Comments on NFSEG v1.1
Case 007h for
Peer Review Panel Consideration

April 18, 2018

Introduction

- NFUCG composed of 8 utilities in northeast Florida
- Integral to the fabric of our communities
  - Provide high-quality, reliable and cost-effective service to over 1.2 million residents
  - Meet the water needs of thousands of businesses and industries
  - Have invested $100s of millions to increase our efficiency and develop alternative water supplies
- Committed to the development of a scientifically-defensible NFSEG model
  - Working on Technical Team/Steering Team since inception
  - Meets the technical and charter goals previously agreed upon
  - Provides reliable information for intended uses beyond v1.0 planning

Purpose

- Peer review scope requires the assessment of several questions about the model and uses
- Developed information on concerns to assist peer reviewers in fulfillment of their task
  - PEST process
  - Recharge and ET estimates
  - Calibration residuals
  - Model suitability
  - Pumps-off simulation

PEST Questions

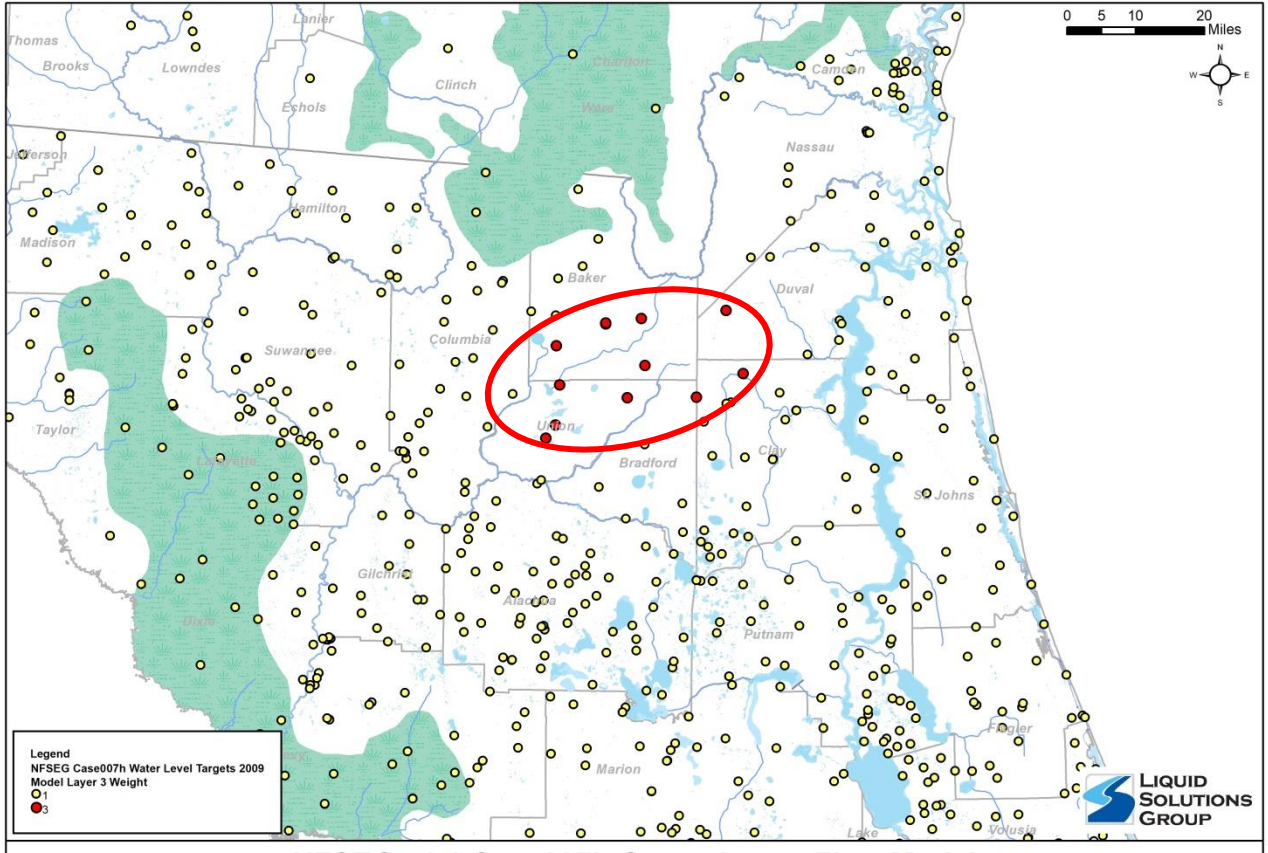
- *Is the parameterization scheme used in the PEST calibration appropriate?*

- *Were the types of observations and their implementation in the PEST calibration appropriate, given the intended use of the model?*

PEST Concerns

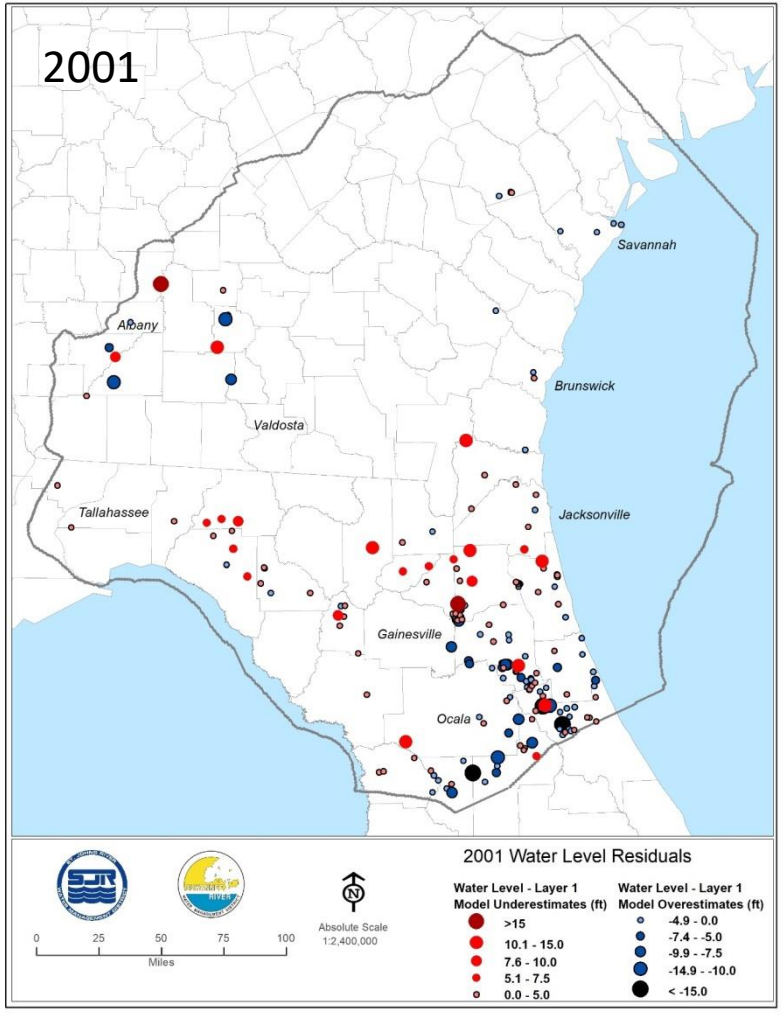
- Weighting of observations is inconsistent
- Use of synthetic targets in 2009 inappropriate given calibration structure
- In large portions of NEF model domain, PEST given 6 to 8 orders of magnitude for key parameters
- Provides opportunity for achieving calibration for wrong reasons

