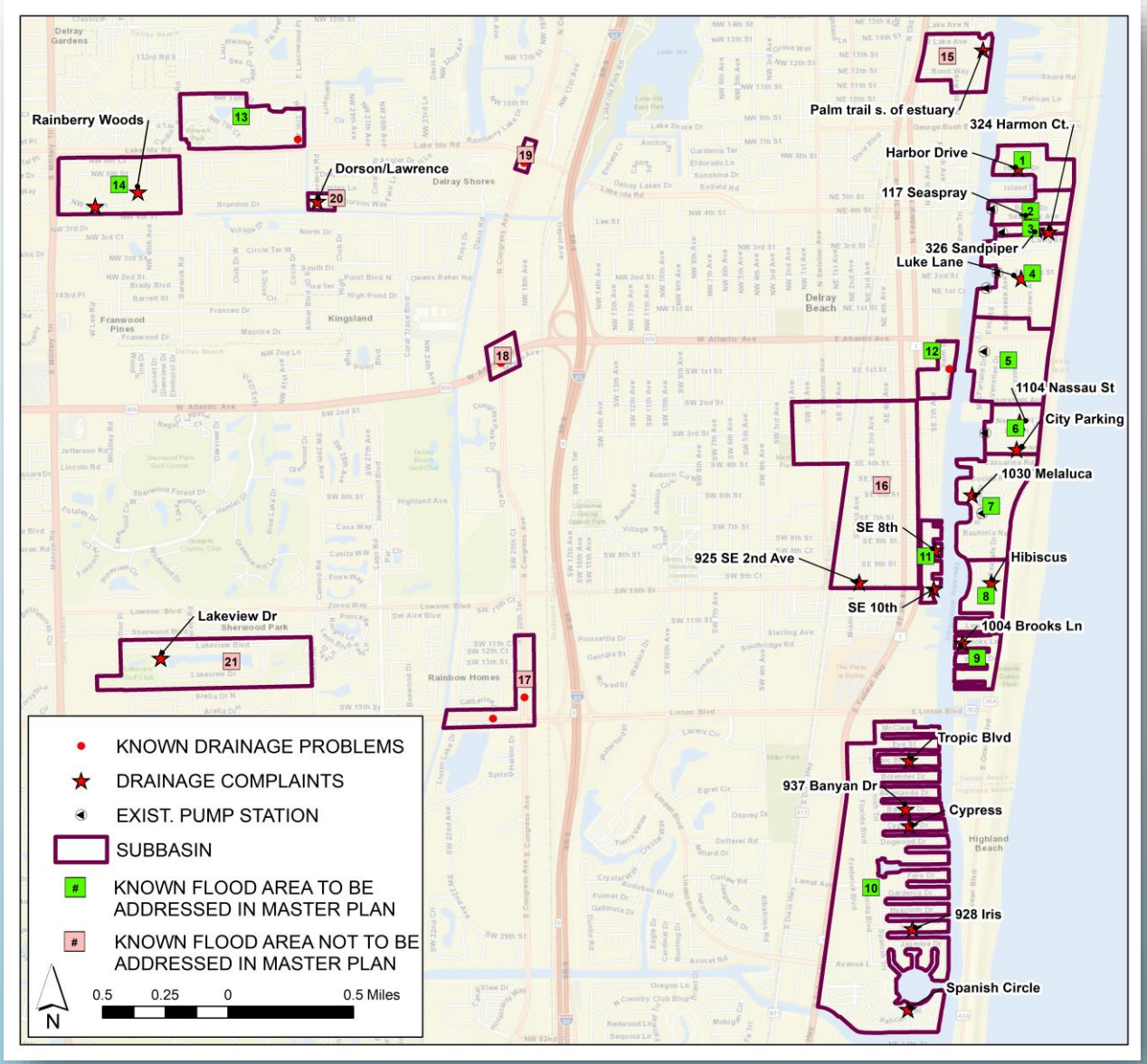


Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.

- **Refined Sub-basin Delineations:**



Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.



➢ Problem Area Identification:

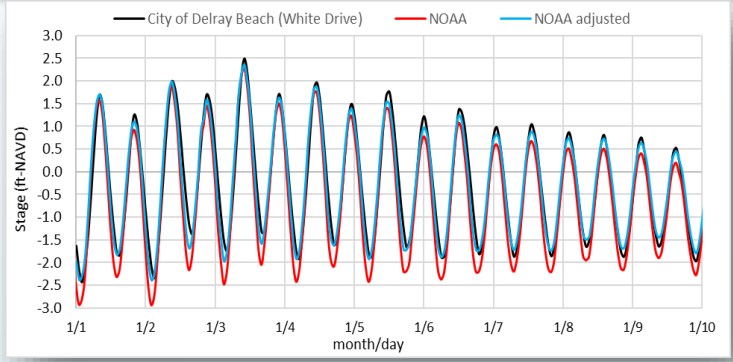
- ✓ Known areas of flooding
- ✓ Know areas or tidal flooding
- ✓ Repetitive flooding complaints

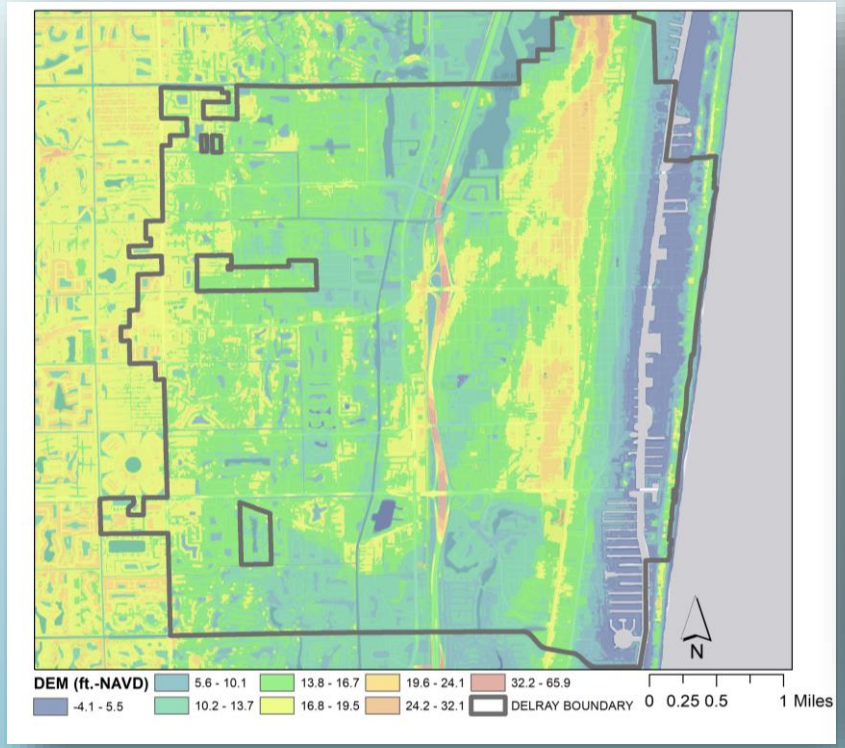
Problem Area	Area (Ac)	Associated Drainage Basin(s)
1	26.2	45-2
2	22.8	45-4
3	7.8	45-5
4	67.3	45-6, 45-7
5	64.8	45-8
6	27.4	45-10
7	61.2	45-11
8	28.5	45-12
9	19.5	45-13
10	281.5	42-2, 42-3, 43-2, 43-6, 43-7, 44-1, 44-2, 44-3
11	14.6	39-1, 39-2
12	15.3	36
13	59.9	2, 3
14	71.0	3

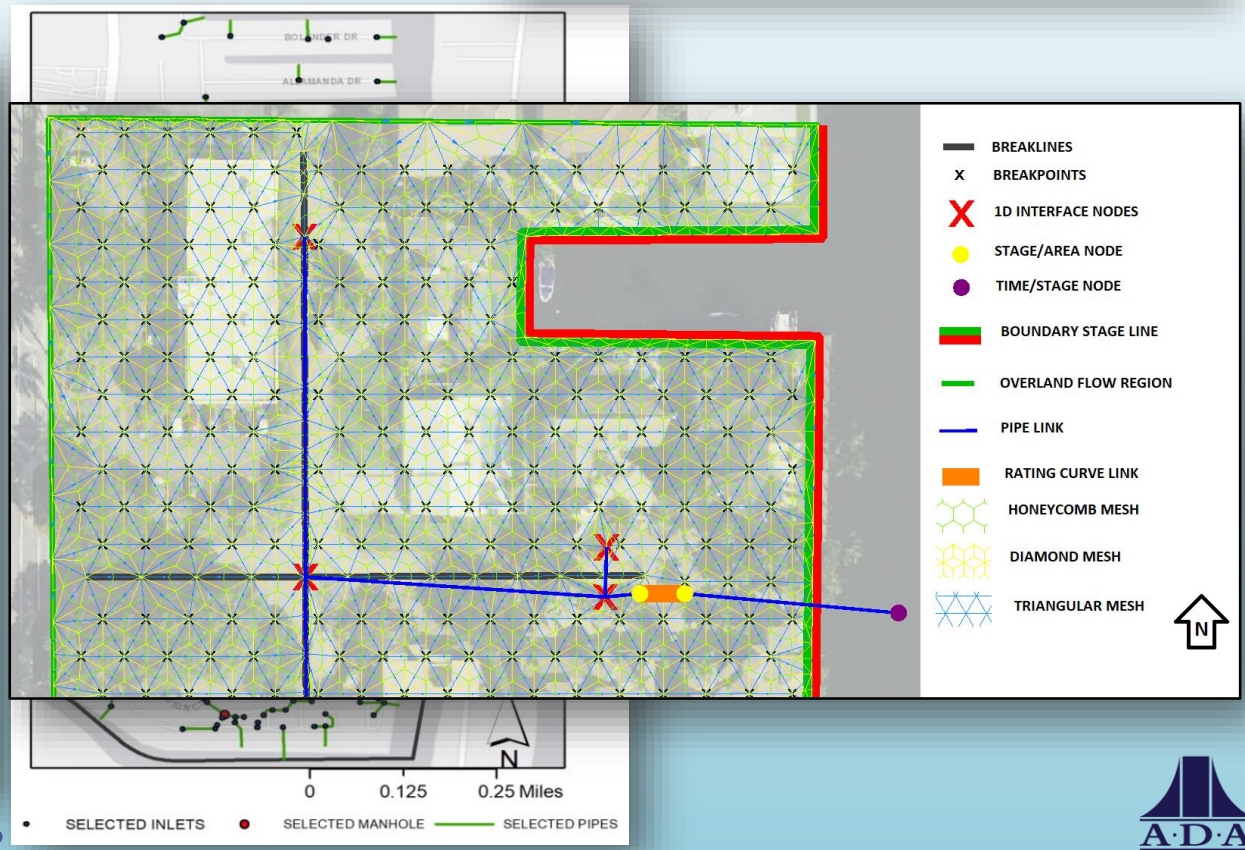
Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.

