An Initial Evaluation of the Effect of Sea Level Rise on Salinity in Florida Bay Using Statistical Methods and Models

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Objective of Study

- Evaluate the effect of sea level rise (SLR) on hydrology (stage and flow) in the Everglades and salinity in Florida Bay:
  - From literature
  - Using statistical salinity models
- Evaluate the effect of SLR on CERP Performance Measures
- Apply the findings to paleosalinity analyses

LITERATURE REVIEW

- Focus on SLR influence on:
  - Coastal aquifers
  - Estuarine salinity
- Most papers were addressing saltwater intrusion into coastal aquifer
- Few papers addressing impact on hydrologic cycle in watershed or salinity changes in receiving water

Halverson and Taylor (2003)

- St Lucia World Heritage site
- Unconsolidated sand aquifer
- 20% of rainfall reaches water table aquifer
- Water table rise will be equal to SLR because of gentle slope of land
- Large area of watershed is affected
- Loss of low salinity areas from groundwater influence that serve as refugia during hypersalinity periods

MASTERSON and PORTNOY (2005)

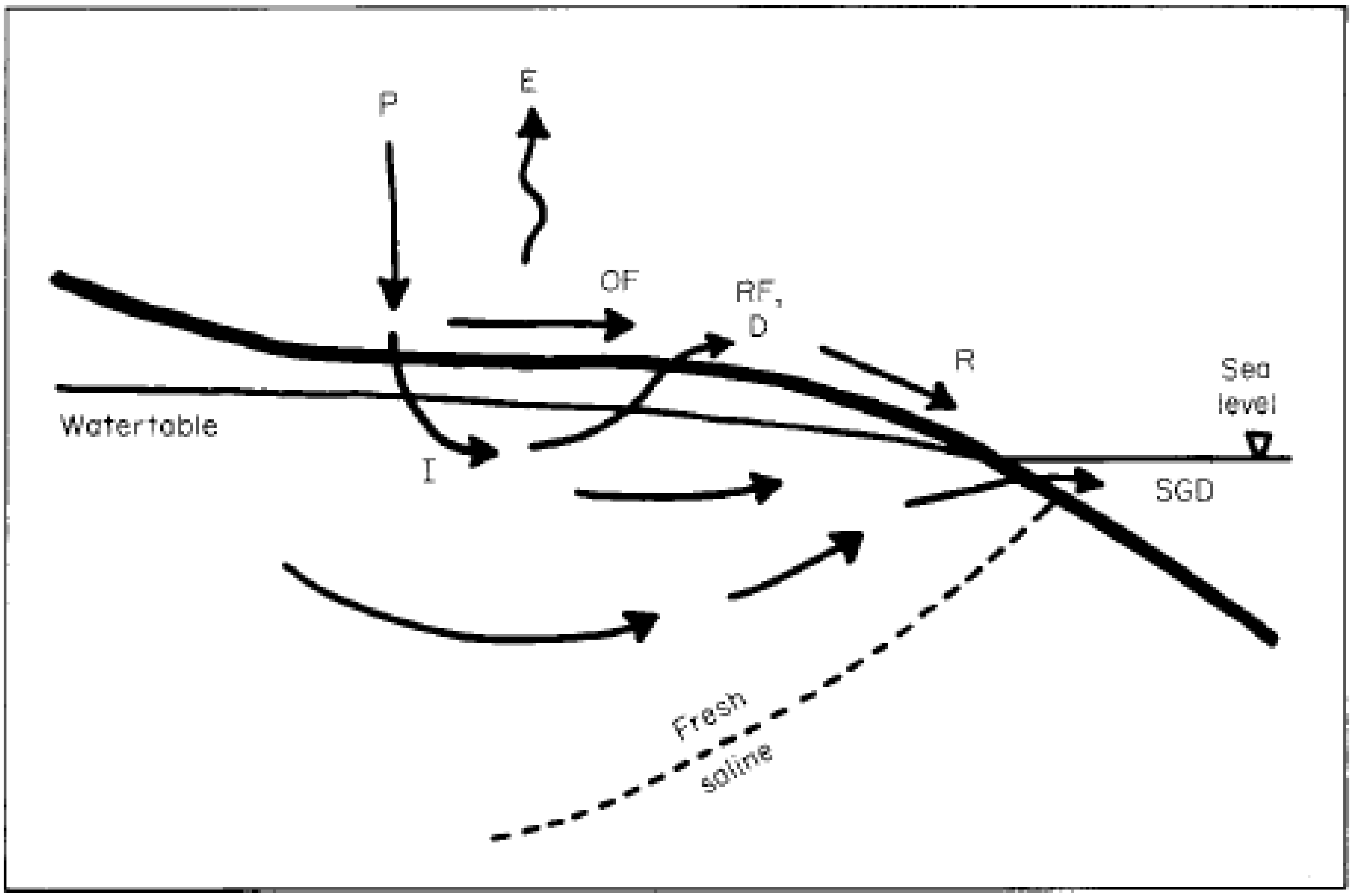
Masterson – USGS; Portnoy - NPS

- Cape Cod coastal aquifer study
- Study based on 2001 IPCC estimates
- SLR will cause water table to rise
- Height of water table relative to sea level will not change
- Effects on coastal habitats
  - Increased erosion rates
  - Damage from higher storm surge flooding
  - Intrusion of seawater in coastal wetlands

Nuttle and Portnoy (1993)

Effect of Sea Level Rise on Runoff and Groundwater Discharge to Coastal Ecosystems

Estuarine and Coastal Shelf Sciences



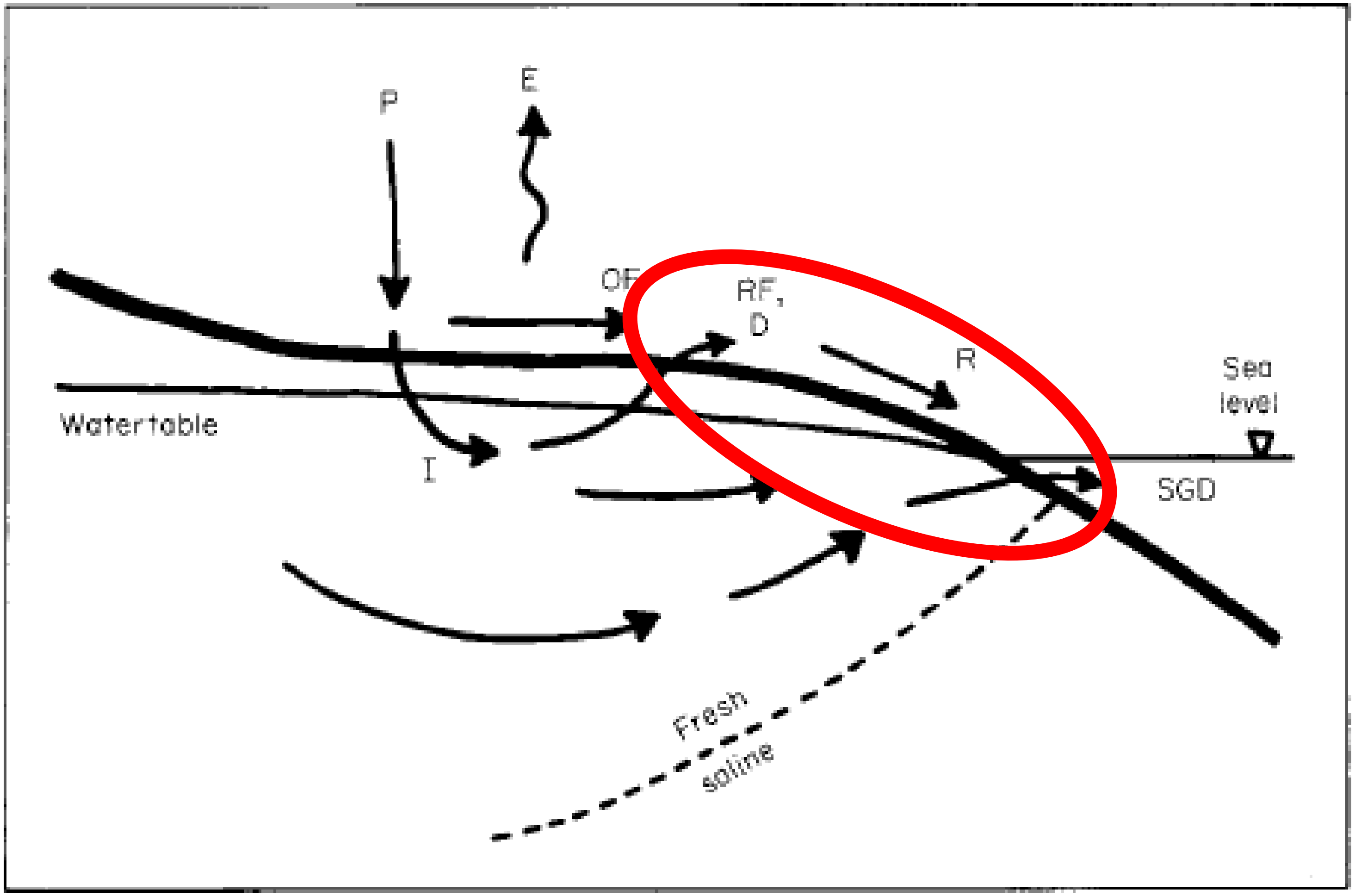
Nuttle and Portnoy (1993)