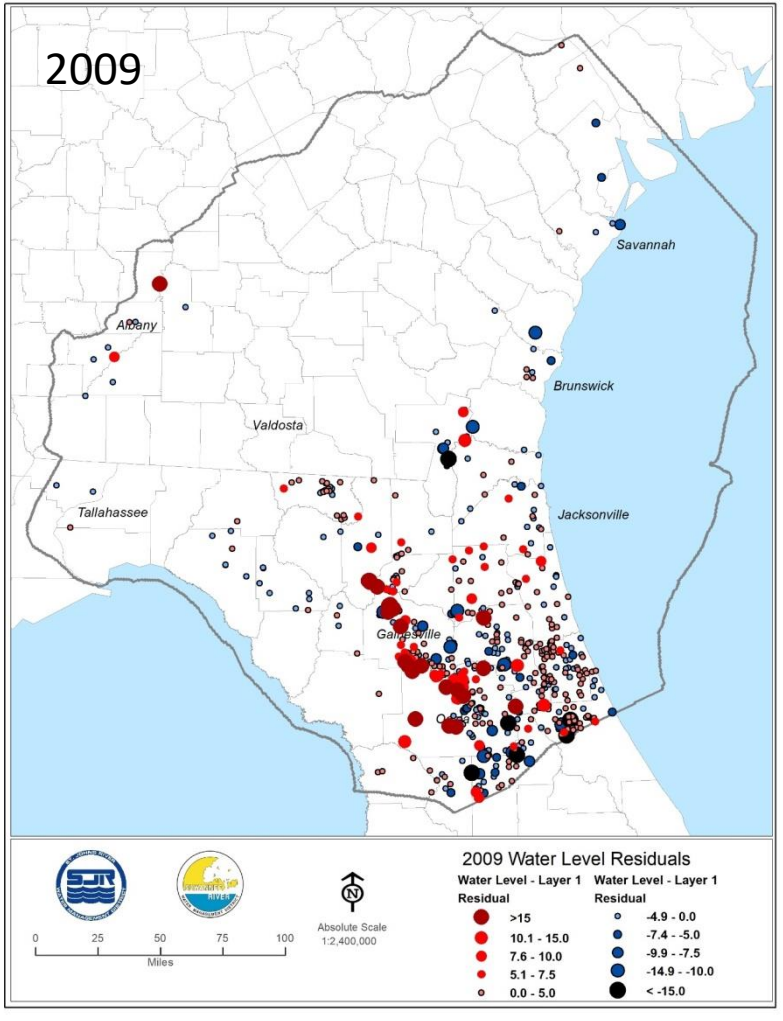
Unusual PEST Weights



NFSEG v1.1 Case007h Groundwater Flow Model
2009 Water Level Targets
Model Layer 3 Weights

