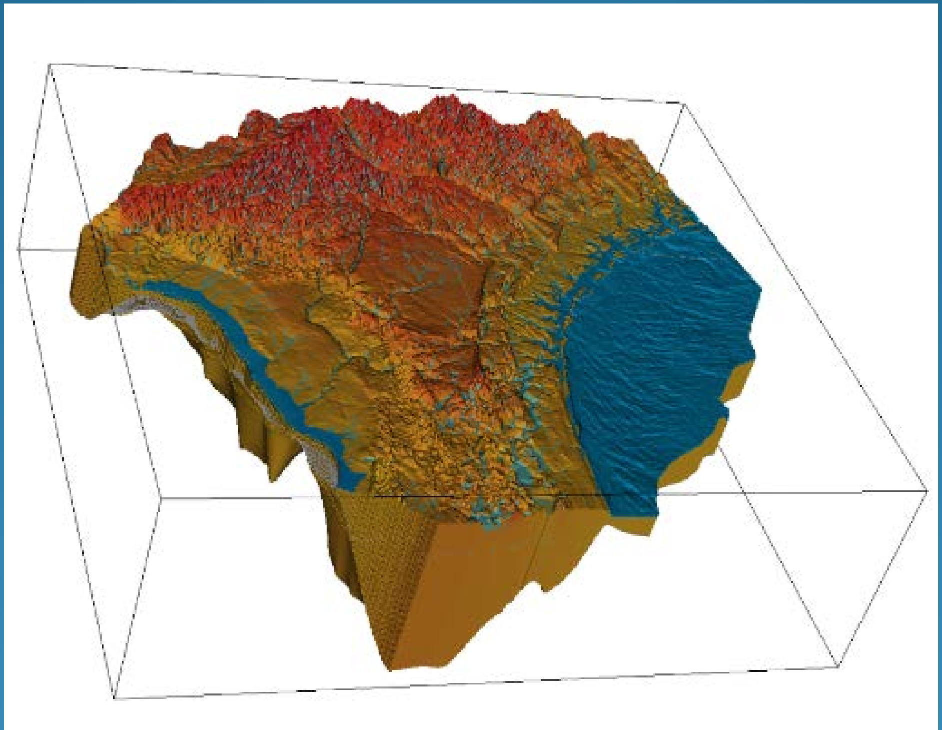
NFSEG v1.1 Phase 2 Task C1 Meeting



July 26, 2017

Outline

- Introduction/Meeting Objectives
- Status of Peer Review Comments to Date
- Baseflow Review
- Sensitivity and Uncertainty Analysis
- 2010 Verification Simulation
- Peer Review Panel Discussion
- Technical Stakeholder Input
- Next Steps
  - NFSEG Case 005 Simulation
  - August 24 Meeting
- Public Comments

Introduction / Meeting Objective

- Update activities currently underway and/or complete
- Refine path forward

Status of Peer Review Comments and Responses to Date

- Update on panel/tech team comments
  - Matrix of Comments and Responses, Including:
    - HSPF
    - APT/Modeled Transmissivity Scatter Plot
    - Hydrostratigraphic Cross Section

Investigation of NFSEG Baseflow Estimates

Summary of Results for 14 Gages

Approach

- Create baseflow hydrographs using hydrograph-separation routines implemented in USGS *Groundwater Toolbox* (i.e., BFI Modified, BFI Standard, HYSEP Fixed Interval, HYSEP Local Minimum, HYSEP Sliding Interval, PART);
- Inspect resulting baseflow hydrographs;
- Select approaches that appear applicable to rivers/streams of the area.
- <u>In addition</u>:
- Include results of a 120-day low-pass filter method by Perry (1995; i.e. "the USF Method"), per suggestion of Ron Basso.
- Include the exceedance-curve approach per suggestion of Dann Yobbi, also implemented in *Groundwater Toolbox*.

Approach (Cont.)

- In the final analysis, average annual estimates for 2001 and 2009 resulting from the following methods were obtained and averaged to provide 2001 and 2009 estimates at fourteen gages:
- **HYSEP Local Minimum hydrograph-separation method;**
- **BFI Standard hydrograph-separation method;**
- **BFI Modified hydrograph-separation method;**
- **USF hydrograph-separation method;**
- **Exceedance-curve method at 70-percent exceedance**

Gage-Selection Criteria

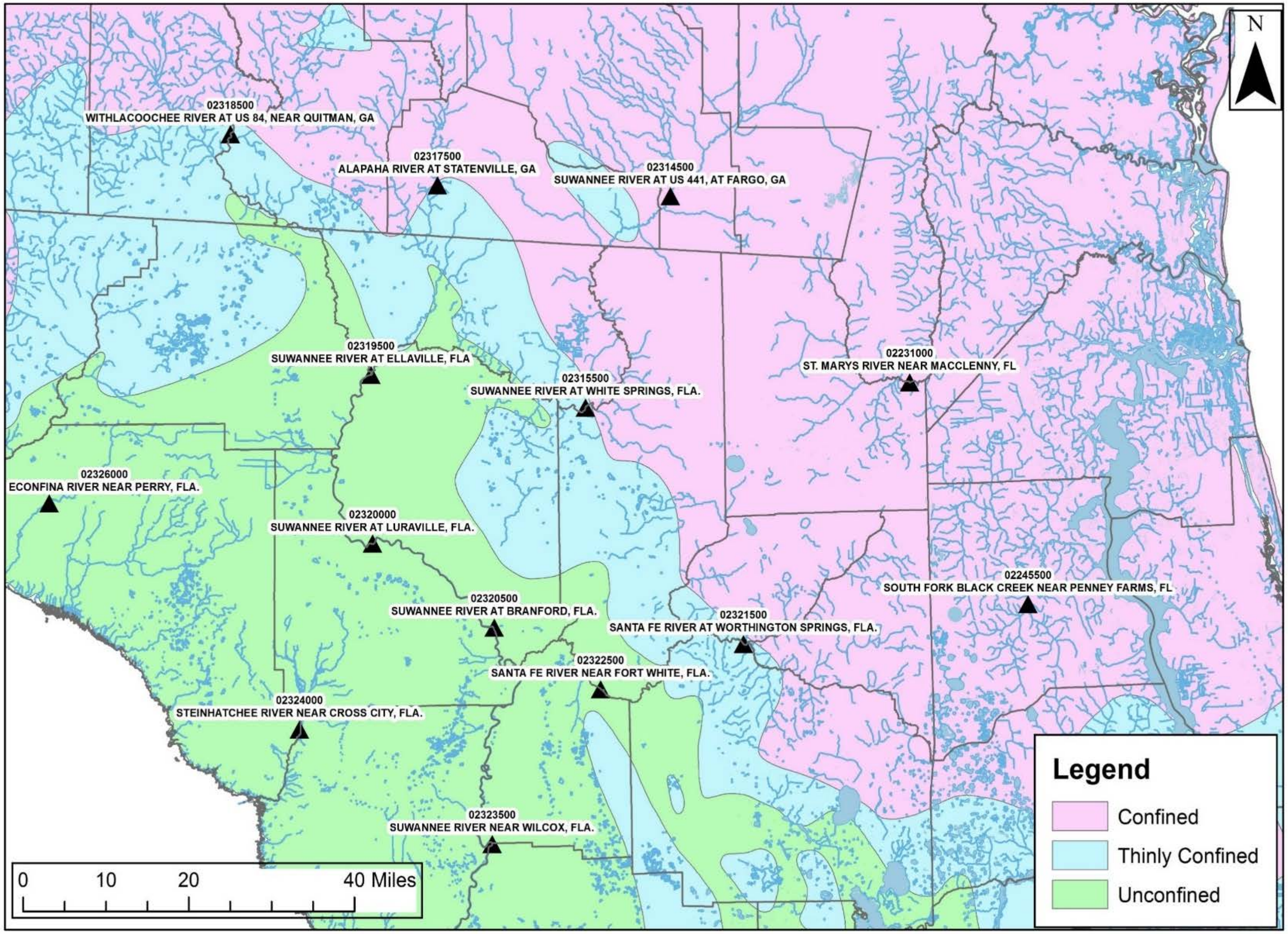
- 14 gages selected;
- Confined, semiconfined, and unconfined conditions;
- Six different rivers/streams (Suwannee, Alapaha, Withlacoochee, Santa Fe, and St Marys Rivers, and Black Creek).

These are as follows:

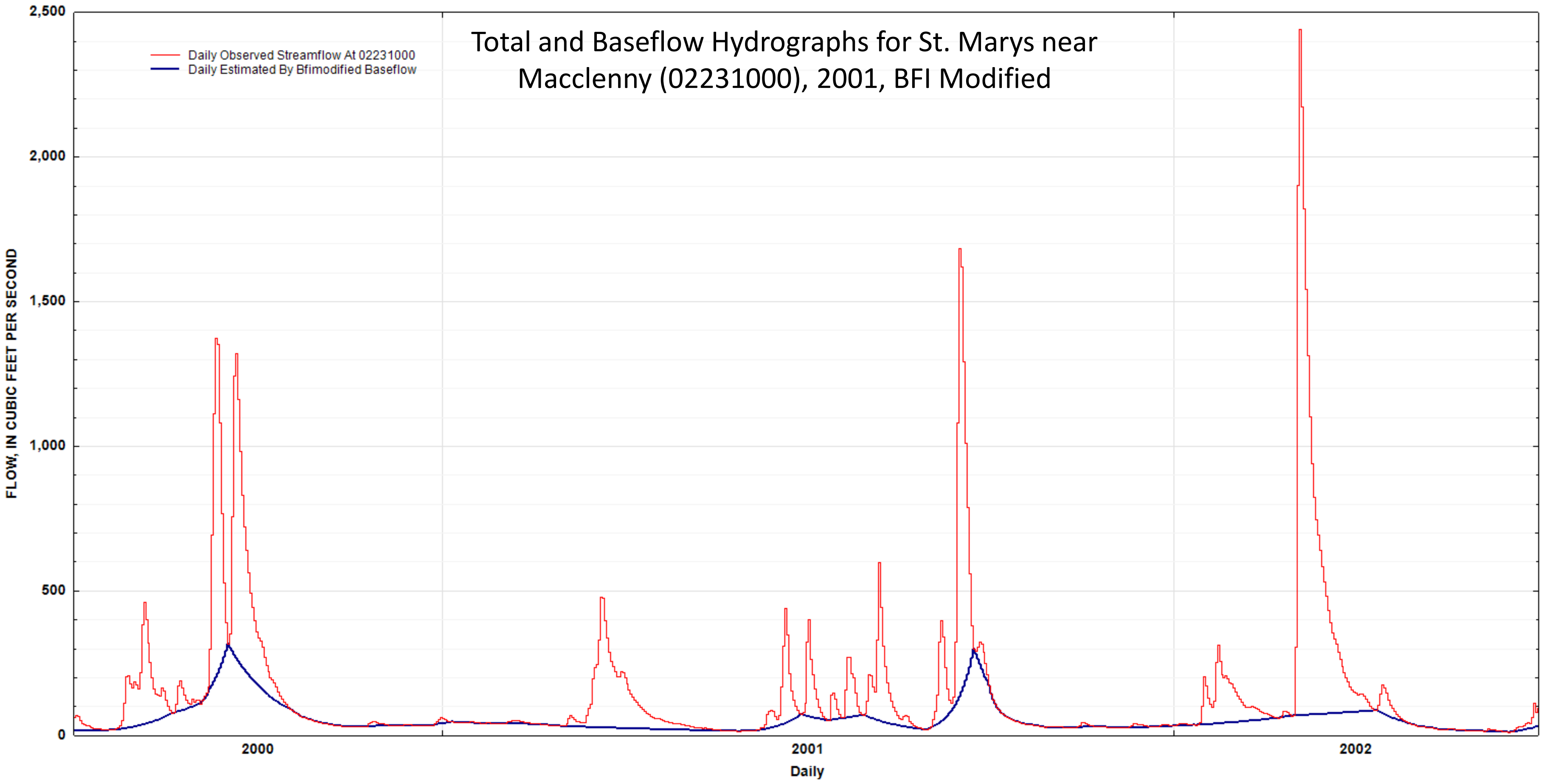
List of Evaluated Gages

USGS Gage ID	Name	Dominant Contributing Aquifer
02318500	WITHLACOOCHEE RIVER AT US 84, NEAR QUITMAN, GA	SAS
02317500	ALAPAHA RIVER AT STATENVILLE, GA	SAS
02314500	SUWANNEE RIVER AT US 441, AT FARGO, GA	SAS
02315500	SUWANNEE RIVER AT WHITE SPRINGS, FLA.	SAS
02319500	SUWANNEE RIVER AT ELLAVILLE, FLA	FAS
02320000	SUWANNEE RIVER AT LURAVILLE, FLA.	FAS
02320500	SUWANNEE RIVER AT BRANFORD, FLA.	FAS
02323500	SUWANNEE RIVER NEAR WILCOX, FLA.	FAS
02321500	SANTA FE RIVER AT WORTHINGTON SPRINGS, FLA.	SAS
02322500	SANTA FE RIVER NEAR FORT WHITE, FLA.	FAS
02324000	STEINHATCHEE RIVER NEAR CROSS CITY, FLA.	FAS
02326000	ECONFINA RIVER NEAR PERRY, FLA.	FAS
02231000	ST. MARYS RIVER NEAR MACCLENNY, FL	SAS
02245500	SOUTH FORK BLACK CREEK NEAR PENNEY FARMS, FL	SAS

