Determining the dominant sources of freshwater, including submarine groundwater discharge, to Biscayne Bay

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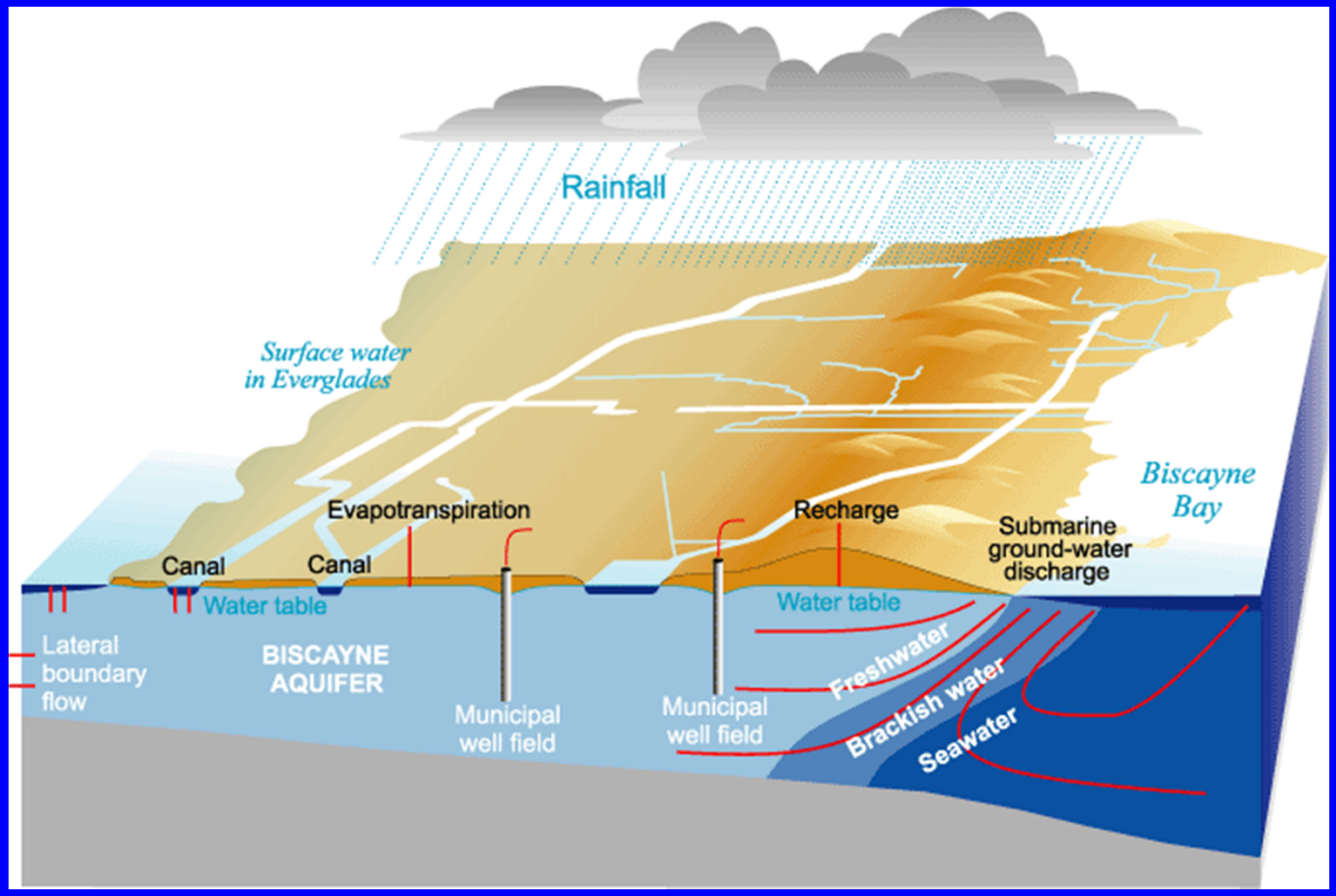
Springs of Biscayne Bay

- In 1513 explorer Juan Ponce de Leon sailed south from St. Augustine and found a “bright nameless great bay…and fresh springs in the rocks.”

- Freshwater springs boiling up from the bottom of Biscayne Bay were described in 1838 by Buck, J. (1979) Biscayne sketches as the far south. Tequesta, 39:70-86.

