Measurement and Modeling of Airboat Flow-cut Hydraulics in the A.R.M. Loxahatchee National Wildlife Refuge

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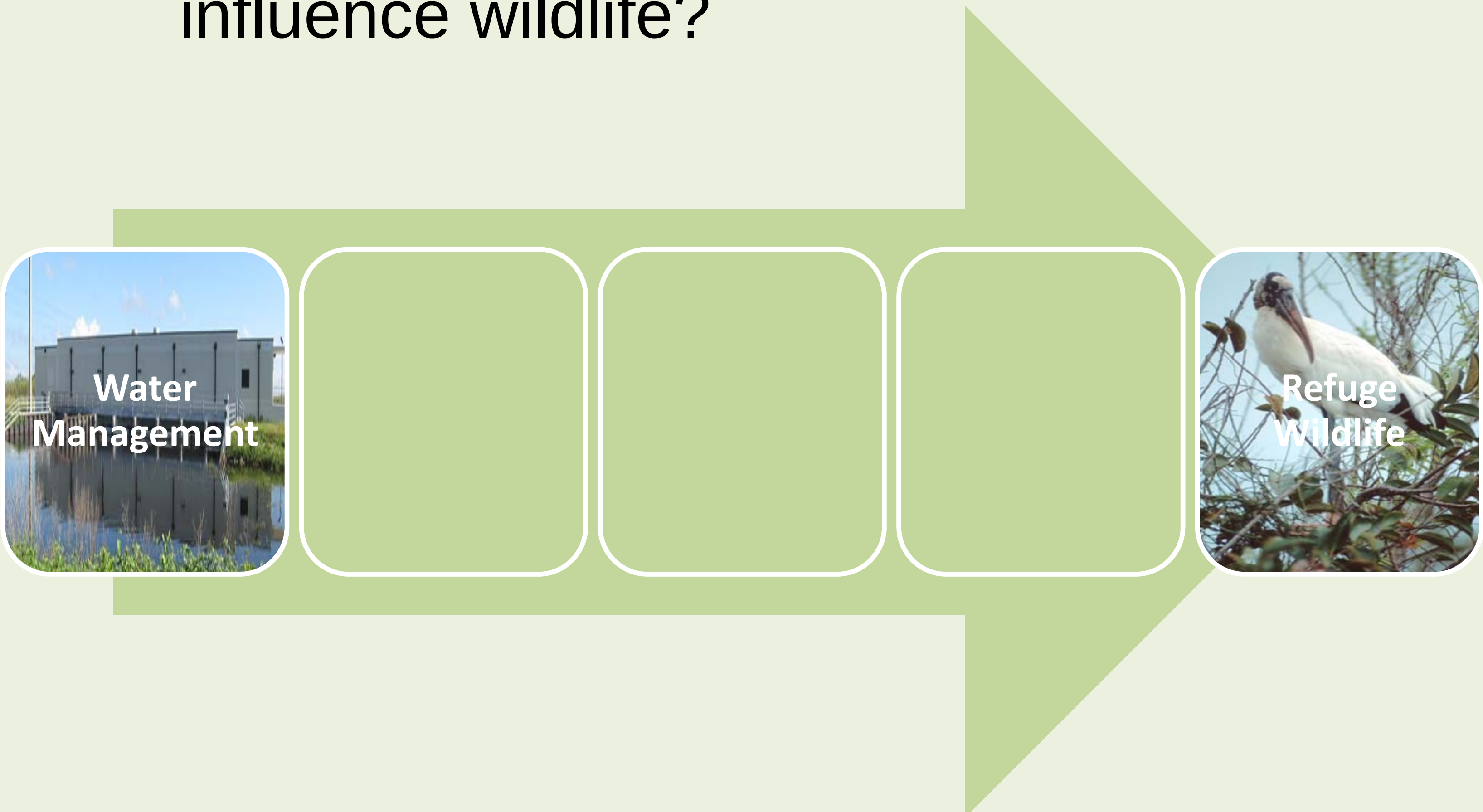
21-23 April 2015

Need for Study

How do Refuge water management actions influence wildlife?



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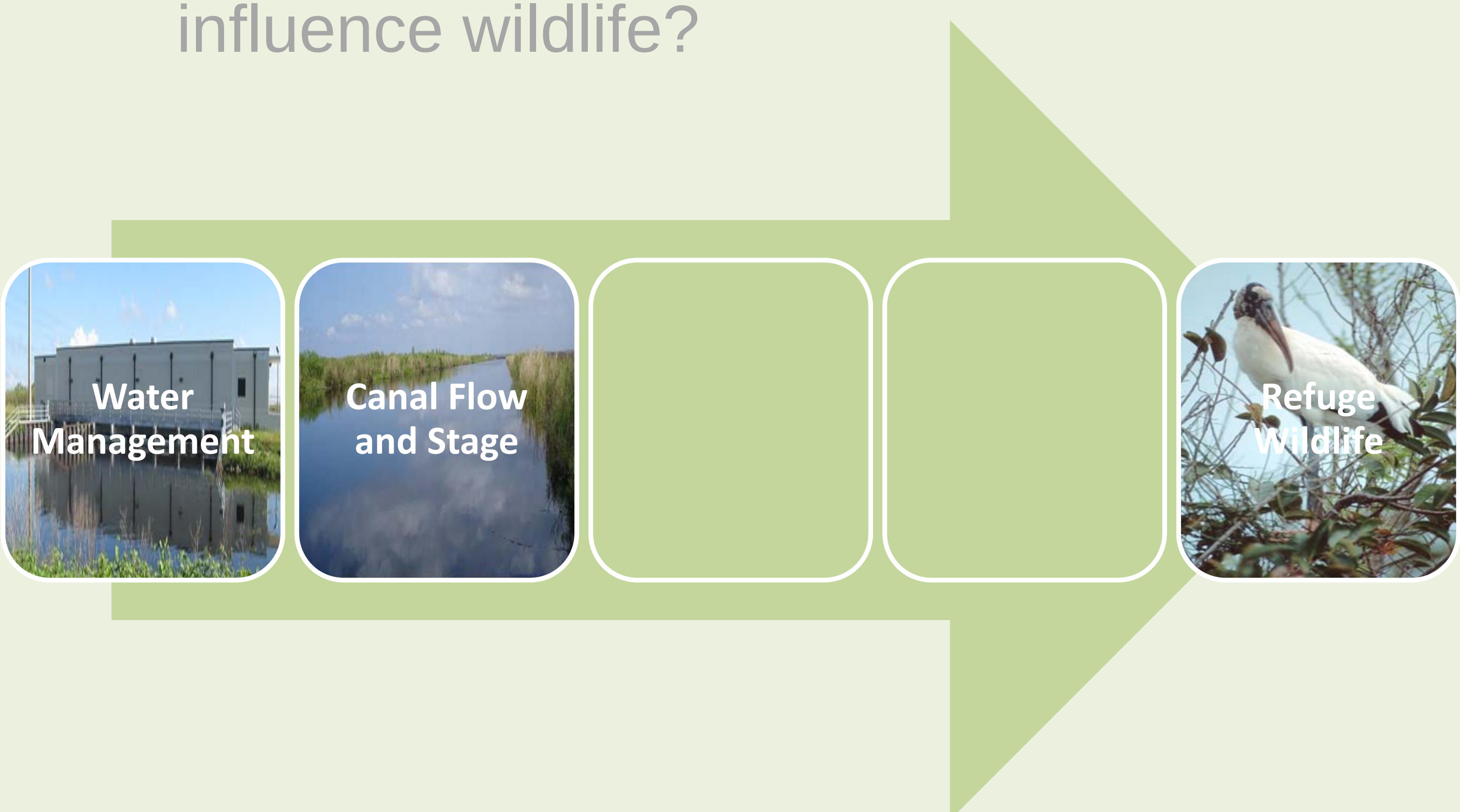