- Darcy's Law application
- Rate of change of discharge is proportional to slope of water table (gradient)
- As water table increases due to SLR, soil saturation in upper soil strata increases, thereby increasing runoff
- In reaction, groundwater discharge must decrease to balance runoff increase

Nuttle and Portnoy (1993)

- If groundwater flow decreases, the slope of water table must decrease
- Height of water table above sea level will decrease in proportion to decrease in groundwater discharge
- So water table rise will be less than SLR due to increased runoff

Nuttle and Portnoy (1993)



Nuttle and Portnoy (1993)

- Mill Creek on Cape Cod
- A 10cm rise in the water table means
  - 70 % increase in surface runoff
  - 20 % decrease in groundwater discharge
- Increased runoff is only significant where:
  - Large portion of watershed is above high tide
  - But not too high above water table (Ex: south Florida)

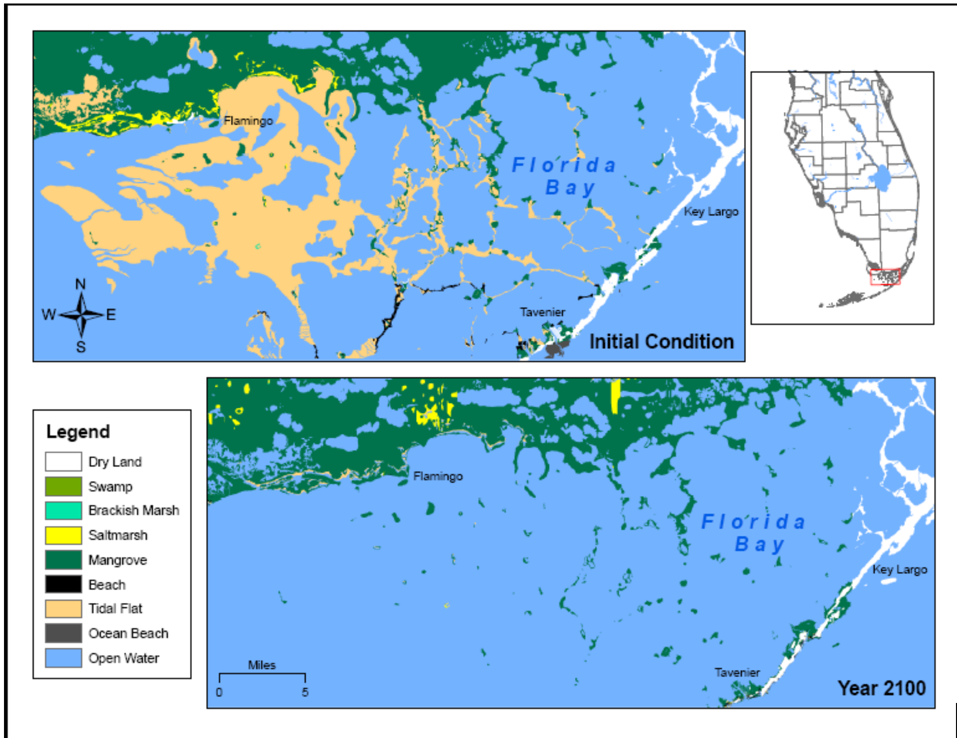
Nuttle and Portnoy (1993)