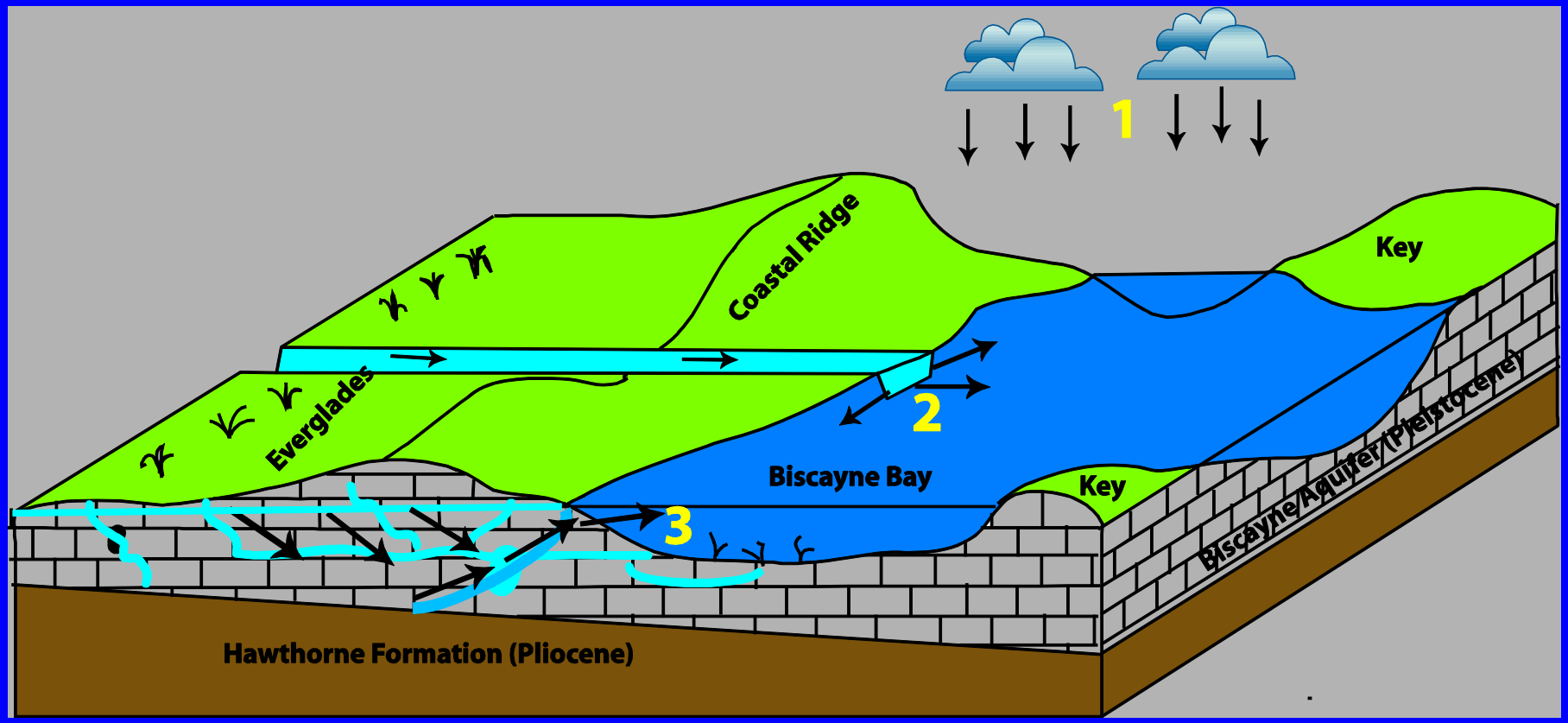
A flowing well in Biscayne Bay. Photograph from Kohout (1967).

Hydrogeology of Biscayne Bay



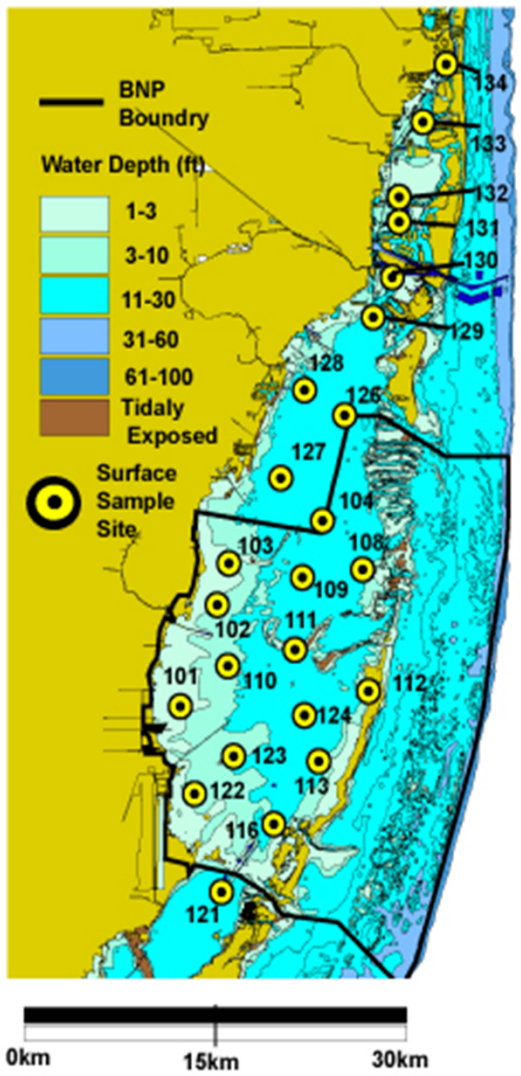
(Langevin, 2001)