Structures directly influence canal stages and flows.

Need for Study

How do Refuge water management actions influence wildlife?

Wildlife respond to marsh hydrologic conditions.

Need for Study

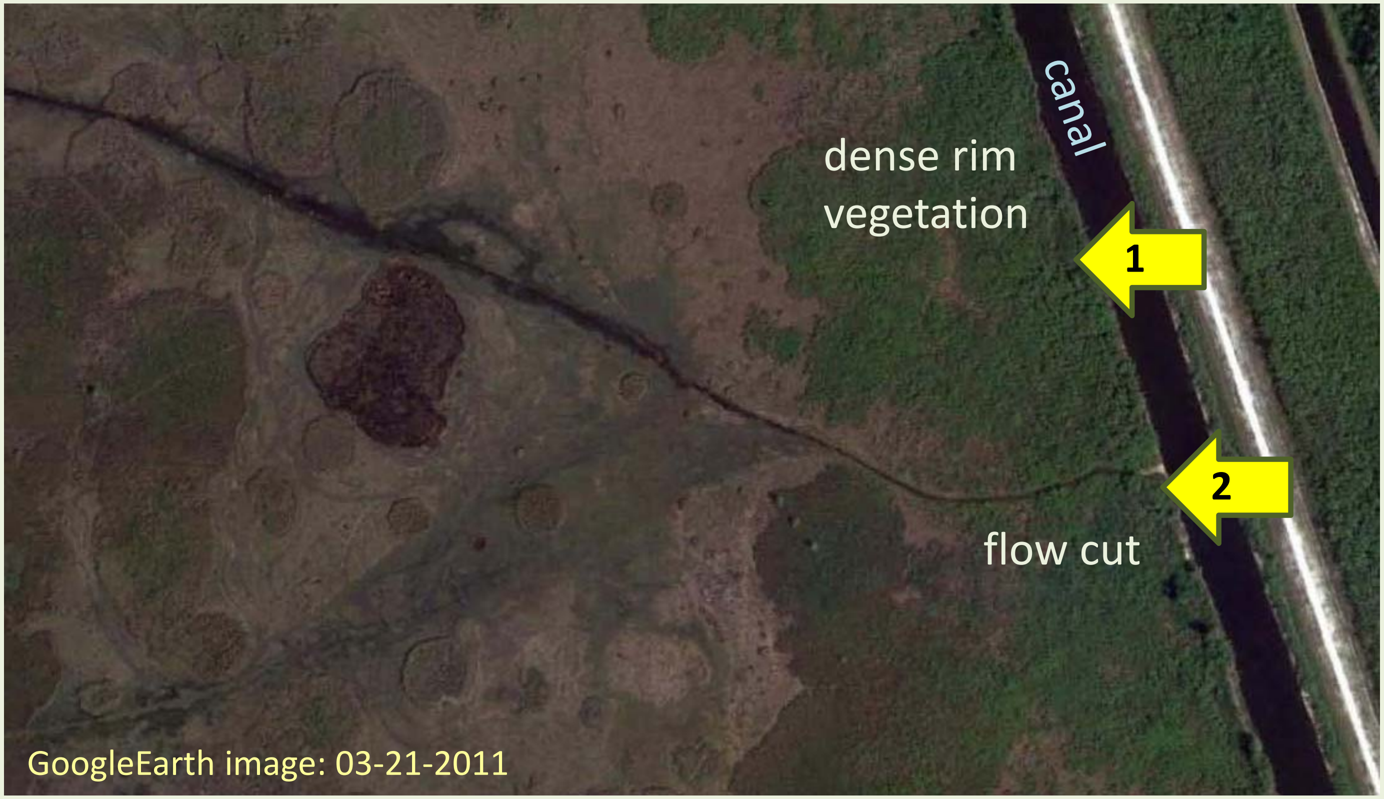
How do Refuge water management actions influence wildlife?

How does water get from canal to marsh?