Synthetic Targets in 2009

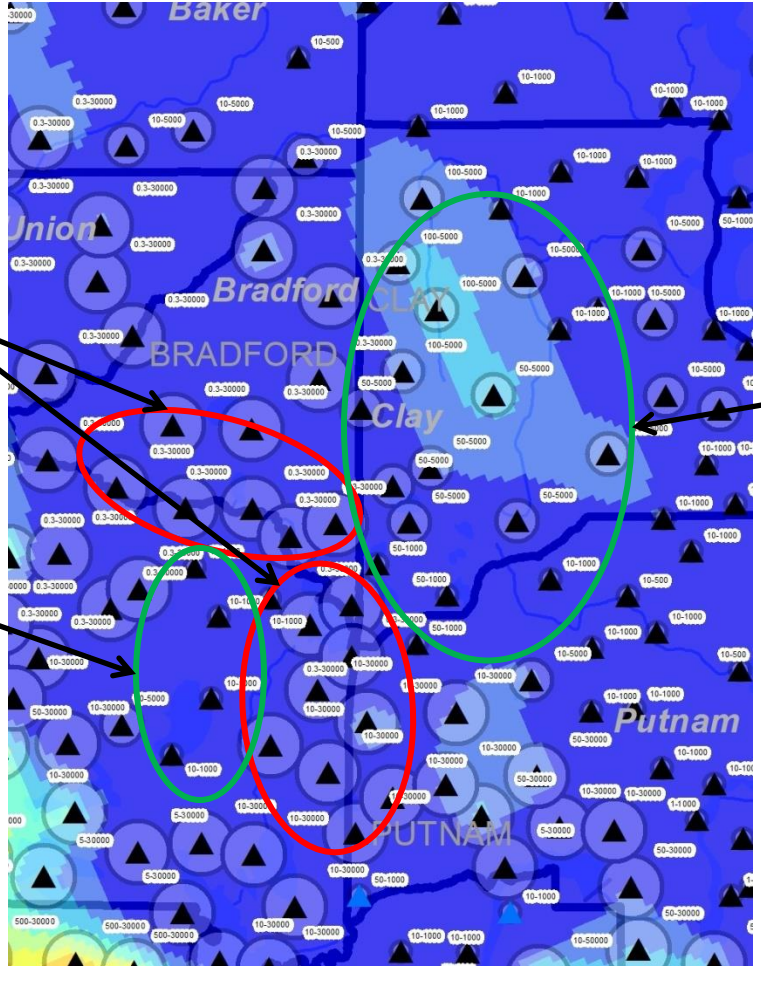




PEST Bounding Example

L3 Kh with 6 orders of magnitude bounds

Kh with <=2 orders of magnitude bounds



Kh with <=2 orders of magnitude bounds

Recharge/ET Questions

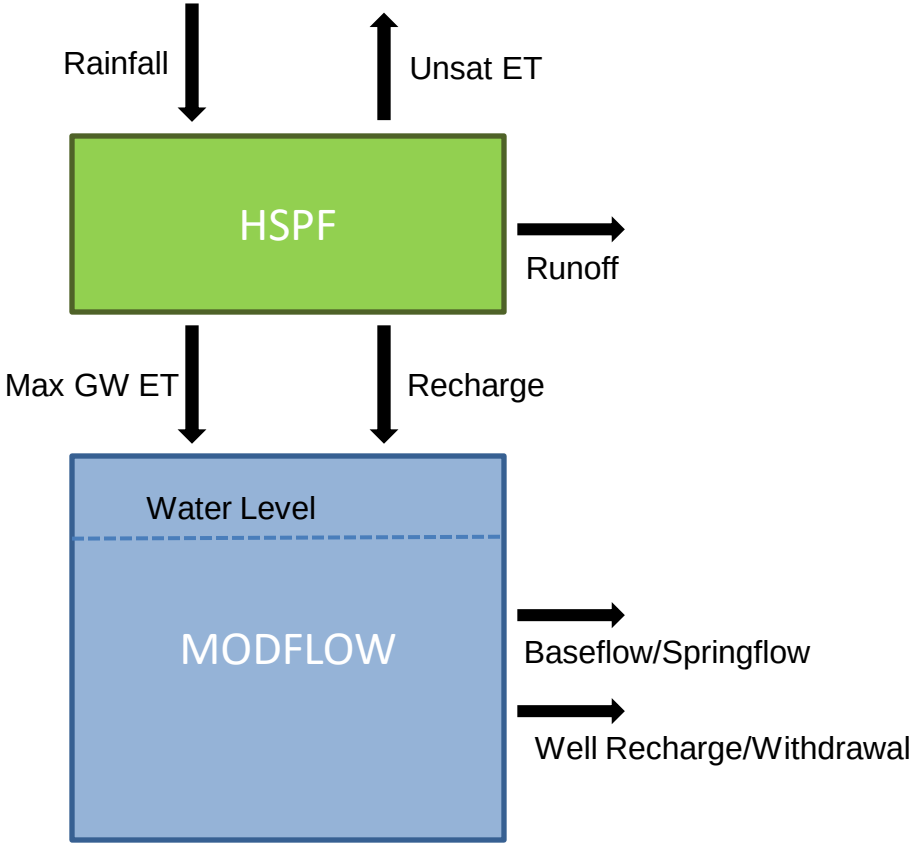
- *Was the use of HSPF as a method to develop recharge and maximum saturated ET that is assigned to the MODFLOW groundwater flow model a valid and defensible method?*

- *Was best available information utilized to develop the HSPF hydrologic models?*

Recharge/ET Concerns

- HSPF method validity should be verified outside of calibration period
- HSPF calibration residuals should be evaluated more closely
- Recharge and ET estimates should be improved, including potential evaluation of other methodologies