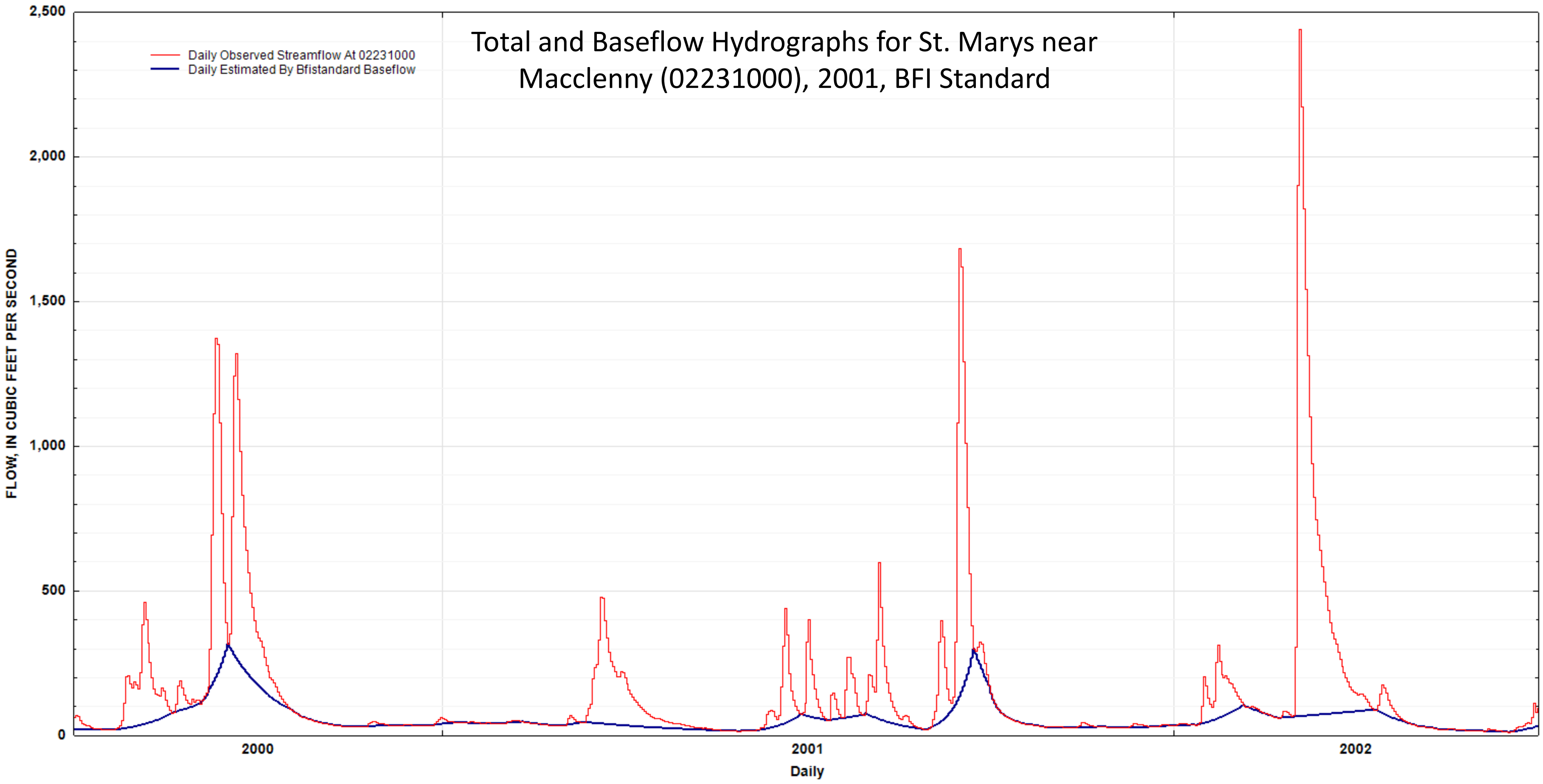
Locations of Selected Gages

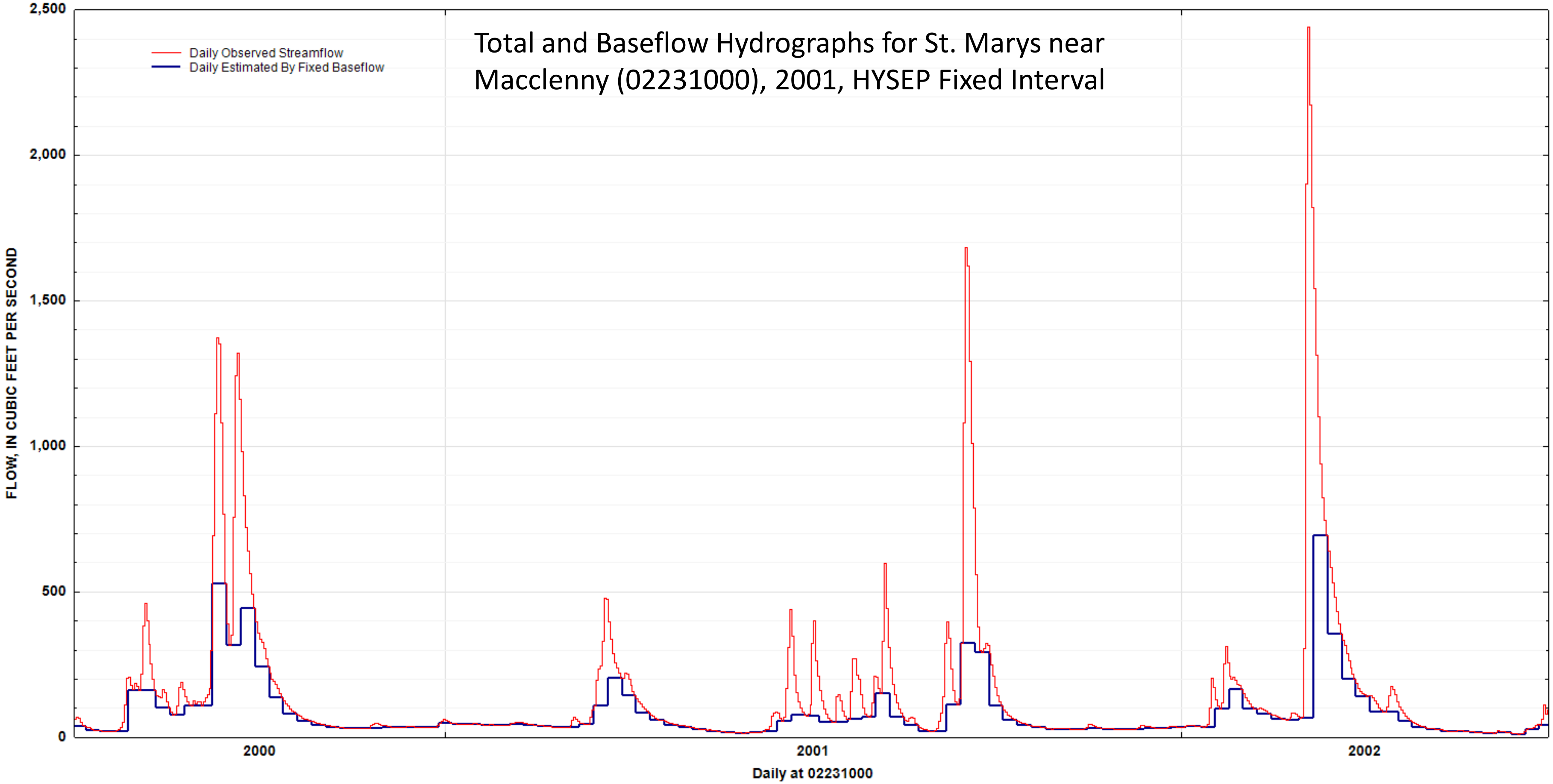


Example Hydrographs/Exceedance Curves for St. Marys River near Macclenny (02231000) for all Available Methods in GWToolbox and USF Method, 2001 and 2009