Conceptual Model of the Surficial Aquifer/Estuary System

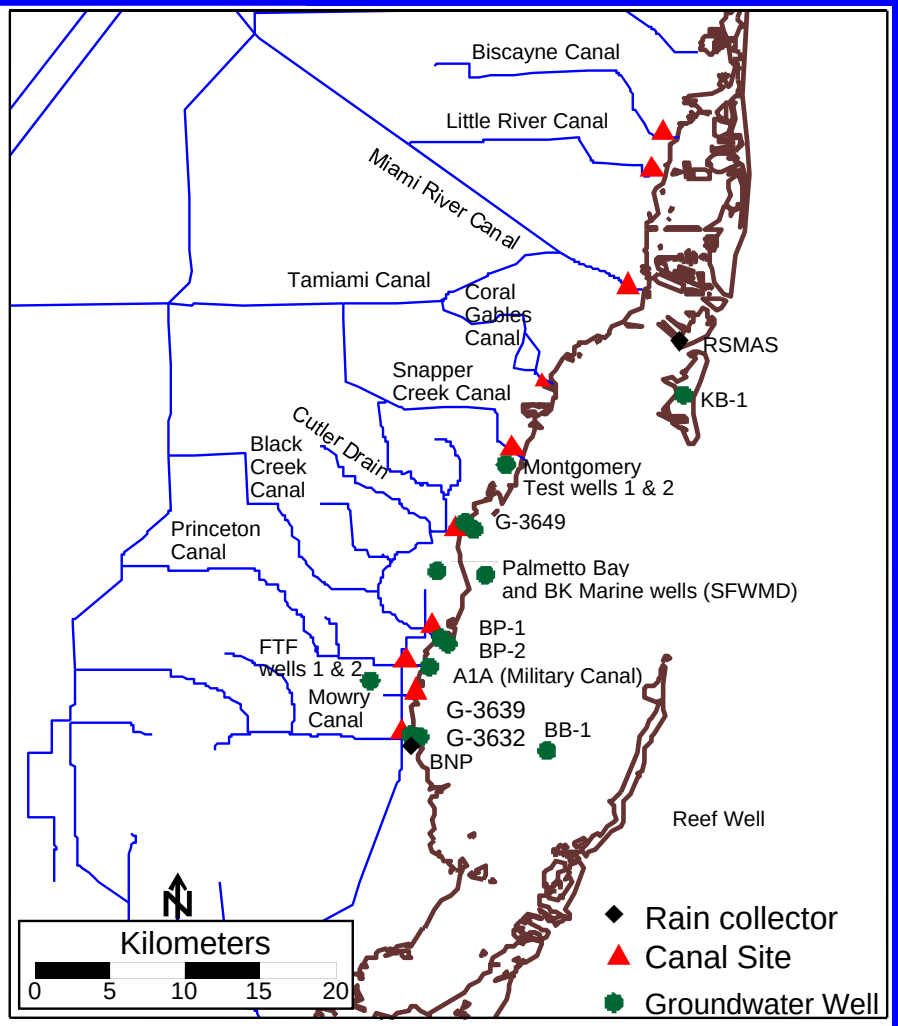


Objective: Quantify the sources of fresh water (precipitation, canal discharge, groundwater discharge) Into Biscayne Bay in time and space.

Surface sampling (1997-2006) from 25 stations



Fresh/brackish end members (Feb. 2004-July 2006)
10 canals , 12 groundwater wells
2 rainfall stations



