Evaluating a Process-Based Mitigation Wetland Water Budget Model

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Overview

- Mitigation Failures
- Current Method of Mitigation Design
- Objectives
- Field Site
- Integrated Pierce Method Model
- MODFLOW-2005 model
- Results
- Conclusions

wetlands impacted or destroyed? mitigate!

- **Mandated by law**
- **Must:**

  Restore

  Create →

  Enhance

  or

  Preserve

hydrology + vegetation + soils = wetland

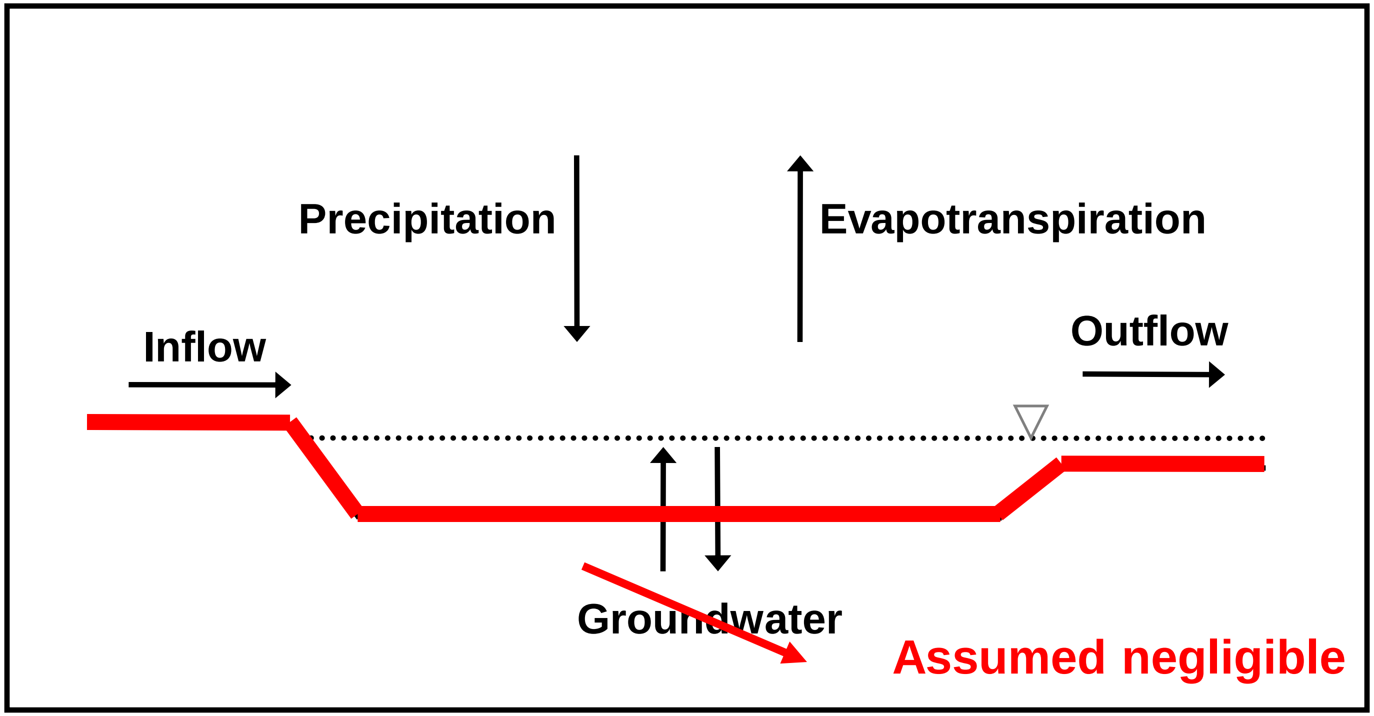
Incorrect water levels are the leading cause of failed mitigation wetlands

- **South Florida Water District – 62.5% of projects exhibited hydrological problems**

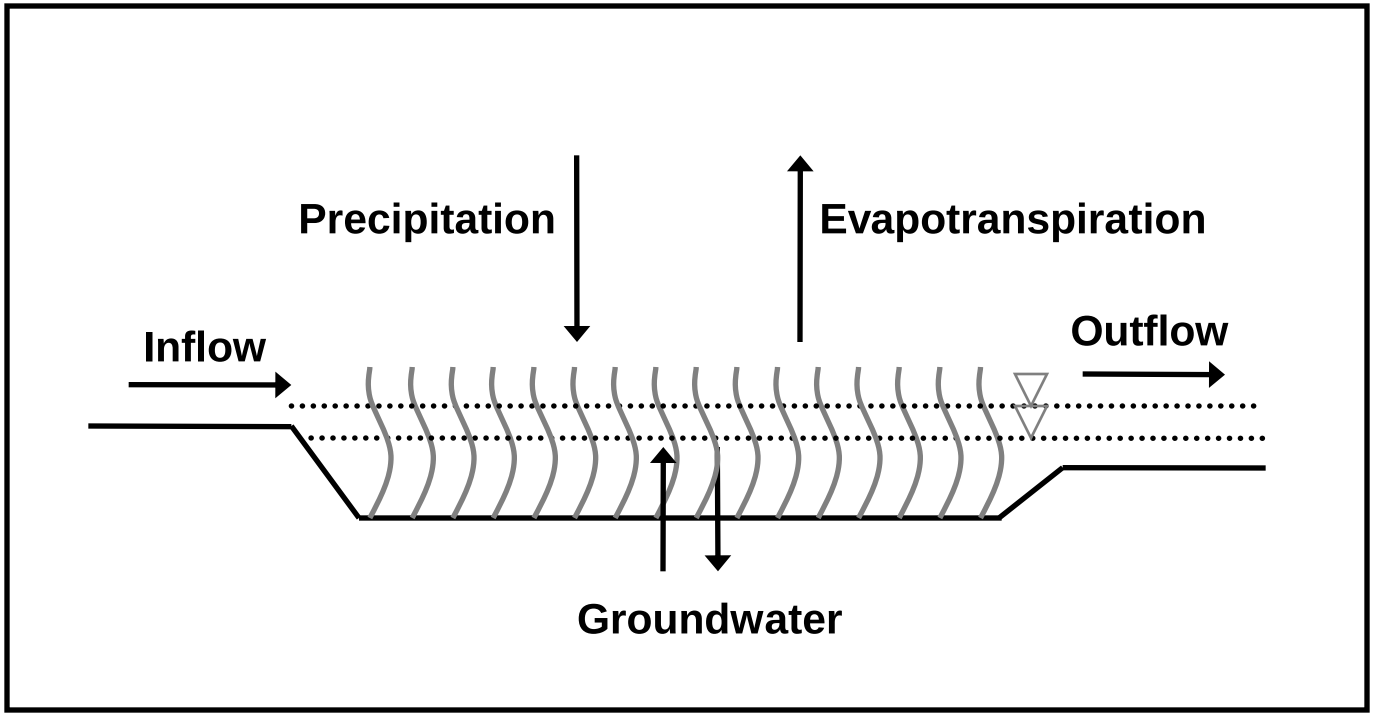
- **Most significant project design problem identified – *improper water levels***

Erwin (1991)

currently, mitigation sites are designed to simplify the water budget by creating a perching system



hydraulic resistance due to vegetation can influence water levels



In densely vegetated wetland systems, outflow is determined, all or in part, by hydraulic resistance due to vegetation

(Kadlec, 1990)

Overall project objectives…

1. Determine the accuracy of water level predictions by a Pierce water balance method model, and a process-based MODFLOW model

2. Evaluate seasonal effects in model performance

3. Determine the sensitivity of models to select input parameters

the modeling site…

Cedar Run Wetland Bank

Completed in October 2001 by Wetland Studies and Solutions Inc.