Water Movement from Canal to Marsh

Two different routes

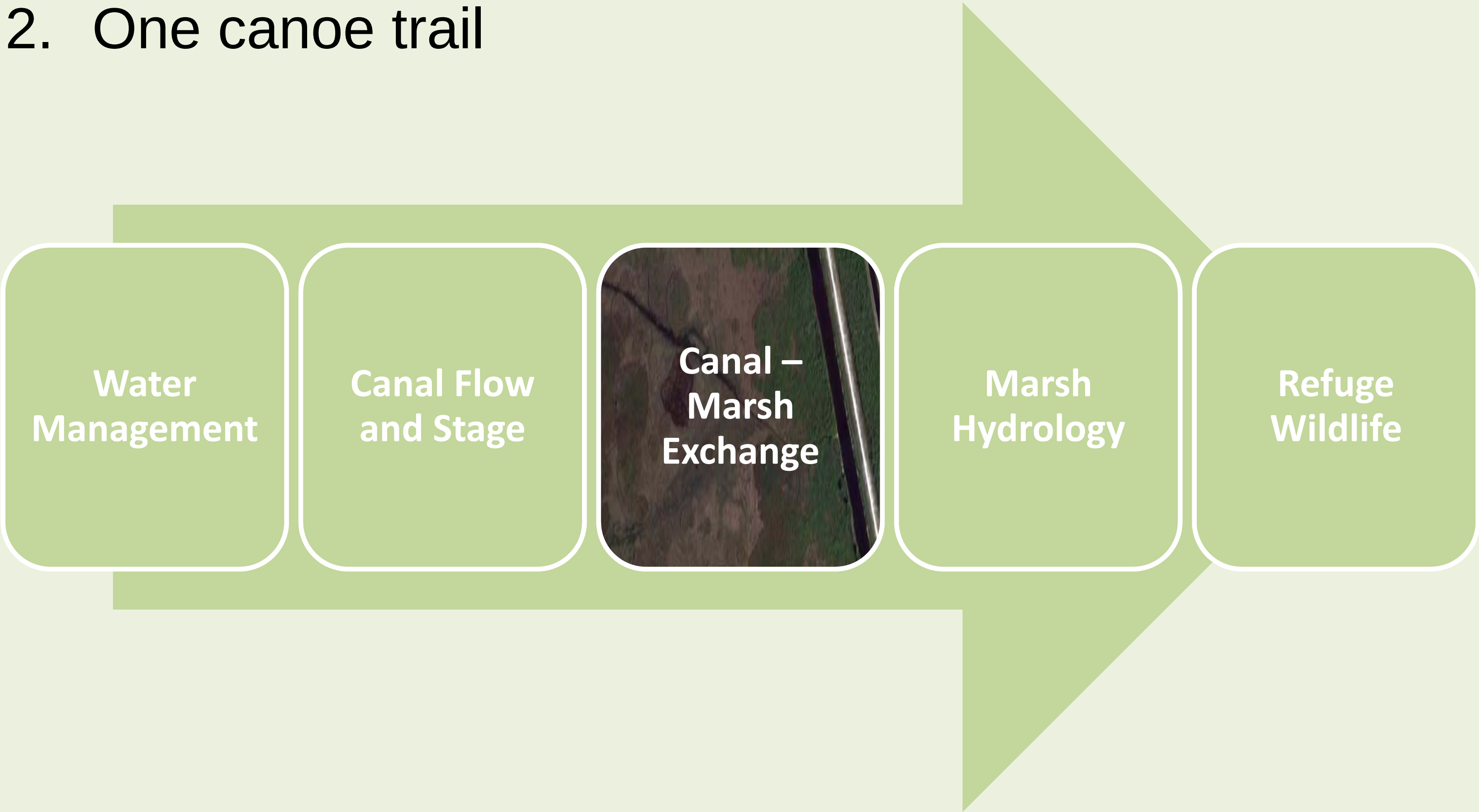
1. Through dense perimeter vegetation
2. Through trails that cut through perimeter vegetation or “flow cuts”



Objectives for Study

Measure and model water velocity through flow cuts

1. Three (of many) airboat trails
2. One canoe trail



Wetland Hydraulics

Two things make water flow faster

1. Steeper downhill water surface slope
2. Less resistance to flow

→*We* <u>*can*</u> *measure slope. We* <u>*can't*</u> *directly measure resistance.*

Wetland Hydraulics

Two things drive resistance

1. Bottom friction (surface material, microtopography)
2. Stem resistance (vegetation type, density)

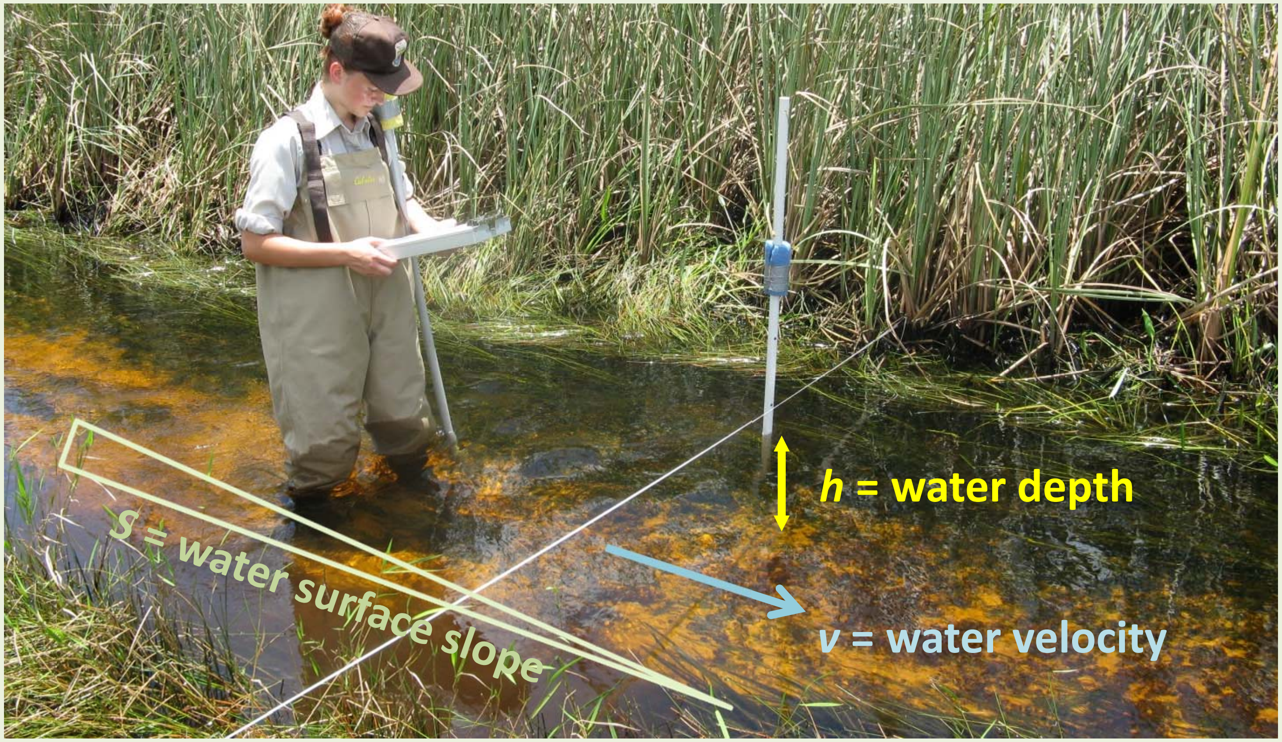
→*Water depth affects the relative proportion of these two*