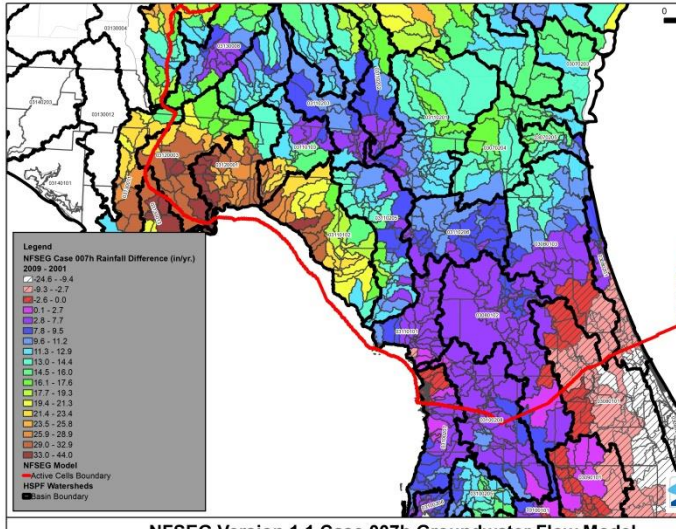
Importance of HSPF Calibration



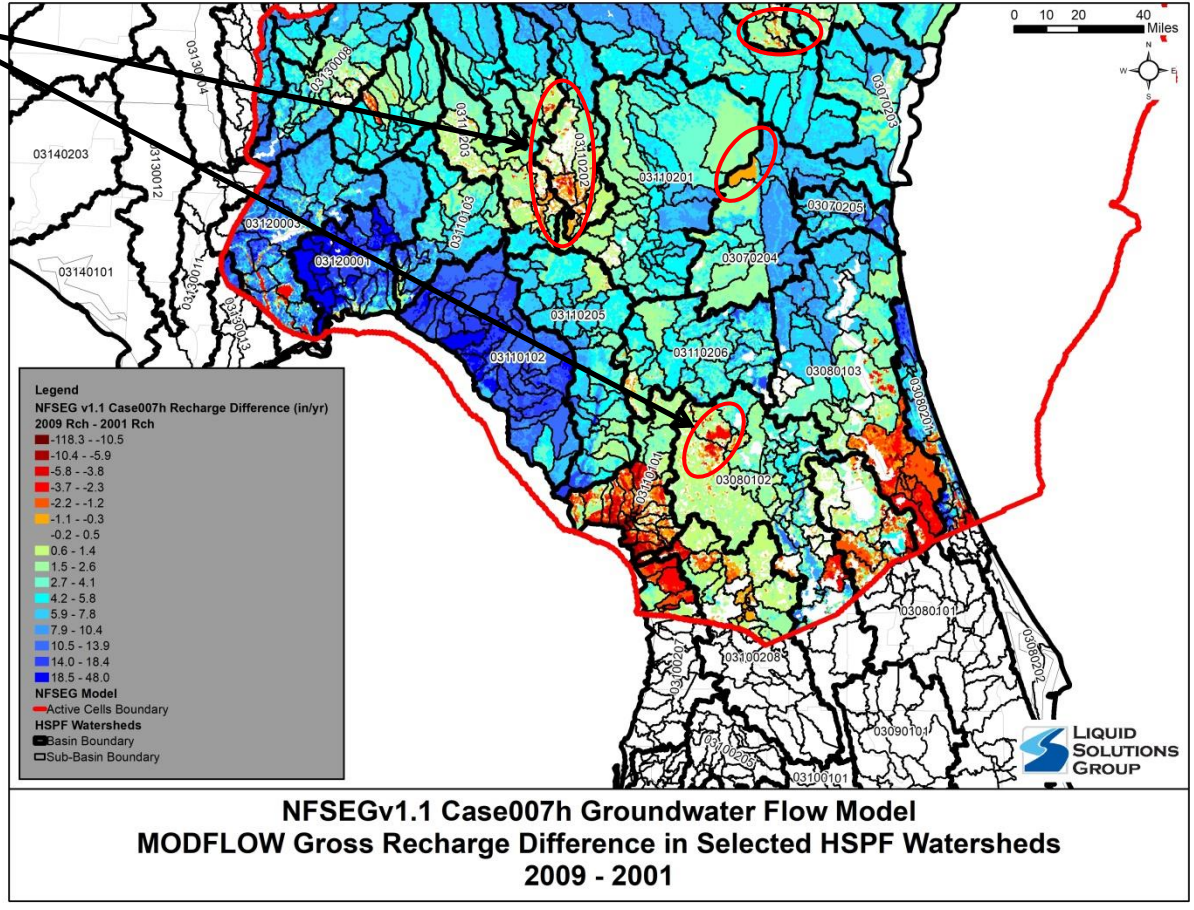
- HSPF runoff/max ET estimates provided to MODFLOW
- Most significant water budget inflows and outflows

Areas of Concern

Areas with higher rainfall and lower recharge



NFSEG Version 1.1 Case 007h Groundwater Flow Model
Rainfall Difference (2009 - 2001)
in Selected HSPF Watersheds

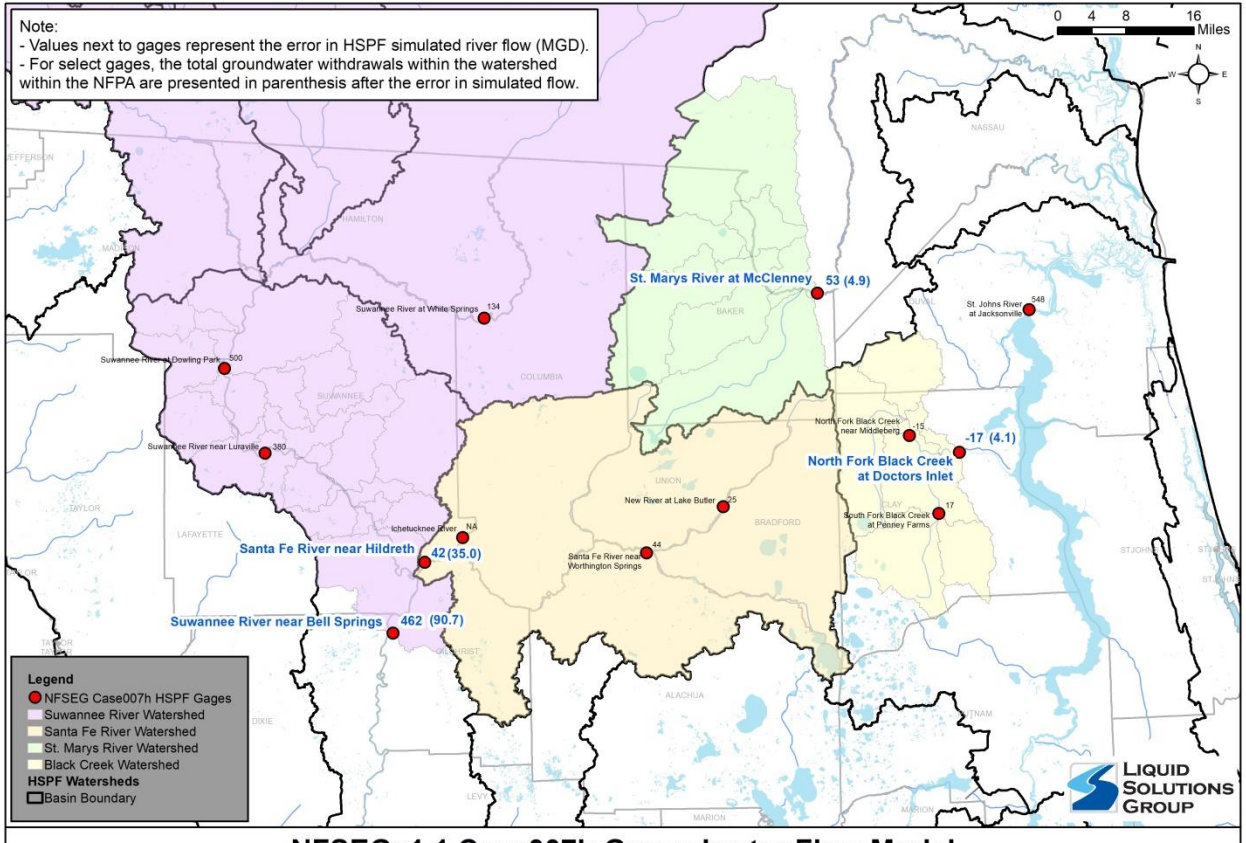


NFSEGv1.1 Case007h Groundwater Flow Model
MODFLOW Gross Recharge Difference in Selected HSPF Watersheds
2009 - 2001