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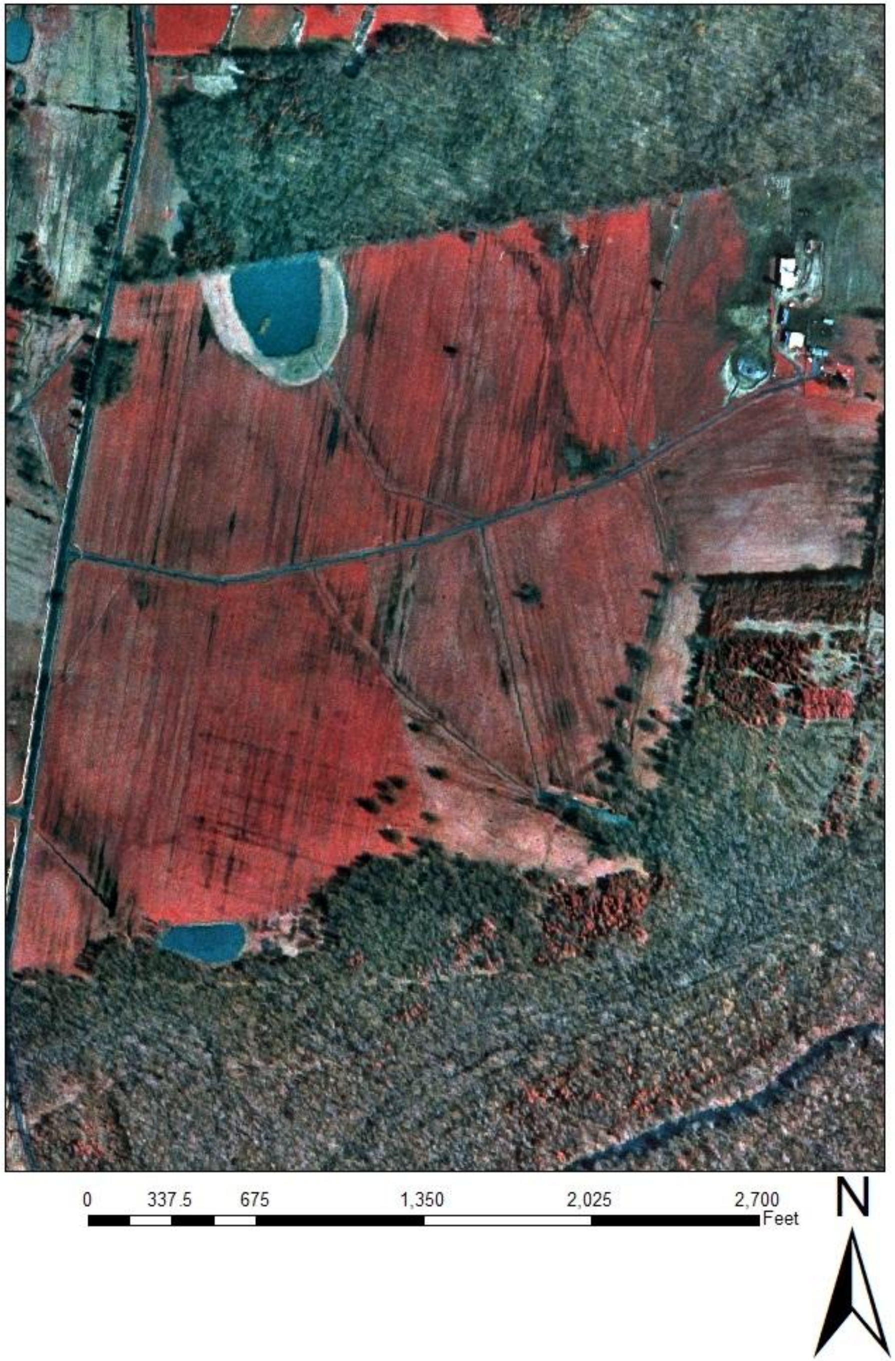
Prince William County, VA

Pre-mitigation



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Post mitigation

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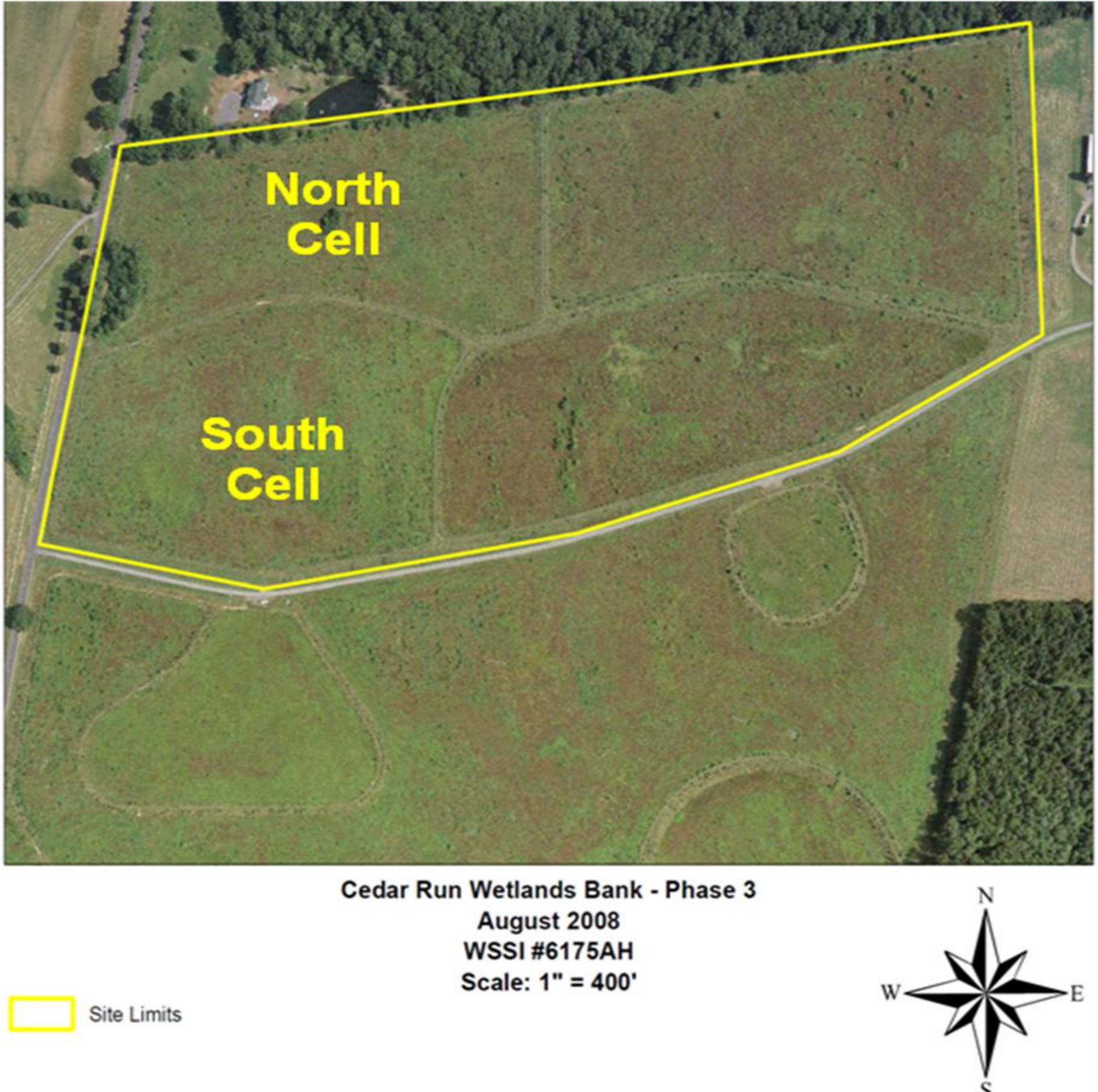
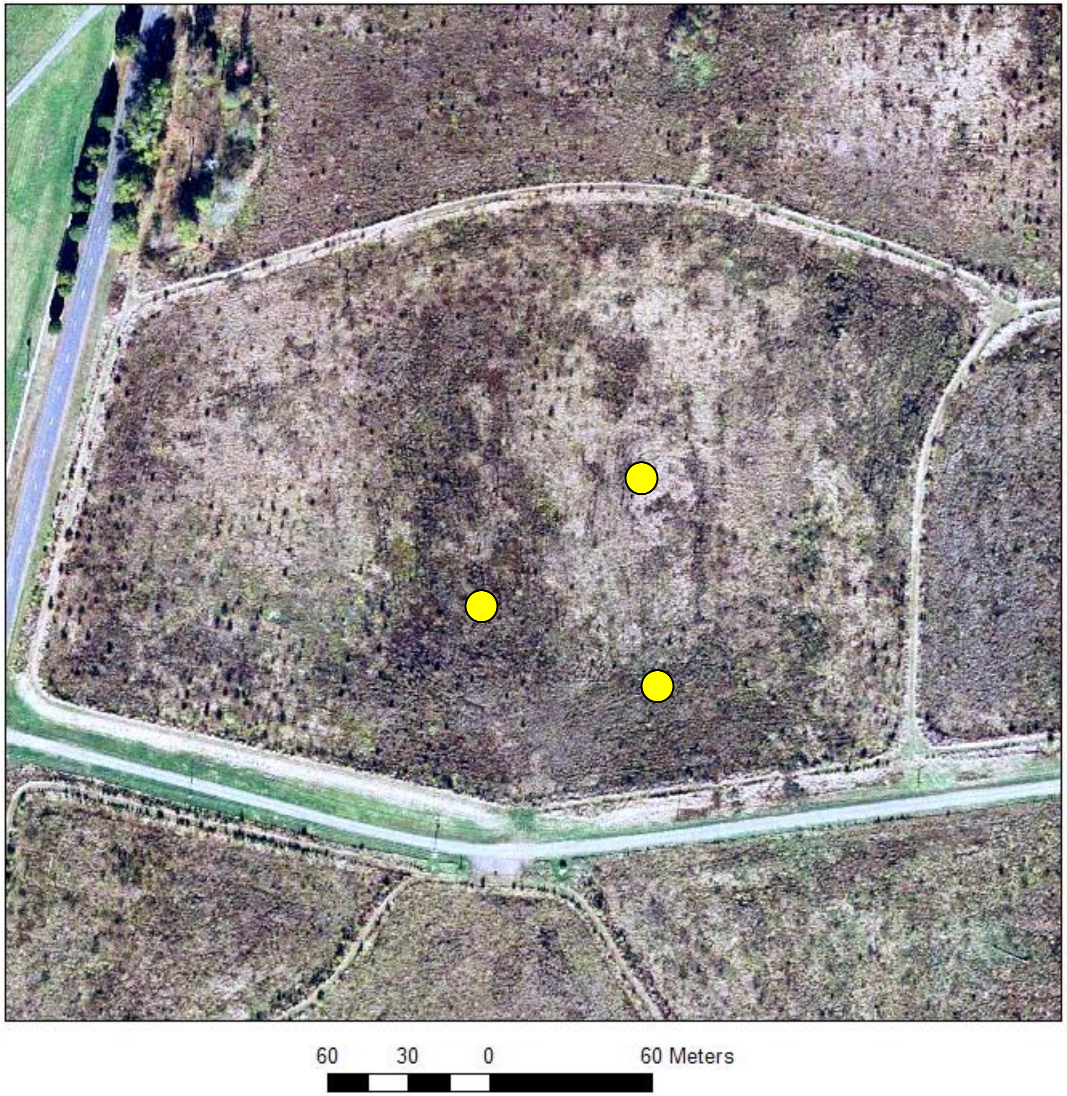