Wetland Hydraulics

Common equations

1. Friction equation: $v = a\, h^{b-1}\, S^{c}$
   - friction (a), water depth (b), and water slope (c) parameters
2. Manning's equation: $v = (1/n)\, h^{2/3}\, S^{1/2}$
   - friction ($a=1/n$), water depth ($b=5/3$), and water slope ($c=1/2$) parameters

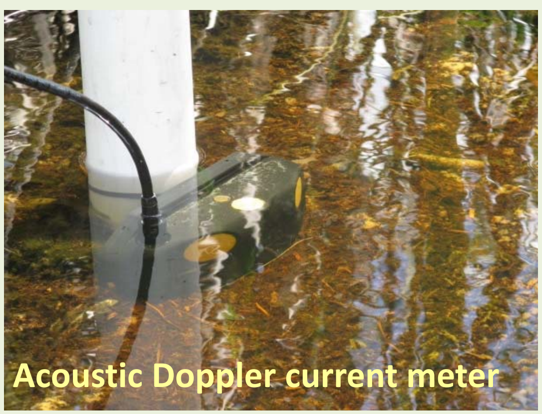
→*Data are needed to put numbers on these parameters (a, b, c, n)*

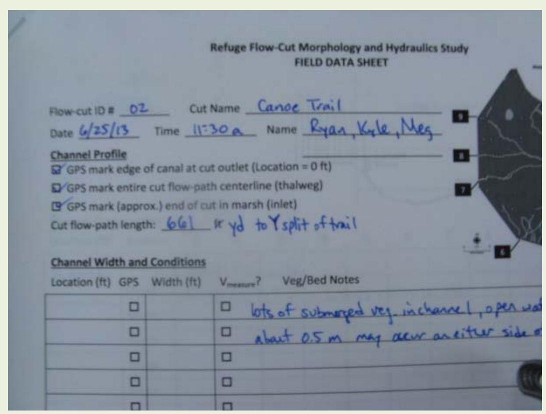


Flow-cut Hydraulics

Field measurements (June 24-27, 2013)

1. Measured depths (*h*) across cross-section
2. Side-facing acoustic Doppler velocity meter
   - Measured velocity of 6-10 equal-width cells for each cross-section on 10-second intervals for a 7.5-minute period (minimum)




Refuge Flow-Cut Morphology and Hydraulics Study
FIELD DATA SHEET

Flow-cut ID # 02 Cut Name Canoe Trail
Date 6/25/13 Time 11:30 a Name Ryan, Kyle, Meg

Channel Profile
☑ GPS mark edge of canal at cut outlet (Location = 0 ft)
☑ GPS mark entire cut flow-path centerline (thalweg)
☑ GPS mark (approx.) end of cut in marsh (inlet)
Cut flow-path length: 661 yd to Y split of trail