All samples analyzed for O, H isotopes, Major/trace Cations and Anions

Water Balance Model

From $\delta^{18}O$ model

From $\delta^{18}O$ and Sr^{2+}, Ca^{2+} model

$$Freshwater_{total} = x_{canal} + y_{precip} + z_{FSGD}$$

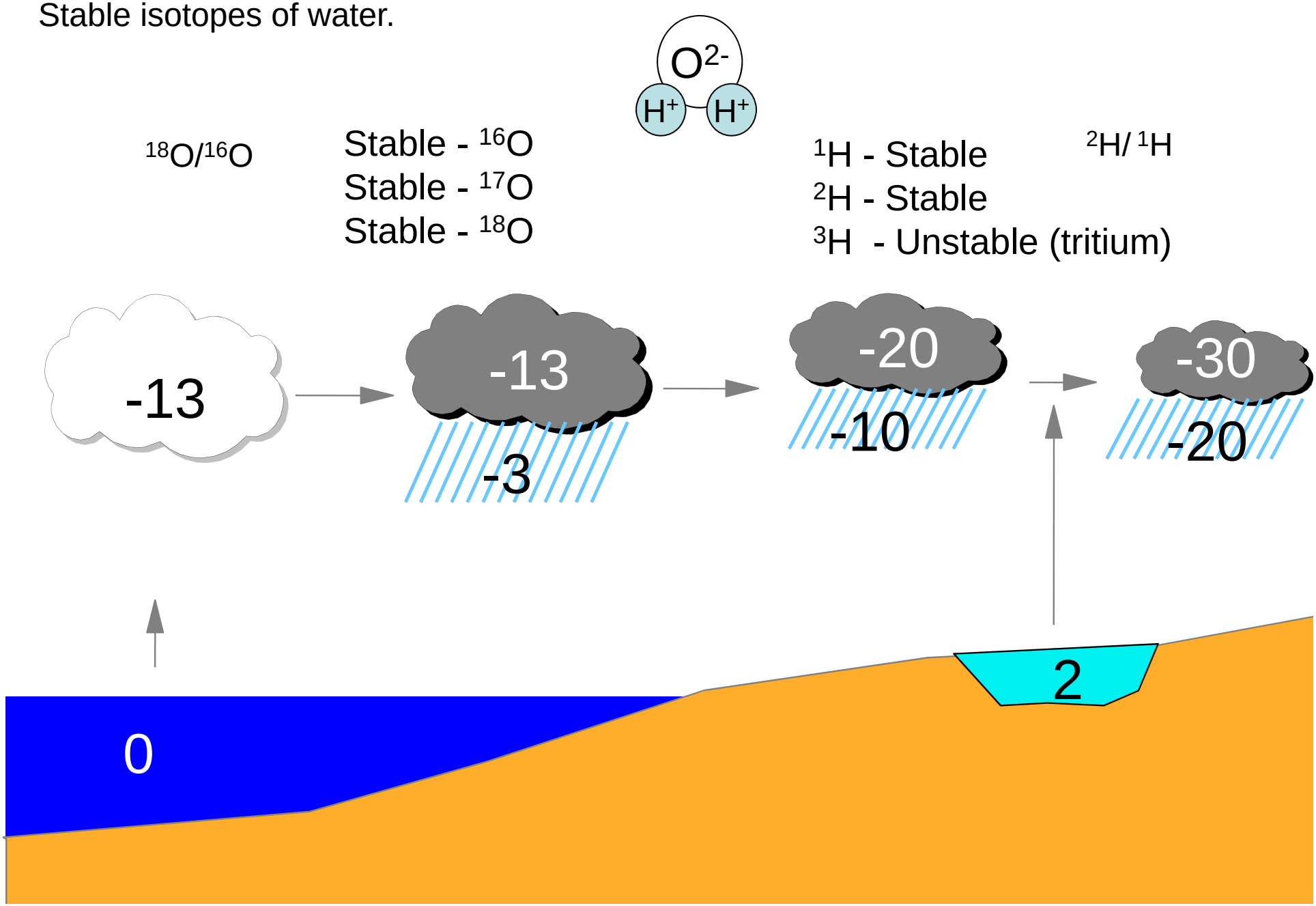
$Freshwater_{total}$ = total flux of freshwater into the bay