North
Cell
South
Cell
Cedar Run Wetlands Bank - Phase 3
August 2008
WSSI #6175AH
Scale: 1" = 400'
Site Limits
N
W
E
S

water level data were collected in the southern cell via USACOE standard observation well installations

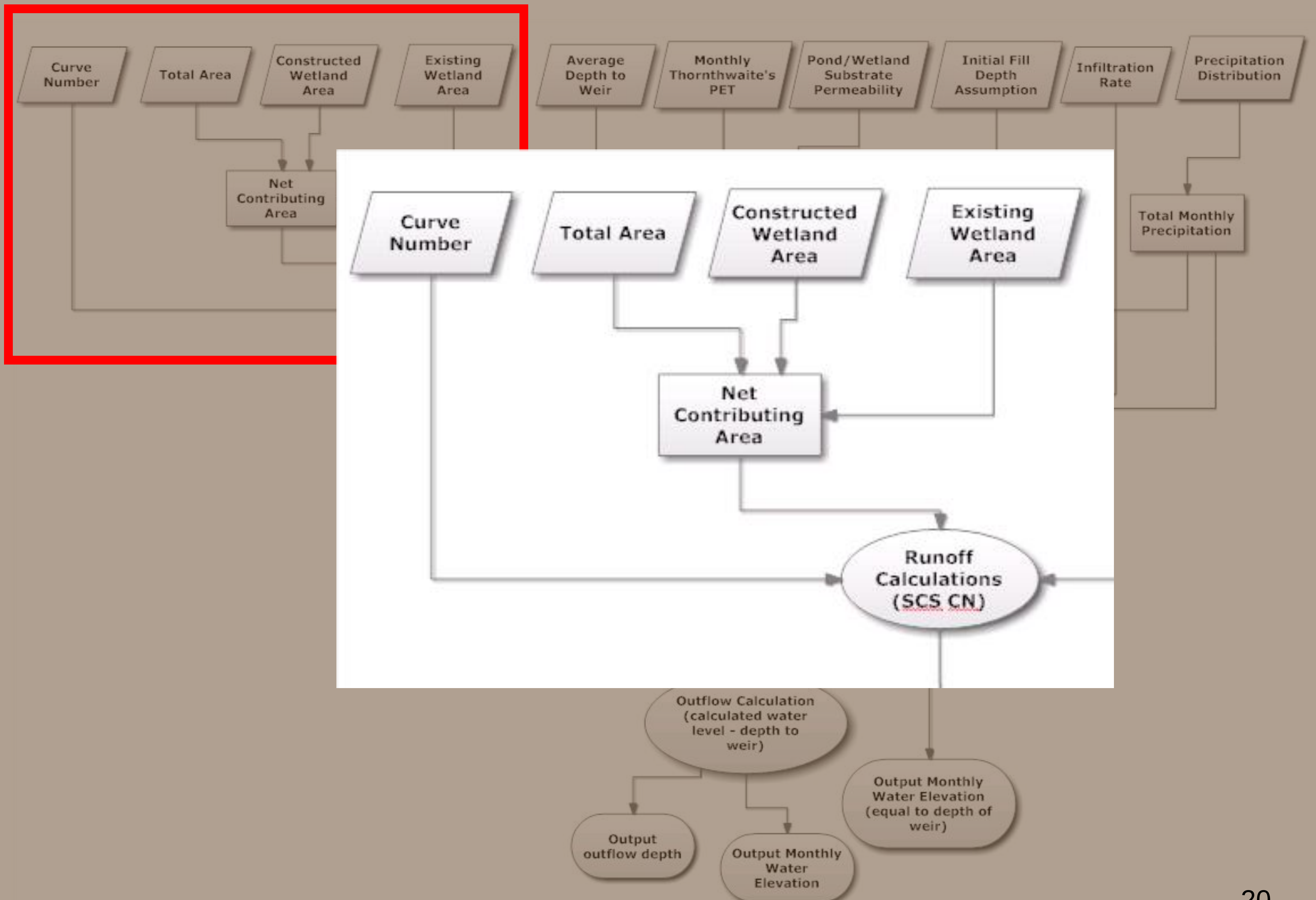


weather data were collected using an onsite weather station

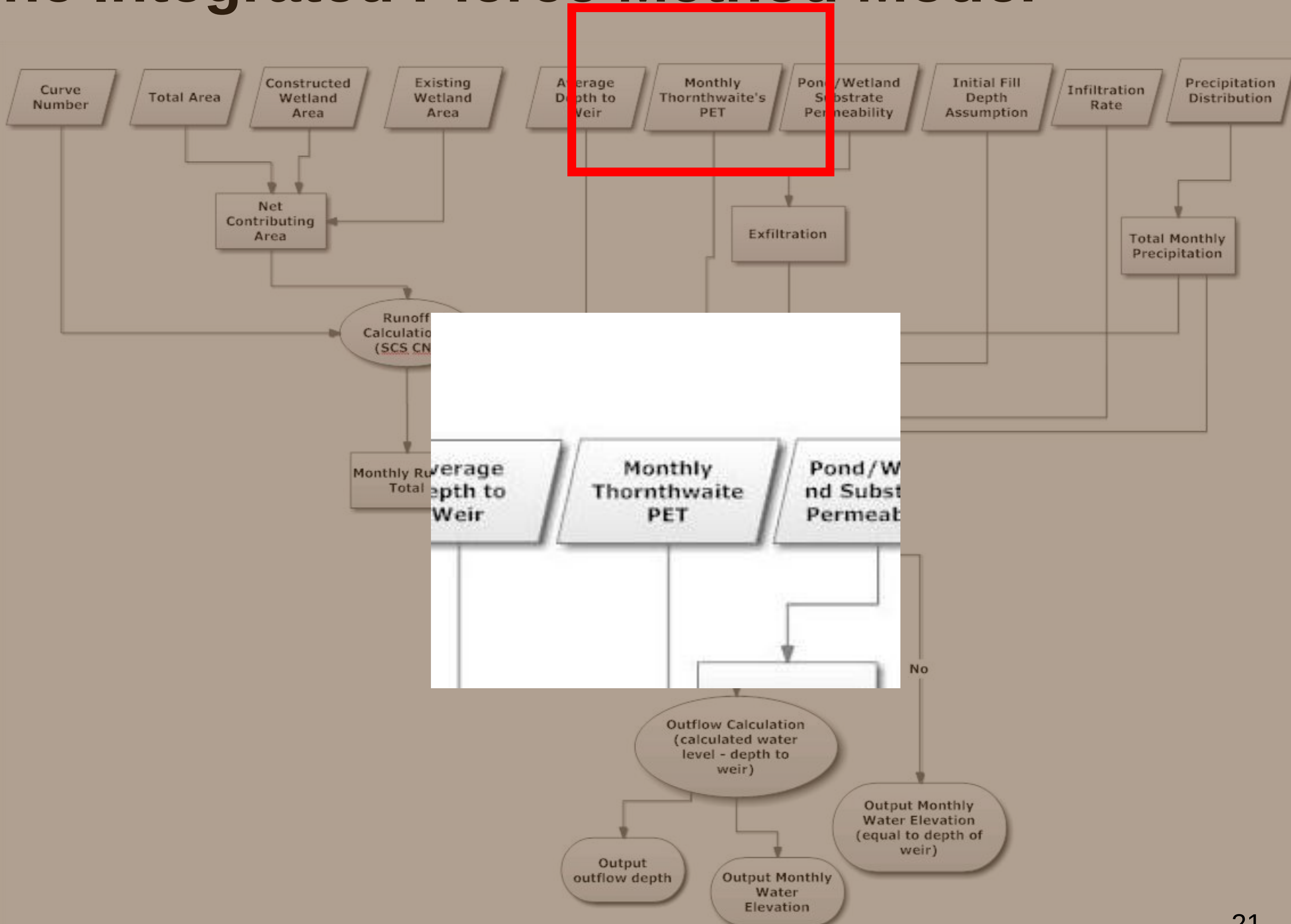
- Daily precipitation
- Daily temperature