- Most affected are watersheds of coastal lagoons:
  - 20% of coastlines in US
  - 13% of coastlines in world
  - Florida Bay, Biscayne Bay
- Changes in hydrology of coastal wetlands may be more important than direct effects of SLR or climate change

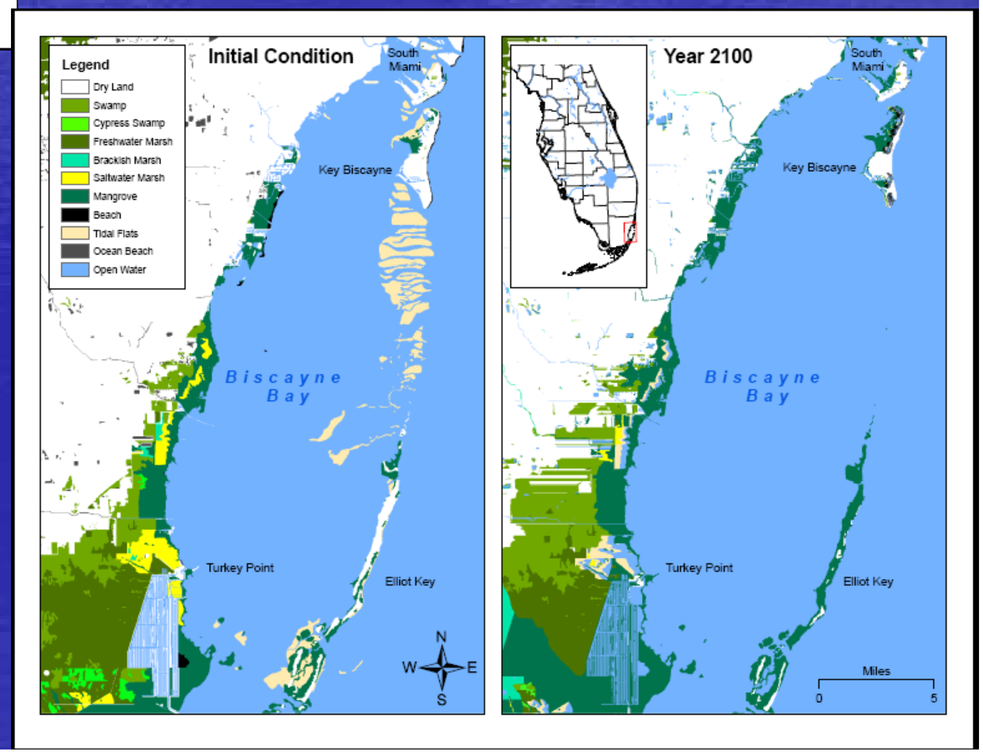
NWF and FWF (2006)

- 2001 IPCC SLR estimates
- Output from SLAMM Model (Seas Level Affecting Marshes Model)
- Florida Bay
  - 99% tidal flat loss; 32,000 acre
  - 29% open estuarine water gain; 34,000 acre
- Biscayne Bay
  - 13% dry land loss; 7,500 acre
  - 33% inland freshwater marsh loss; 2500 acre
  - 3% estuarine open water gain; 2,500 acre
  - 71% mangrove gain; 6,000 acre
  - 52% open ocean gain; 3,000 acre