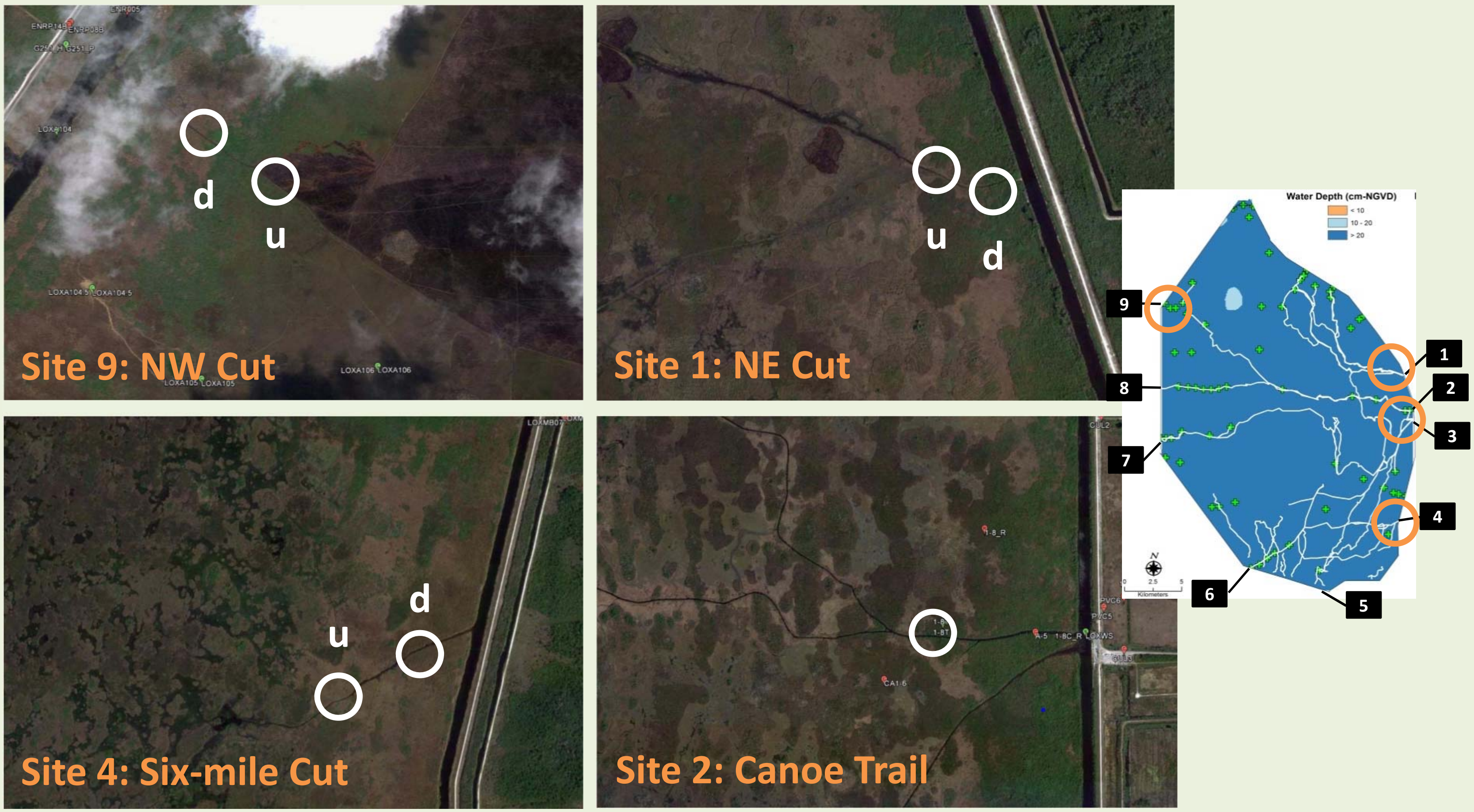
Channel Width and Conditions

Location (ft)	GPS	Width (ft)	$V_{measure}$?	Veg/Bed Notes
	☐		☐	lots of submerged veg. in channel, open wa[ter]
	☐		☐	about 0.5 m may occur on either side [of]
	☐		☐	
	☐		☐	
	☐		☐	

Field Sites

4 flow-cut sites, 7 locations (upstream/downstream)

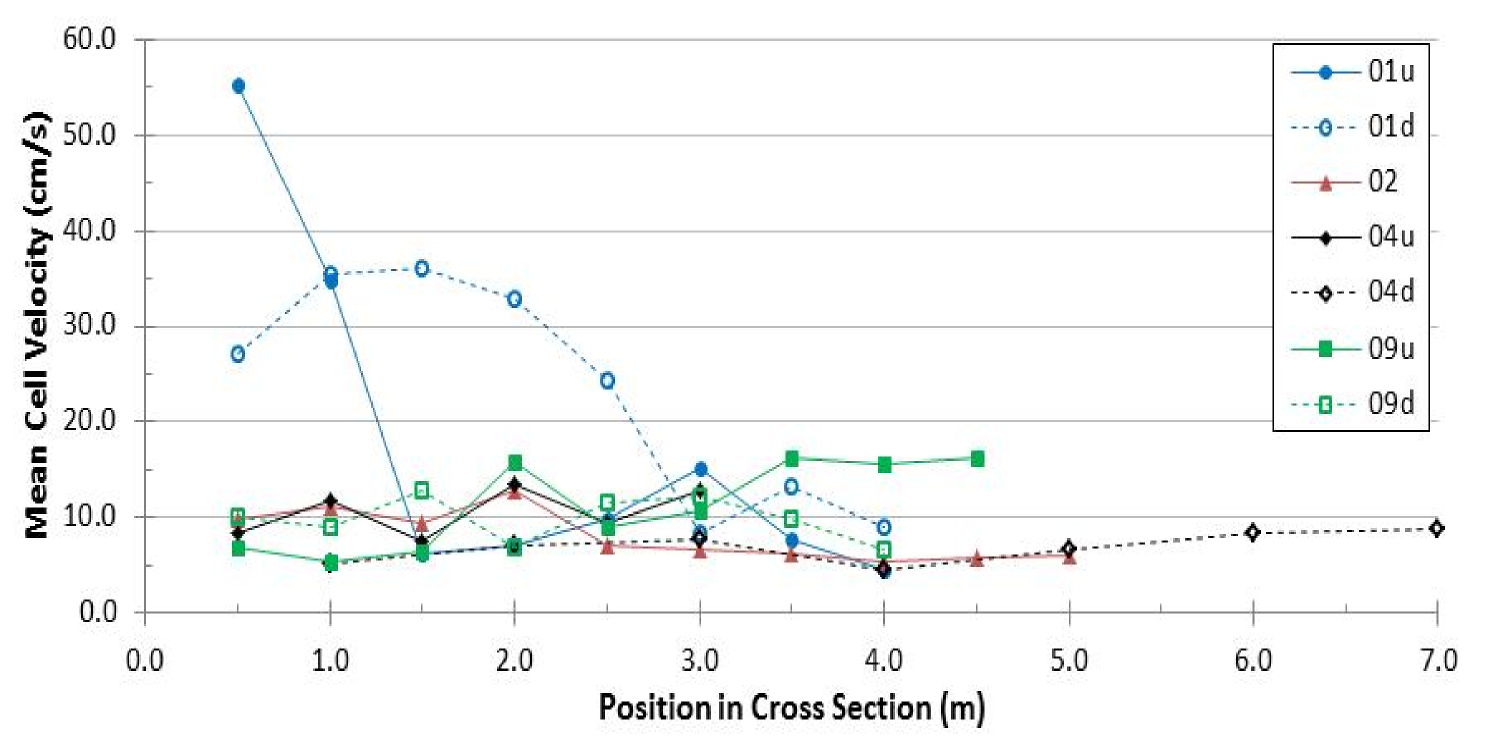
1. Airboat trails (Sites 1u, 1d, 4u, 4d, 9u, 9d)
2. Canoe trail (Site 2)