the water budget models…

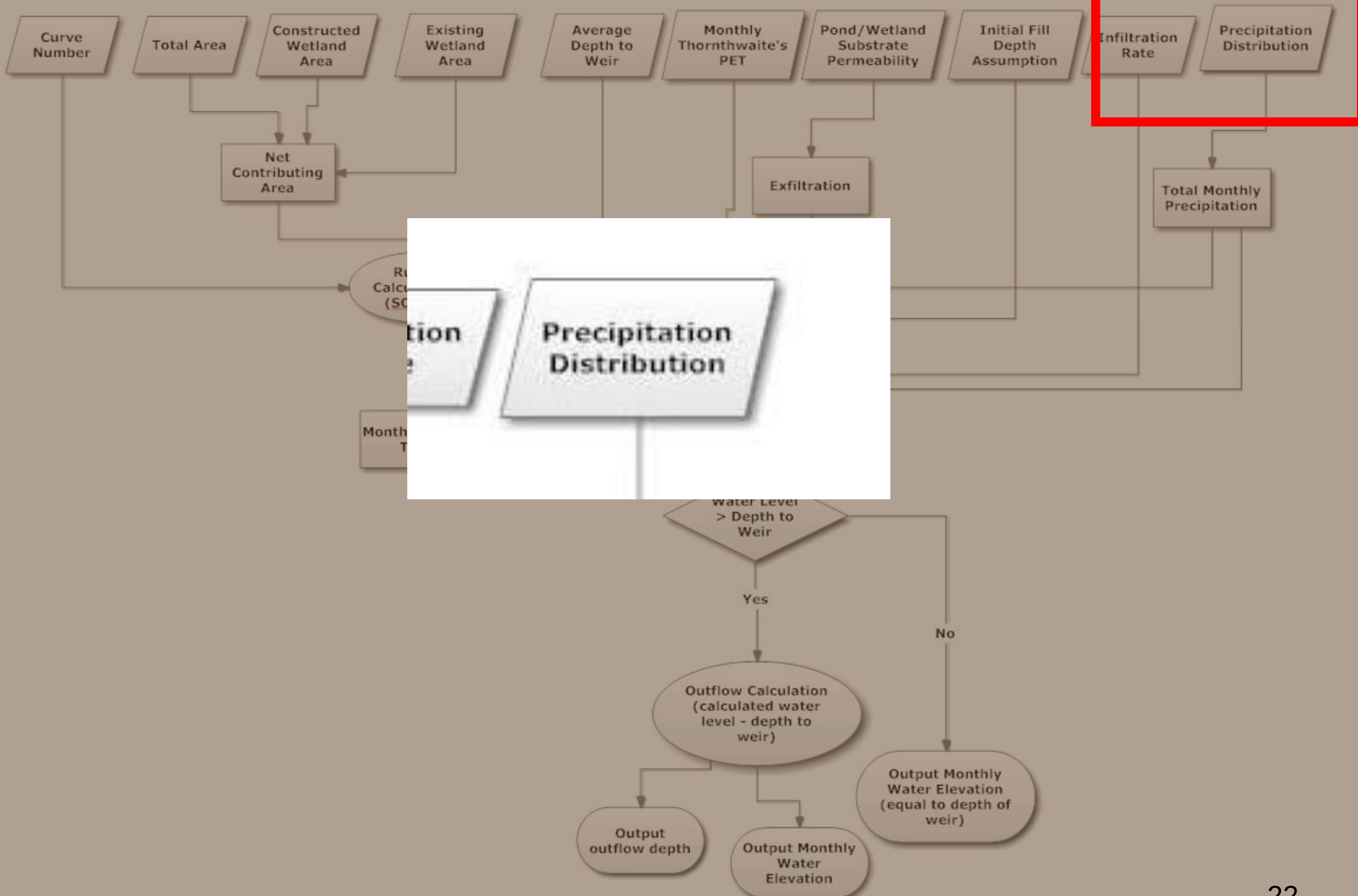
The Integrated Pierce Method Model



The Integrated Pierce Method Model



The Integrated Pierce Method Model



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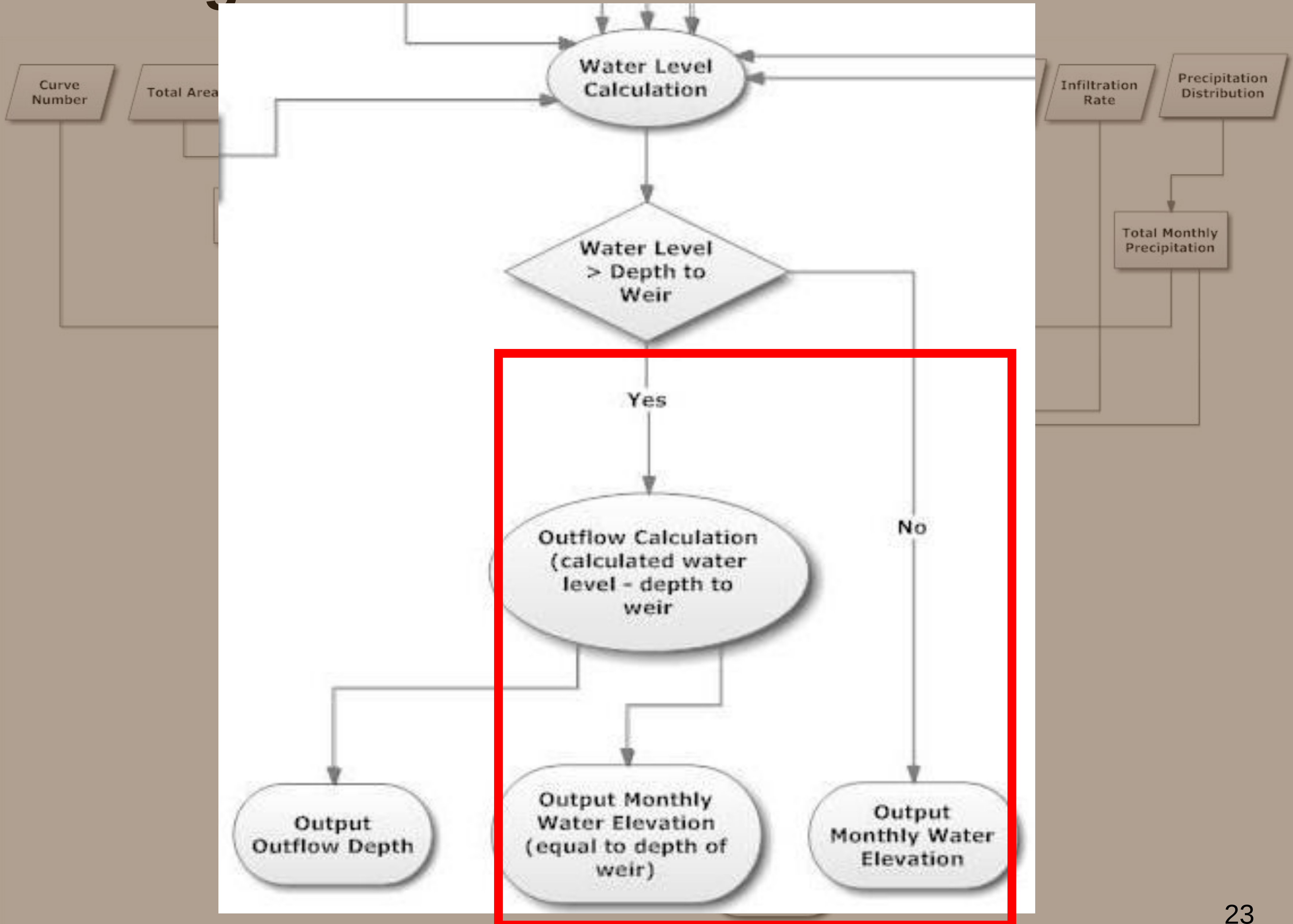
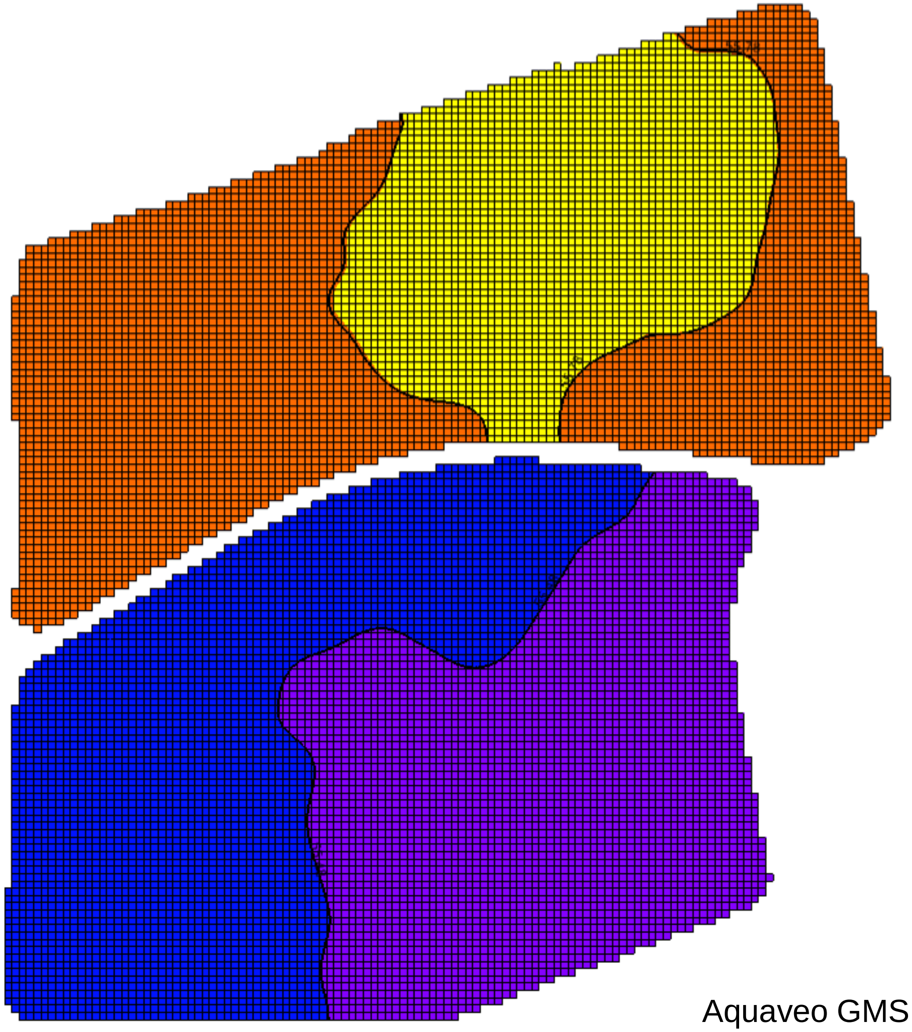
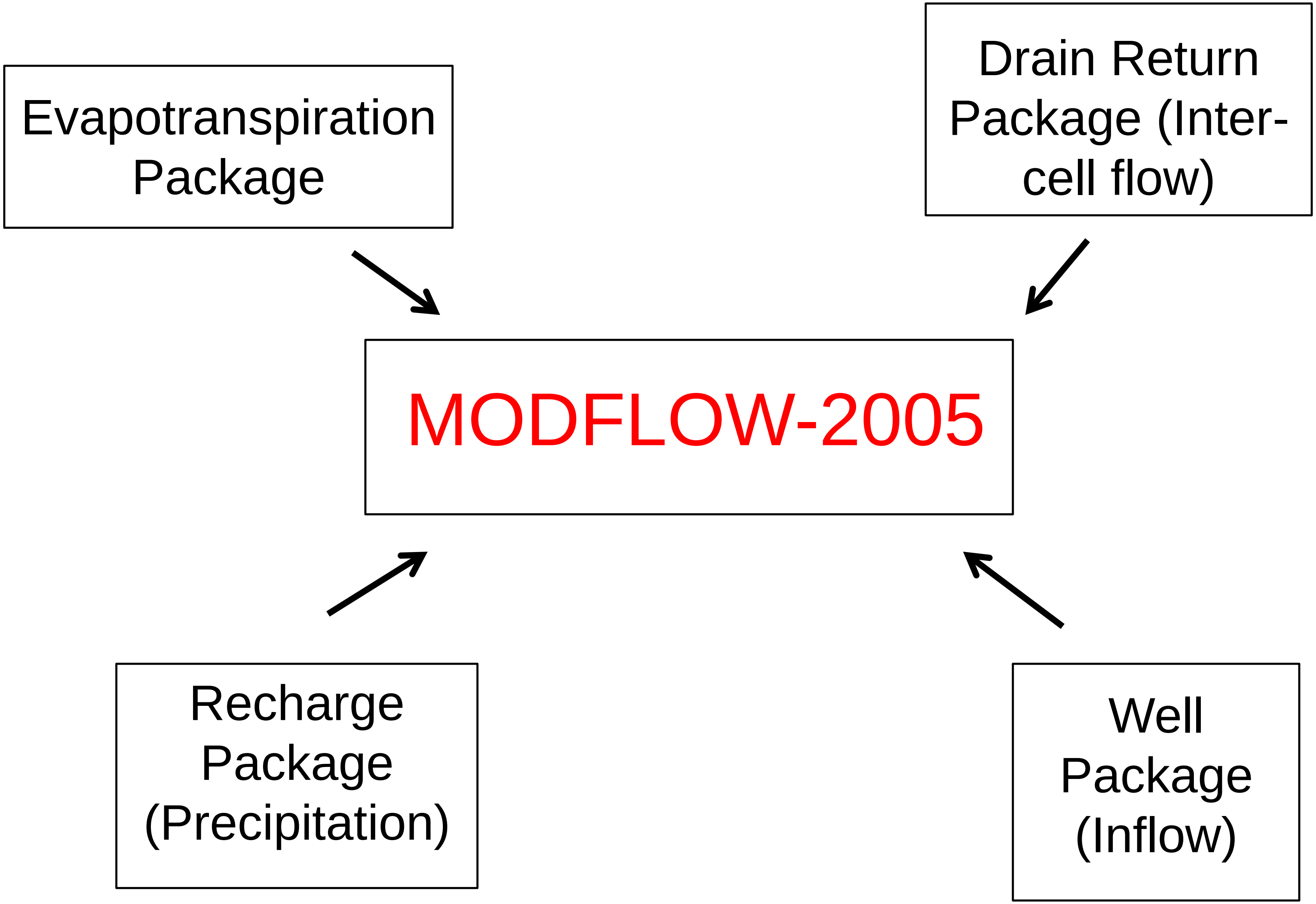