Q_{canal} = canal discharge to bay

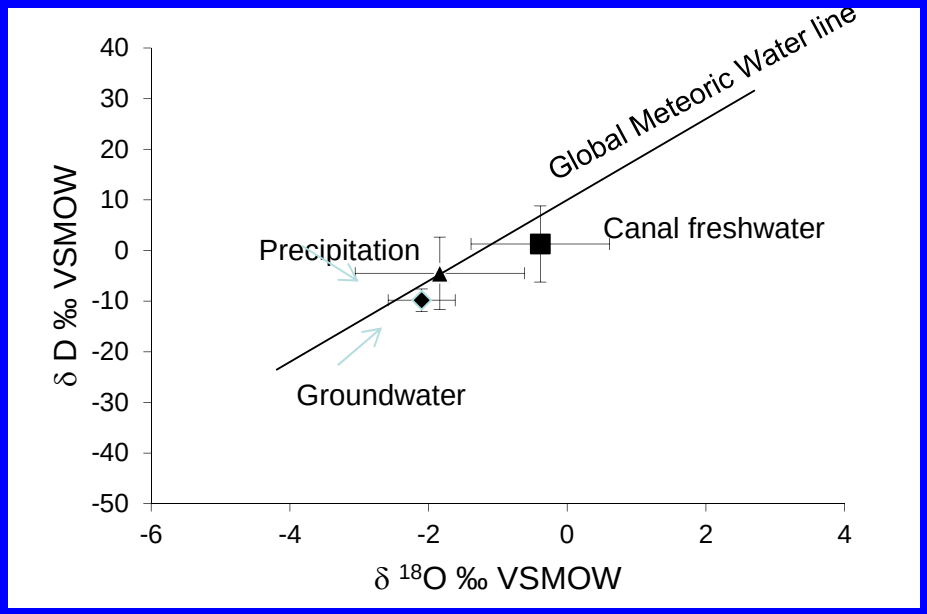
Q_{precip} = precipitation into the bay

Q_{FSGD} = fresh groundwater discharge to the bay

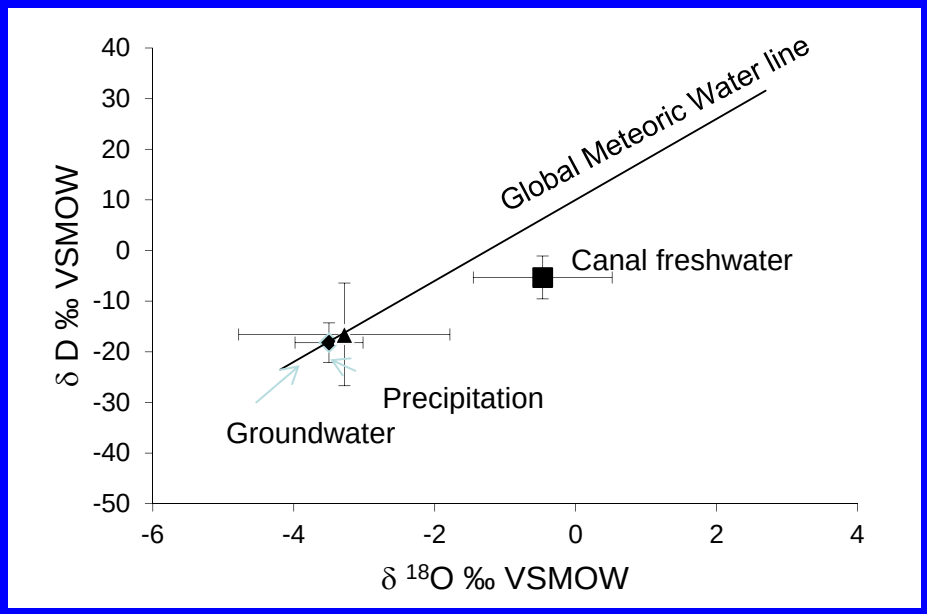
This investigation included the Stable isotopes of water.



End-member Isotope Comparison

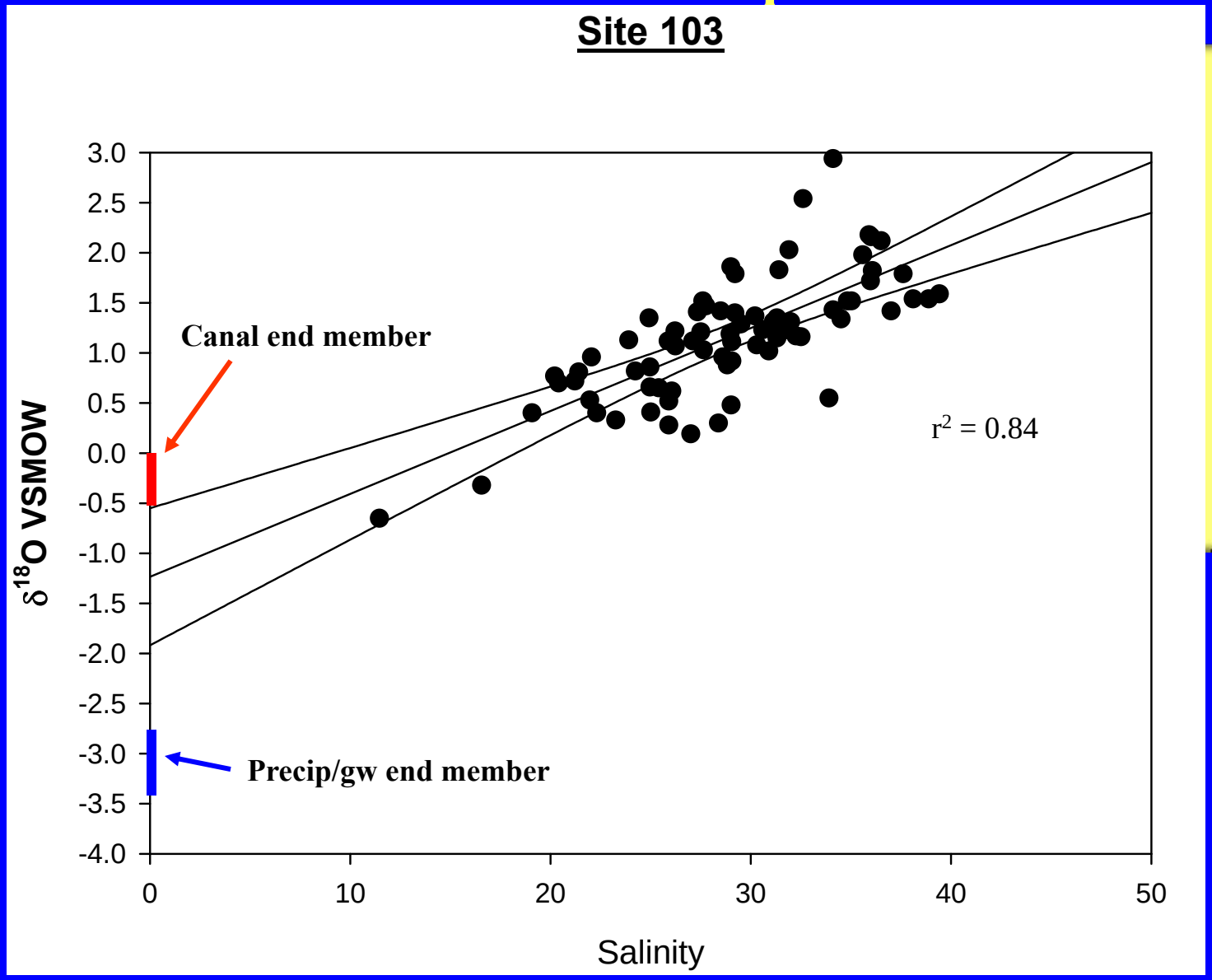


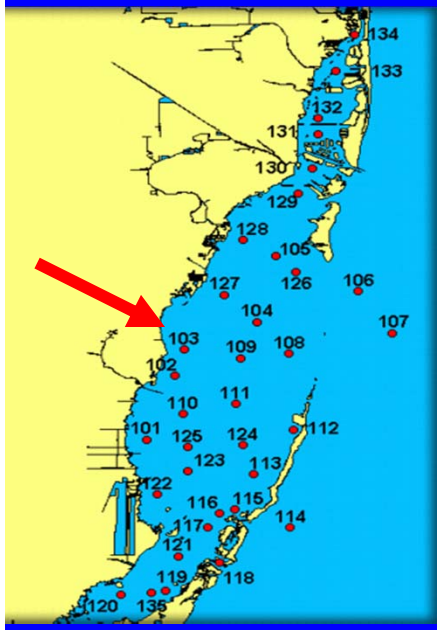
Dry Season
(Dec-May)