FLORIDA BAY



BISCAYNE BAY



Trimble et al, (no date, circa 2000)

INCREASE IN WATER LEVELS IN C&SF SYSTEM DUE TO SLR OF 15 CM

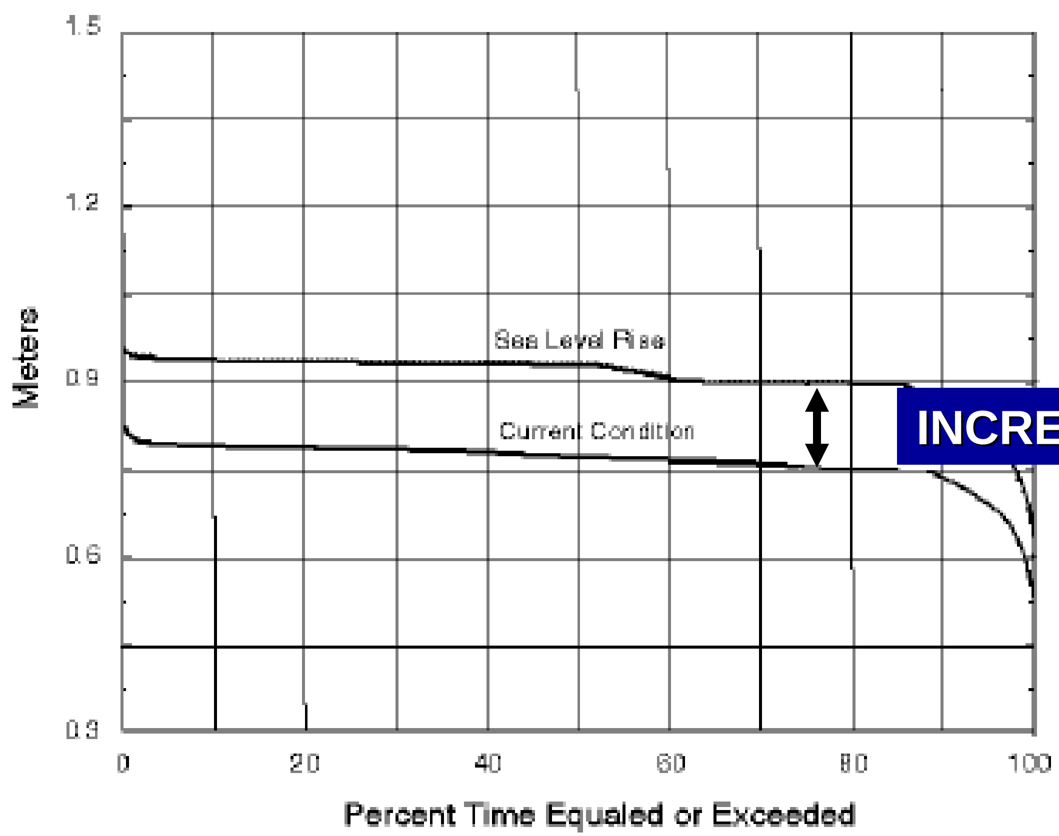


Figure 2. Example Canal Stage-Duration Curve for Developed Coastal Region.

INCREASE = 15 CM

ANALYSIS OF SLR EFFECTS ON MLR SALINTIY MODELS

- Direct Method
  - Analyze partial R^2 of MLR models
  - Increase Key West water level and stage, use MLR models to estimate salinity
- Indirect Method – Increase salinity at western, open-Gulf monitoring station, use new univariate models to estimate salinity at other stations

SLR EFFECTS ON MLR MODELS

- SLR will cause salt/fresh water interface in estuary to move landward
- Literature says that SLR will increase stage in coastal aquifers
- How much stage will increase?
- Much debate
- Highest estimates are equal to SLR
- Safe range is 50% of SLR – 100% of SLR