➢ Hydrologic/Hydraulic Model Setup:

- Used available data to develop an integrated one (1D) / two (2D) dimensional hydrologic/hydraulic model using the ICPRV4 Pro model:
  - ✓ Topography (5' LiDar data from Palm Beach County)
  - ✓ Available stormwater system infrastructure GIS database recently developed by the City
  - ✓ Soils maps
  - ✓ Tidal data
  - ✓ Rainfall data

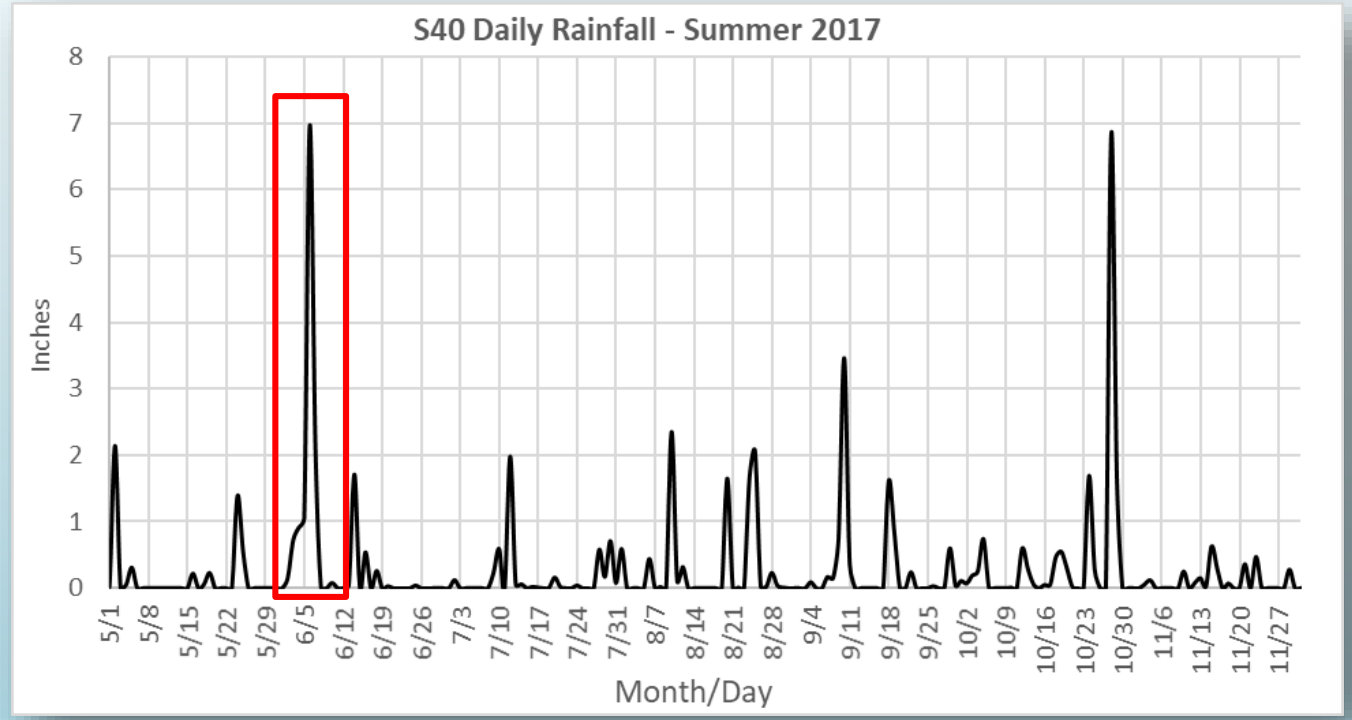


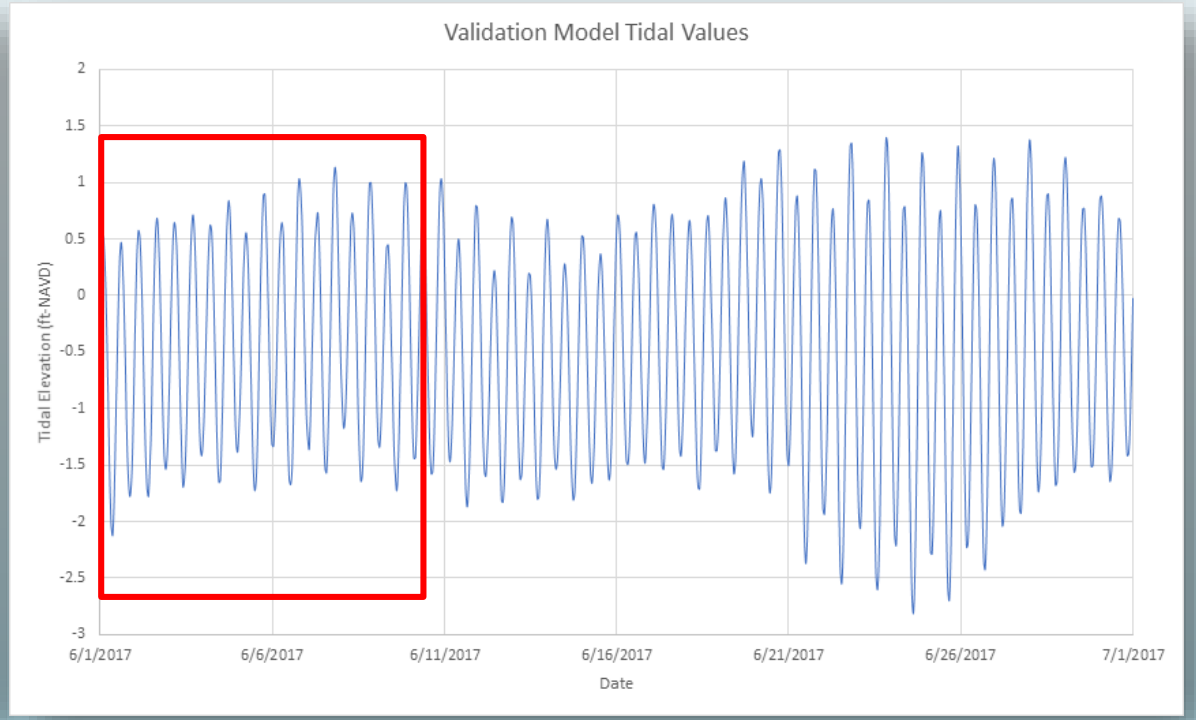




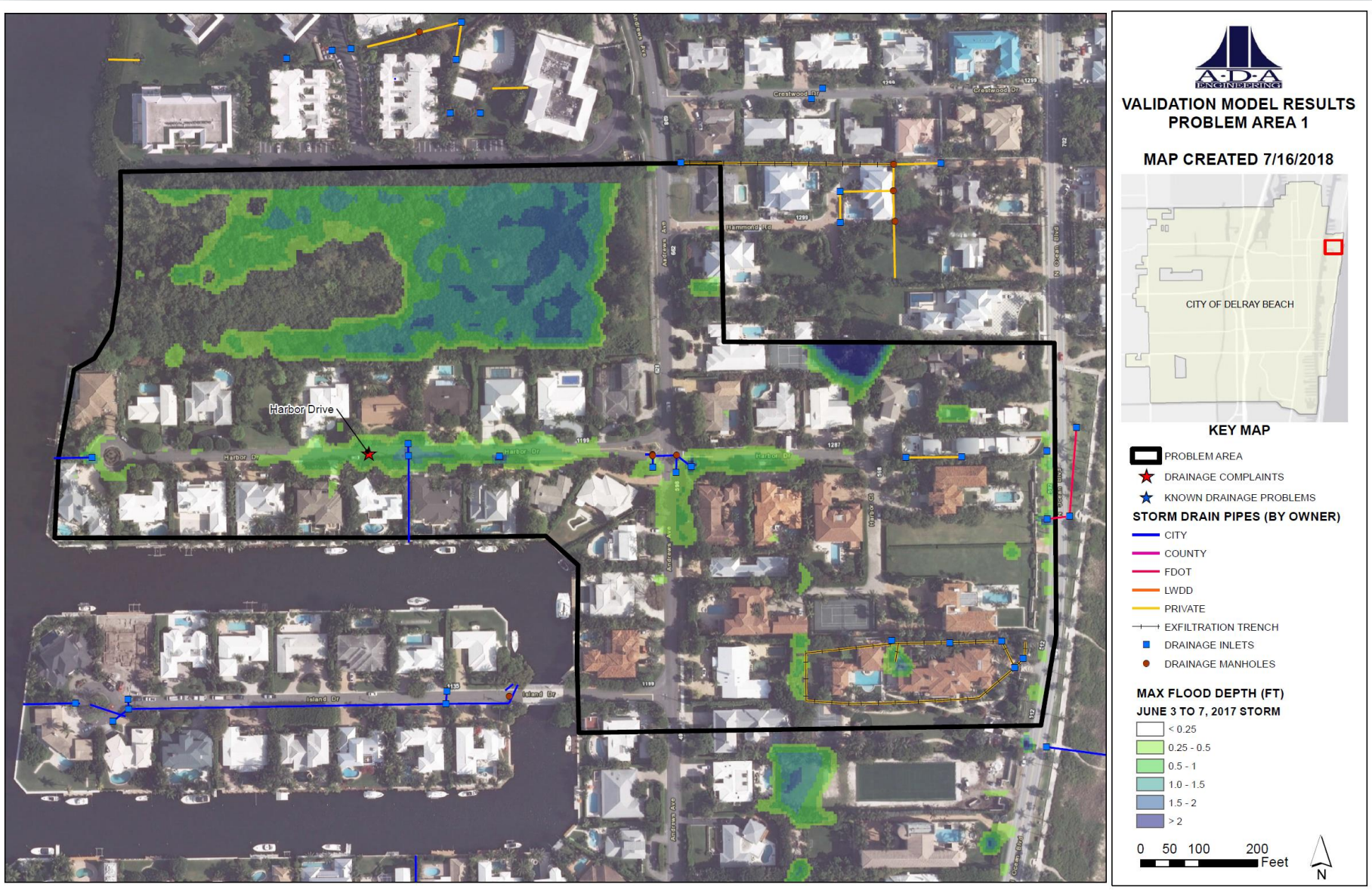
Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.

