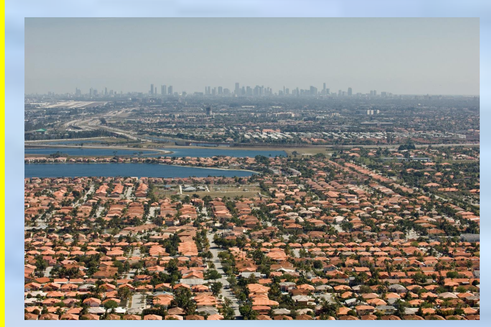
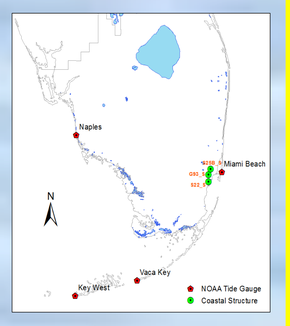
Development of future tidal boundary conditions at coastal structures for hydraulic modeling in south Florida

Tibebe Dessalegne (tdessale@sfwmd.gov), Jayantha Obeysekera (jobey@sfwmd.gov),
Luis Cadavid (cadavid@sfwmd.gov), Sashi Nair (snair@sfwmd.gov) and Rodrigo Musalem (rmusalem@sfwmd.gov)
Hydrology & Hydraulics Bureau, South Florida Water Management District

Background

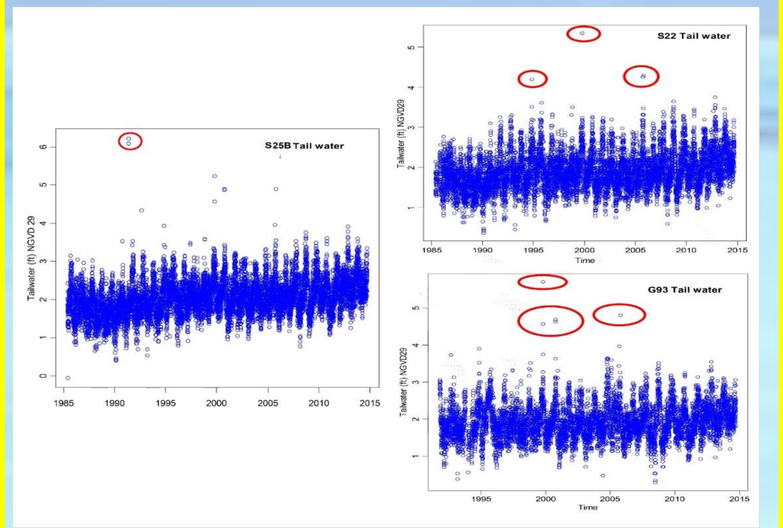
- South Florida Water Management District (District) has launched a flood protection level of service (LOS) analysis program at a basin level.
- The LOS analysis employs a hydraulic model to simulate water levels in canals and flood plains, and operation of hydraulic structures in the basin.
- As a pilot LOS project, the C-4 watershed in Miami, Florida was selected.
- The C-4 hydraulic model requires tidal boundary conditions for existing condition (2015) and future condition (2065) for different return levels at various sea level rise projection scenarios.
- The three coastal structure included in the C-4 hydraulic model are S-25B, S-22 and G-93.





Data Collection & Preparation

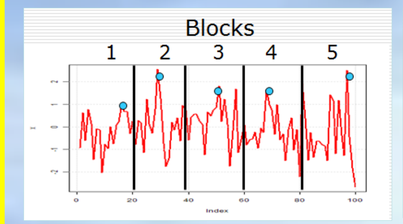
- The instantaneous archived tailwater stages at S-25B, S-22 and G-93 were utilized for extreme value analysis (1985-2014).
- Outliers in the data were detected and removed.

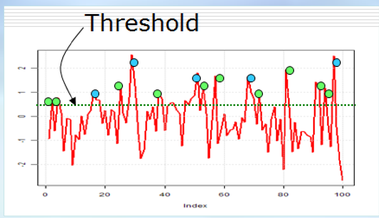


Time series plot of the tailwater stages at S-25B, S-22 and G-93 Structure for their period of record.