HSPF Errors Have Potential to Impact Calibration

2001

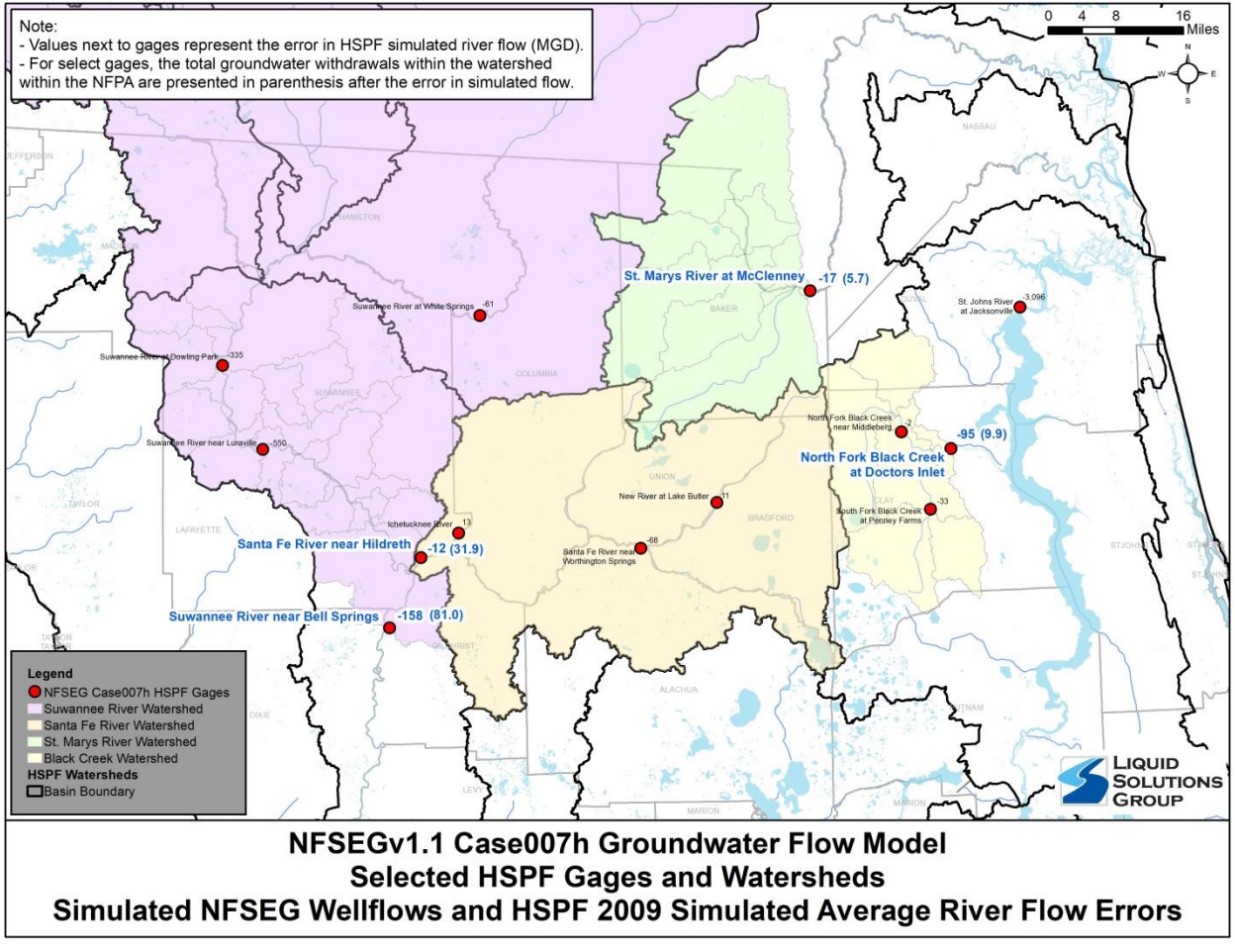
Q=135 mgd
HSPF Abs Resid = 574 mgd



HSPF Errors Have Potential to Impact Calibration

2009

Q=129 mgd
HSPF Abs Resid = 282 mgd



Evaluation of HSPF Errors in Context

River Flow Gage	2001 Observed Average River Flow (MGD)	2001 Simulated Average River Flow (MGD)	2001 Error in Simulated Average River Flow (MGD)	2001 Error in Simulated Average River Flow (%)
Ichetucknee River	NA	NA	**NA**	NA
New River at Lake Butler	22	47	**25**	112
North Fork Black Creek near Middleberg	77	62	**-15**	-20
North Fork Black Creek at Doctors Inlet	208	191	**-17**	-8
South Fork Black Creek at Penney Farms	41	58	**17**	41
St. Johns River at Jacksonville	3,922	4,470	**548**	14
St. Marys River at McClenney	69	122	**53**	77
Santa Fe River near Worthington Springs	46	90	**44**	95
Santa Fe River near Hildreth	656	698	**42**	6
Suwannee River at White Springs	254	389	**134**	53
Suwannee River at Dowling Park	1,951	2,451	**500**	26
Suwannee River near Luraville	2,138	2,518	**380**	18
Suwannee River near Bell Springs	3,176	3,638	**462**	15

11 MGD recovery need → Santa Fe River near Hildreth

River Flow Gage	2009 Observed Average River Flow (MGD)	2009 Simulated Average River Flow (MGD)	2009 Error in Simulated Average River Flow (MGD)	2009 Error in Simulated Average River Flow (%)
Ichetucknee River	164	177	**13**	8
New River at Lake Butler	63	74	**11**	17
North Fork Black Creek near Middleberg	127	125	**-2**	-2
North Fork Black Creek at Doctors Inlet	408	313	**-95**	-23
South Fork Black Creek at Penney Farms	125	92	**-33**	-26
St. Johns River at Jacksonville	7,007	3,911	**-3096**	-44
St. Marys River at McClenney	283	266	**-17**	-6
Santa Fe River near Worthington Springs	180	112	**-68**	-38
Santa Fe River near Hildreth	929	917	**-12**	-1
Suwannee River at White Springs	813	752	**-61**	-8
Suwannee River at Dowling Park	3,701	3,366	**-335**	-9
Suwannee River near Luraville	3,994	3,444	**-550**	-14
Suwannee River near Bell Springs	4,956	4,798	**-158**	-3