- **Hydrologic/Hydraulic Model Validation:**
  - ✓ Model was validated with a documented high-intensity 9-day rainfall event from June 1 to June 10, 2018





Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.

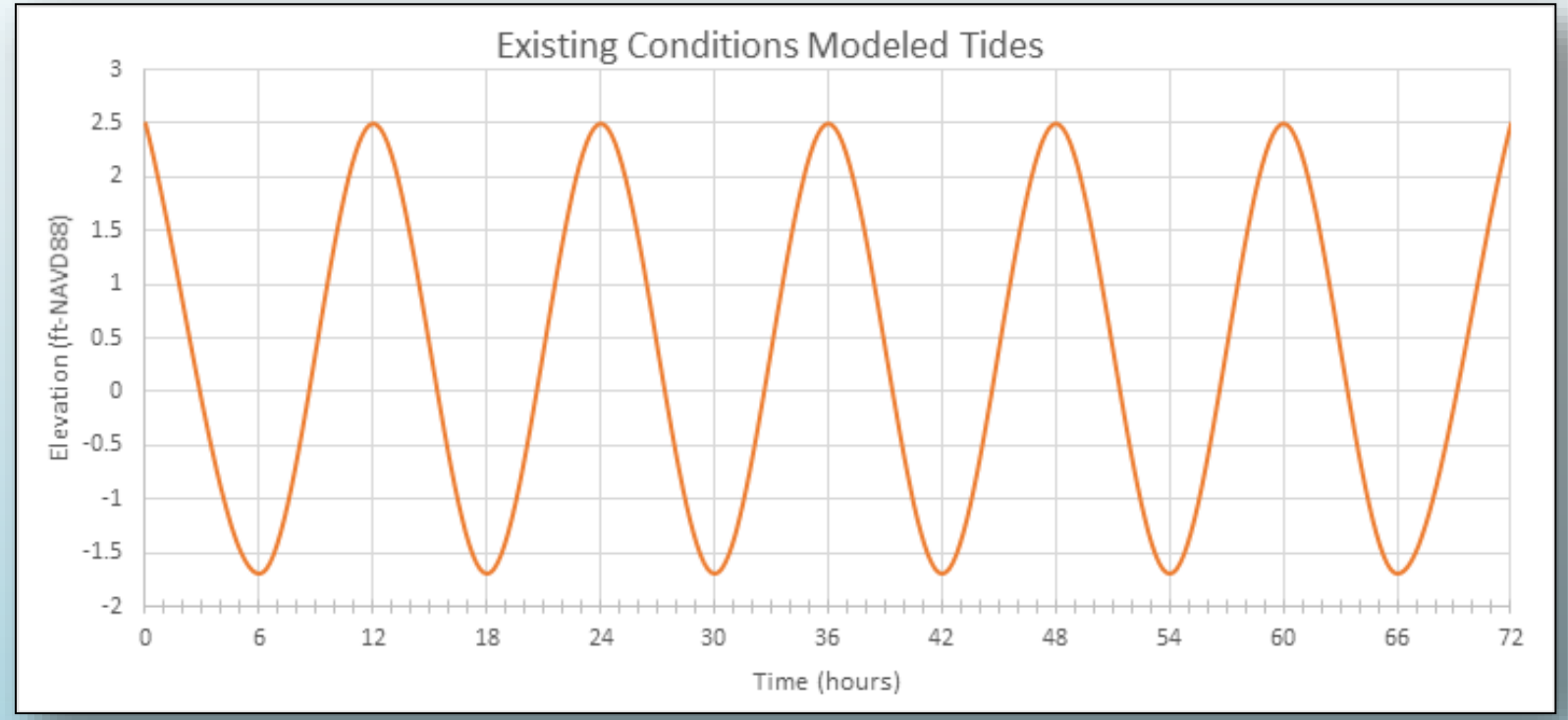


Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.



Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.

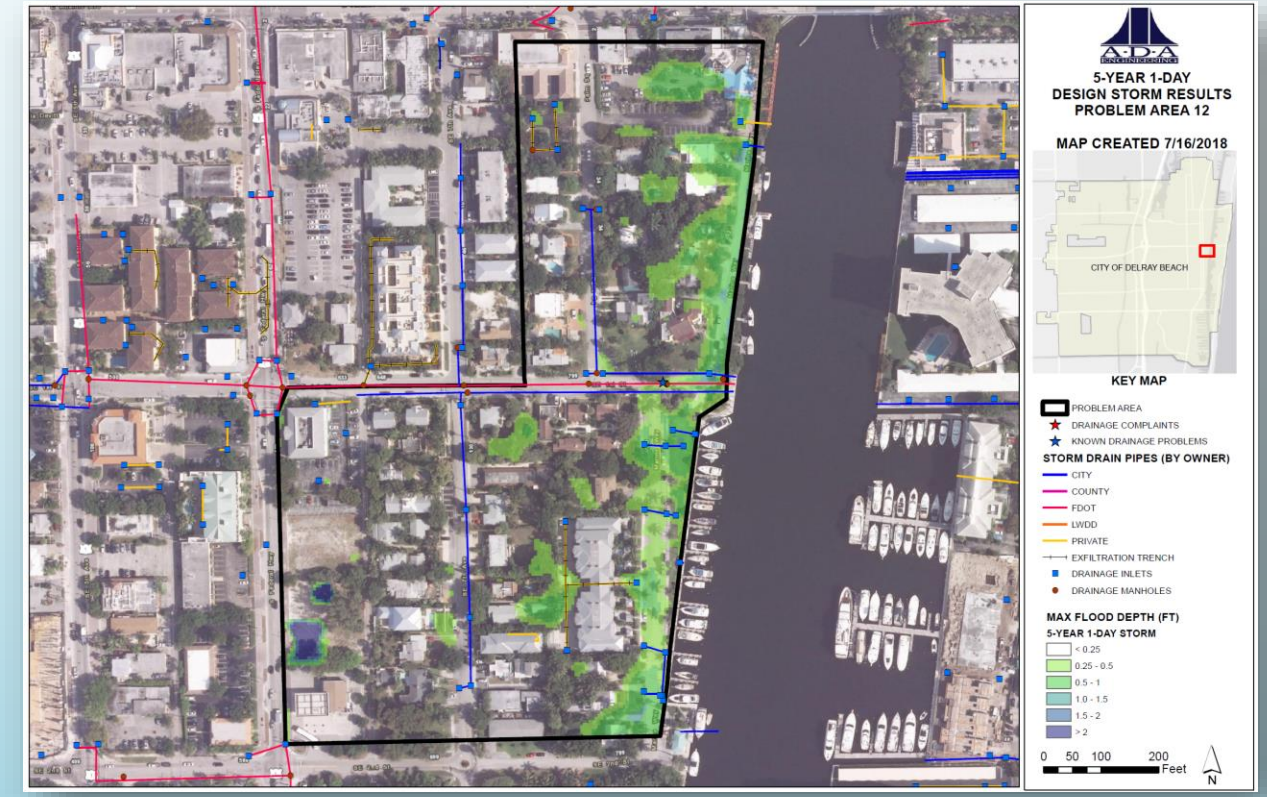
- **Used validated model to simulate design storm events to determine the existing flood protection level of service (LOS) during current King-tide events:**
  - Design storm events simulated:
    - ✓ 5-year, 24-hour (8 to 8.5 inches)
    - ✓ 10-year, 24-hour (10.5 to 11 inches)
    - ✓ 25-year, 72-hour (14.3 to 15.6 inches)
    - ✓ 100-year, 72-hour (17 to 18.5 inches)
  - Tidal condition simulated (3-year Kind-tide average):



Existing Conditions Hydrologic/Hydraulic Modeling (TM1) – Cont.