Frequency Analysis for Peak Stages

- Peak tailwater elevation corresponding to a series of return periods (RP) were calculated using statistical methods.
- Statistical methods include:
  - Extreme Value of Modeling of Block Maxima (BM)
  - Extreme Value Modeling of Peaks over Threshold (POT)
  - Mixture Distributions (MD)
  - Monte-Carlo Joint Probability Methods





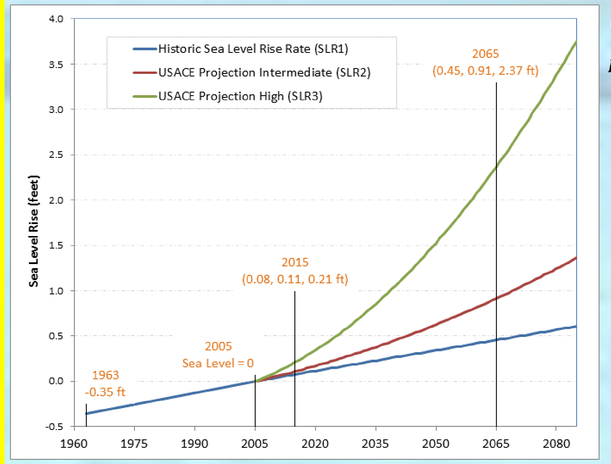
Block Maxima and Peaks Over Threshold in extreme value modeling

Structure	RP (years)					
	2	5	10	25	50	100
S-25B	3.68	4.10	4.50	5.06	5.56	6.15
S-22	3.54	3.85	4.15	4.61	4.98	5.38
G-93	3.58	4.04	4.48	5.11	5.65	6.26

Tailwater Stage Return Levels (feet NGVD) at coastal structures

Determination of Sea Level Change

- The USACE Engineering Regulation (ER 1100-2-8162) was used to evaluate sea-level change (SLC).
- Long-term water level data from Key west tidal gage (NOAA) was used to determine rate of sea level change.



Global SLC

$$E(t) = 0.0017t + bt^2$$

Local SLC

$$E(t) = Mt + bt^2$$

M is published or the regionally corrected rate.

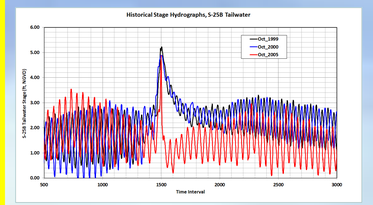
Sea Level Change Projections at Key West Tide Gage (M = 2.31mm/year)

Identification of Storm Hydrograph

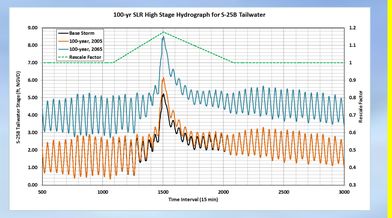
Base storm stage hydrograph was selected based on the following criteria:

- When the king tide dominates (typically in the October due to seasonal highs)
- Exhibiting three well differentiated periods, regular tide, storm surge and regular tide, in that order.
- The longer the storm surge period the better.

The October 1999 storm was selected as base stage storm.



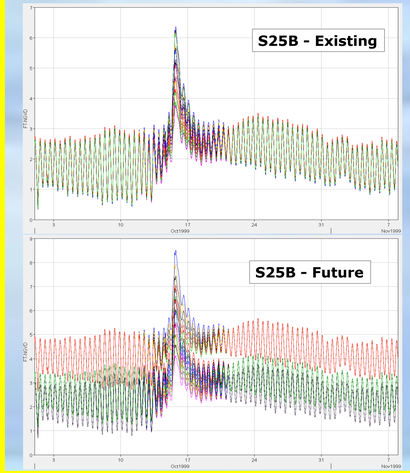
Base storm stage hydrographs



Re-scaled hydrographs with extreme values

Construction of Tailwater Hydrographs

- Base stage hydrograph re-scaled to peak stage and adjusted for SLC.
- A total of 126 stage hydrographs were developed.



Year	Low	Intermediate	High
2005	0.00	0.00	0.00
2010	0.04	0.05	0.10
2015	0.08	0.11	0.21
2020	0.11	0.17	0.34
2025	0.15	0.23	0.49
2030	0.19	0.30	0.66
2035	0.23	0.38	0.85
2040	0.27	0.46	1.06
2045	0.30	0.54	1.28
2050	0.34	0.63	1.53
2055	0.38	0.72	1.79
2060	0.42	0.81	2.07
2065	0.45	0.91	2.37
2070	0.49	1.02	2.69
2075	0.53	1.13	3.02
2080	0.57	1.24	3.38
2085	0.61	1.36	3.75
2090	0.64	1.48	4.14
2095	0.68	1.61	4.55
2100	0.72	1.74	4.98

SLC (feet) at Key West Tide gage with respect to 2005

Applications

- Developed stage hydrographs used as boundary conditions in the C-4 watershed hydraulic model.
- Enabled the assessment of level of service of the C-4 basin under different return levels and sea level change scenarios.
- Enabled evaluation of structure capacity analysis at coastal water control structures.
- Provided insights to future water levels at coastal water control structures.