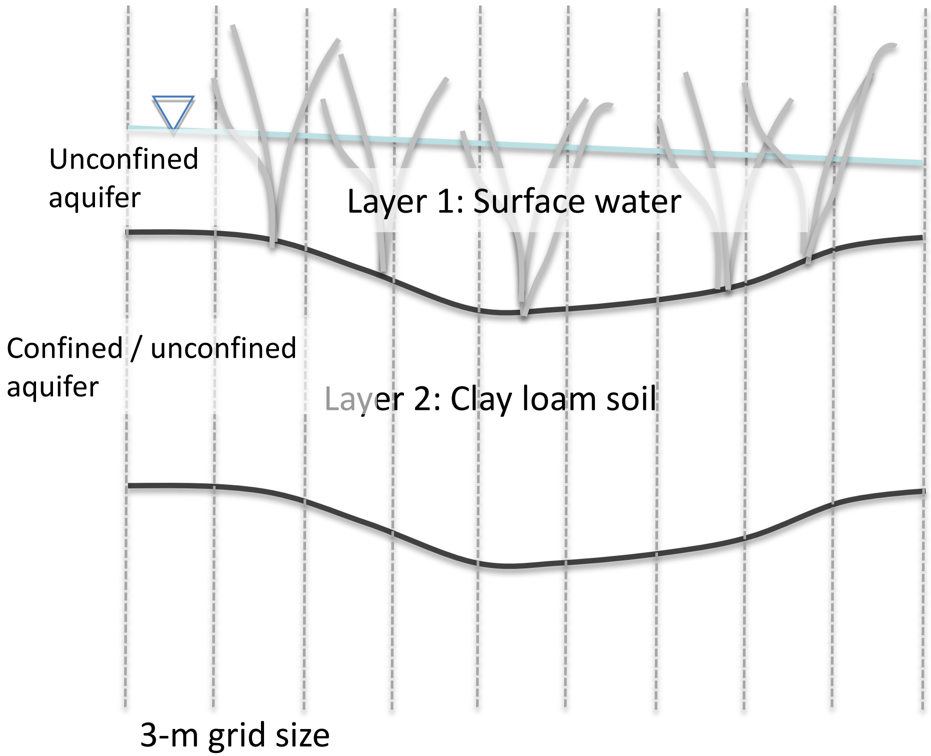
MODFLOW-2005



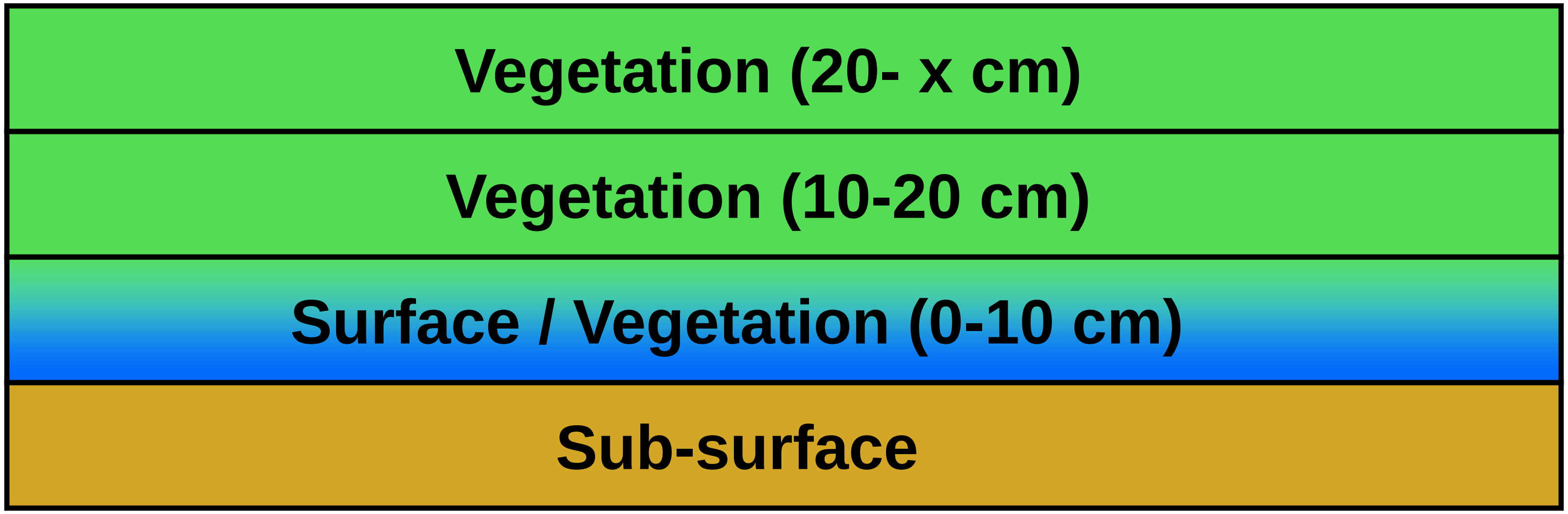
Aquaveo GMS 8.0


Evapotranspiration Package
Drain Return Package (Inter-cell flow)
MODFLOW-2005
Recharge Package (Precipitation)
Well Package (Inflow)