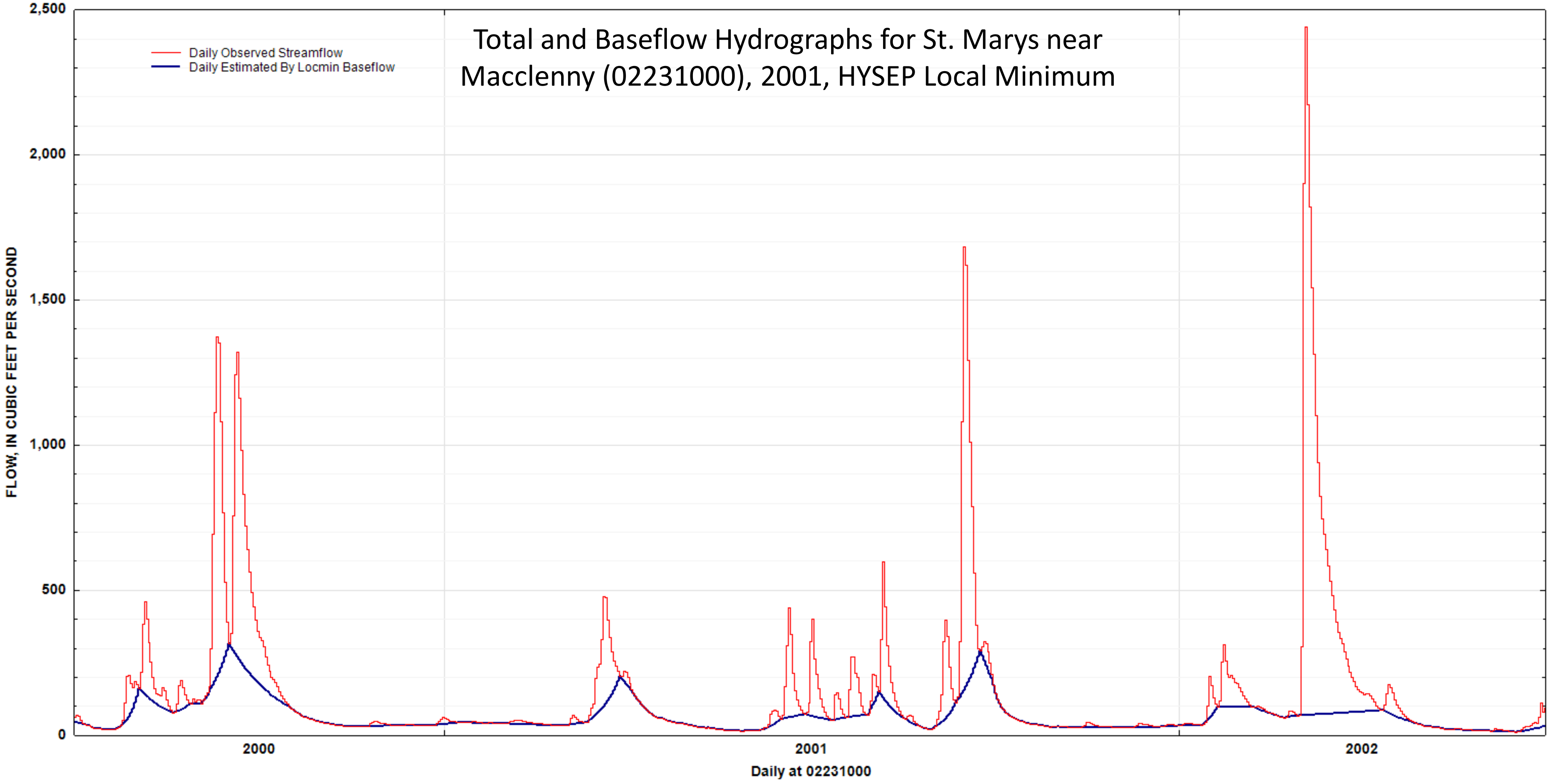


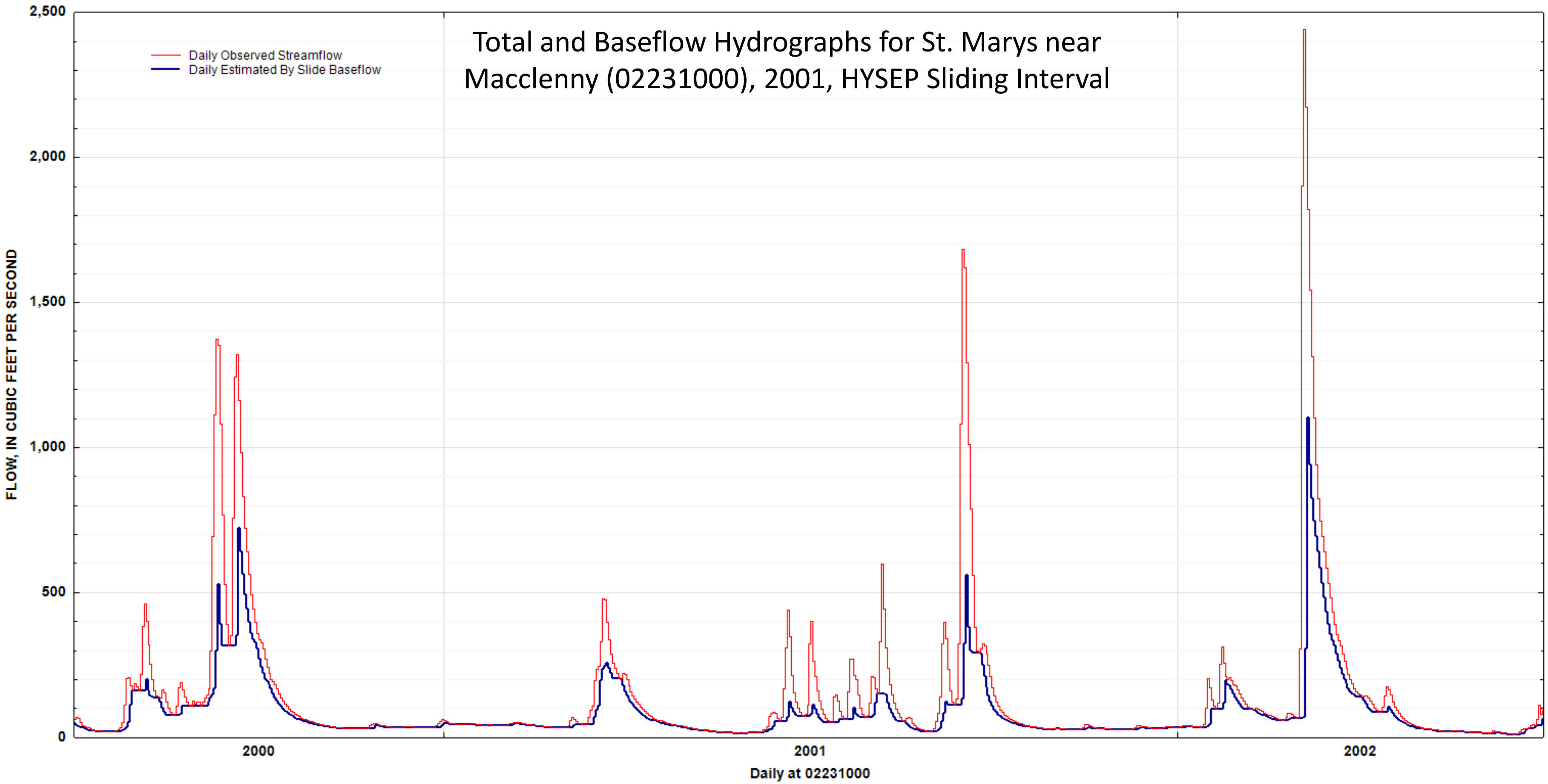
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, BFI Modified
Daily Observed Streamflow At 02231000
Daily Estimated By Bfimodified Baseflow
FLOW, IN CUBIC FEET PER SECOND
2,500
2,000
1,500
1,000
500
0
2000
2001
2002
Daily

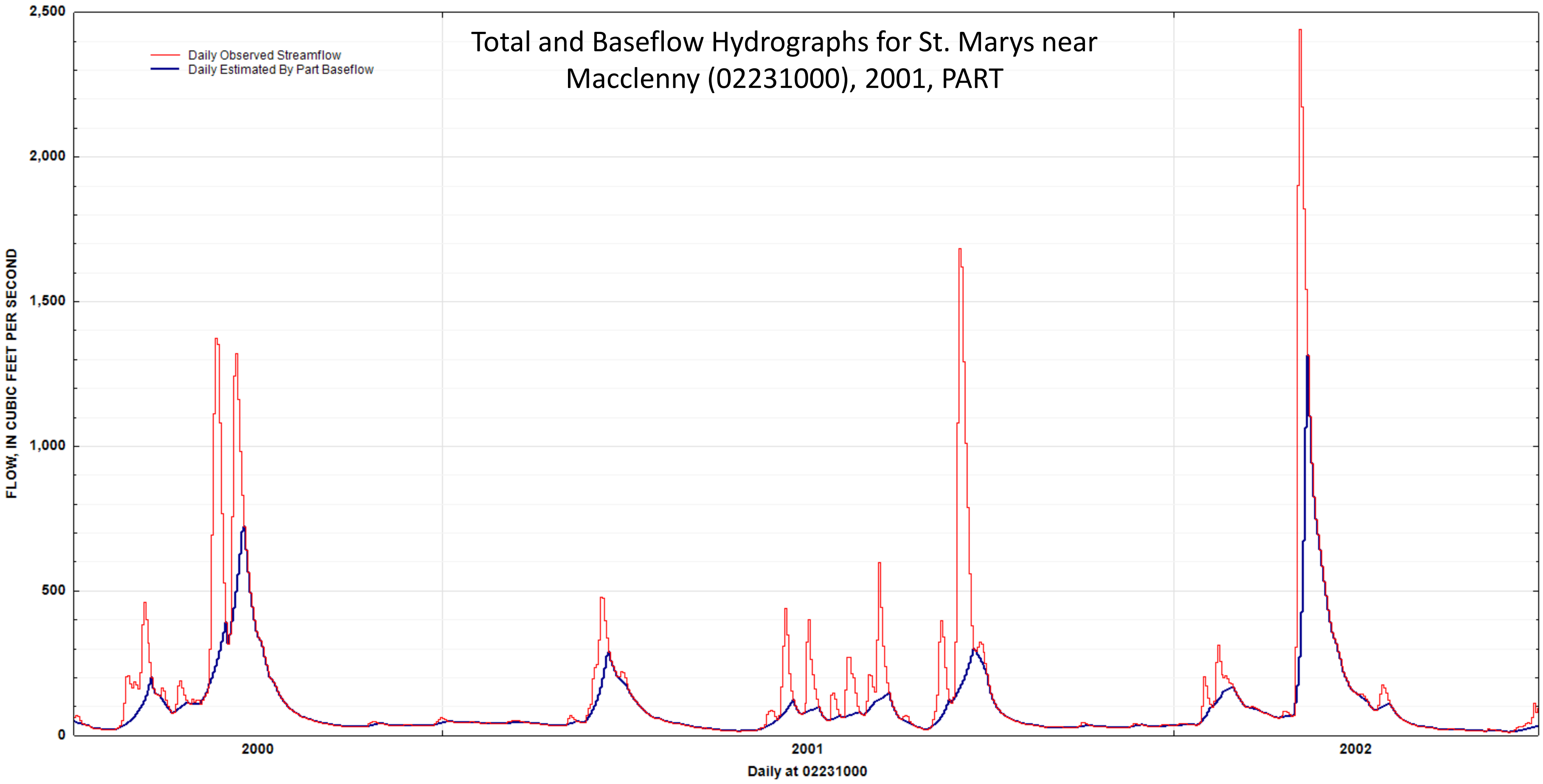

Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, BFI Standard
Daily Observed Streamflow At 02231000
Daily Estimated By Bfistandard Baseflow
FLOW, IN CUBIC FEET PER SECOND
2,500
2,000
1,500
1,000
500
0
2000
2001
2002
Daily


Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, HYSEP Fixed Interval
Daily Observed Streamflow
Daily Estimated By Fixed Baseflow
FLOW, IN CUBIC FEET PER SECOND
2,500
2,000
1,500
1,000
500
0
2000
2001
2002
Daily at 02231000

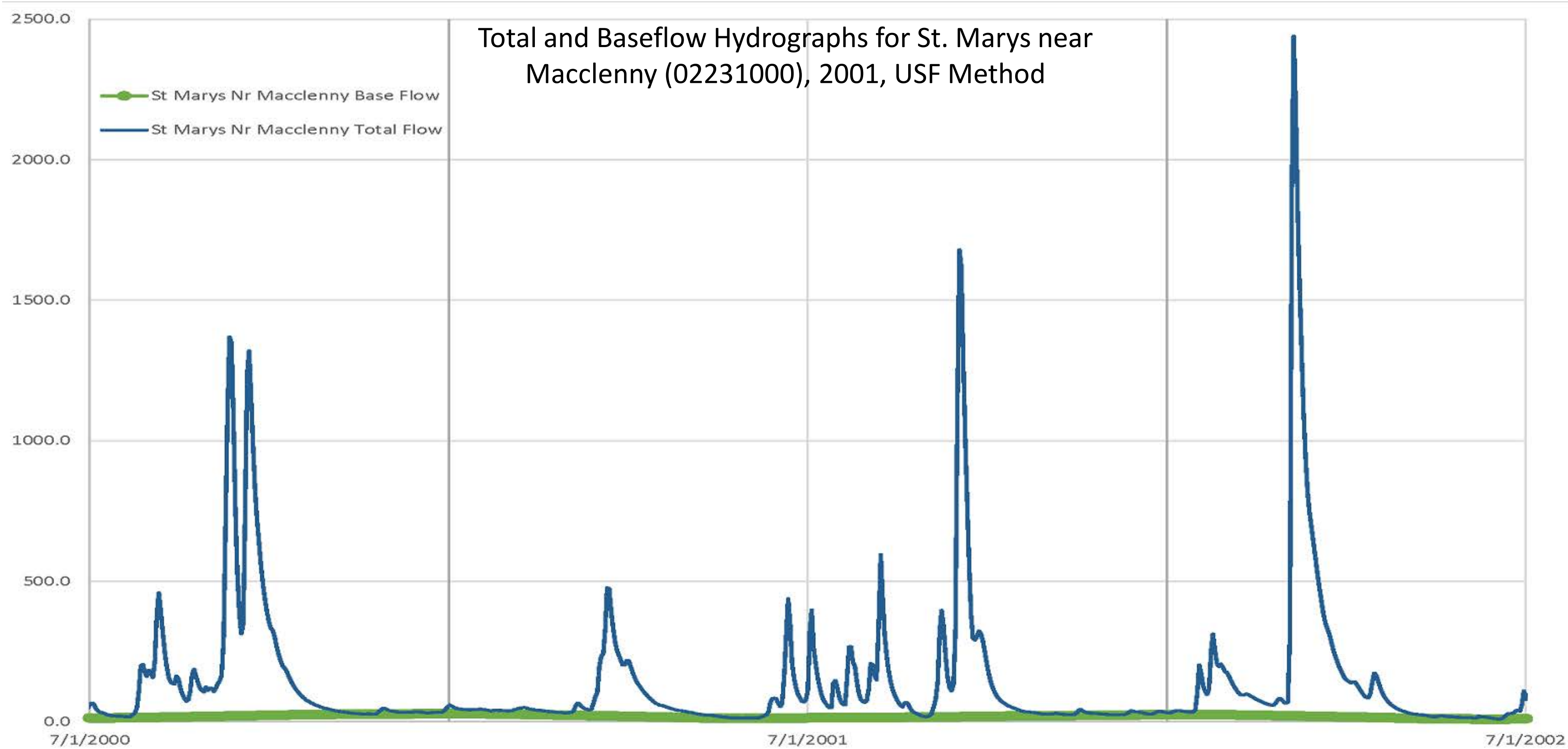
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, HYSEP Local Minimum



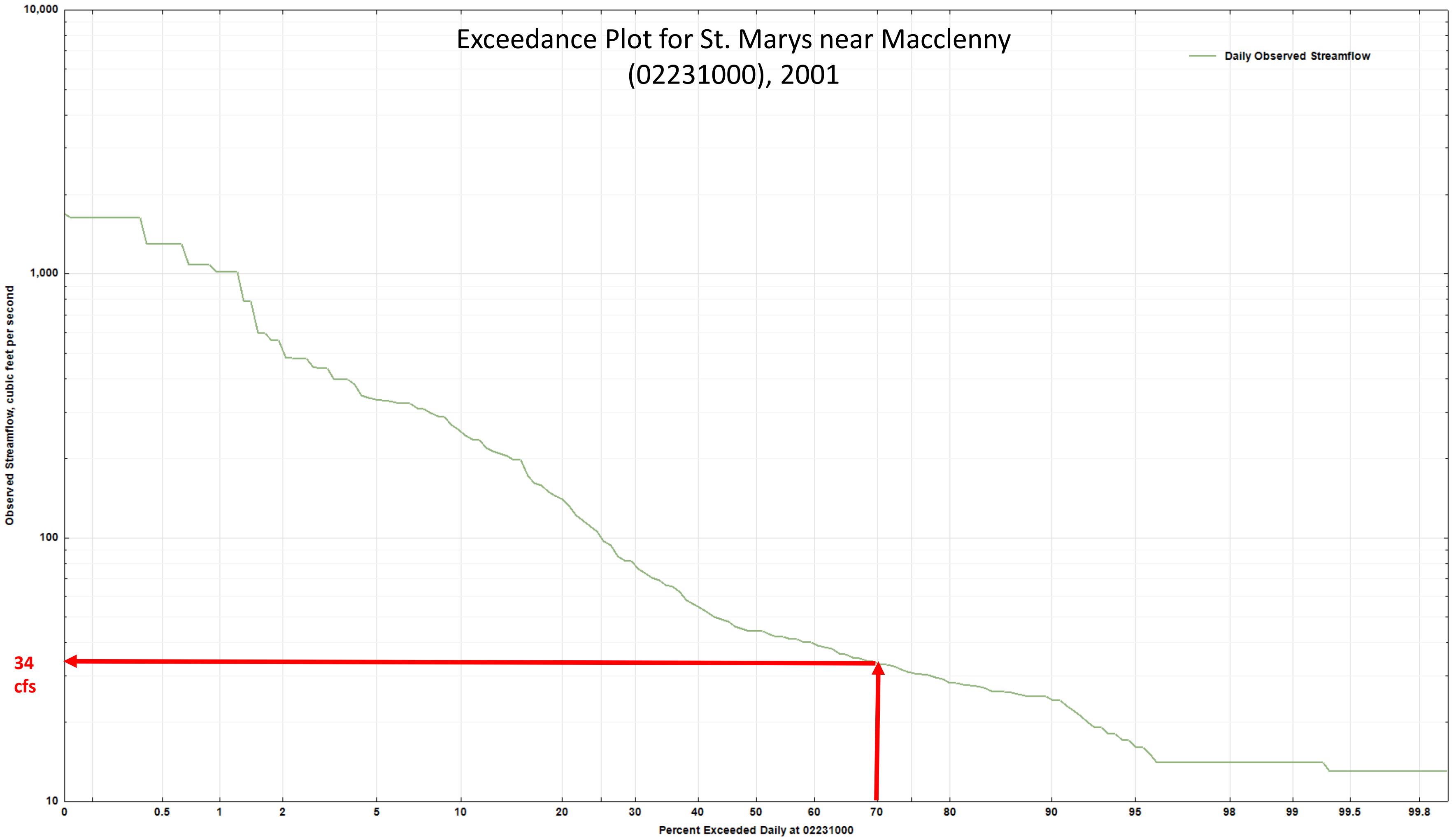

Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, HYSEP Sliding Interval
Daily Observed Streamflow
Daily Estimated By Slide Baseflow
FLOW, IN CUBIC FEET PER SECOND
2,500
2,000
1,500
1,000
500
0
2000
2001
2002
Daily at 02231000