2 MGD recovery need → Ichetucknee River

11 MGD recovery need → Santa Fe River near Hildreth

Residuals Questions

- *Have differences between observations and their simulated equivalents (model residuals) been described sufficiently. For example, have an appropriate set of summary statistics, plots, and maps been presented that allow for evaluation of model limitations, (such as model bias and uncertainty) in a manner that meets or exceeds existing professional practices?*

- *Does the final version of the model appear to be adequately calibrated given the available data for calibration, and the state of knowledge (and lack thereof) of the hydrologic system prior to development of the model?*

Calibration Residual Concerns

- Metrics have degraded since v1.0
- Do not meet goals for NFSEG
- Do not meet standards achieved by other models
- Display spatial and temporal bias that should be examined further

Water Level Residuals Have Degraded And Fail To Meet Goals

Statistical Criterion	Goal	All Wells					Layer 3 (UFA) Wells				
		V 1.0		V1.1(Case 007h)			V 1.0		V1.1(Case 007h)		
		2001	2009	2001	2009	2010	2001	2009	2001	2009	2010
-5 ft < Res < 5 ft	80%	77%	77%	72%	74%	70%	82%	81%	76%	76%	73%
-2.5 ft < Res < 2.5 ft	50%	50%	52%	42%	48%	40%	54%	56%	43%	49%	43%
Mean Error		0.2	0.5	0.1	0.3	0.7	-0.4	-0.2	-0.4	-0.9	0.0
Abs Mean Error		3.8	3.7	4.4	4.4	4.8	3.0	3.0	3.6	3.4	4.1
RMSE		6.3	6.0	6.6	8.4	7.4	4.2	4.1	4.8	4.6	6.0

Statistical Criterion	Goal	Layer 1 (SAS) Wells					Layer 5 (LFA) Wells				
		V 1.0		V1.1(Case 007h)			V 1.0		V1.1(Case 007h)		
		2001	2009	2001	2009	2010	2001	2009	2001	2009	2010
-5 ft < Res < 5 ft	80%	72%	79%	71%	75%	71%	64%	76%	44%	68%	56%
-2.5 ft < Res < 2.5 ft	50%	48%	51%	46%	51%	43%	46%	46%	21%	27%	20%
Mean Error		1.0	1.5	-0.1	1.8	1.2	0.0	0.7	2.6	1.1	3.2
Abs Mean Error		4.1	3.6	4.2	5.1	4.8	3.4	3.9	5.4	4.3	5.5
RMSE		6.1	5.2	6.2	11.4	7.6	4.4	5.5	6.2	5.3	6.5

"The degree of calibration is typically measured by the degree to which various simulated aquifer responses match corresponding observed or estimated values, the primary one being aquifer water levels."

Spring/Baseflow Residuals Don't Meet Goals

Statistical Criterion	Goal	Springs (qspring)				Spring Groups (qs_spring)			
		V 1.0		V1.1(Case 007h)		V 1.0		V1.1(Case 007h)	
		2001	2009	2001	2009	2001	2009	2001	2009
Ave Obs Flow (cfs)		16.1	21.0	14.8	20.7	414.4	515.9	454.3	535.1
Mean Error		-0.1	-0.8	-1.0	-1.1	13.8	-14.5	7.6	-8.9
Abs Mean Error		1.5	1.6	2.4	2.8	15.9	15.7	11.1	11.8
RMSE		3.0	3.2	10.8	20.6	17.1	19.3	14.5	15.0
RMSE (<10%/20%)	100%			59.5	71.9			100%	100%

Statistical Criterion	Goal	Baseflow Pickups (qr)				Baseflow (qs)			
		V 1.0		V1.1(Case 007h)		V 1.0		V1.1(Case 007h)	
		2001	2009	2001	2009	2001	2009	2001	2009
Ave Obs Flow (cfs)		131.9	278.3	90.3	206.2	1108.2	1665.5	877.6	676.9
Mean Error		-32.0	-105.0	26.0	43.3	-27.0	-94.4	75.9	170.5
Abs Mean Error		55.3	141.9	44.0	106.5	91.0	97.1	108.4	232.2
RMSE		107.4	436.7	91.5	177.3	149.5	128.6	182.4	317.2
RMSE <20%	100%			26.3	23.9			40.0	33.3
RMSE <50%				51.3	56.5			70.0	44.4

"Regarding spring discharges, the objective will be to have the root-mean square of error within 10 percent of the measured flows for spring flows larger than or equal to 10 cubic feet per second (cfs) and within 20 percent for smaller springs (Sepulveda et al., 2012). For baseflows, the objective will be to have the root-mean square of error within 20 percent for all baseflows."

WL Residuals Not As Good As Other Regional Models

Statistical Criterion	All Wells			Layer 3 (UFA) Wells			
	V1.1(Case 007h)		ECFT	V1.1(Case 007h)		ECFT	INTB
	2001	2009	1995-2006	2001	2009	1995-2006	1989-1998
-5 ft < Res < 5 ft	72%	74%	92%	76%	76%	94%/93%	--
-2.5 ft < Res < 2.5 ft	42%	48%	71%	43%	49%	77%/70%	--
Mean Error	0.1	0.3	--	-0.4	-0.9	--	-0.2
Abs Mean Error	4.4	4.4	2.1	3.6	3.4	1.9/2.1	1.5
RMSE	6.6	8.4	2.6	4.8	4.6	2.4/2.7	1.9