Wet Season
(June-Nov)

δ ^{18}O intercept for Site 103





Isotope mixing model

- Binary mixing equation

$$\delta^{18}O intercept = (x)\delta^{18}O\ cw + (1-x)\delta^{18}O\ pcp/gw$$

Where:

$\delta^{18}O intercept$ **= linear regression intercept of BB surface water**

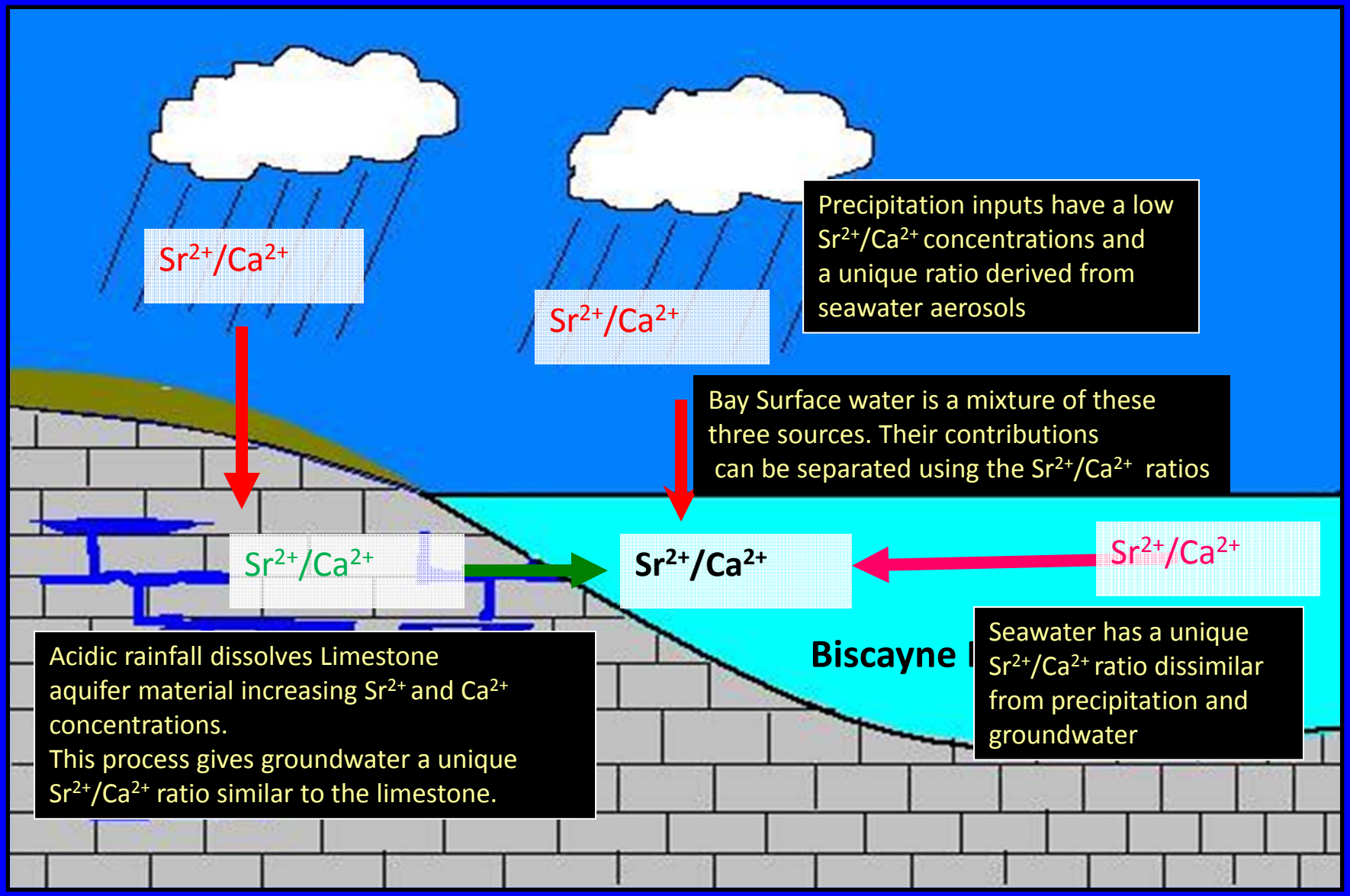
$\delta^{18}O cw$ **= average δ^{18}O value of the canal waters**