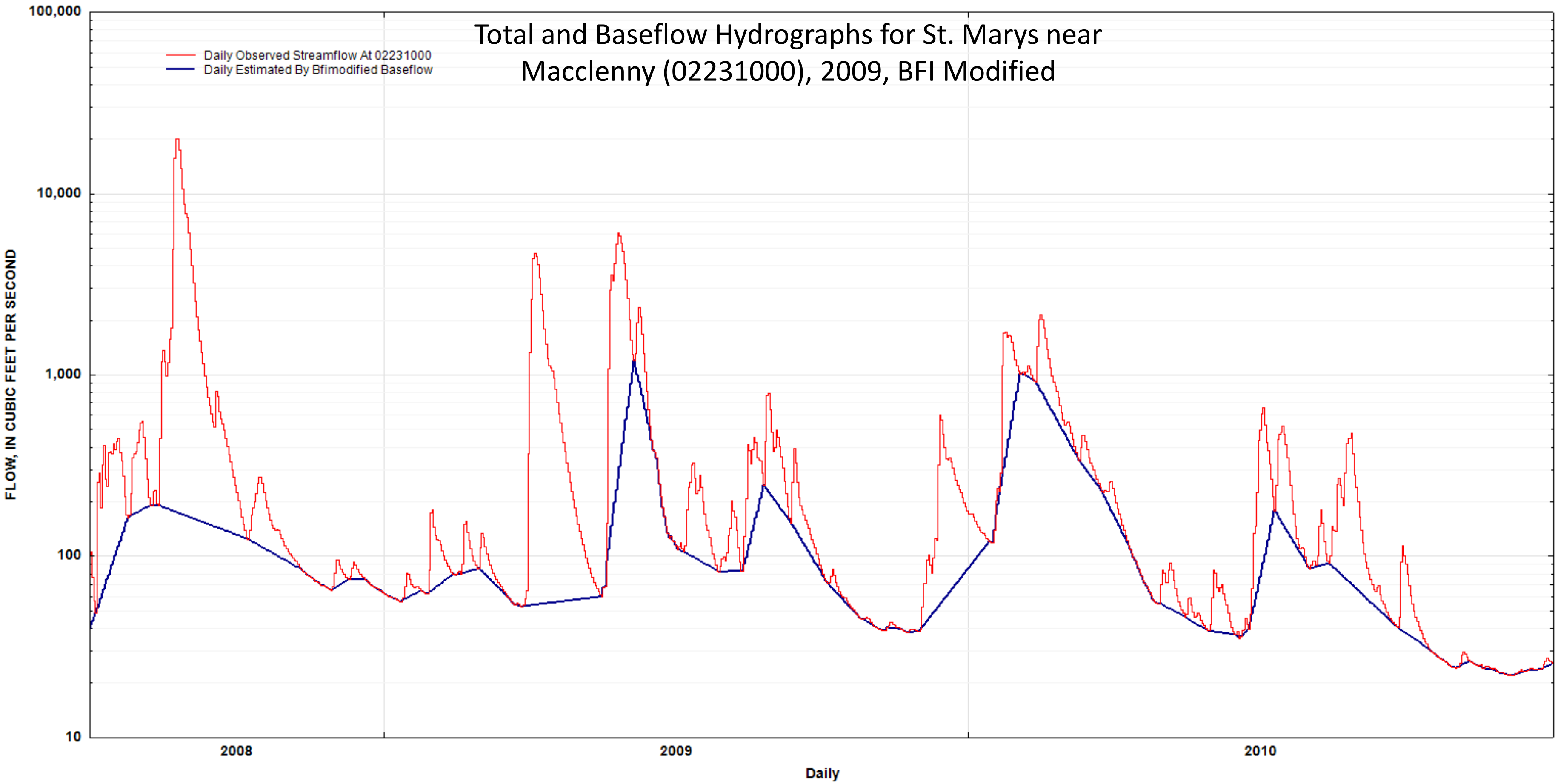
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, PART
Daily Observed Streamflow
Daily Estimated By Part Baseflow
FLOW, IN CUBIC FEET PER SECOND
2,500
2,000
1,500
1,000
500
0
2000
2001
2002
Daily at 02231000

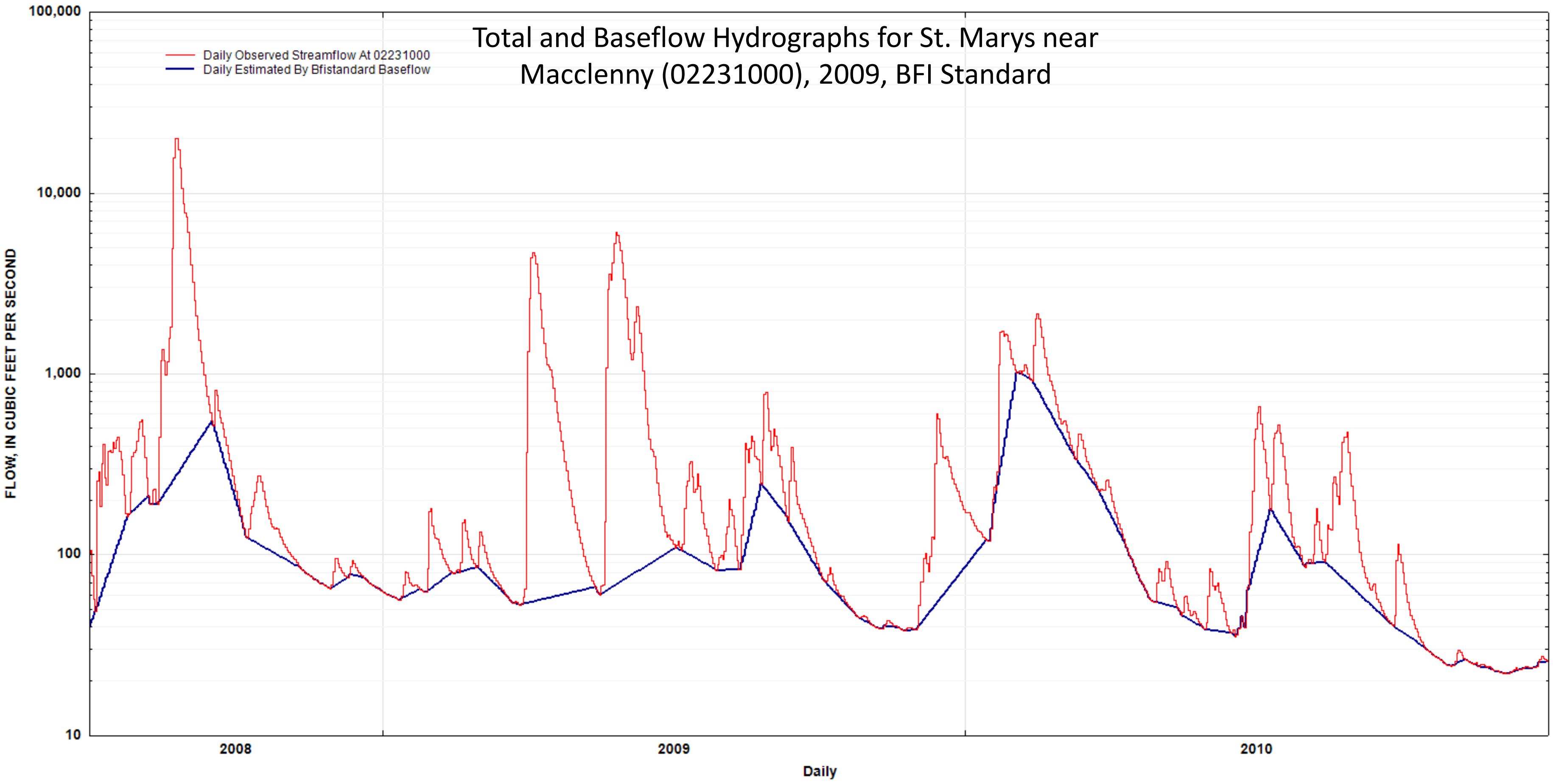


Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2001, USF Method
St Marys Nr Macclenny Base Flow
St Marys Nr Macclenny Total Flow
2500.0
2000.0
1500.0
1000.0
500.0
0.0
7/1/2000
7/1/2001
7/1/2002