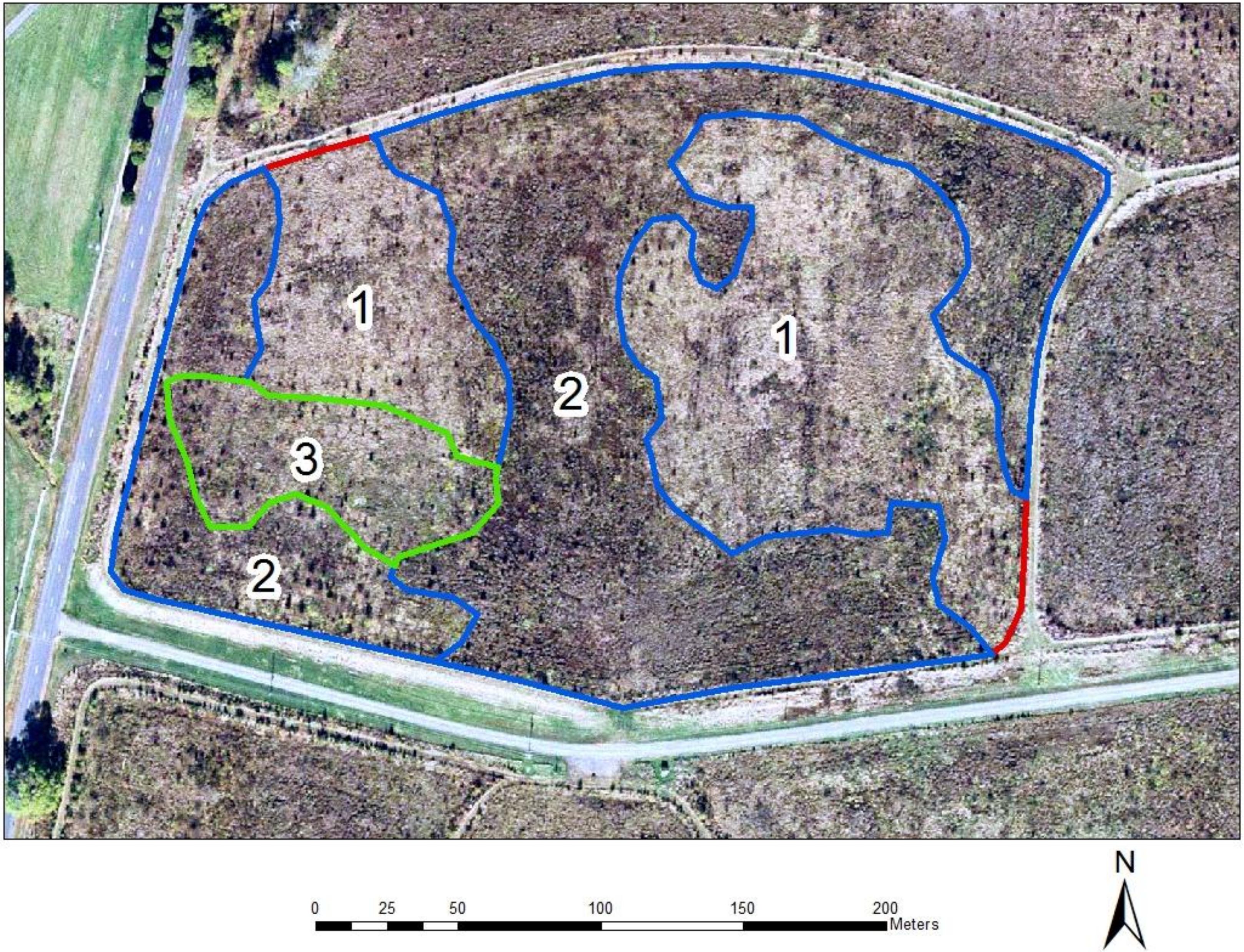
the wetland was represented as…



the wetland was represented as…



vegetation conductivities were calculated from community collections and measurements of momentum absorbing area (maa)


1
1
2
3
2
0
25
50
100
150
200
Meters
N

hydraulic conductivity, *k*

K (m/s) Spring/Summer			
	Zone 1	*Zone 2*	*Zone 3*
0-10 cm	2.67	1.49	2.26
10-20 cm	2.55	1.50	2.22
20-30cm	2.40	1.42	2.22

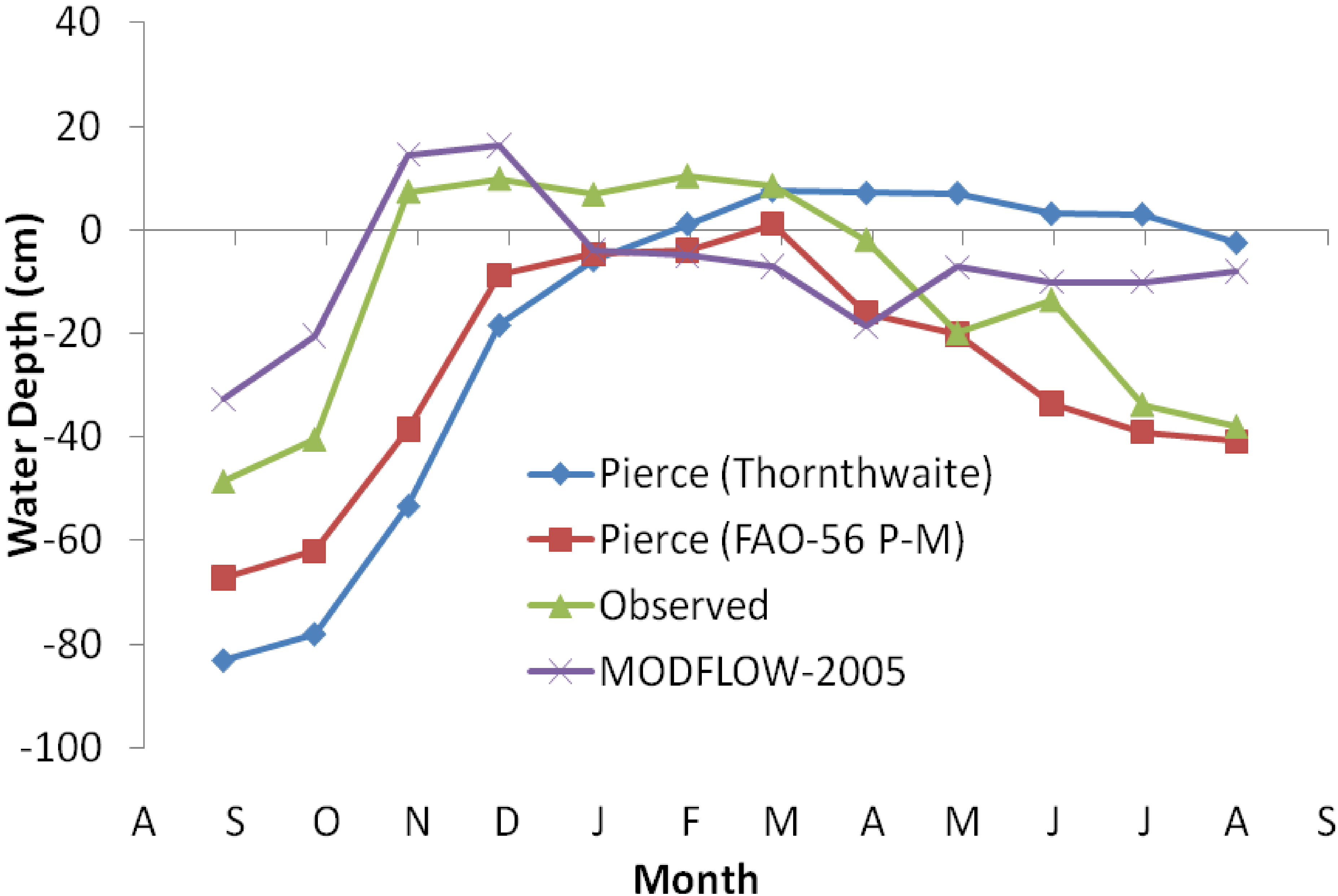
K (m/s) Fall/Winter			
	Zone 1	*Zone 2*	*Zone 3*
0-10 cm	2.38	2.00	2.63
10-20 cm	2.79	1.84	2.82
20-30cm	2.96	2.82	2.42