Statistical Criterion	Layer 1 (SAS) Wells				Layer 5 (LFA) Wells		
	V1.1(Case 007h)		ECFT	INTB	V1.1(Case 007h)		ECFT
	2001	2009	1995-2006	1989-1998	2001	2009	1995-2006
-5 ft < Res < 5 ft	71%	75%	93%	--	44%	68%	86%
-2.5 ft < Res < 2.5 ft	46%	51%	71%	--	21%	27%	68%
Mean Error	-0.1	1.8	--	-0.2	2.6	1.1	--
Abs Mean Error	4.2	5.1	2.1	1.3	5.4	4.3	2.1
RMSE	6.2	11.4	2.6	1.6	6.2	5.3	2.5

Temporal Bias in HSPF Results

River Flow Gage	2001 Error in Simulated Average River Flow (MGD)	2001 Error in Simulated Average River Flow (%)
Ichetucknee River	NA	**NA**
New River at Lake Butler	25	**112**
North Fork Black Creek near Middleberg	-15	**-20**
North Fork Black Creek at Doctors Inlet	-17	**-8**
South Fork Black Creek at Penney Farms	17	**41**
St. Johns River at Jacksonville	548	**14**
St. Marys River at McClenney	53	**77**
Santa Fe River near Worthington Springs	44	**95**
Santa Fe River near Hildreth	42	**6**
Suwannee River at White Springs	134	**53**
Suwannee River at Dowling Park	500	**26**
Suwannee River near Luraville	380	**18**
Suwannee River near Bell Springs	462	**15**

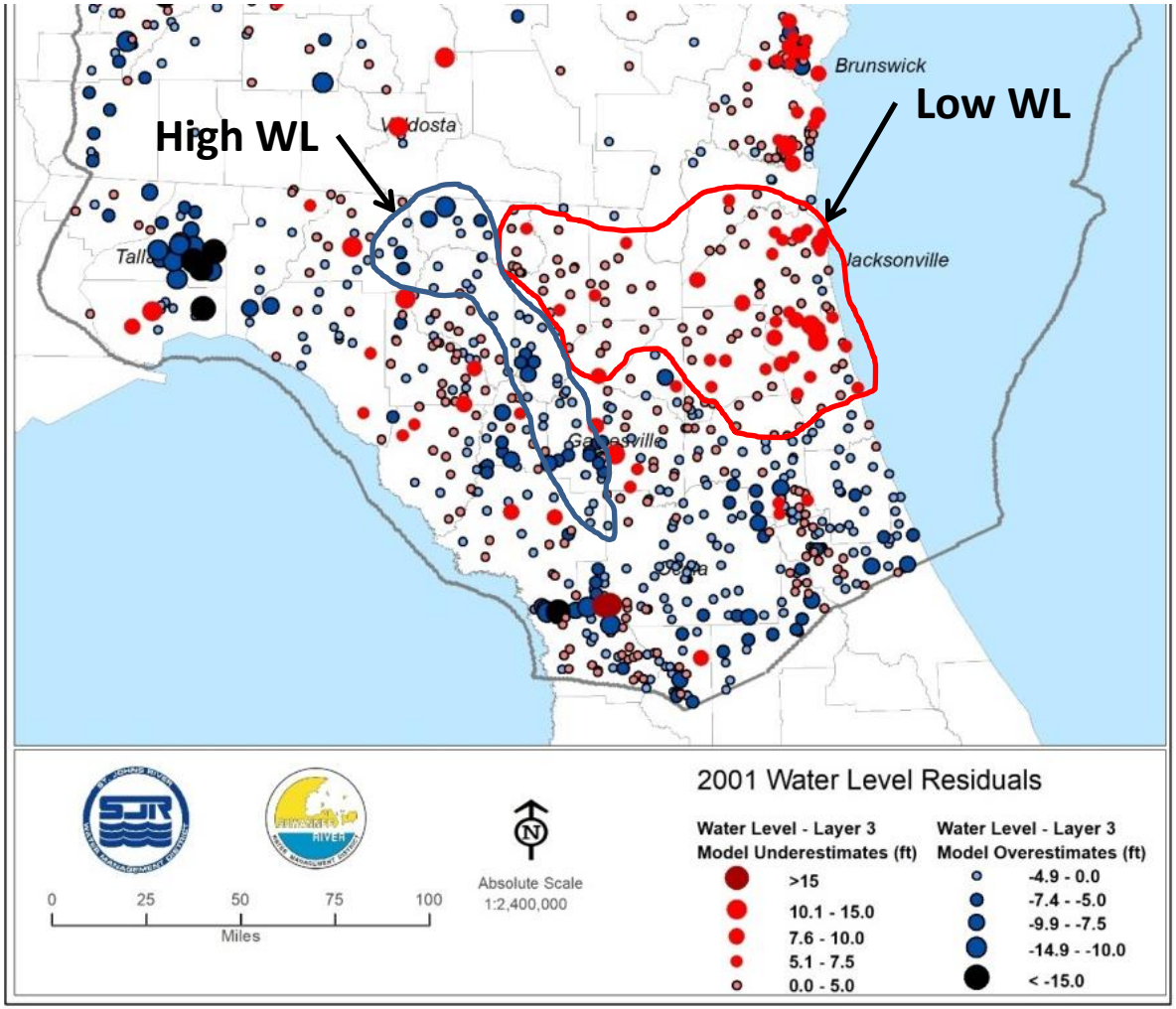
Overpredicted Flows

River Flow Gage	2009 Error in Simulated Average River Flow (MGD)	2009 Error in Simulated Average River Flow (%)
Ichetucknee River	13	**8**
New River at Lake Butler	11	**17**
North Fork Black Creek near Middleberg	-2	**-2**
North Fork Black Creek at Doctors Inlet	-95	**-23**
South Fork Black Creek at Penney Farms	-33	**-26**
St. Johns River at Jacksonville	-3096	**-44**
St. Marys River at McClenney	-17	**-6**
Santa Fe River near Worthington Springs	-68	**-38**
Santa Fe River near Hildreth	-12	**-1**
Suwannee River at White Springs	-61	**-8**
Suwannee River at Dowling Park	-335	**-9**
Suwannee River near Luraville	-550	**-14**
Suwannee River near Bell Springs	-158	**-3**