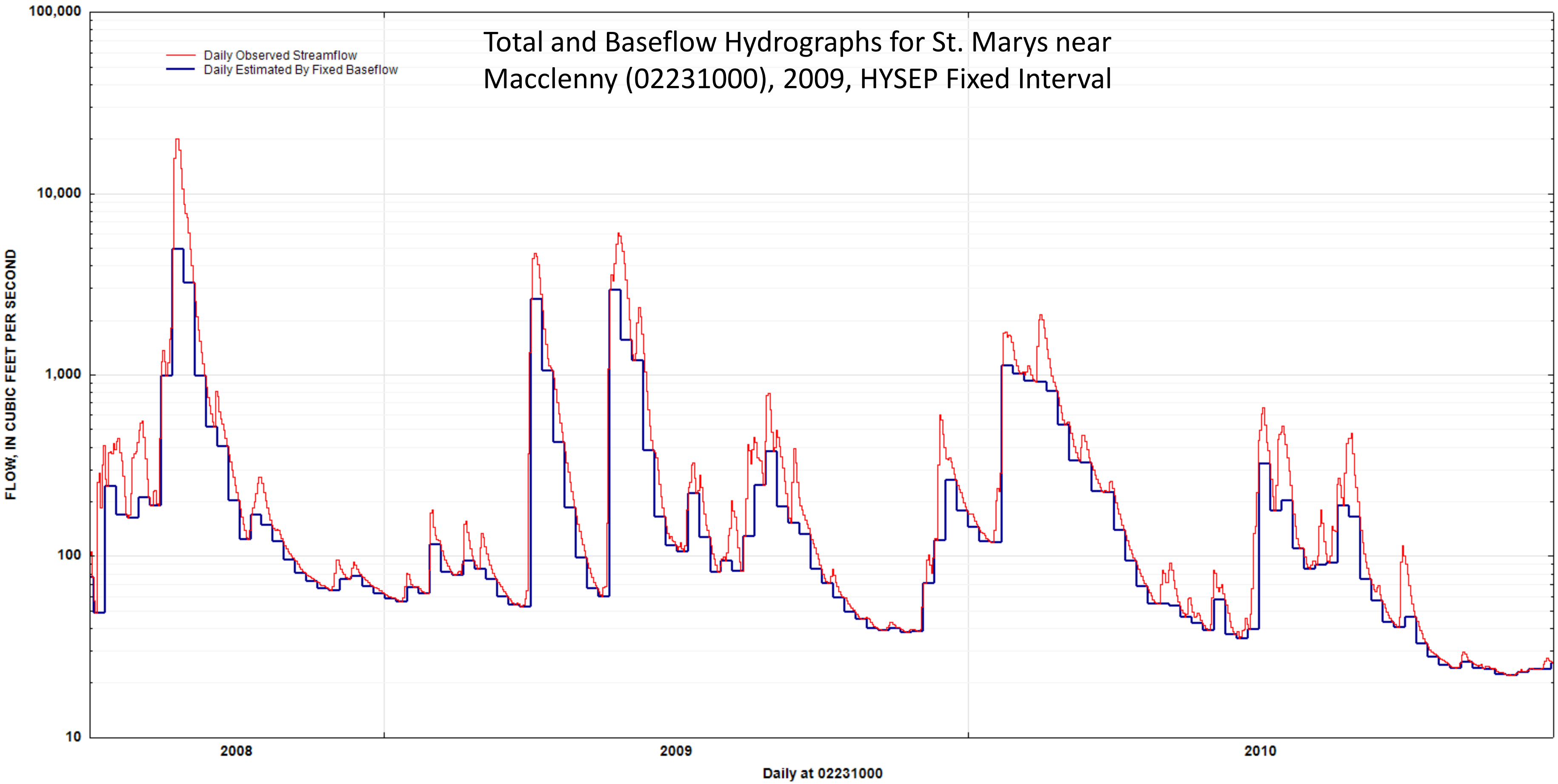


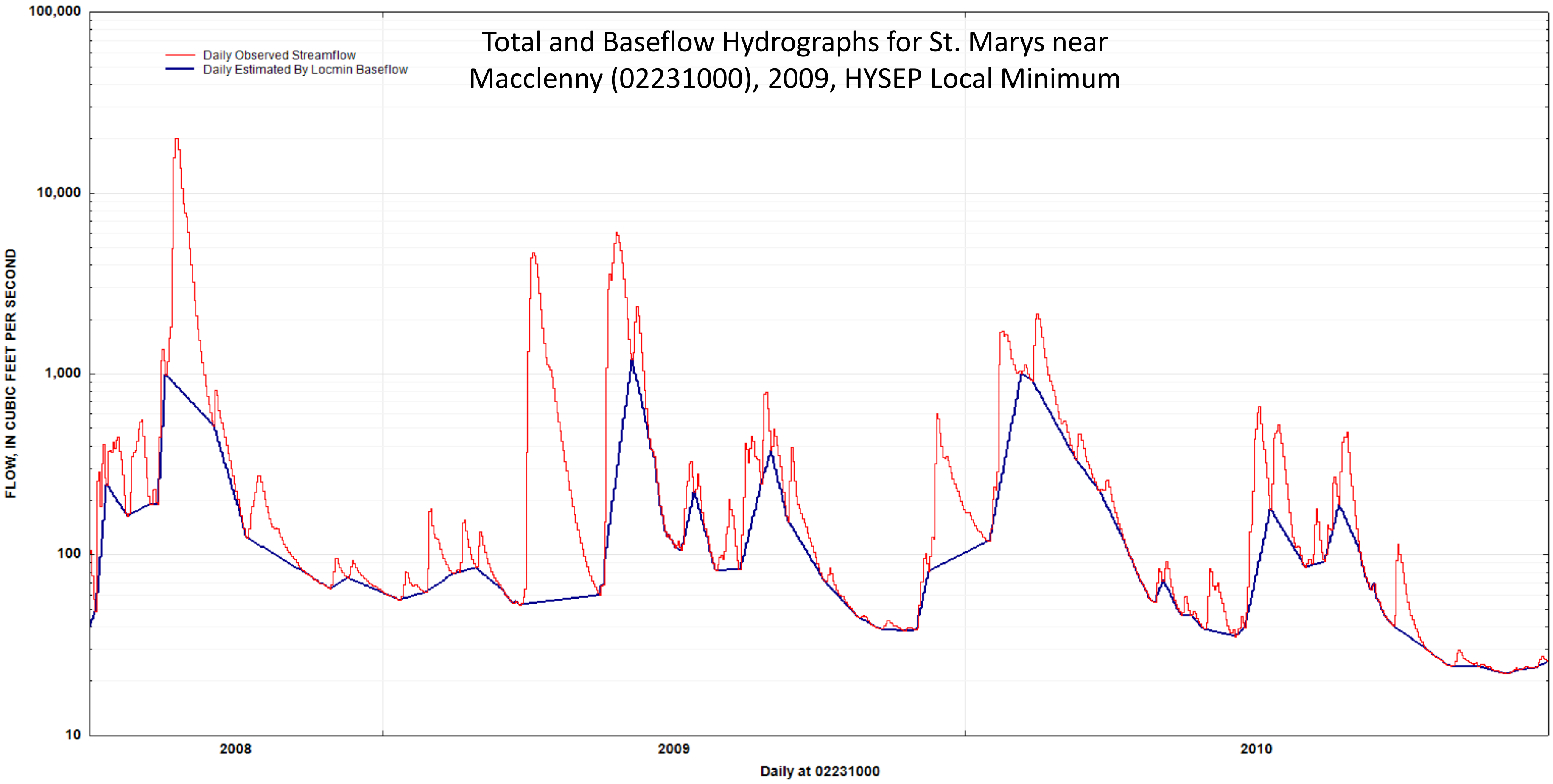
Exceedance Plot for St. Marys near Macclenny
(02231000), 2001
Daily Observed Streamflow
Observed Streamflow, cubic feet per second
10,000
1,000
100
10
34
cfs
0
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
Percent Exceeded Daily at 02231000

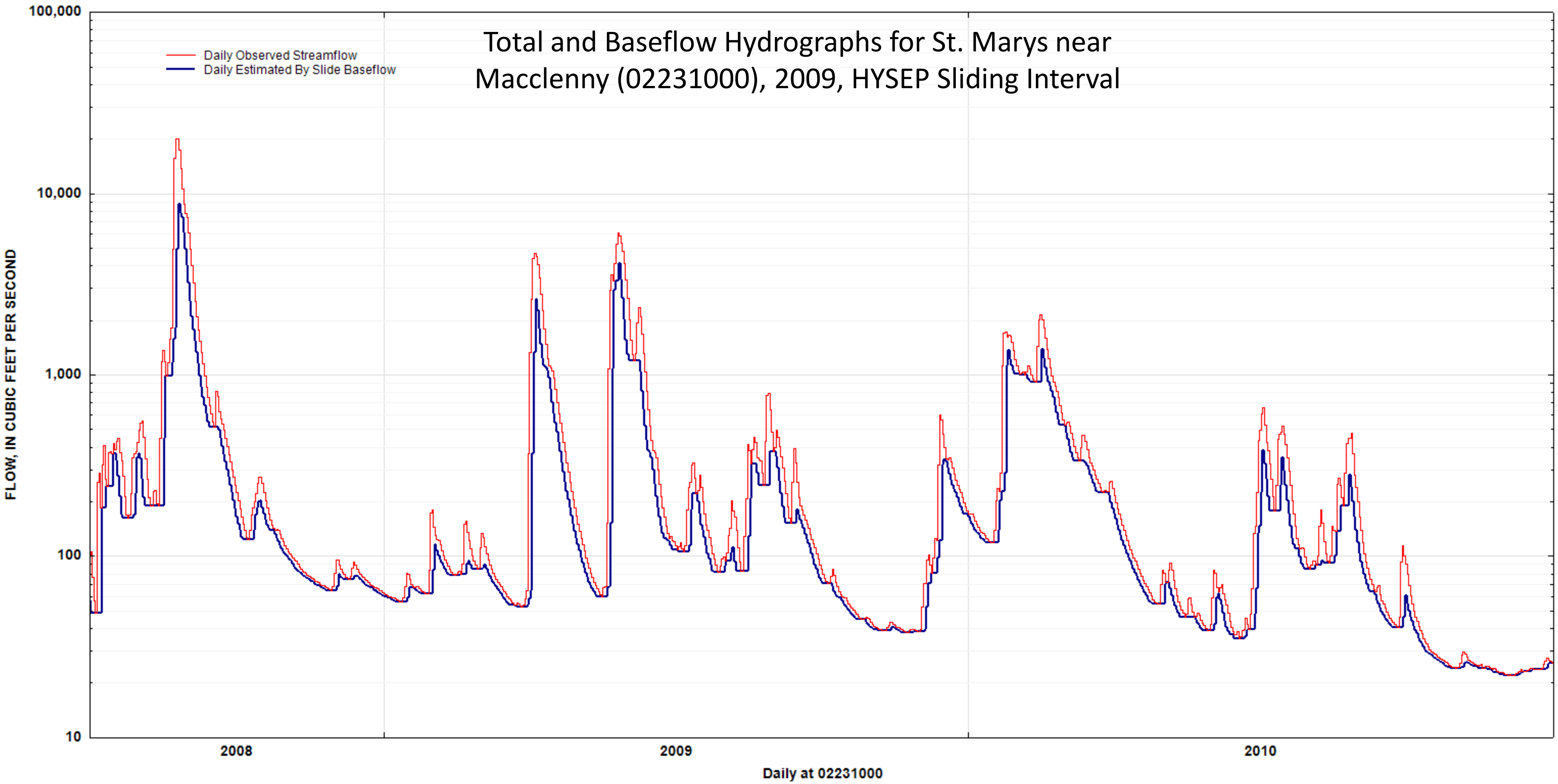

Total and Baseflow Hydrographs for St. Marys near
Macclenny (02231000), 2009, BFI Modified
Daily Observed Streamflow At 02231000
Daily Estimated By Bfimodified Baseflow
FLOW, IN CUBIC FEET PER SECOND
100,000
10,000
1,000
100
10
2008
2009
2010
Daily



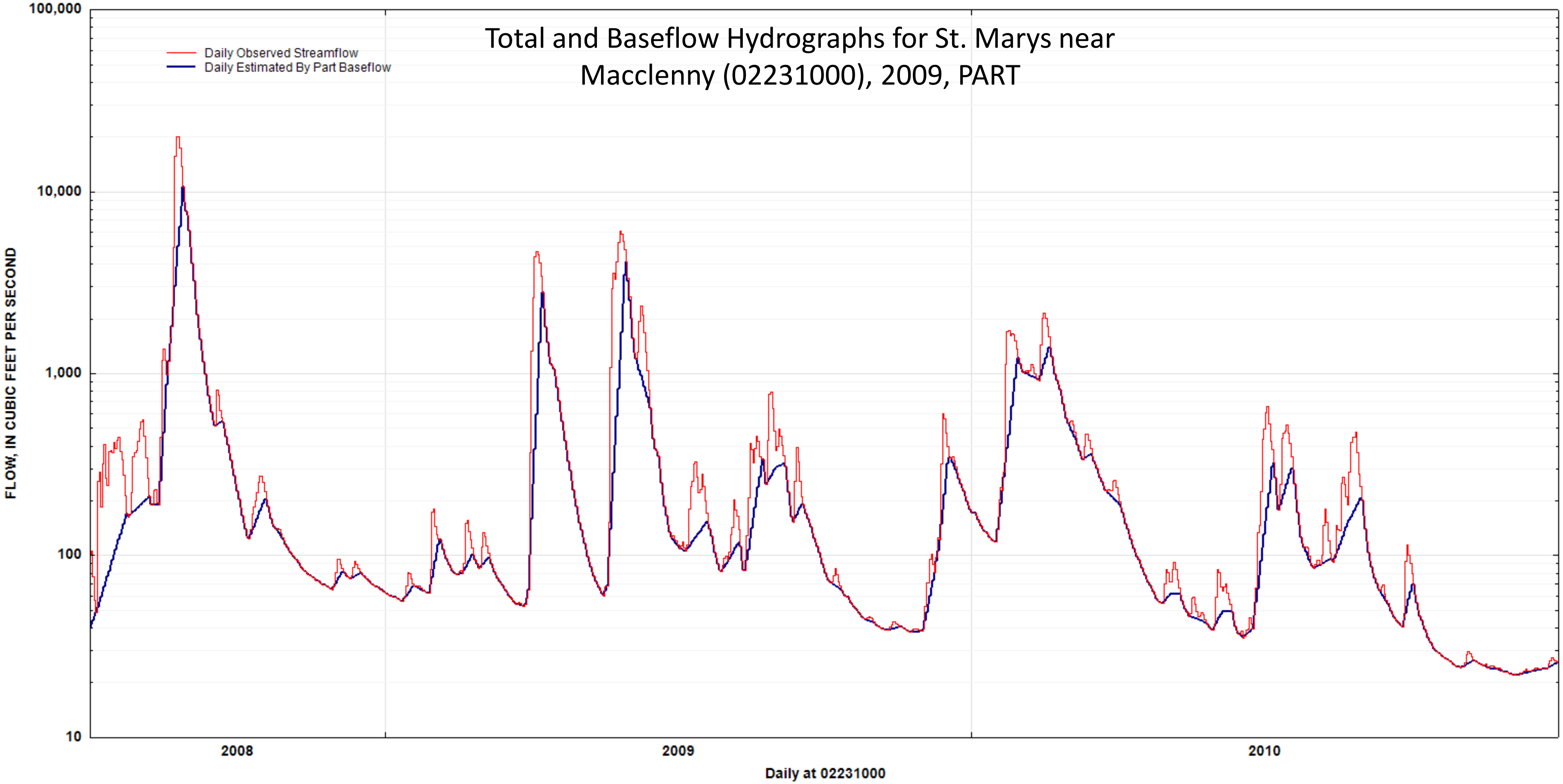
Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, BFI Standard
Daily Observed Streamflow At 02231000
Daily Estimated By Bfistandard Baseflow
100,000
10,000
1,000
100
10
FLOW, IN CUBIC FEET PER SECOND
2008
2009
2010
Daily