Integrated Perce Method (IPM)
Thornthwaite's PET
Monthly Time Step

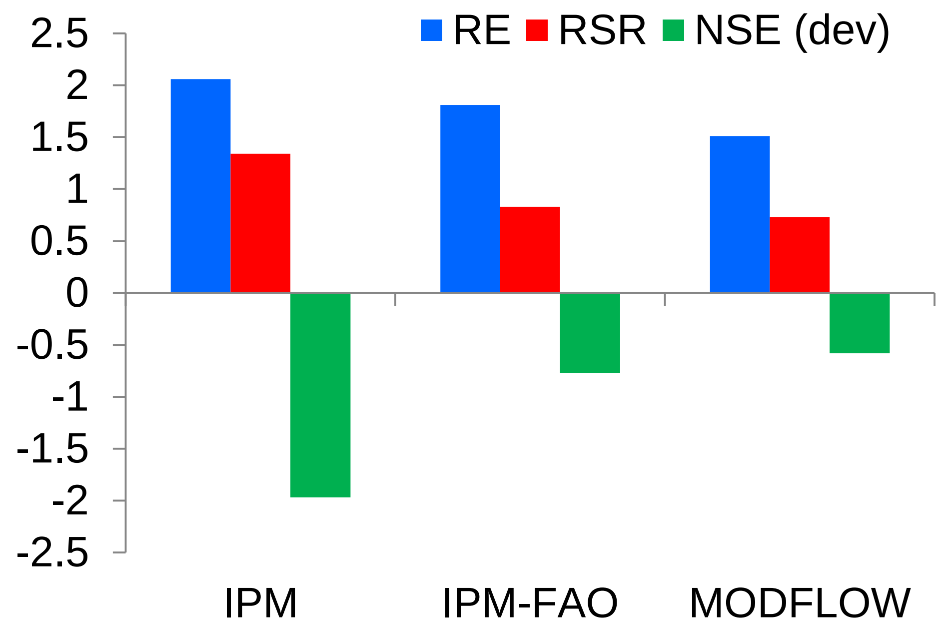
Integrated Perce Method with FAO P-M (IPM-FAO)
FAO Penman-Monteith Reference Crop PET
Monthly Time Step

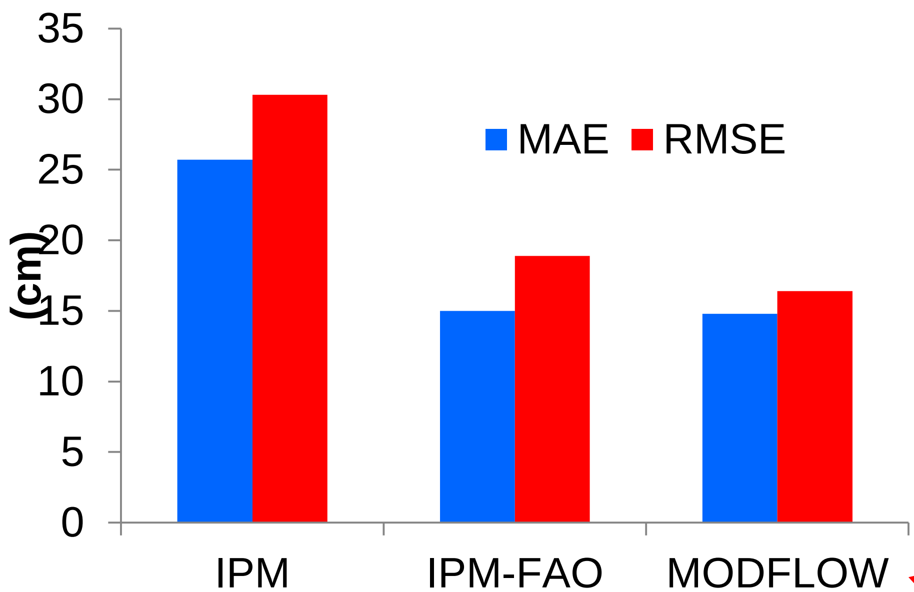
MODFLOW-2005 (Modflow)
FAO Penman-Monteith Reference Crop PET
Daily Time Step
Uncalibrated

the modeling results…


Water Depth (cm)
40
20
0
-20
-40
-60
-80
-100
A
S
O
N
D
J
F
M
A
M
J
J
A
S
Month
Pierce (Thornthwaite)
Pierce (FAO-56 P-M)
Observed
MODFLOW-2005