$\delta^{18}O pcp/gw$ **= average δ^{18}O values for precip/gw**

X= % of canal water in freshwater member

(1-X)= % of precip/gw in freshwater member

	Canal water	Precip/GW	
Wet Season	**38%**	**62%**	**+/- 20%**
Dry Season	**40%**	**60%**	**+/- 20%**


Sr^{2+}/Ca^{2+}
Sr^{2+}/Ca^{2+}
Precipitation inputs have a low Sr^{2+}/Ca^{2+} concentrations and a unique ratio derived from seawater aerosols
Bay Surface water is a mixture of these three sources. Their contributions can be separated using the Sr^{2+}/Ca^{2+} ratios
Sr^{2+}/Ca^{2+}
Sr^{2+}/Ca^{2+}
Sr^{2+}/Ca^{2+}
Biscayne
Acidic rainfall dissolves Limestone aquifer material increasing Sr^{2+} and Ca^{2+} concentrations.
This process gives groundwater a unique Sr^{2+}/Ca^{2+} ratio similar to the limestone.
Seawater has a unique Sr^{2+}/Ca^{2+} ratio dissimilar from precipitation and groundwater

Trace Element model

$$y = \frac{\left(Salinity_{fresh} - Salinity_{sample}\right)}{\left(Salinity_{fresh} - Salinity_{ocean}\right)}$$

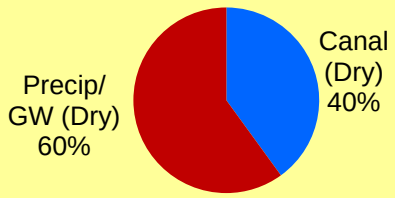
$$\frac{Sr^{2+}{}_{sample}}{Ca^{2+}{}_{sample}} = \frac{Sr^{2+}{}_{sea}\left(y\right) + \left(Sr^{2+}{}_{gw}\left(x\right) + Sr^{2+}{}_{precip}\left(1-x\right)\right)\left(1-y\right)}{Ca^{2+}{}_{sea}\left(y\right) + \left(Ca^{2+}{}_{gw}\left(x\right) + Ca^{2+}{}_{precip}\left(1-x\right)\right)\left(1-y\right)}$$

$$x = \frac{\frac{[(Sr^{2+}{}_{sample}*Ca^{2+}{}_{sea}*y)-(Ca^{2+}{}_{sample}*Sr^{2+}{}_{sea}*y)]}{(1-y)} - [(Ca^{2+}{}_{sample}*Sr^{2+}{}_{precip})+(Sr^{2+}{}_{sample}*Sr^{2+}{}_{precip})]}{(Ca^{2+}{}_{sample}*Sr^{2+}{}_{gw})-(Ca^{2+}{}_{sample}*Sr^{2+}{}_{precip})-(Sr^{2+}{}_{sample}*Ca^{2+}{}_{gw})+(Sr^{2+}{}_{sample}*Ca^{2+}{}_{precip})}$$

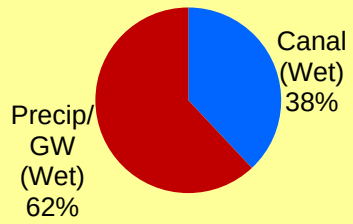
Groundwater discharge ranged from 0 – 68 % at individual sites

Sr^{2+}/Ca^{2+} model	Precipitation	Groundwater	
Wet Season	85%	15%	+/- 5%
Dry Season	92%	8%	+/- 5%

$\delta^{18}O$ Model Freshwater Inputs (Dry)

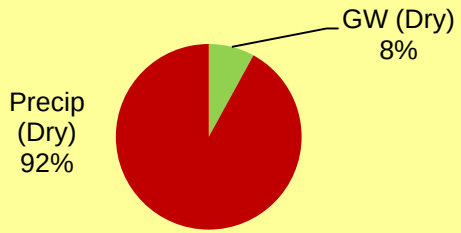


$\delta^{18}O$ Model Freshwater Inputs (Wet)

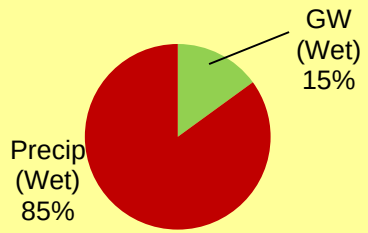


$1 = x + yz$

Sr^{2+}/Ca^{2+} Model Freshwater Inputs (Dry)

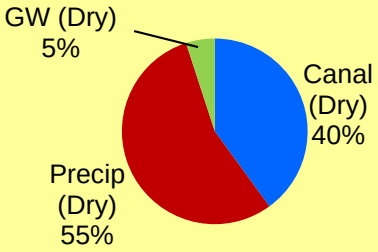


Sr^{2+}/Ca^{2+} Model Freshwater Inputs (Wet Season)