Results

Field measurements

1. Depths (*h*) = 19–100 cm (0.6–3.3 feet)
2. Slopes (*S*) = 0.03–0.11% (1½–5¾ feet drop per mile)
3. Cell velocities (*v*) = 3.5–28.5 cm/sec (7–56 feet per min)



Results

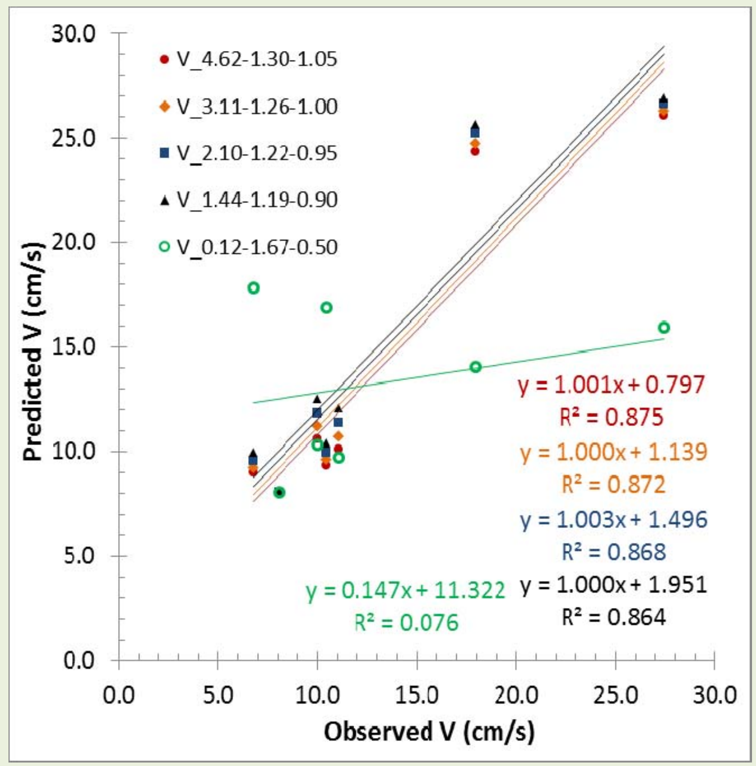
	a_1 airboat	a_2 canoe	*b*	*c*	r^2	*Model efficiency*
Manning's	0.12E7	0.03E7	1.67	0.50	0.076	0.01
Best fit (*not shown*)	4.39E7	1.84E7	1.30	1.05	0.875	0.64
Best fit, slope=1.0[a]	4.62E7	1.84E7	1.30	1.05	0.875	0.64
Best fit, slope=1.0, *c*=1.0[b]	3.11E7	1.27E7	1.26	1.00	0.873	0.64

(Ideal = 1.0)

[a]For regression slope=1.0, predicted values increase in proportion to observed values

[b]For laminar or vegetated flow, *c* should = 1.0

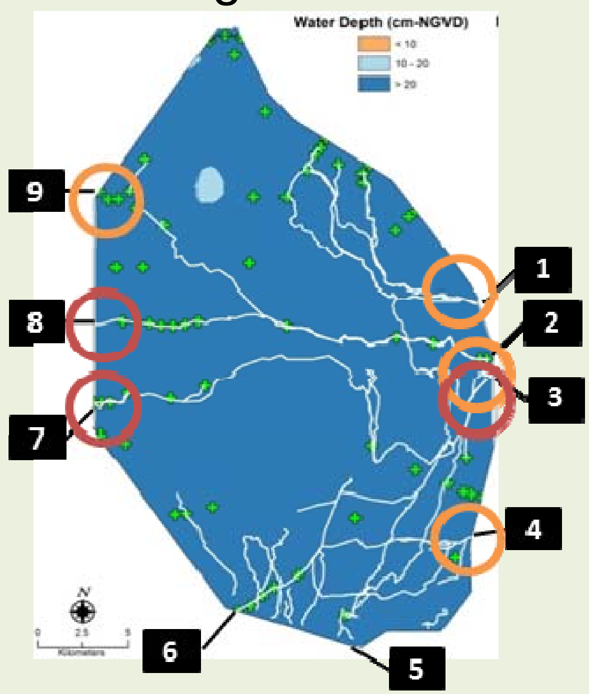
(Kadlec and Wallace, 2009)



Application Example

How have flow-cuts affected Marsh Stage (2004-14)?

1. Calculate daily flow volume through 7 flow cuts
    - Used friction equation parameters from this study
    - *when* |Canal – Marsh| > 0.05 ft difference, Marsh stage > 16.0 ft
2. Simulate closing flow cuts (Refuge water balance)
    - Add back water that was lost from Marsh→Canal
    - Subtract water that was gained from Canal→Marsh