- **Problem Area 12 sample Design Storm Event flood maps:**

Problem Area 12: 5-year, 24-hour Storm Flooding



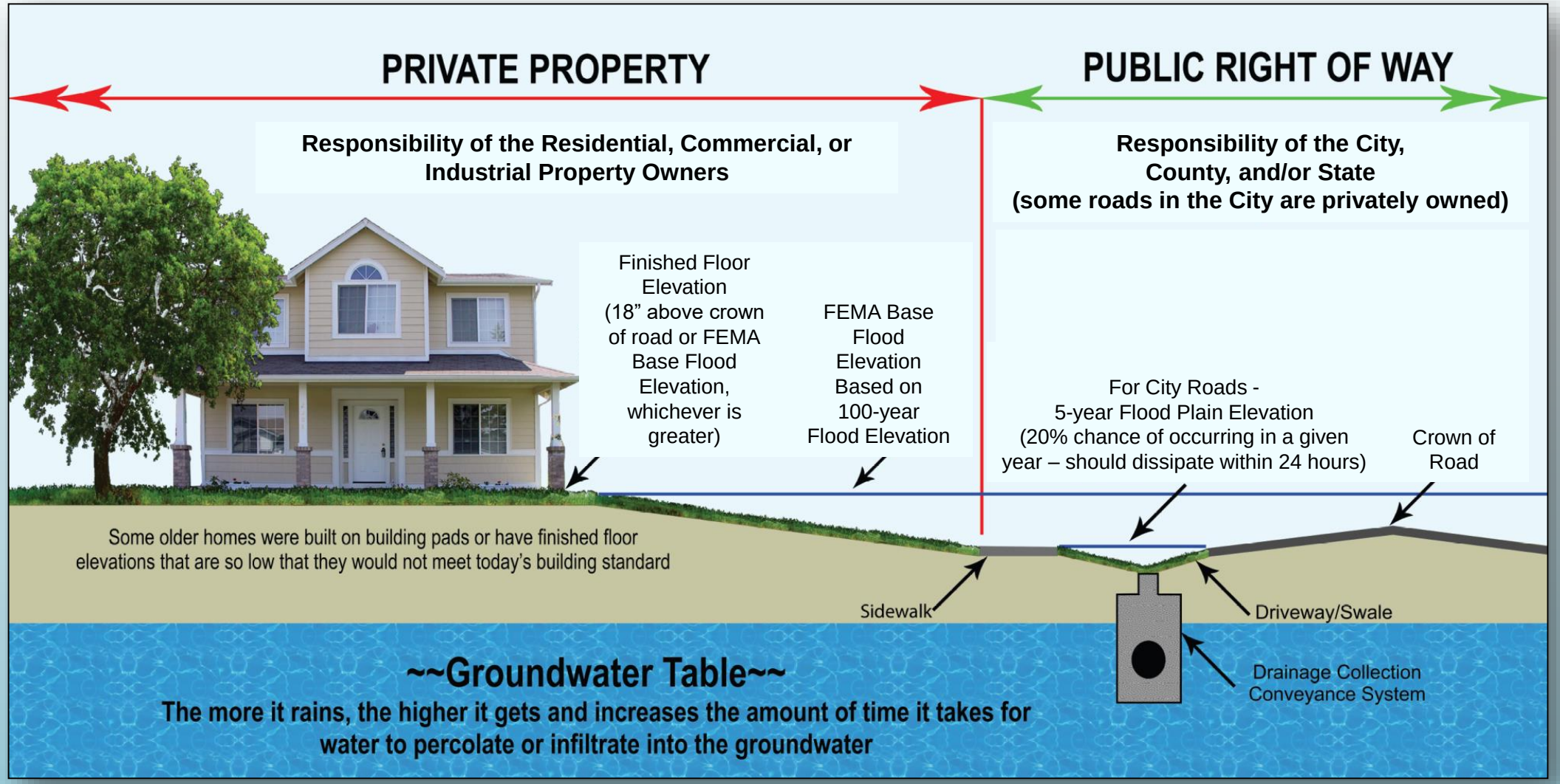
Problem Area 12: 100-year, 72-hour Storm Flooding



Task 4
Existing Conditions Flood Protection Level of Service (TM2)

Existing Conditions Flood Protection Level of Service (TM2)

➢ Flood Protection Level of Service (LOS) Criteria:



Existing Conditions Flood Protection Level of Service (TM2) – Cont.

- **Established flood protection level of service (LOS) based on a Flood Protection Severity Score (FPSS):**

- **FPSS based on two (2) Flood Severity Indicators and Weighting Factors (WF):**

1. **NS: Number of structures** anticipated to flood by a 100-year, 3-day design storm event, which can include commercial, residential, and public buildings. All structures and/or buildings are considered equivalent, regardless of their size or value. **(WF = 4)**

2. **MCLRS: Miles of collector and local residential streets** anticipated to be impassable during 5-year, 1-day design storm event. All collector and local residential streets are considered impassable if the depth of flooding exceeds the crown of the road during the 5-year, 1-day design storm event. **(WF = 2)**

Existing Conditions Flood Protection Level of Service (TM2) – Cont.

- **In addition to the Flood Severity Indicators and Weighting Factor, implemented a Flooding Exceedance (E) Factor:**

Depth of Flooding Above Flooding Severity Indicator	**(E)**
Less than or equal to 6 inches:	1
Greater than 6 inches and less than or equal to 12 inches:	2
Greater than 12 inches	3

- **The FPSS is computed as:**

$$FPSS = \sum 4E_i * NS + \sum 2E_i * MCLRS$$

- **The FPSS is then divided by the Problem Area drainage area to normalize the score.**

Existing Conditions Flood Protection Level of Service (TM2) – Cont.

- **Summary of Problem Area Ranking based on FPSS:**

Rank	Problem Area Name	Sub-Basin Area (Acres)	FPSS	Weighted FPSS
1	Beach Drive (2)	22.84	105.7	4.63
2	Thomas Street & Basin Drive (4)	67.34	234.4	3.48
3	Rainberry Woods (14)	71.02	190.3	2.68
4	Hibiscus (8)	28.53	63.4	2.22
5	Bay Street (6)	27.42	55.2	2.01
6	Seasage Drive (7)	61.22	63.4	1.04
7	Waterway Lane (3)	7.85	4.6	0.59
8	Atlantic Ave (5)	64.79	33.7	0.52
9	Tropic Isles (10)	281.49	144.6	0.51
10	Beach Drive (1)	26.22	9.2	0.35
11	Barwick Park (13)	59.92	17.9	0.3
12	7th Ave (11)	14.65	1.6	0.11
13	Brooks Lane (9)	19.54	1.4	0.07
14	Marine Way (12)	15.28	0.8	0.05

Task 5
Projected Sea Level Rise and Groundwater Rise Impacts (TM3)

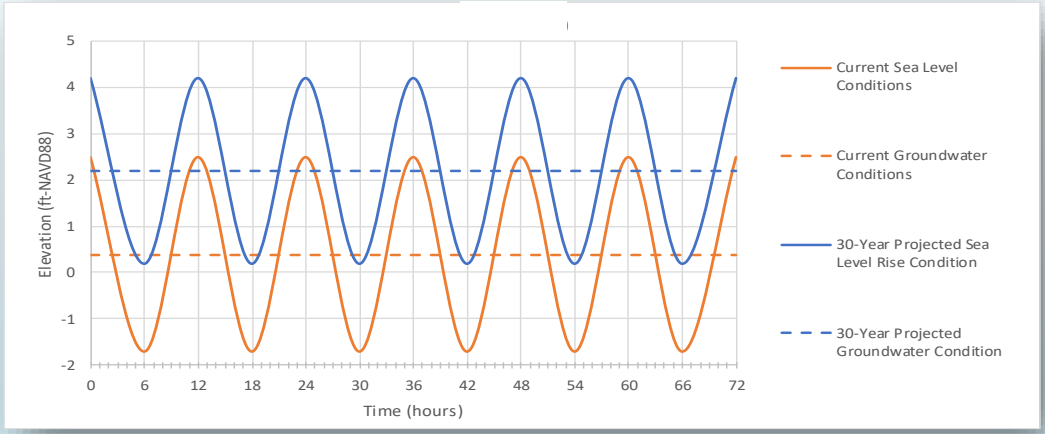
Projected Sea Level and Groundwater Rise Impacts (TM3)

➢ Implemented recommendations from Seawall Vulnerability Study:

✓ 30- and 75-year Planning Horizons for Sea Level and Groundwater Rise:

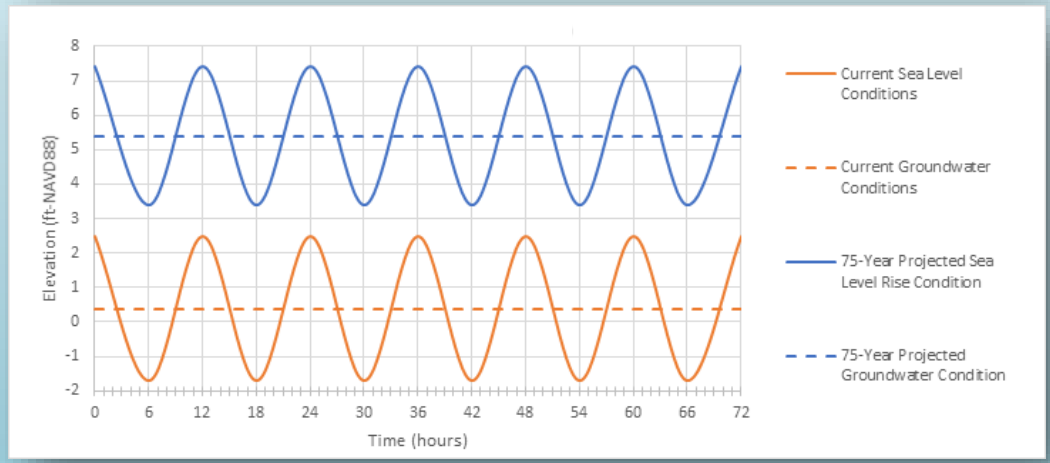
- 30-year Planning Horizon:

30-Year Planning Horizon Model Parameter	Elevation (ft-NAVD)
High Tide Elevation (ft-NAVD)	4.2
Low Tide Elevation (ft-NAVD)	0.2
Avg Wet Season Groundwater Elevation (ft-NAVD)	2.2



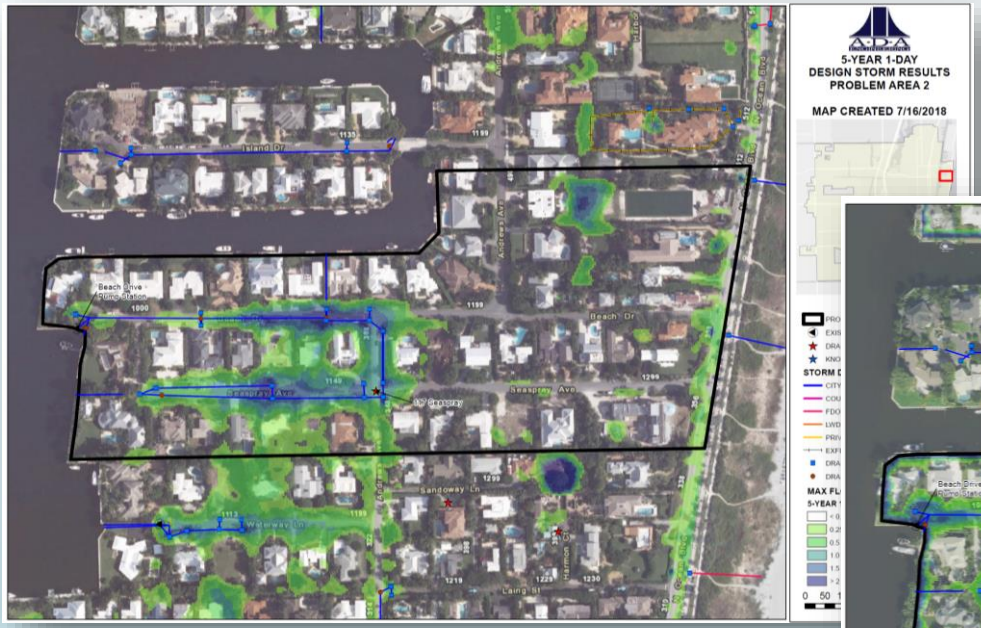
- 75-year Planning Horizon:

75-Year Planning Horizon Model Parameter	Elevation (ft-NAVD)
High Tide Elevation (ft-NAVD)	7.4
Low Tide Elevation (ft-NAVD)	3.4
Avg West Season Groundwater Elevation (ft-NAVD)	5.4



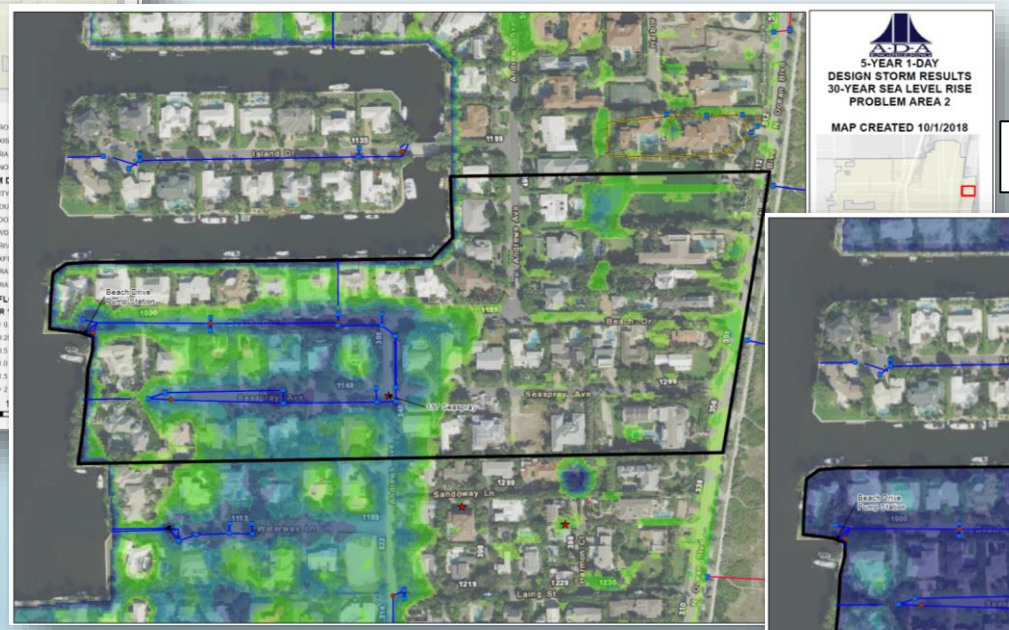
Projected Sea Level and Groundwater Rise Impacts (TM3) – Cont.

Existing Conditions: 5-yr, 24hr Storm

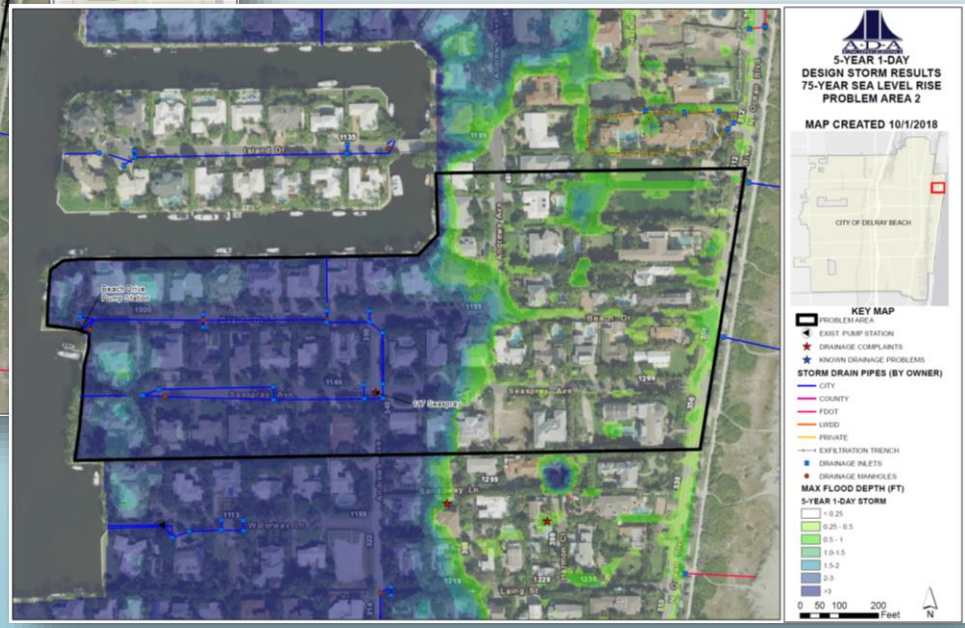


➢ **Problem Area 2 sample Sea Level Rise Impact:**

30-year: 5-yr, 24hr Storm



75-year: 5-yr, 24hr Storm



Projected Sea Level and Groundwater Rise Impacts (TM3) – Cont.

- **30-Year Planning Horizon degradation in FPSS:**

Problem Area	Problem Area Description	Existing Conditions FPSS	30-Year Sea Level Rise FPSS	Percent Increase of FPSS
1	Harbor Drive	9.2	57.4	524%
2	Beach Drive	105.7	246.4	133%
3	Waterway Lane	4.6	61	1226%
4	Basin Drive	234.4	1181.8	404%
5	Atlantic Avenue	33.7	872	2488%
6	Bay Street	55.2	388.3	603%
7	Seasage Drive	63.40	535.6	745%
8	Hibiscus Road	63.4	368.7	482%
9	Brooks Lane	1.4	382.7	27236%
10	Tropic Isles	144.6	673.2	366%
11	7th Avenue	1.6	50.2	3038%
12	Marine Way	0.8	142.2	17675%
13	Barwick Park	17.9	41.9	134%
14	Rainberry Woods	190.3	294.5	55%

Task 7
Capital Improvement Projects (TM5)

Capital Improvement Projects (TM5)

- **Key assumptions and criteria for proposed Capital Improvement Projects:**

  - ✓ Projects conceptually designed to mitigate 30-year Planning Horizon sea level and groundwater rise to meet desired flood protection LOS.

    (**Achieve FPSS of 0 to the maximum extent practical**)

  - ✓ All seawalls (private or public) or access to the intracoastal must be elevated to the recommend minimum elevation of 4.2 ft-NAVD88.

  - ✓ All existing gravity outfalls (private or public) to remain must be protected with backflow preventers.

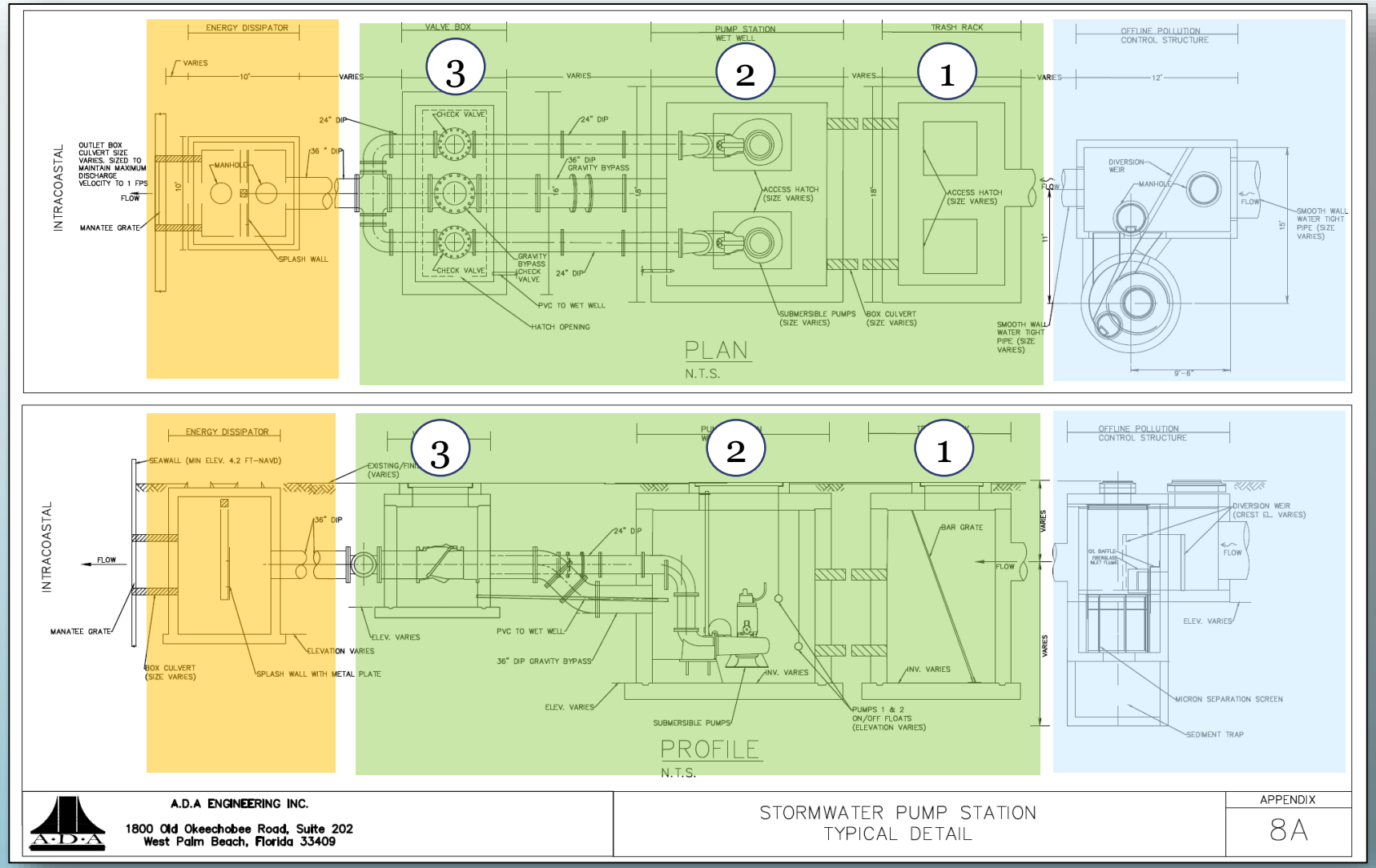
  - ✓ Known existing gravity pipes (private or public) to remain that show signs of infiltration must be slipped lined to prevent groundwater intrusion through cracks or non-watertight joints.