LITTLE MADEIRA BAY MLR MODEL

Little Madeira Bay = 106.1 - 0.3 CP[lag2] - 12.5 P33[lag2] - 1.7 (P33-NP206) - 0.25 UWNDKW + 0.13 UWNDMIA - 0.19 VWNDMIA[lag1] + 0.95 kwwatlev[lag2]

Variable	Partial R^2	% Variation Explained
P33 lag2	0.5092	91.35%
CP lag2	0.0203	3.64%
Vwndmia lag1	0.0076	1.36%
uwndkw	0.0094	1.69%
Kwwatlev lag2	0.0045	0.81%
P33-NP206	0.0038	0.68%
uwndmia	0.0026	0.47%

TERRAPIN BAY MLR MODEL

Terrapin Bay = 106.9 - 6.3 CP[lag1] - 11.1 P33[lag2] -0.45 UWNDKW - 0.23 UWNDKW [lag1] - 0.2 UWNDKW [lag2] - 0.14 VWNDKW[lag2] + 0.46 UWNDMIA + 1.9 kwwatlev [lag2]

Variable	Partial R^2	% Variation Explained
P33lag2	0.6602	91.81%
cplag1	0.0262	3.64%
kwwatlevlag2	0.0089	1.24%
uwndkwlag2	0.0061	0.85%
uwndkw	0.0054	0.75%
uwndmia	0.0082	1.14%
uwndkwlag1	0.0019	0.26%
vwndkwlag2	0.0022	0.31%

COMPARISON OF STAGE AND KEY WEST WATER LEVEL ELEVATION DATA (VALUES IN CM)

	N	Mean	Std Dev	Range
CP	2912	66.1	16.8	105
P33	2956	201.5	17.1	100.9
kwwatlev	2999	1.2	18.9	109.1

SLR OVER PERIOD OF RECORD = 6 CM

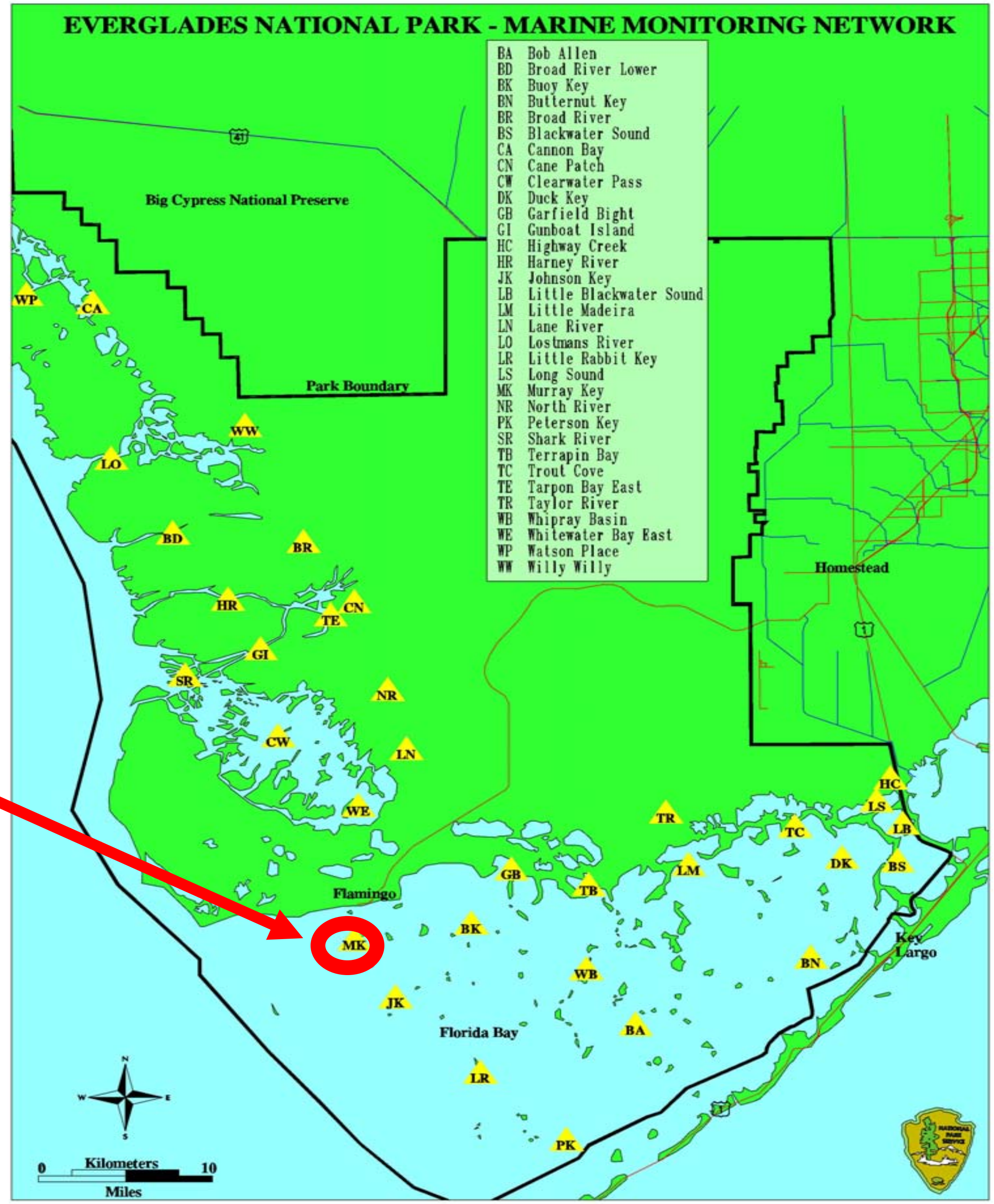
INCREASE KEY WEST WATER LEVEL ONLY (TABLE VALUES ARE SALINITY, PSU)