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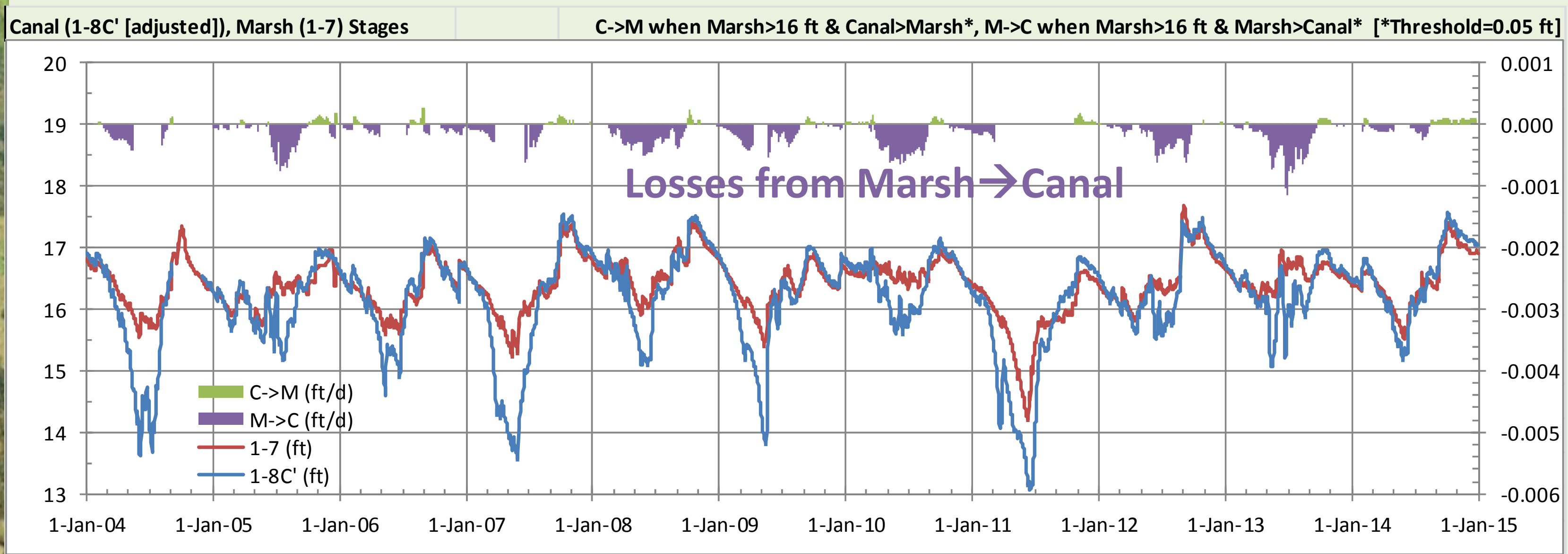
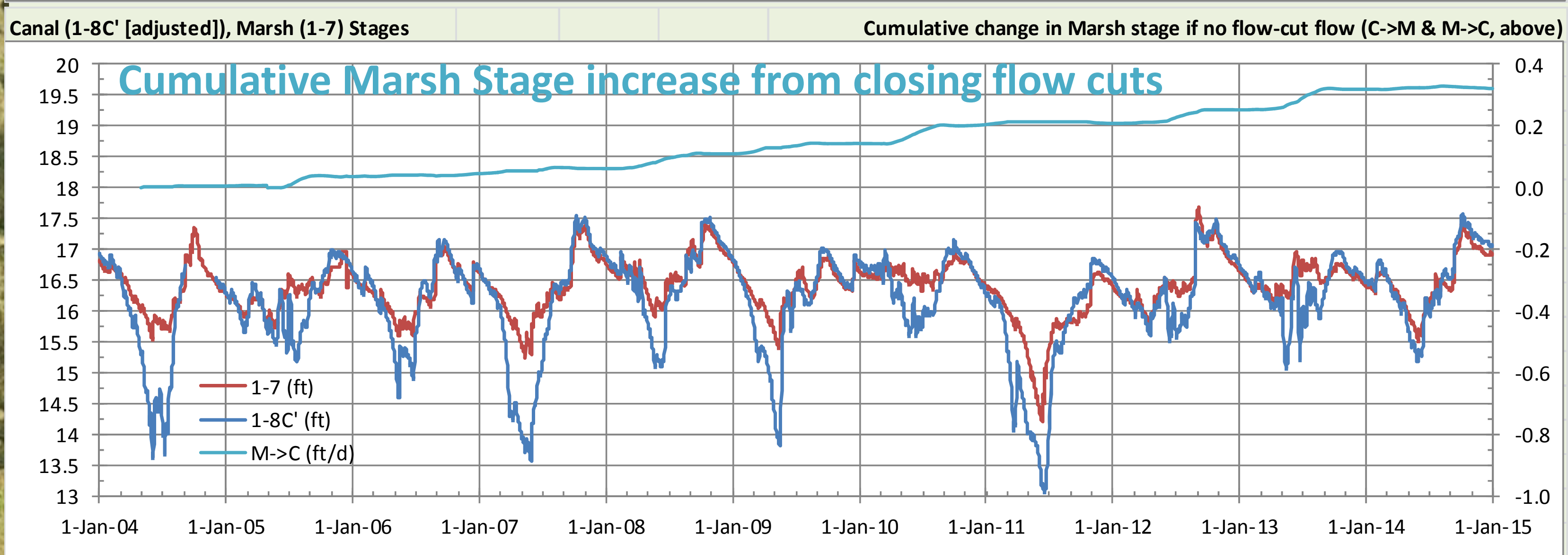
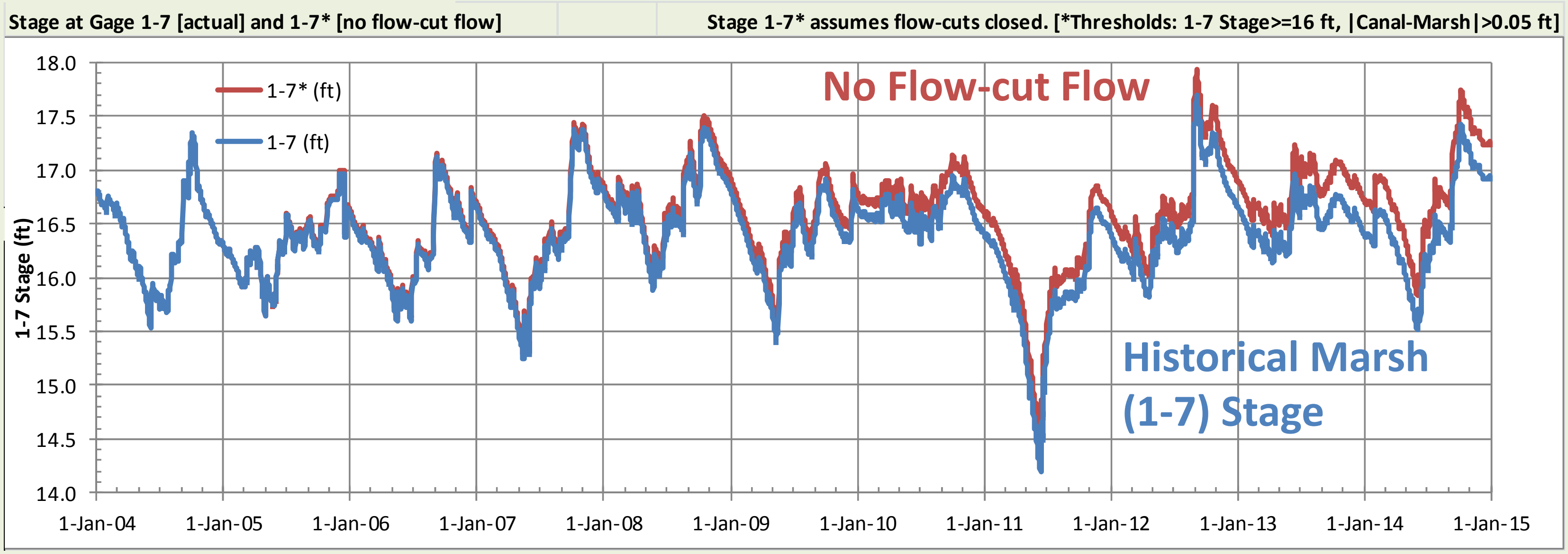