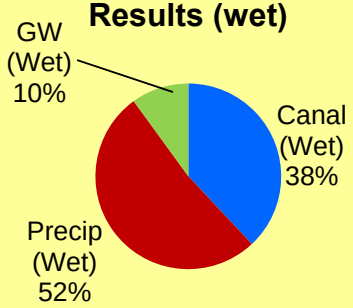


$1 = y + z$

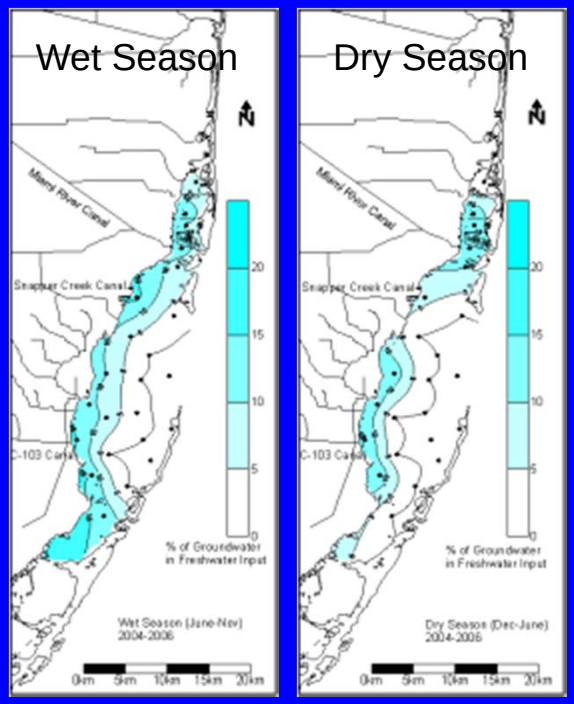
Combined Model Freshwater Inputs (Dry)



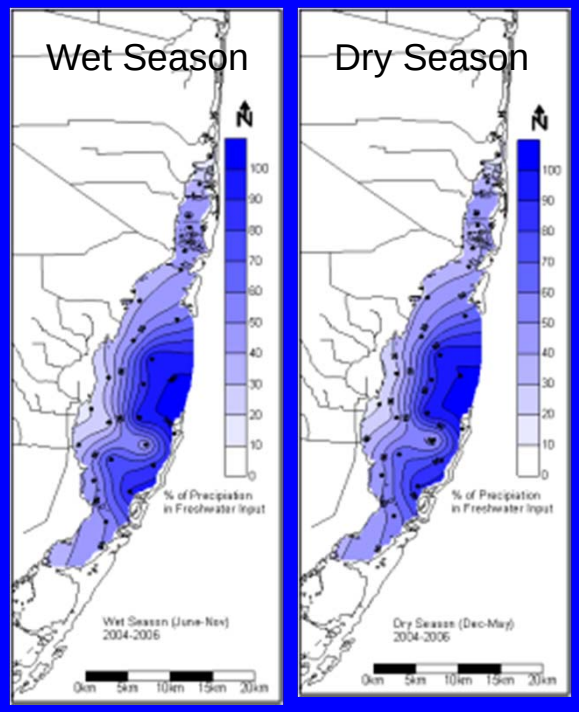
Combined Model Freshwater Results (wet)



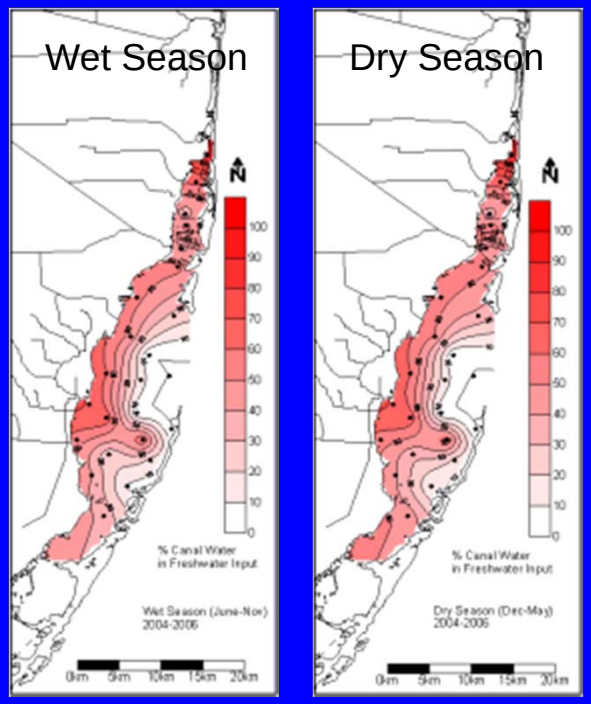
$1 = x + y + z$



Groundwater Input



Precipitation Input



Canal Water Input

Spatial inputs can be critical for habitats and nutrient inputs i.e. Groundwater is loaded with N, P compared to the other sources

Conclusions

• Rainfall is the dominant source of freshwater to Biscayne Bay (50-55%);

most important in eastern Bay

•Canal inputs account between 38-40% of freshwater inputs;

from coastline to central Bay

•Fresh groundwater inputs range from 5-10%;

along the coastline

•Stalker, J C, **R. M. Price,** P.K. Swart, 2009. *Determining Spatial and Temporal Inputs of Freshwater, including Submarine Groundwater Discharge, to a Subtropical Estuary using Geochemical tracers, Biscayne Bay, South Florida*, Estuaries and Coasts, 32(4): 694-708.

Conclusions

•For a Bay-Wide budget including seawater and freshwater inputs, fresh groundwater accounts for 1-2% of total water in the Bay.

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FIU

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