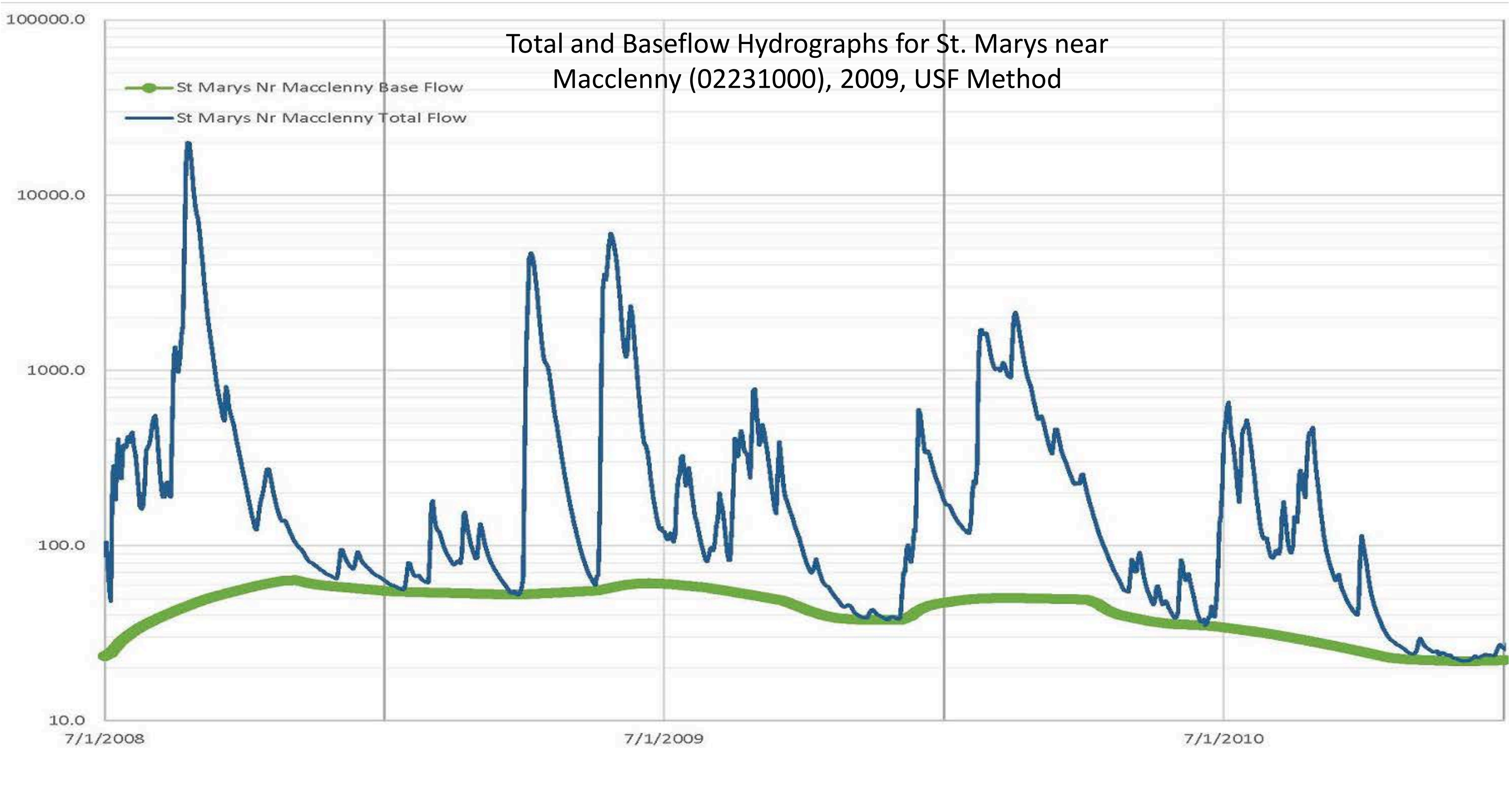

Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, HYSEP Fixed Interval
Daily Observed Streamflow
Daily Estimated By Fixed Baseflow
FLOW, IN CUBIC FEET PER SECOND
100,000
10,000
1,000
100
10
2008
2009
2010
Daily at 02231000


Total and Baseflow Hydrographs for St. Marys near
Macclenny (02231000), 2009, HYSEP Local Minimum
Daily Observed Streamflow
Daily Estimated By Locmin Baseflow
100,000
10,000
1,000
100
10
FLOW, IN CUBIC FEET PER SECOND
2008
2009
2010
Daily at 02231000

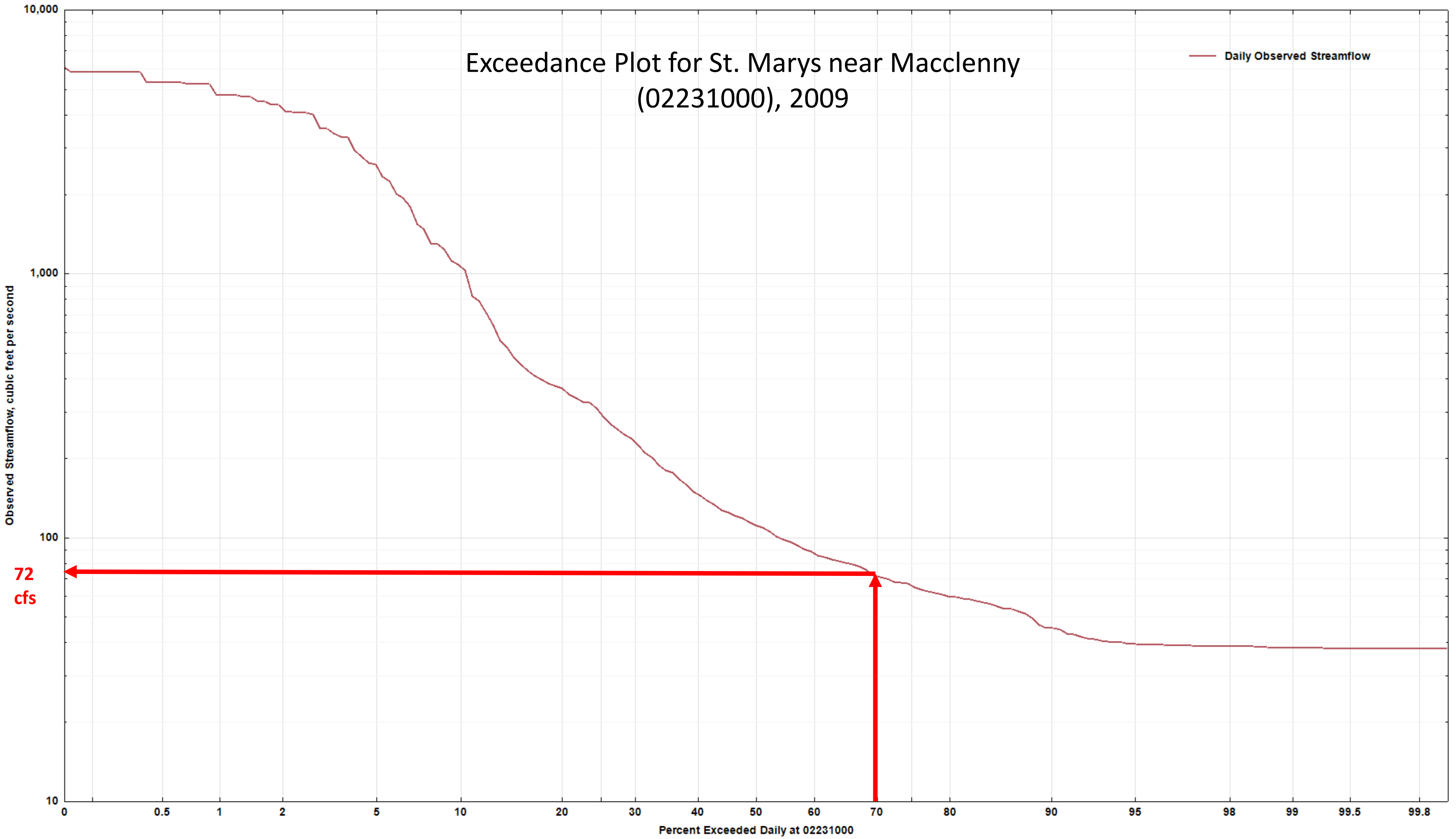


Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, HYSEP Sliding Interval
Daily Observed Streamflow
Daily Estimated By Slide Baseflow
100,000
10,000
1,000
100
10
FLOW, IN CUBIC FEET PER SECOND
2008
2009
2010
Daily at 02231000


Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, PART
Daily Observed Streamflow
Daily Estimated By Part Baseflow
100,000
10,000
1,000
100
10
FLOW, IN CUBIC FEET PER SECOND
2008
2009
2010
Daily at 02231000

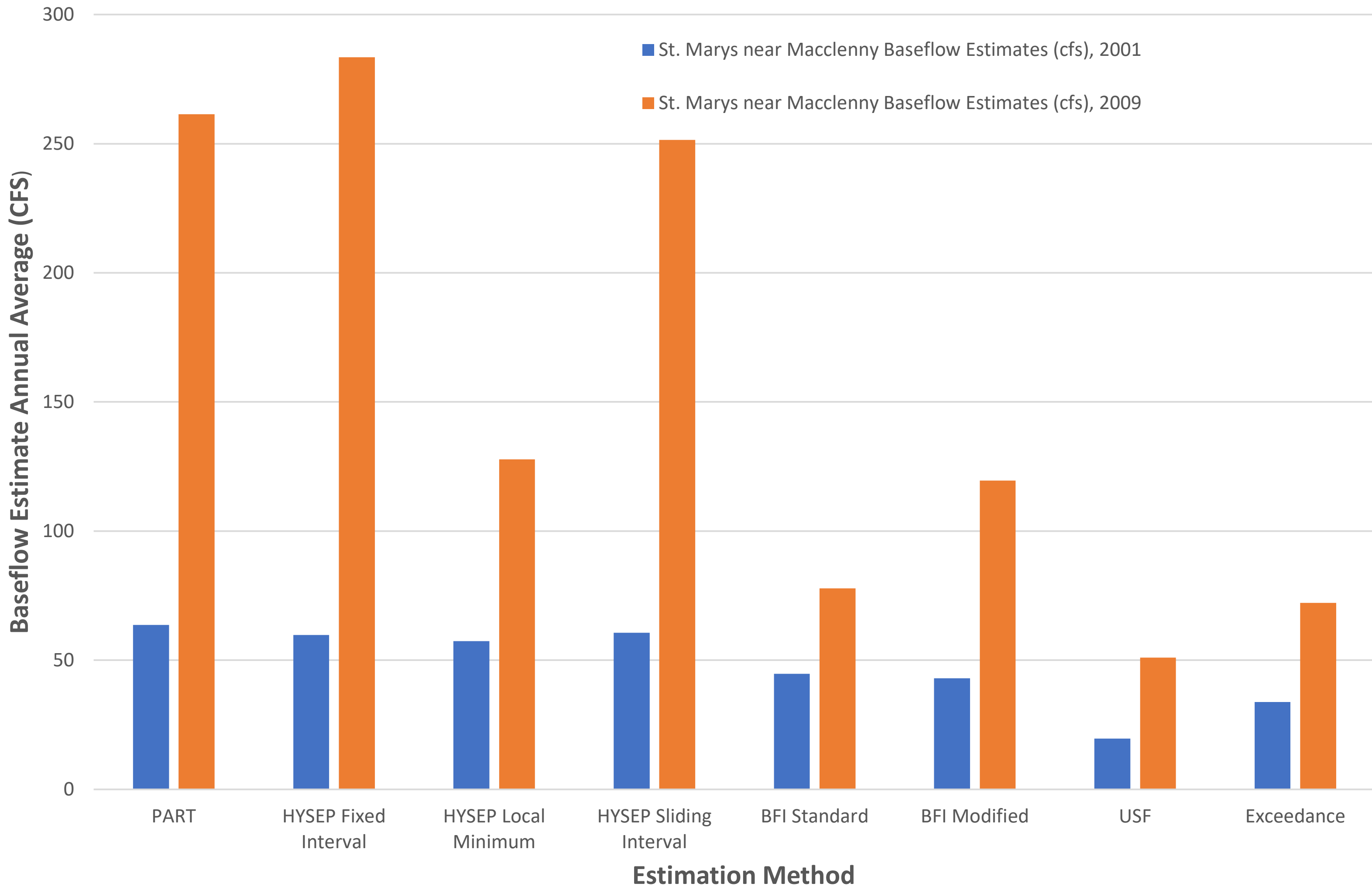


Total and Baseflow Hydrographs for St. Marys near Macclenny (02231000), 2009, USF Method
St Marys Nr Macclenny Base Flow
St Marys Nr Macclenny Total Flow
100000.0
10000.0
1000.0
100.0
10.0
7/1/2008
7/1/2009
7/1/2010



Exceedance Plot for St. Marys near Macclenny (02231000), 2009
Daily Observed Streamflow
Observed Streamflow, cubic feet per second
10,000
1,000
100
10
72 cfs
0
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.5
99.8
Percent Exceeded Daily at 02231000

Summary of Estimated Baseflows by Method for St. Marys near Macclenny (0223100)



Final Proposed Estimates

- Final proposed method is an average of annual averages derived from the following methods:
- HYSEP Local Minimum
- BFI Standard
- BFI Modified
- USF
- Exceedance curves at 70-percent exceedance
- **Other separation techniques implemented in *Groundwater Toolbox* were judged to be consistently too peaky**

Additional Noteworthy Results

- The HYSEP Local Minimum, BFI Standard, and BFI Modified approaches provide similar results that are almost always higher than corresponding estimates resulting from the USF and exceedance-curve approaches.
- The USF and exceedance-curve approaches also provide similar results.