Capital Improvement Projects (TM5) – Cont.

- **Key structural elements for formulating Capital Improvement Projects:**
  - ✓ Constructing Stormwater pump stations with pollution control devices
  - ✓ Raising roads and low-laying areas
  - ✓ Implementing backflow preventers for gravity outfalls to remain
  - ✓ Lining gravity pipes to remain
  - ✓ Constructing exfiltration trenches

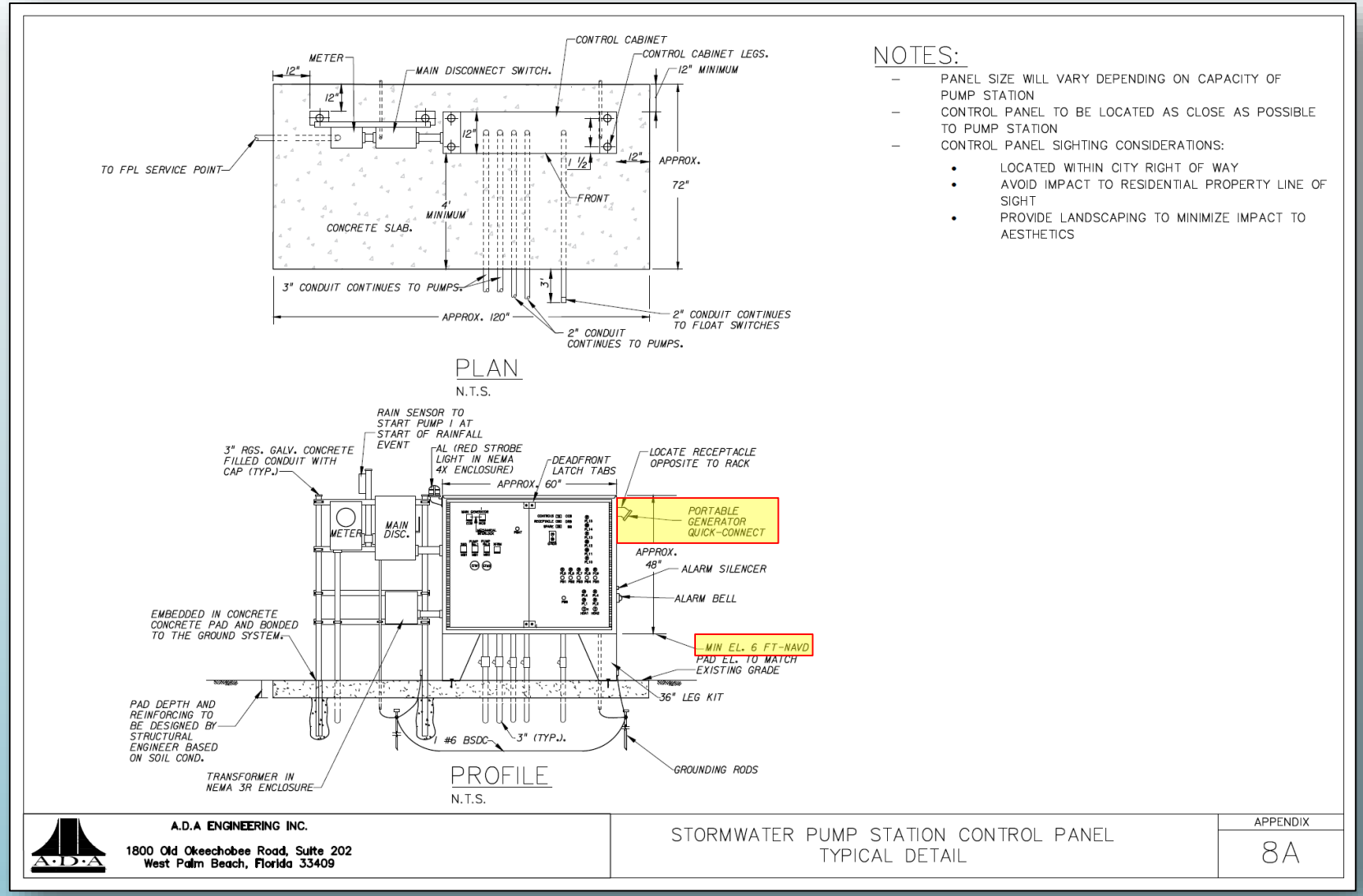
Capital Improvement Projects (TM5) – Cont.

- **Stormwater pump stations with pollution control devices:**



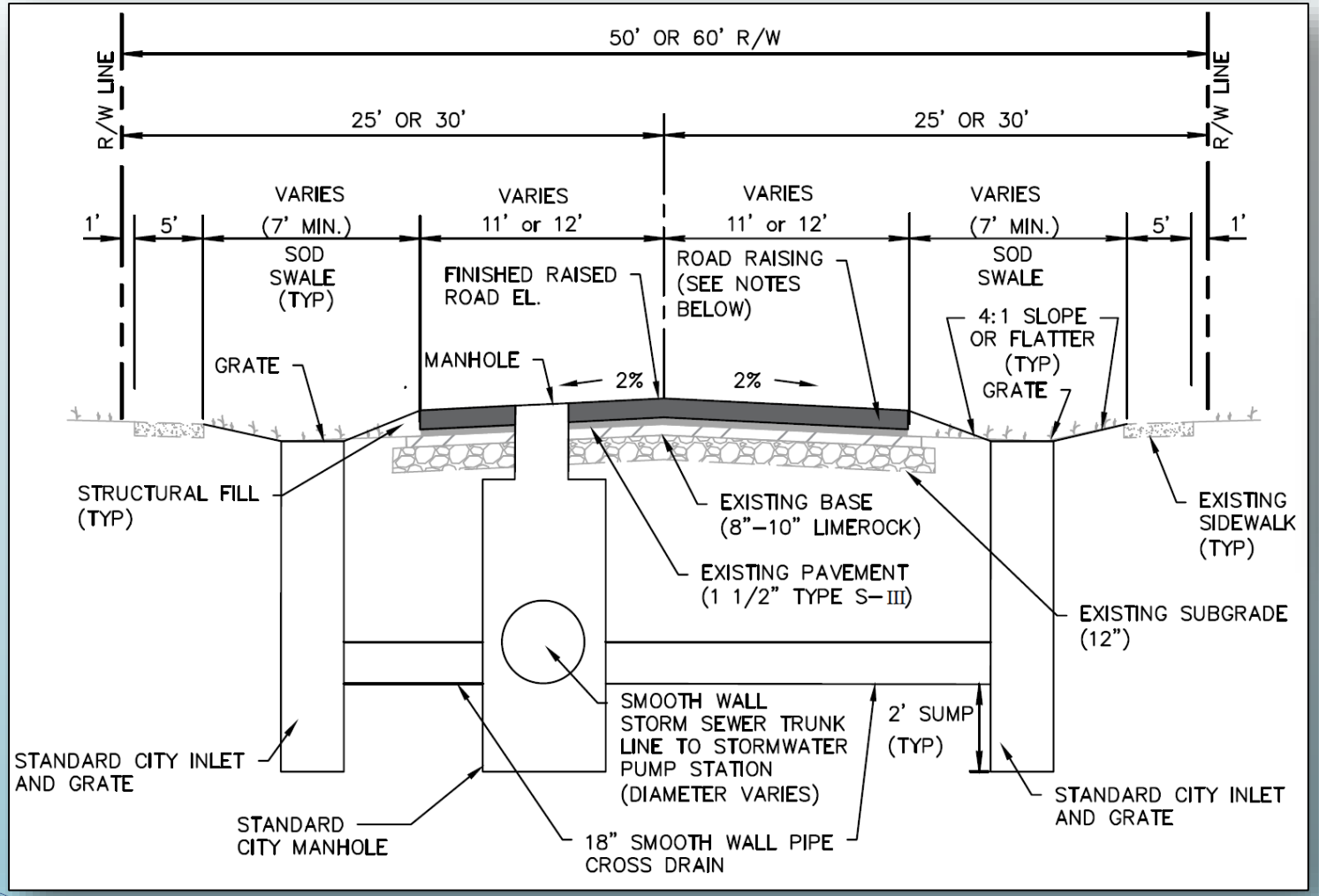
Capital Improvement Projects (TM5) – Cont.

➢ Stormwater pump stations electrical panel:



Capital Improvement Projects (TM5) – Cont.

➢ Raising of roads and low-laying areas:

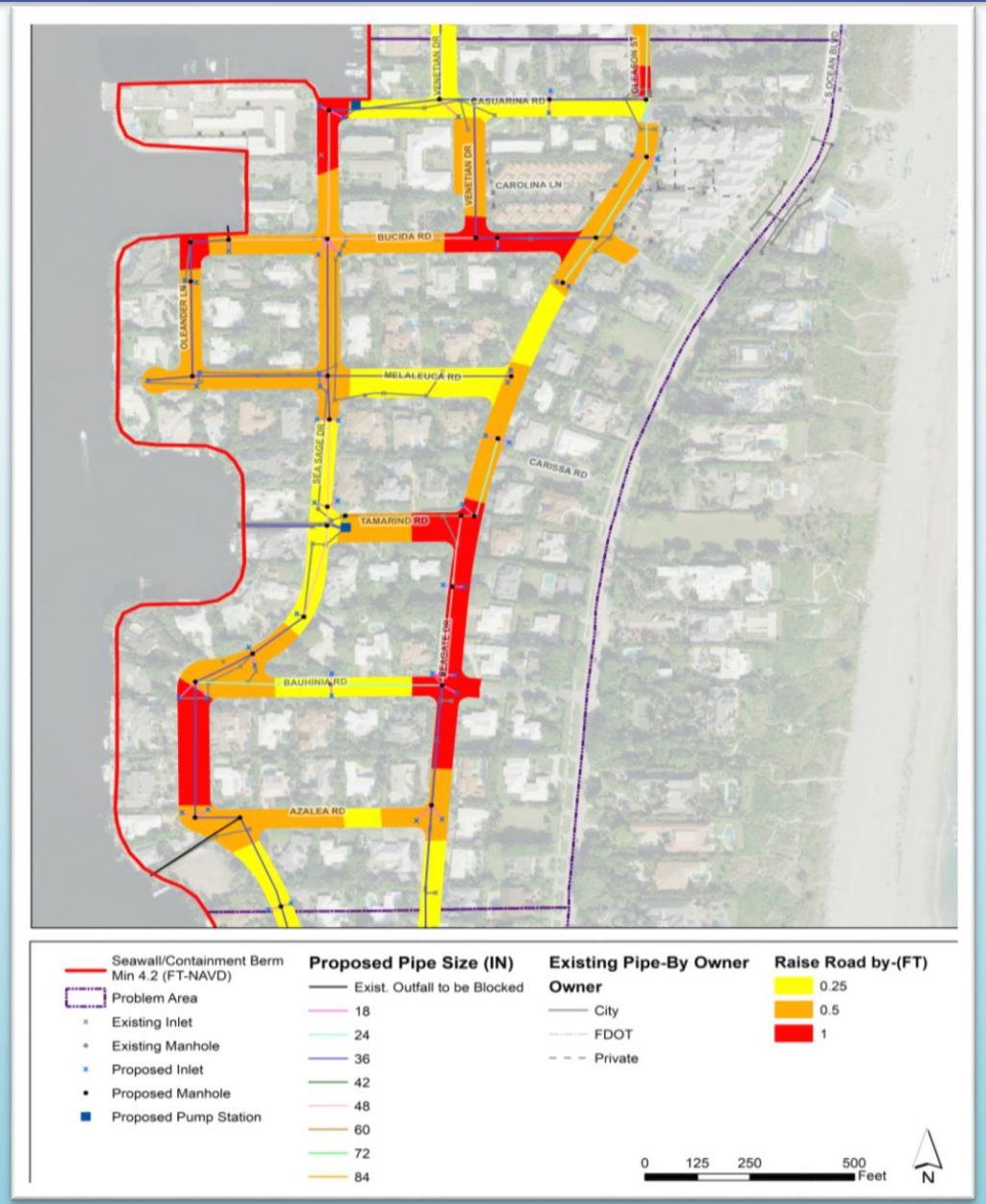


ROADWAY RAISING NOTES:

1. FOR ROADWAY RAISING BETWEEN 0.25' TO 0.5':
   - TOP LAYER 1 1/2" FDOT SP–9.5 ASPHALT.
   - BETWEEN EXISTING PAVEMENT AND TOP ASPHALT LAYER, PLACE 2"–4" LIFTS OF FDOT SP–19.0 ASPHALT.
2. FOR ROADWAY RAISING BETWEEN 0.5' TO 1.0':
   - MILL EXISTING ASPHALT TO TOP OF LIMEROCK BASE.
   - TOP LAYER 1 1/2" FDOT SP–9.5 ASPHALT.
   - PLACE COMPACTED LIMEROCK BETWEEN TOP ASPHALT LAYER AND EXISTING TOP OF LIMEROCK BASE.

Capital Improvement Projects (TM5) – Cont.

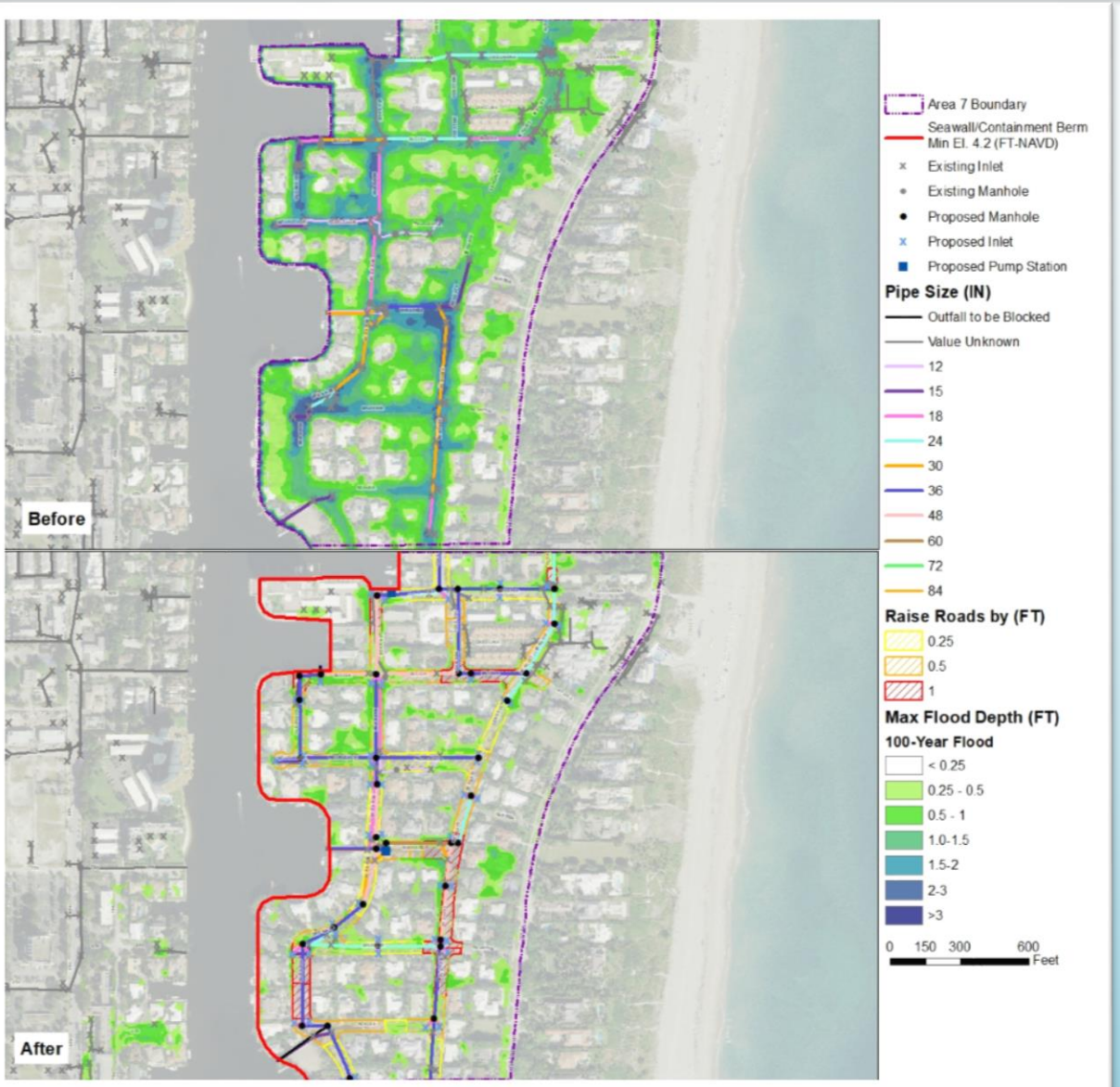
- **Sample Capital Improvement Project for Problem Area 7 (61 acres)**
- **FPSS = 0**
  - **Existing FPSS = 63.4**
  - **30-year FPSS = 535.6**



Capital Improvement Projects (TM5) – Cont.

- **Problem Area 7 improvements for 100-year, 72-hour event:**

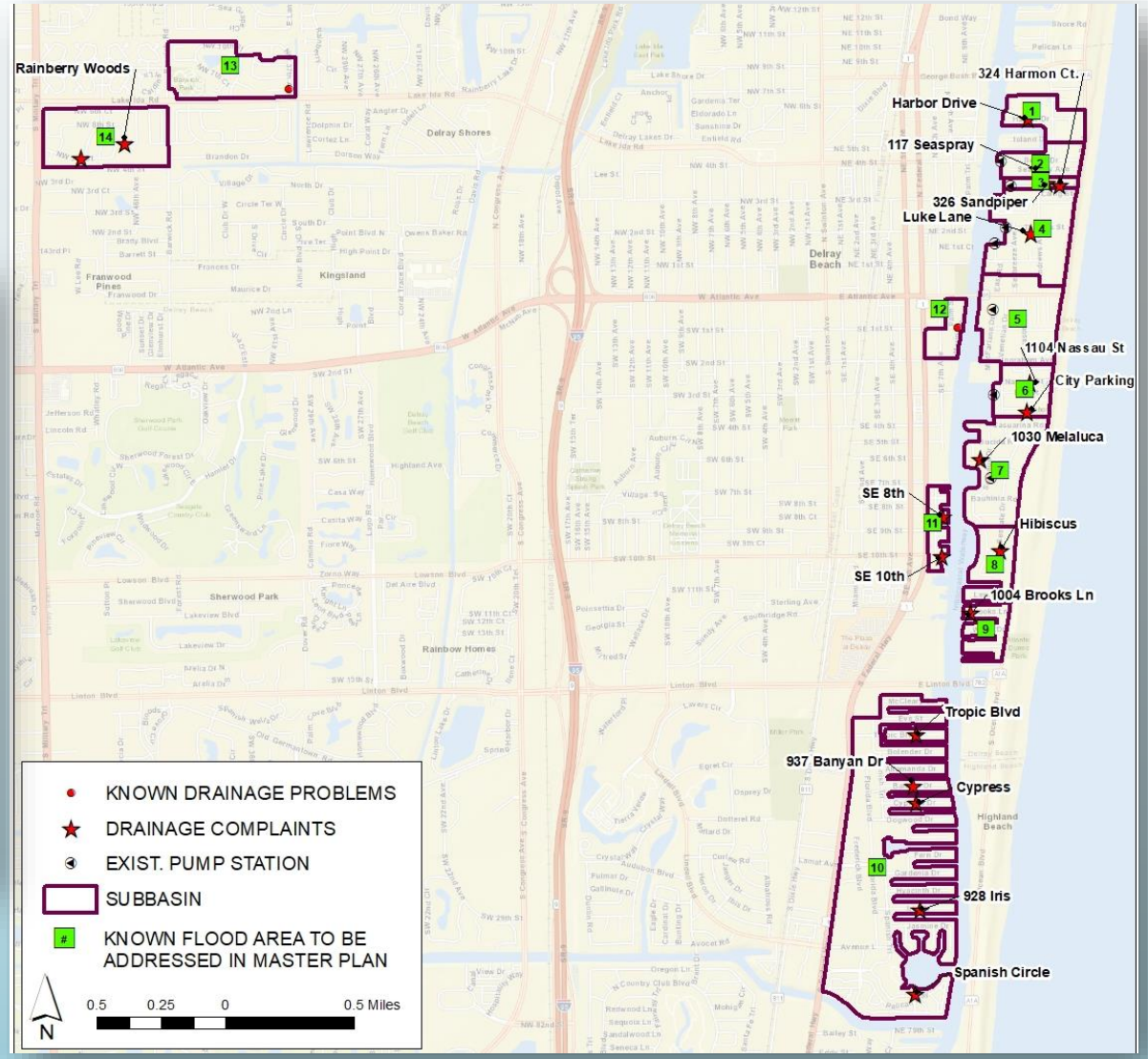
- **Planning-level cost approx. $33 Million**



Capital Improvement Projects (TM5) – Cont.