Application Example

How have flow-cuts affected Marsh Stage (2004-14)?

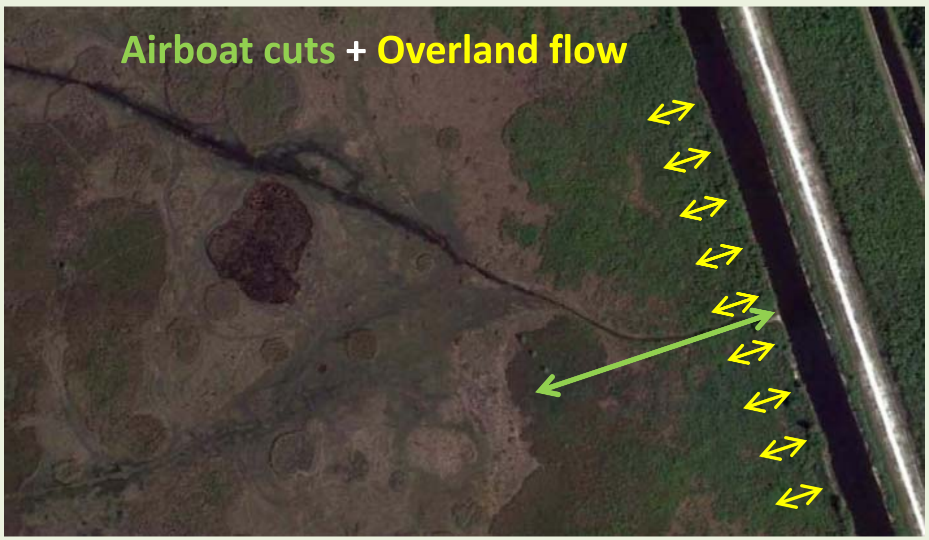
1. Net loss from Marsh over past 11 years
   - Cumulative loss: 0.32 ft [44.8 kac-ft]
2. Flow cuts draw water to East-West rather than historical North-South flow path

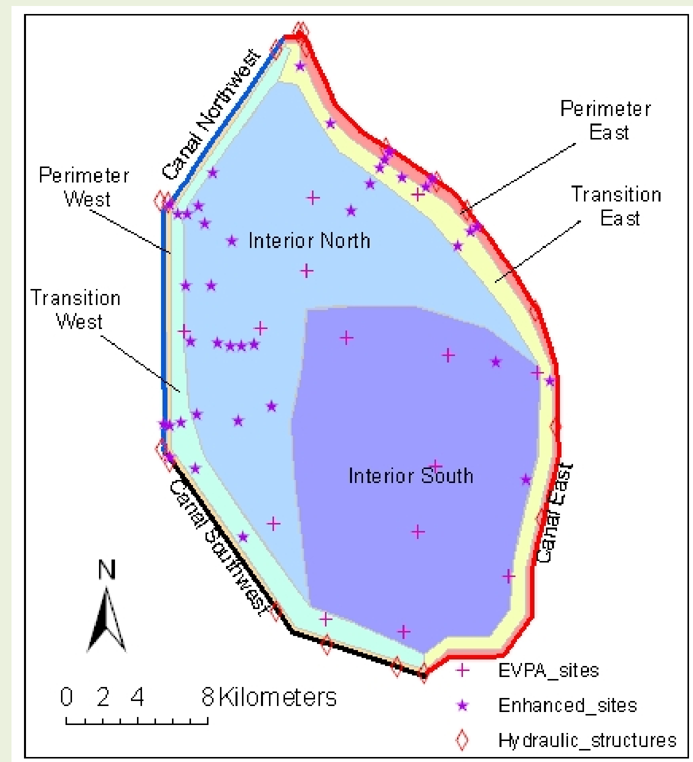


Future Applications

Test management scenarios

1. Evaluate impacts of adding new airboat trails
2. Local impacts of airboat trails on marsh ecohydrology
3. Enhance modeling of flow between canal and marsh in Simple Refuge Screening Model (Waldon et al.)





Wang et al. (2008) J. Env. Hydrol. 16 (Paper 36)
Wang et al. (2012) Ecol. Mod. 247: 273– 285

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QUESTIONS?

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Changes in Refuge over Time

Series of images near current Refuge Visitor Center

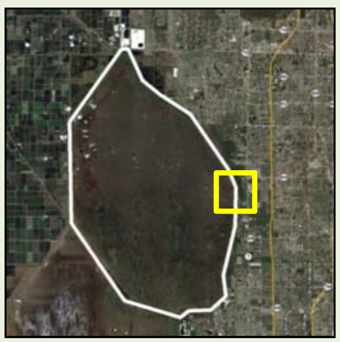

Photo credits: http://palmm.fcla.edu/

Refuge Topography

4.88 m (16.0 ft) msl

4.72 m (15.5 ft) msl

4.57 m (15.0 ft) msl

4.27 m (14.0 ft) msl

3.66 m (12.0 ft) msl