Underpredicted Flows

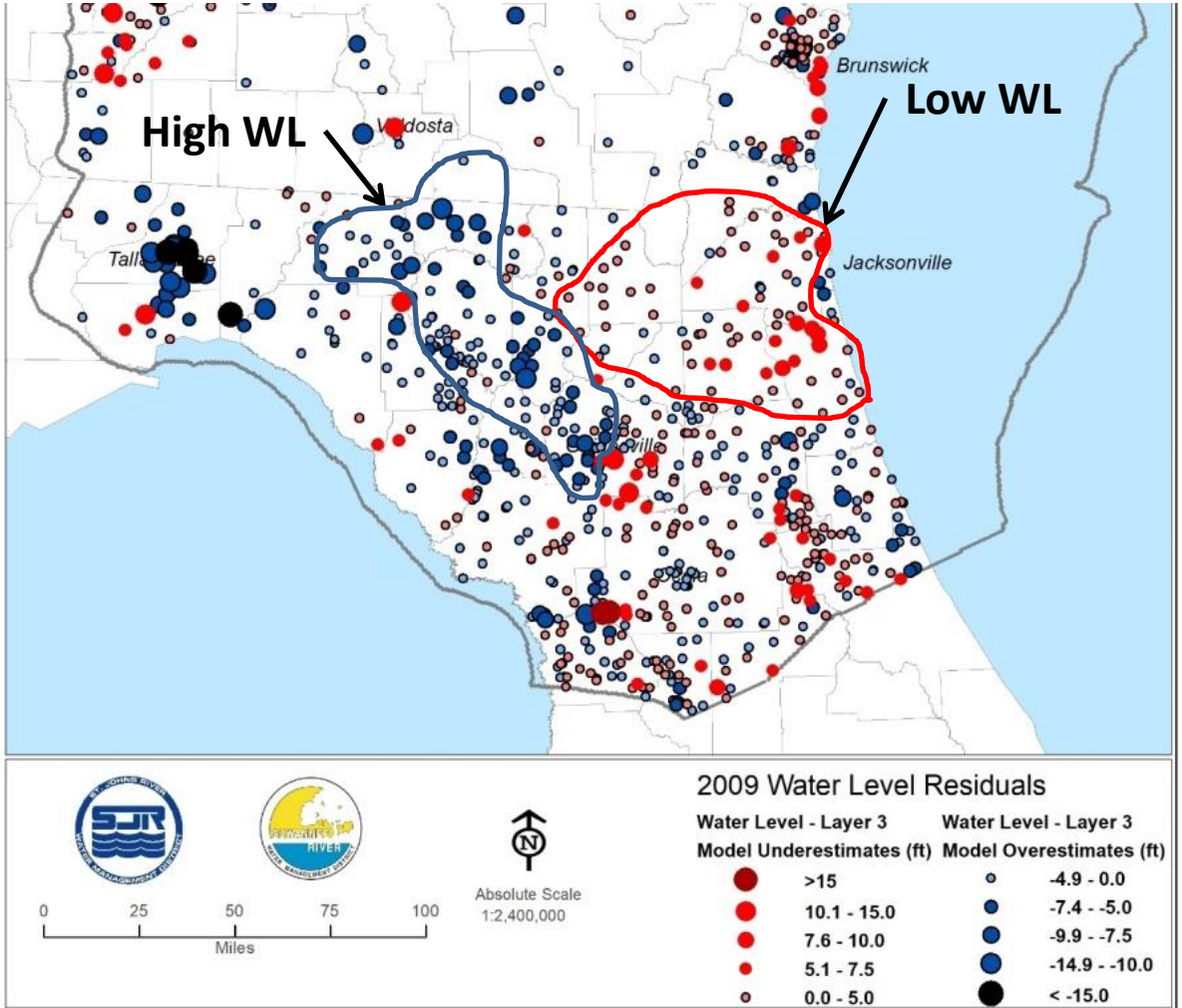
Spatial Distribution of WL Error

2001
Layer 3



Spatial Distribution of WL Error

2009
Layer 3



Model Use Questions

- *Is the final version of the model appropriate for the intended planning and regulatory uses in the SRWMD and SJRWMD areas of the model domain?*

- *Is the NFSEG v1.1 groundwater flow model a sufficient tool for evaluating individual CUPs and compliance with individual spring MFLs?*

Model Use Concerns

- The Districts have not shown that the NFSEG is ready to replace existing models for regulatory evaluations, including MFLs
- The Districts have not shown that the NFSEG is sufficient for individual CUPs

Groundwater Model Use for CUPs

- Used to assess potential impacts and define avoidance, mitigation and monitoring activities
- Regulated stakeholders invest millions per year on these activities and required infrastructure
  - Stability and consistency are required to allow expenditure planning and rate adjustments
- Critical for environment and ratepayers to have accurate model

SJRWMD CUP Model Calibration

Groundwater Model	SAS Calibration Metrics			UFA Calibration Metrics		
	Mean Err (ft)	Abs Mean Err (ft)	RMSE (ft)	Mean Err (ft)	Abs Mean Err (ft)	RMSE (ft)
NCF	-0.80	--	4.51	-0.07	--	3.27
Volusia	-0.18	1.49	1.86	0.52	2.27	2.76
ECF	0.12	2.97	4.32	0.40	2.41	3.04
NEF	--	--	--	0.36	2.39	2.85
NFSEG v 1.1 (2009)	**1.82**	**5.05**	**11.24**	**-0.9**	**3.4**	**4.6**

Pump-Off Simulation

- Detailed discussion premature until 2001/2009 calibration improved
- Not sure that it is required or a suitable surrogate for data-driven information
- Outside reasonable range of calibration and a condition that never existed

General Pump-Off Concerns

- Significant deviation from USGS pre-development surface
- Flooding increase is meaningful
- Dependent on internal BCs

Summary

We request that the Peer Reviewers propose improvements required to achieve model goals:

- Address concerns with PEST
- Update HSPF to reduce errors and evaluate other methods for improved recharge and ET estimates
- Thoroughly examine residual errors, identify causes, and develop plan to improve calibration prior to regulatory use
- Conclude that pumps-off is not appropriate until the calibration is improved