- **Planning-Level costs for all Problem Areas (2019 Dollars):**

Problem Area Name	Problem Area	Project Cost Estimate
Harbor Drive	1	$10,343,628.80
Beach Drive	2	$10,621,968.41
Waterway Lane	3	$19,400,414.09
Basin Drive	4	$42,085,705.66
Atlantic Avenue	5	$27,975,112.98
Bay Street	6	$21,087,575.32
Seasage Drive	7	$32,943,700.48
Hibiscus Road	8	$25,470,832.60
Brooks Lane	9	$15,902,001.70
Tropic Isles	10	$157,191,957.44
7th Avenue	11	$6,396,712.90
Barwick Park	13	$3,743,110.48
Rainberry Woods	14	$5,200,277.37
TOTAL		**$378,362,998.23**



Capital Improvement Projects (TM5) – Cont.

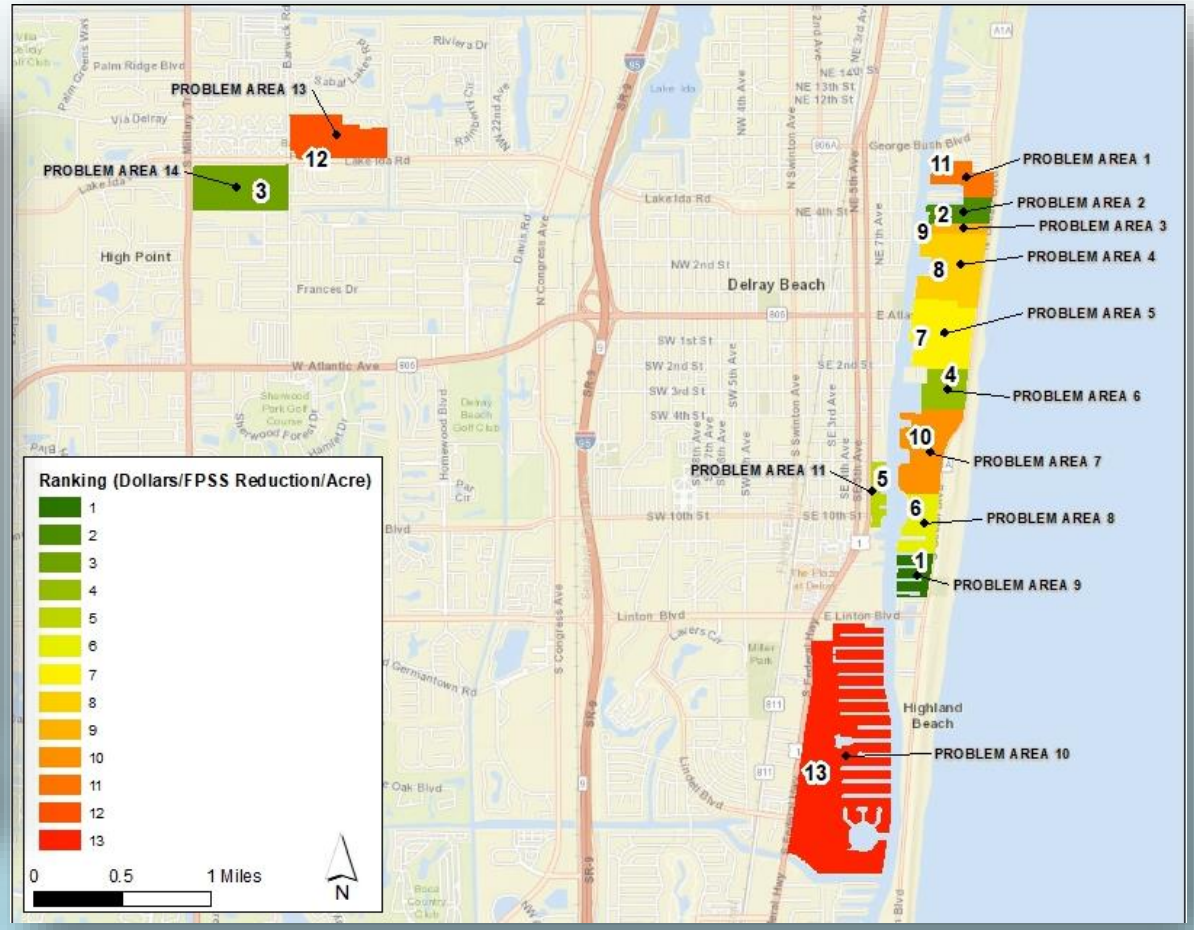
- **Approach for ranking Capital Improvement Projects based on cost effectiveness:**

Problem Area Name	Problem Area (Acres)	Flood Protection Severity Score (FPSS)			FPSS Difference (30-Year Sea Level Rise FPSS minus Capital Improvements FPSS)	Percent Reduction of FPSS with Capital Improvements	Area-Weighted FPSS Difference (points reduced per acre)	Dollars per FPSS Point Reduced per Acre
		Current Tidal Conditions	30-Year Sea Level Rise	30-Year Sea Level Rise				
		Existing Infrastructure	Existing Infrastructure	Capital Improvements				
1	26.22	9.20	57.40	0.00	57.40	100%	2.19	$ 4,724,911.97
2	22.84	105.70	246.40	0.00	246.40	100%	10.79	$ 984,601.29
3	7.85	4.60	61.00	0.00	61.00	100%	7.77	$ 2,496,610.67
4	67.34	234.40	1181.80	12.00	1169.80	99%	17.37	$ 2,422,680.30
5	64.79	33.70	872.00	12.00	860.00	99%	13.27	$ 2,107,566.94
6	27.42	55.20	388.30	24.10	364.20	94%	13.28	$ 1,587,647.76
7	61.22	63.40	535.60	0.00	535.60	100%	8.75	$ 3,765,521.55
8	28.53	63.40	368.70	0.00	368.70	100%	12.92	$ 1,970,932.61
9	19.54	1.40	382.70	0.00	382.70	100%	19.59	$ 811,928.70
10	281.49	144.60	673.20	64.00	609.20	90%	2.16	$ 72,632,902.33
11	14.65	1.60	50.20	0.00	50.20	100%	3.43	$ 1,866,769.80
12	-	0.80	142.20	-	-	-	-	-
13	59.92	17.90	41.90	0.00	41.90	100%	0.70	$ 5,352,915.99
14	71.02	190.30	294.50	8.00	286.50	97%	4.03	$ 1,289,087.95

Capital Improvement Projects (TM5) – Cont.

➢ Ranking of Capital Improvement Projects based on cost effectiveness:

Rank	Problem Area	Problem Area Name	Dollars per Weighted FPSS Point Reduced per Acre	Project Cost Estimate
1	9	Brooks Lane	$811,928.70	$15,902,001.70
2	2	Beach Drive	$984,601.29	$10,621,968.41
3	14	Rainberry Woods	$1,289,087.95	$5,200,277.37
4	6	Bay Street	$1,587,647.76	$21,087,575.32
5	11	7th Avenue	$1,866,769.80	$6,396,712.90
6	8	Hibiscus Road	$1,970,932.61	$25,470,832.60
7	5	Atlantic Avenue	$2,107,566.94	$27,975,112.98
8	4	Basin Drive/Thomas Street	$2,422,680.30	$42,085,705.66
9	3	Waterway Lane	$2,496,610.67	$19,400,414.09
10	7	Seasage Drive	$3,765,521.55	$32,943,700.48
11	1	Harbor Drive	$4,724,911.97	$10,343,628.80
12	13	Barwick Park	$5,352,915.99	$3,743,110.48
13	10	Tropic Isles	$72,632,902.33	$157,191,957.44
-	12	Marine Way	-	-
TOTAL COST				$378,362,998.23



Questions?

Conclusions and Recommendations

Current Efforts:

1. Public Seawalls and Pipe Connections to ICW
   - Establish Minimum Seawall Height (30-year Planning Horizon is 4.2 ft-NAVD88)
   - Repair and Elevate City Owned Seawalls
   - Install Check Valves at City Owned Pipes
   - Line or Replace City Owned Pipes

2. Private Seawalls and Pipes Connections to ICW
   - Seawall Study Evaluated Implementation Strategies (other South Florida Coastal Communities)
   - Ordinances Options to Protect City and Residents from Projected Sea Level Rise:
     - ✓ 1) Public/Private Partnership – Uses Existing Comp Plan Requirements
     - ✓ 2) Ordinance with Minimum Elevation and Timeline Requirement
     - ✓ 3) Ordinance with Elevation Requirement only
     - ✓ 4) City Implementation – Assess Significant Fees, Take Ownership

Conclusions and Recommendations

Next Steps:

1. The Stormwater Master Plan provides a roadmap to implement projects as part of the Capital Improvement Plan (CIP).
   - Prioritize Projects
     - based on available funding
     - Coordination with other projects
     - Input from residents
2. City should adopt the Final Stormwater Master Plan to obtain credit for CRS improvements.
3. Fund through Bonds or Federal Grants for addressing sea level rise and Climate Change and Revising Stormwater Utility Fee (currently underway)

Conclusions and Recommendations – Cont.

1. Update Stormwater Master Plan every 5-years as required by FEMA:
    1. Maximize Community Rating Score (CRS)
    2. Re-assess sea-level and groundwater rise trends
    3. Re-prioritize projects based on projects previously implemented

2. City to adopt a policy on how to move forward to implement change in line with goals of the Comprehensive Plan

THANK YOU FOR YOUR ATTENTION
- DISCUSSION -

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