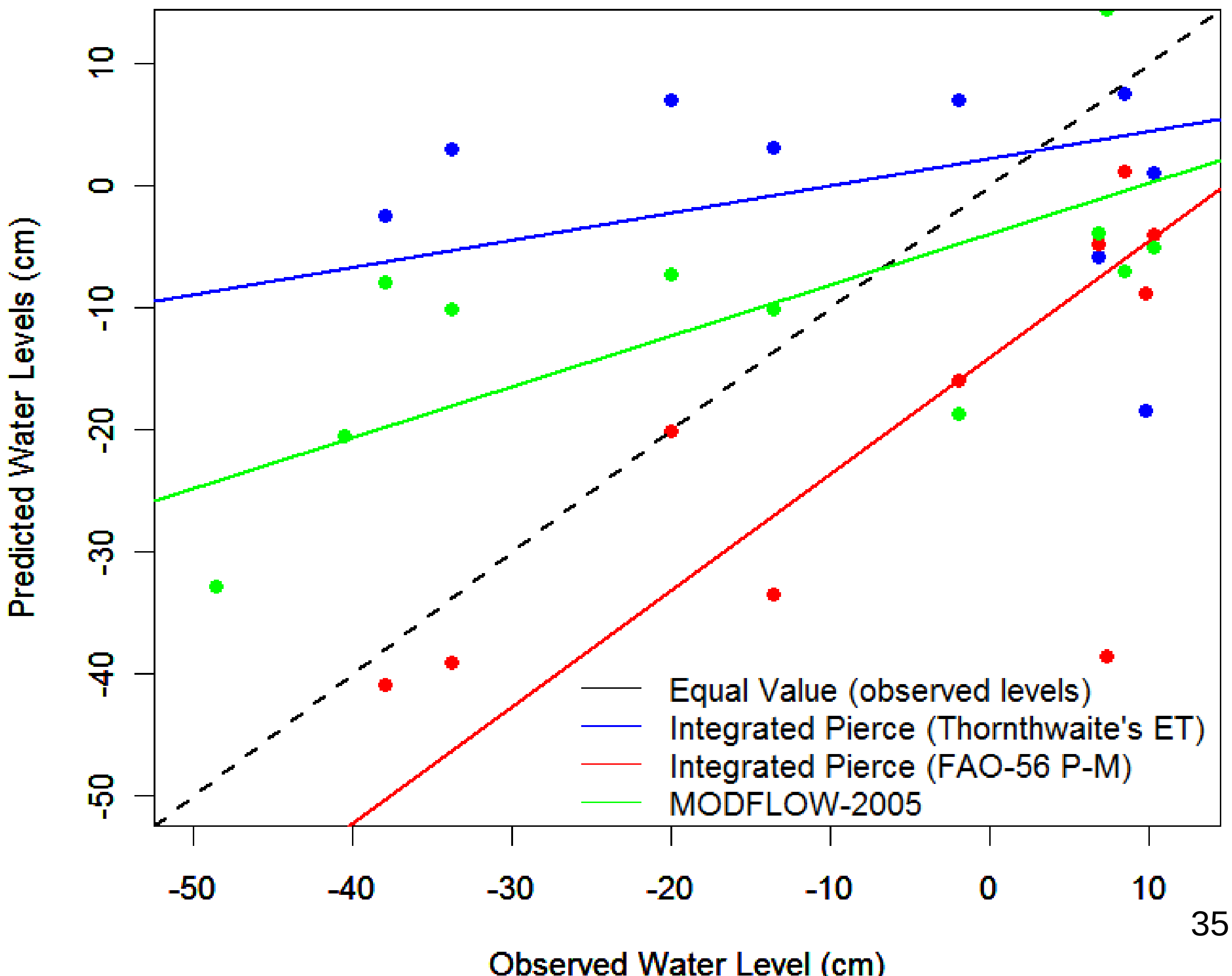
annual error statistics



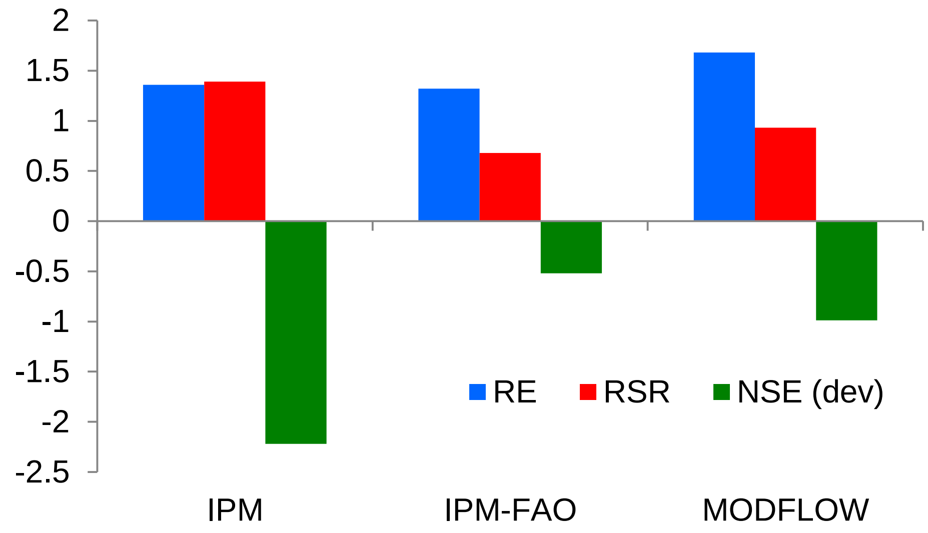


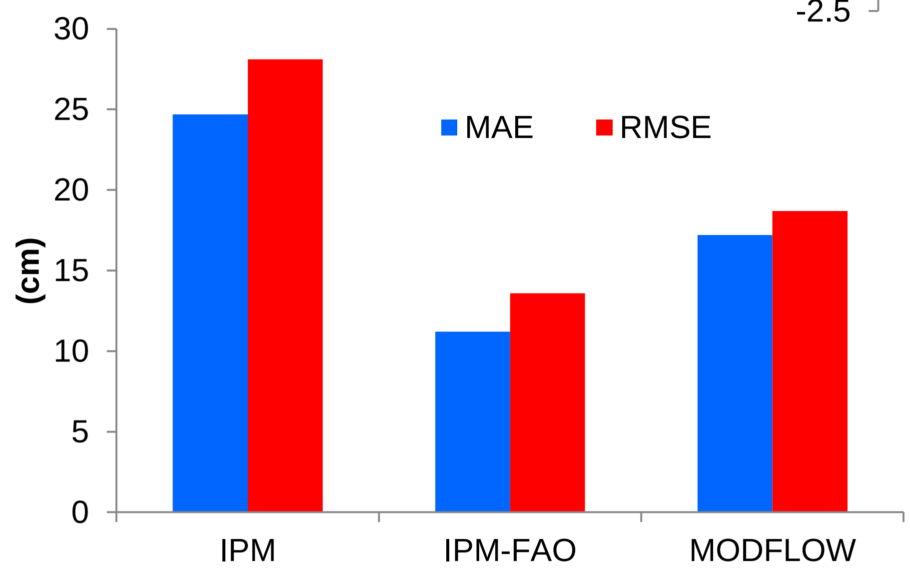
	Intercept	p-value	Slope	p-value	Relative Error
Integrated Pierce (Thornthwaite's)	2.28	0.51	0.22	0.03	38.39
Integrated Pierce (FAO-56 P-M)	-13.99	0.0005	0.95	1.8e-06	12.48
MODFLOW-2005	-3.95	0.47	0.42	2.7e-05	10.37

Theil-Sen Analysis



growing season error statistics





spring time Modflow errors

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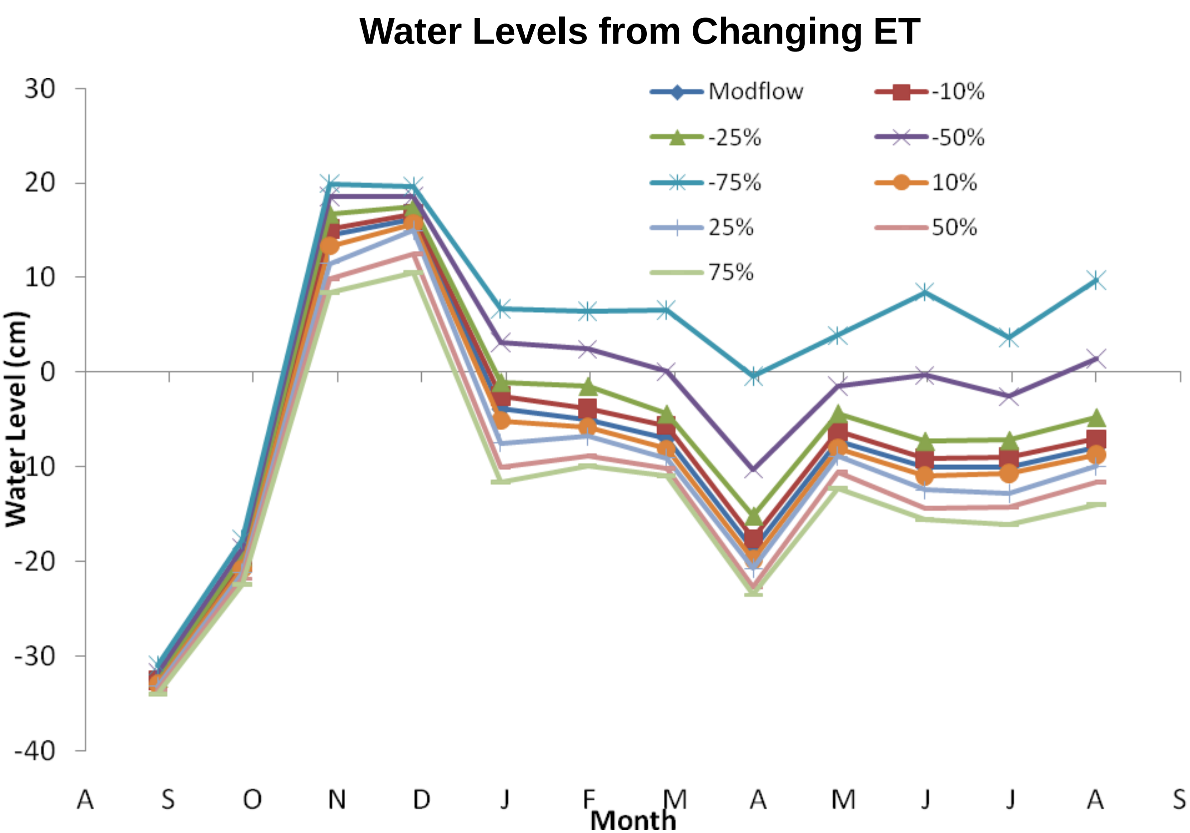
sensitivity analysis



Percent Change in Parameter	*ET*	*k*
-75%	1.26	NC*
-50%	1.52	-0.001
-25%	2.32	NC*
-10%	5.18	-0.020
10%	-5.24	-0.017
25%	-2.07	-0.015
50%	-0.93	-0.034
75%	-0.61	NC*

*Indicates model non-convergence

revisiting the objectives…

MODFLOW-2005 most accurately predicted water levels on an annual basis

determine the accuracy of water level predictions by a Pierce water balance method model, and a process based MODFLOW model

MAE = 14.8 cm

NSE = 0.42

seasonality affects modeling results. IPM-FAO most accurately predicted water levels during the growing season

evaluate seasonal effects in model performance

MAE = 11.2 cm

NSE = 0.48

Poiani and Johnson (1993) – Calibrated predictions within 10cm of observed 75% of time

Su and others (2000) – calibrated wetland model, standard error = 19cm

IPM-FAO and MODFLOW-2005 showed sensitivity to changes in ET. MODFLOW-2005 was not significantly sensitive to changes in *k*

determine the sensitivity of models to select input parameters

as such, ET estimation methods need to be carefully chosen, calculated with site-specific data

implications

> Results will guide future wetland water budget modeling, especially wetland mitigation related

- ET critical for estimation
- Improved pre-construction modeling will potentially increase mitigation success

> While IPM-FAO better seasonally, MODFLOW has advantages

- Daily time step
- Assess design variances (soils, topography)

future work

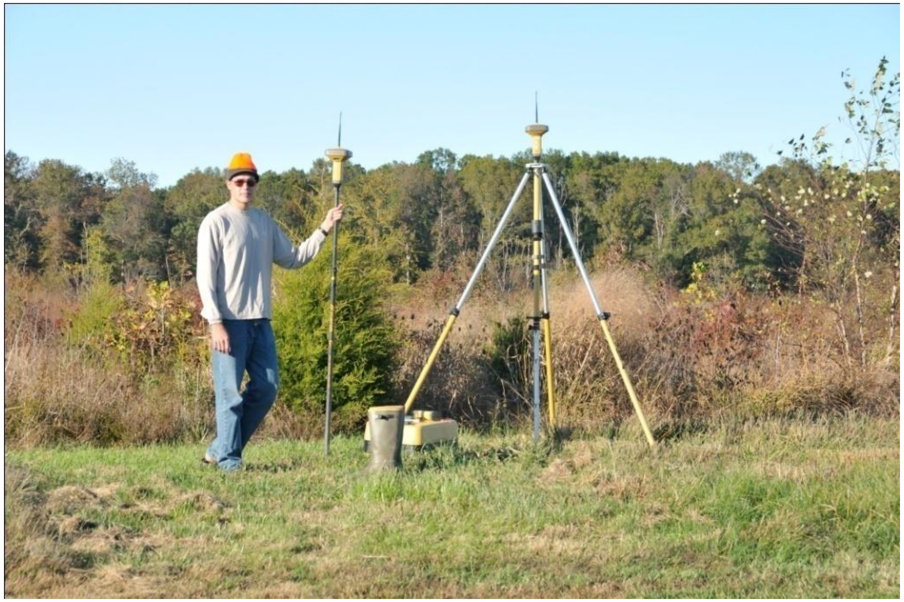
> Improved ET estimation

> Wetland Crop Coefficients

> *k* calculation improvements for
> wetlands with higher veg. density

> Incorporation of local groundwater hydrology!

Questions?



Piedmont Wetlands Research Program

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