MODEL	Observed	5cm SLR	20cm SLR	40cm SLR	50cm SLR
ltmad	20.65	20.98	21.45	22.06	22.38
terbay	23.97	23.31	24.23	25.44	26.07

INCREASE STAGE, SLR = 50 CM (TABLE VALUES ARE SALINITY, PSU)

MODEL	Obs.	50cm SLR, stage	50cm SLR plus 5 cm	50cm SLR plus 10 cm	50cm SLR plus 20 cm	50cm SLR plus 50 cm
ltmad	20.65	22.38	20	17.63	12.92	2.15
terbay	23.97	26.07	23.21	20.37	14.8	2.9

INDIRECT METHOD: INCREASE SALINITY AT MURRAY KEY (mean = 33.2 psu)



- Murray Key plus 1 psu

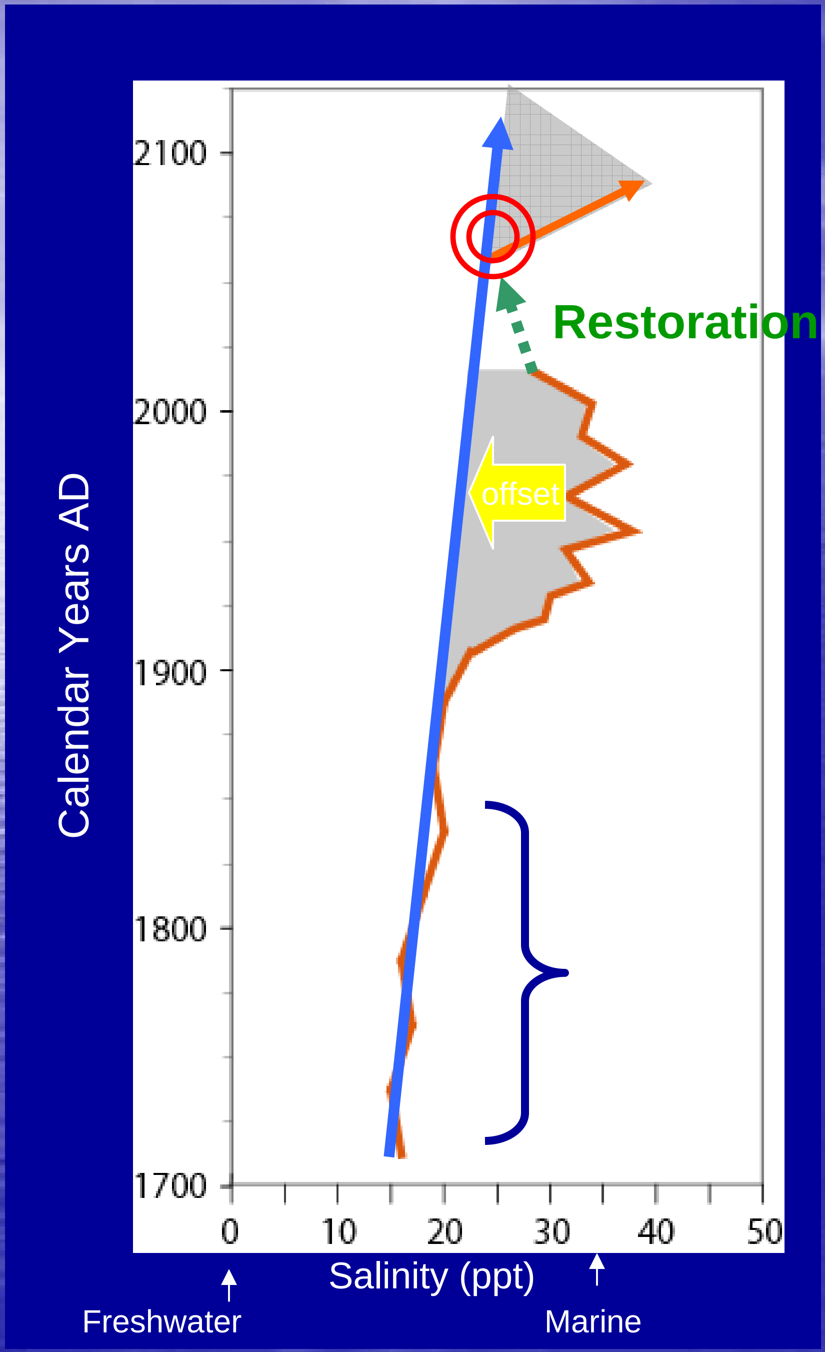
Variable	Mean salinity increase
joebay	1.49
ltmad	1.2
terbay	2.24
ltblackwater	1.11
longsound	1.07
taylor	1.83
garbight	2.01
whipray	1.25
duck	0.75
buoy	1.17
boballen	1.04

- Murray Key plus 3 psu

Variable	Mean salinity increase
joebay	4.27
ltmad	3.6
terbay	6.52
ltblackwater	3.03
longsound	3.18
taylor	4.54
garbight	6.02
whipray	3.76
duck	2.26
buoy	3.51
boballen	3.11

RECOMMENDATIONS FOR MLR SALINITY MODELS USED FOR CERP PERFORMANCE MEASURE EVALUATIONS

- Allowance for SLR salinity increase over 50-year horizon:
  - Near shore embayments: 1-2 psu
  - Mid-Bay locations: 0.75-1.5 psu
  - Outer stations: 0-0.75 psu
- As a starting point, same allowances should be applied to paleosalinity estimates as an offset



From Lynn Wingard – See presentation Thursday, Adaptive Management Session

SUMMARY

- Freshwater stage much more important than sea surface elevation in MLR salinity models
- The error in salinity simulations over the next 100 years due to SLR alone (25-50 cm) is less than the model error limits (RMS)
- Because models were developed during period of SLR, SLR effect on MLR model uncertainty is small

SUMMARY

- The importance of restoring water levels in the Everglades to protect the Florida Bay ecosystem is supported by this analysis
- All models (hydro, mass-balance, statistical) should be updated with new data at least every 10 years to incorporate climate variations and to make them more robust
- Pre-drainage salinity estimates are still less than existing conditions when SLR adjustments are made

Up Coming Work

- Use the estimated adjustments as a starting point with paleosalinity estimates from USGS and FIU collaborations to help interpret paleo analyses in the context of current conditions

THANKS!