Results of Selected Methods, All Gages

Gage Name	Dominant Contributing Aquifer	Beginning Observation Period	Baseflow, HYSEP Local Minimum, 2001 (CFS)	Baseflow, HYSEP Local Minimum, 2009 (CFS)	Baseflow, BFI Standard, 2001 (CFS)	Baseflow, BFI Standard, 2009 (CFS)	Baseflow, BFI Modified, 2001 (CFS)	Baseflow, BFI Modified, 2009 (CFS)	Baseflow, USF, 2001 (CFS)	Baseflow, USF, 2009 (CFS)	Baseflow, Exceedance, 2001 (CFS)	Baseflow, Exceedance, 2009 (CFS)
ST. MARYS RIVER NEAR MACCLENNY FL	SAS	1-Oct-26	57	128	45	78	43	120	20	51	34	72
SOUTH FORK BLACK CREEK NEAR PENNEY FARMS FL	SAS	1-Oct-39	28	71	24	54	24	57	14	27	21	40
SUWANNEE RIVER AT US 441 AT FARGO GA	SAS	21-Apr-37	89	524	82	432	79	531	17	163	41	149
SUWANNEE RIVER AT WHITE SPRINGS FLA.	SAS	2-Feb-27	197	495	240	496	239	518	28	199	66	211
ALAPAHA RIVER AT STATENVILLE GA	SAS	11-Dec-31	205	322	204	329	203	329	84	127	127	128
WITHLACOOCHEE RIVER AT US 84 NEAR QUITMAN GA	SAS	1-Jun-93	408	413	366	472	367	408	37	76	28	126
SUWANNEE RIVER AT ELLAVILLE FLA	FAS	1-Feb-27	1,704	2,551	2,637	3,001	2,644	2,986	1,108	1,842	1,496	2,378
SUWANNEE RIVER AT LURAVILLE FLA.	FAS	28-Sep-96	2,097	3,024	2,872	3,355	2,867	3,344	1,620	2,115	1,996	2,713
SUWANNEE RIVER AT BRANFORD FLA.	FAS	1-Jul-31	3,373	3,513	3,457	3,814	3,452	3,800	2,029	2,463	2,519	3,013
SANTA FE RIVER AT WORTHINGTON SPRINGS FLA.	SAS	1-Oct-31	23	100	14	101	12	97	4	30	10	52
SANTA FE RIVER NEAR FORT WHITE FLA.	FAS	2-Jun-32	554	767	594	795	594	793	519	591	552	706
SUWANNEE RIVER NEAR WILCOX FLA.	FAS	1-Oct-41	3,611	4,887	4,506	5,507	4,529	5,475	2,624	4,004	3,819	4,946
STEINHATCHEE RIVER NEAR CROSS CITY FLA.	FAS	1-Mar-50	151	48	148	33	146	33	6	12	9	22
ECONFINA RIVER NEAR PERRY FLA.	FAS	1-Feb-50	37	60	30	59	26	59	15	19	18	26

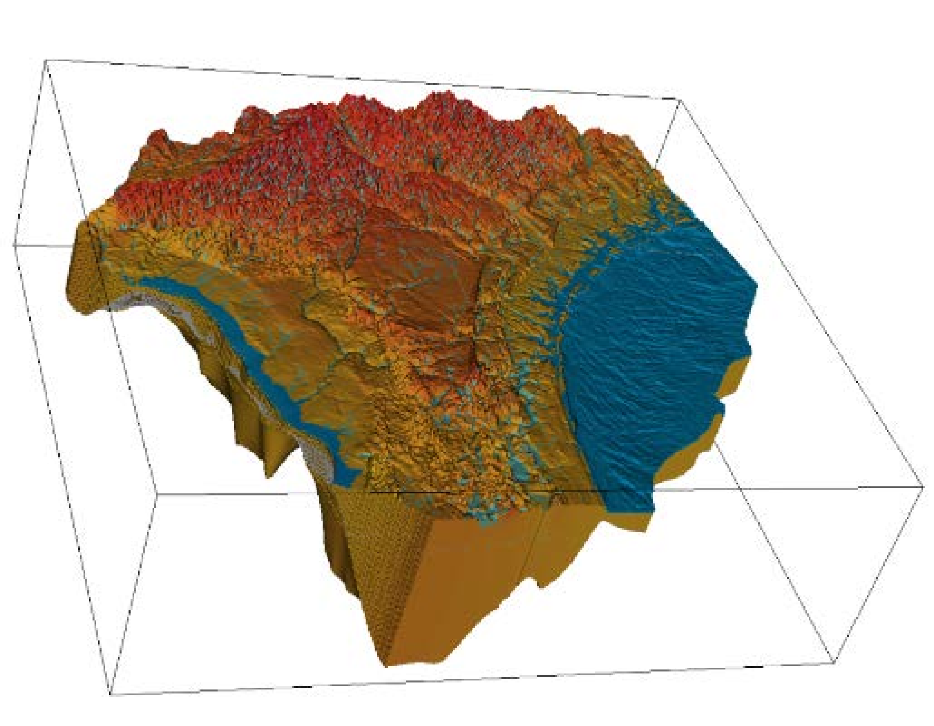
Table of Proposed Estimates

USGS Gage ID	Gage Name	Dominant Contributing Aquifer	Current Baseflow Estimate, 2001 (CFS)	Current Baseflow Estimate, 2009 (CFS)	Current Estimation Method, 2001	Current Estimation Method, 2009	Proposed Baseflow Estimate, 2001 (CFS)	Proposed Baseflow Estimate, 2009 (CFS)	HDAVIS Longterm, Low-End Baseflow Estimate (CFS)	HDAVIS 2001 Preferred Baseflow Estimate (CFS)	HDAVIS 2009 Preferred Baseflow Estimate (CFS)
2231000	ST. MARYS RIVER NEAR MACCLENNY FL	SAS	**63**	**261**	PART	PART	**40**	**90**	N/A	**N/A**	**N/A**
2245500	SOUTH FORK BLACK CREEK NEAR PENNEY FARMS FL	SAS	**33**	**98**	PART	PART	**22**	**50**	N/A	**N/A**	**N/A**
2314500	SUWANNEE RIVER AT US 441 AT FARGO GA	SAS	**156**	**630**	PART	PART	**62**	**360**	15	**N/A**	**N/A**
2315500	SUWANNEE RIVER AT WHITE SPRINGS FLA.	SAS	**302**	**925**	PART	PART	**154**	**384**	25	**192**	**493**
2317500	ALAPAHA RIVER AT STATENVILLE GA	SAS	**588**	**1,145**	HSPF Ratio	HSPF Ratio	**164**	**247**	40	**N/A**	**N/A**
2318500	WITHLACOOCHEE RIVER AT US 84 NEAR QUITMAN GA	SAS	**651**	**1,372**	HSPF Ratio	HSPF Ratio	**241**	**299**	15	**N/A**	**N/A**
2319500	SUWANNEE RIVER AT ELLAVILLE FLA	FAS	**N/A**	**N/A**	N/A	N/A	**1,918**	**2,552**	800	**1,462**	**1,754**
2320000	SUWANNEE RIVER AT LURAVILLE FLA.	FAS	**N/A**	**N/A**	N/A	N/A	**2,290**	**2,910**	1,100	**1,559**	**2,156**
2320500	SUWANNEE RIVER AT BRANFORD FLA.	FAS	**3,568**	**N/A**	PART	N/A	**2,966**	**3,320**	1,500	**2,067**	**2,326**
2321500	SANTA FE RIVER AT WORTHINGTON SPRINGS FLA.	SAS	**36**	**185**	PART	PART	**13**	**76**	N/A	**N/A**	**N/A**
2322500	SANTA FE RIVER NEAR FORT WHITE FLA.	FAS	**608**	**869**	PART	PART	**563**	**730**	N/A	**555**	**682**
2323500	SUWANNEE RIVER NEAR WILCOX FLA.	FAS	**4,296**	**6,014**	HSPF Ratio	HSPF Ratio	**3,818**	**4,964**	2,300	**3,250**	**3,315**
2324000	STEINHATCHEE RIVER NEAR CROSS CITY FLA.	FAS	**196**	**65**	PART	PART	**92**	**30**	N/A	N/A	N/A
2326000	ECONFINA RIVER NEAR PERRY FLA.	FAS	**39**	**71**	PART	PART	**25**	**45**	N/A	N/A	N/A

Summary of Proposed Method/Recommendation

- Final proposed method is to determine an average of annual averages derived from the following methods:
  - HYSEP Local Minimum
  - BFI Standard
  - BFI Modified
  - USF
  - Exceedance curves at 70-percent exceedance
  - **Exclude the following methods due to excessive peakiness of resulting baseflow hydrographs: HYSEP Fixed Interval, HYSEP Sliding Interval, PART**
- Apply the proposed method to all other gages used in the model calibration.

NFSEG Uncertainty Analysis: Previous and Planned Work



July 26, 2017

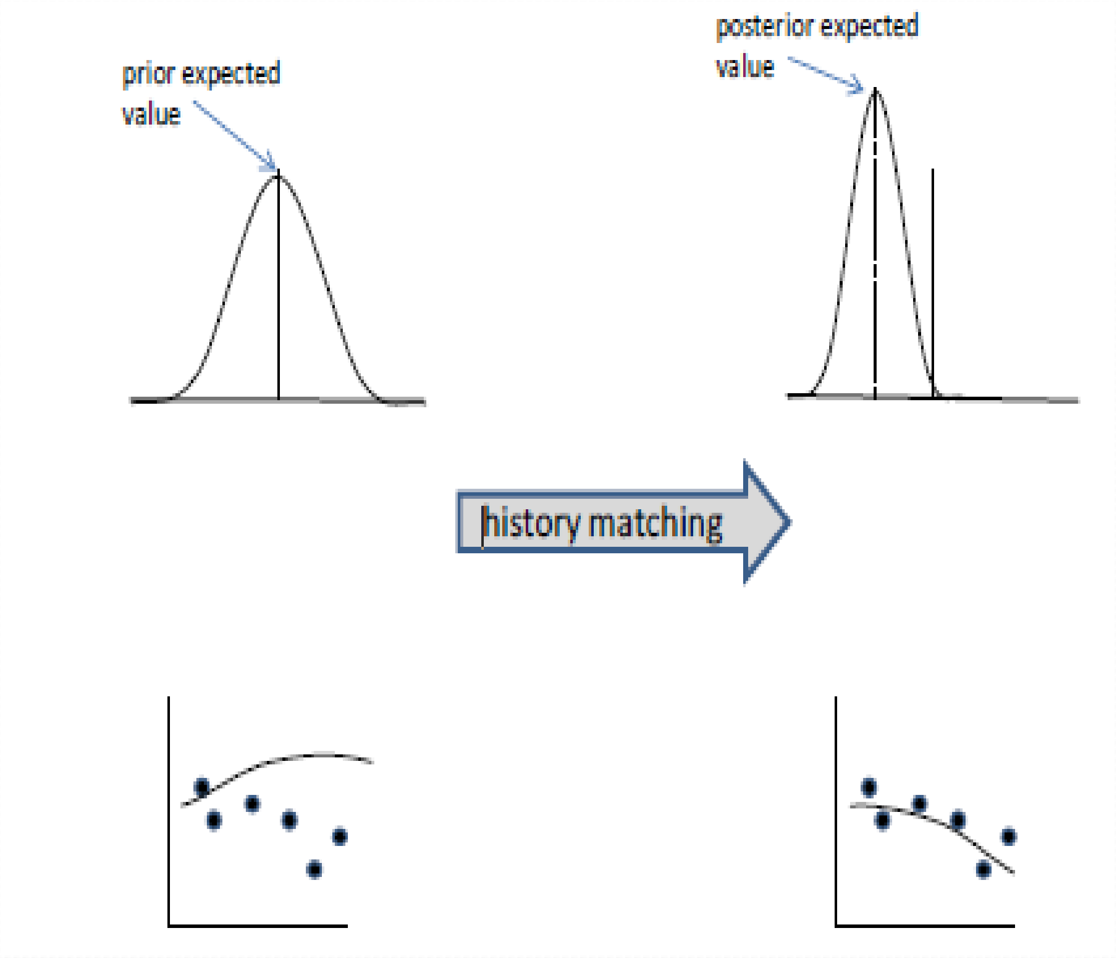
Outline

- Background info
- Review of NFSEG v1.0 analyses
  - Parameter uncertainty
  - Predictive uncertainty
- Discussion of planned analyses/products for NFSEG v1.1

Background

- Motivation:
  - More informative calibration diagnostics
  - Uncertainty estimates (confidence intervals for parameters and predictions)
  - Framework for improved decision-making and future model development
- Uncertainty analysis theory is well established, and has been implemented in modeling studies around the world
- NFSEG v1.0 work one of the few examples of parameter and prediction uncertainty analysis in Florida

Linear Uncertainty Analysis



Source: Doherty, J.D., 2010, Methodologies and software for PEST-based model predictive uncertainty analysis

Uncertainty Analysis

- Parameter uncertainty
- Predictive uncertainty
- Uncertainty analysis includes sensitivity analysis
- Recognizes that parameters can't be estimated uniquely – quantifies consequences of parameter insensitivity and correlation

NFSEG v1.0 Uncertainty Analysis

- Documented in Appendix J of NFSEG v1.0 Draft Report (Watermark Numerical Computing, 2016)
- Based on highly-parameterized history match:
  - Some parameters are insensitive from a history-match/calibration perspective, but …
  - … might be important with respect to making certain types of predictions

NFSEG v1.0 Uncertainty Analysis Components

- Parameter uncertainty
  - Linear analysis
- Predictive uncertainty
  - Linear analysis
  - Semi-linear analysis

NFSEG v1.0 Uncertainty Analysis: Parameter Uncertainty

- Relative parameter uncertainty variance reduction ***(r$_i$)***:

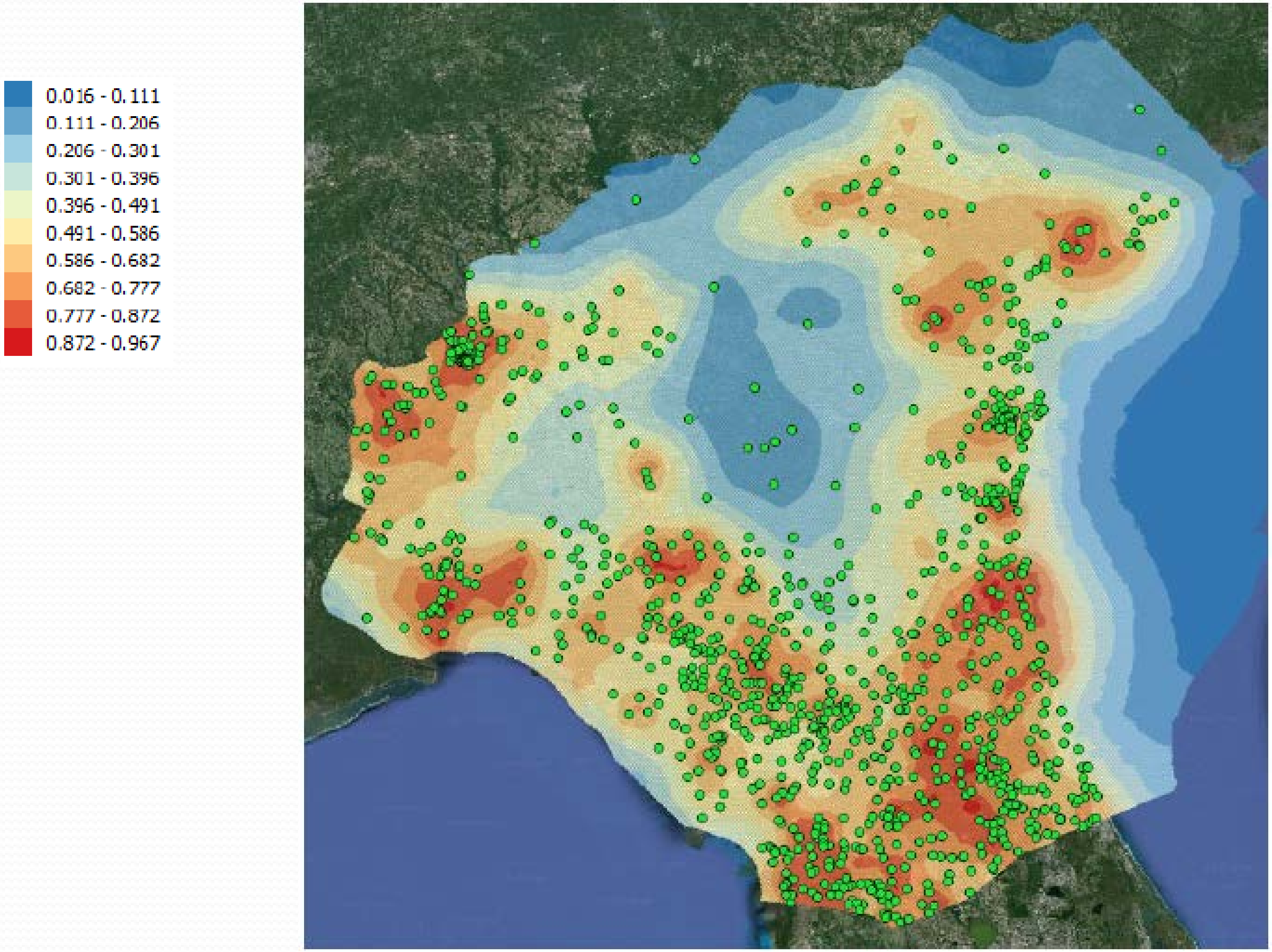
$$r_i = \frac{\text{reduction in uncertainty from calibration}}{\text{precalibration uncertainty}}$$

  - A value of 0 indicates no reduction in uncertainty through calibration
  - A value of 1 indicates that that the parameter is known with absolute certainty after calibration

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

NFSEG v1.0 Uncertainty Analysis: Parameter Uncertainty

Relative uncertainty variance reduction



Layer 3

Kh

pilot points

Figure 4.3b Relative parameter uncertainty variance reduction of k3x parameters together with observation wells in layer 3; see figure 4.3a for colour scale.

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

NFSEG v1.0 Uncertainty Analysis: Parameter Uncertainty

Relative uncertainty variance reduction

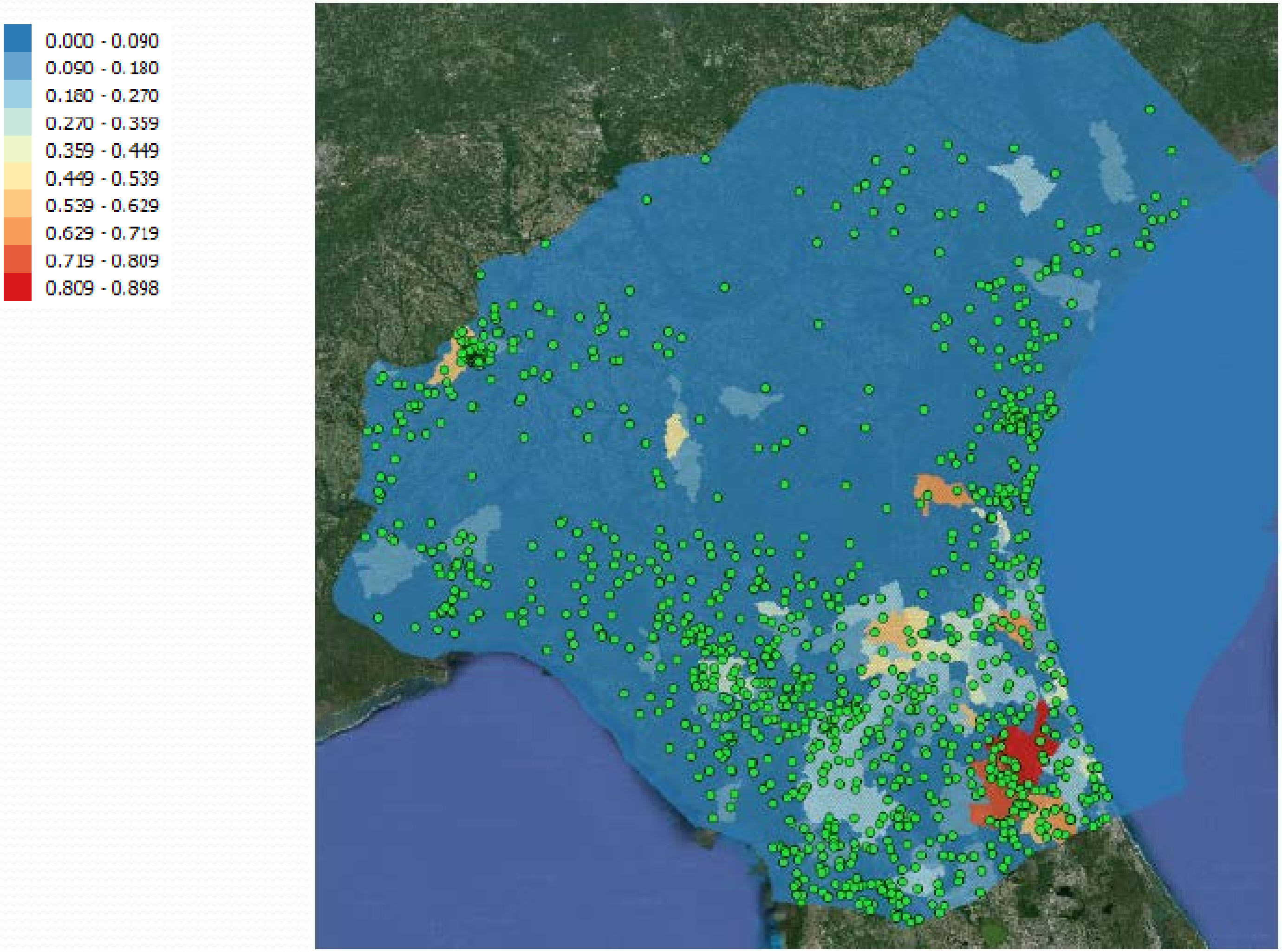


Figure 4.4 Relative parameter uncertainty variance reduction of recharge multiplier parameters together with observation wells in layer 3.

Recharge multipliers

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

NFSEG v1.0 Uncertainty Analysis: Predictive Uncertainty

- GW levels and GW discharge to rivers and springs (predictive absolutes)
- Changes in levels and flows (predictive differences)
- Predictions at 23 key locations:
  - GW levels in Keystone Heights
  - Flows in SRWMD

NFSEG v1.0 Linear Analysis of Uncertainty: Predictive Absolutes

Assessing parameter contributions to predictive uncertainty

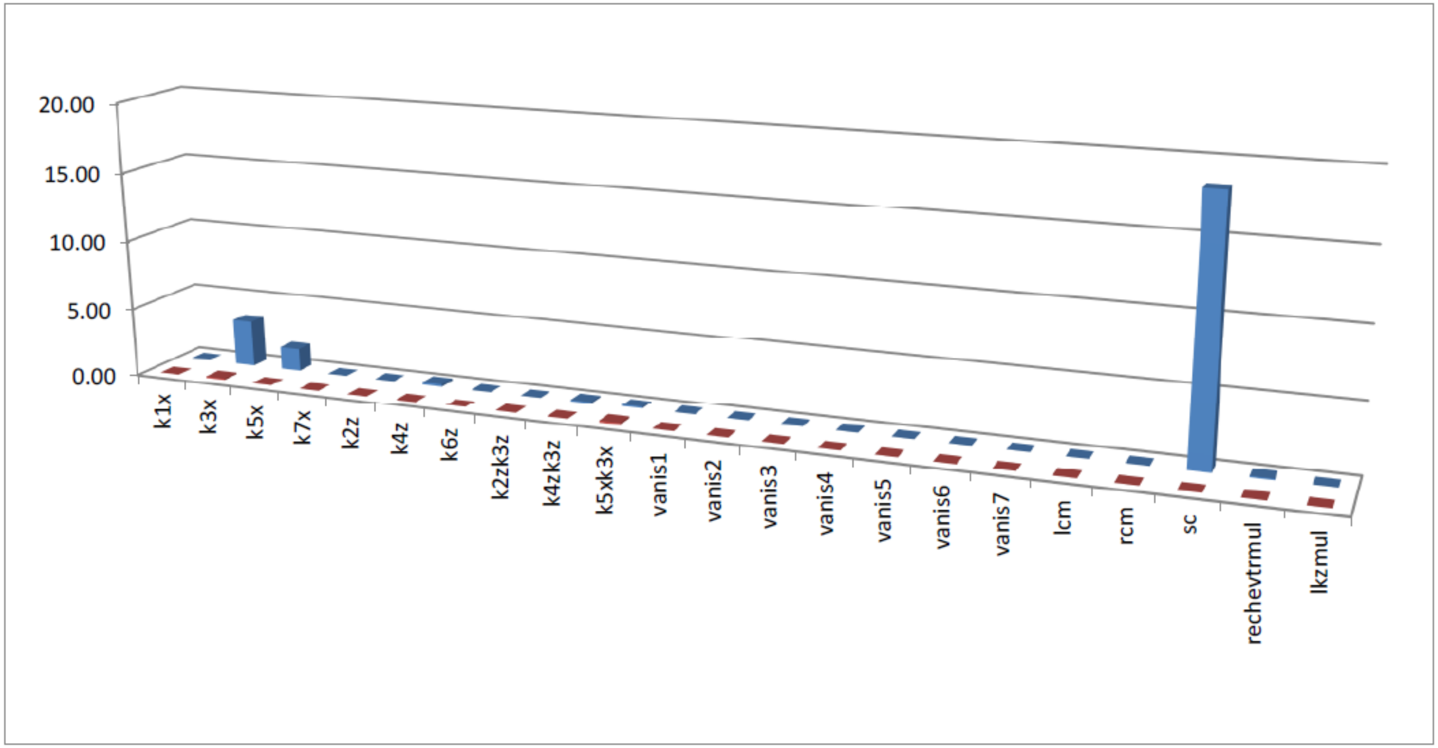


Figure 5.1 Contributions made by different parameter groups to the uncertainty variance of prediction qspring09_s12161002. Pre- and post-calibration predictive variances are 23.87 $(ft^3/day)^2$ and 0.257 $(ft^3/day)^2$, respectively.

Source: Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

NFSEG v1.0 Linear Analysis of Uncertainty: Predictive Absolutes

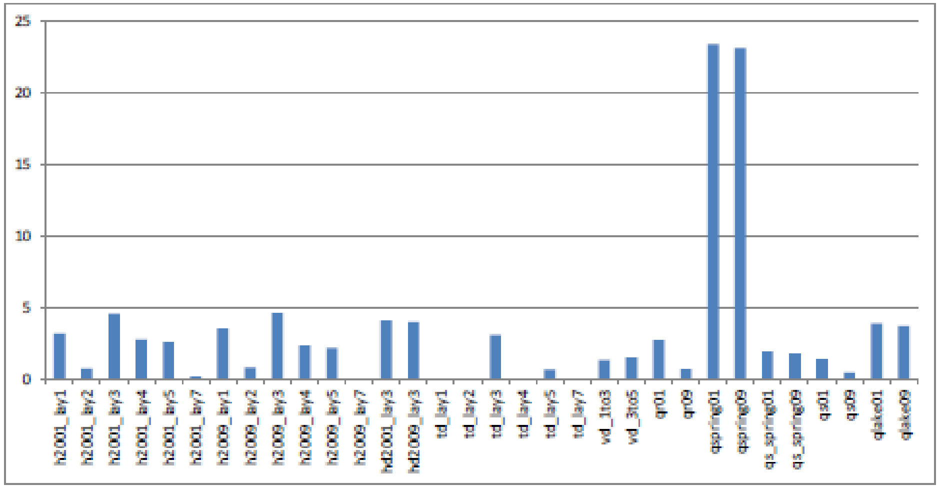


Figure 5.3a Decrease in the uncertainty variance of prediction *qspring09_s12161002* from its pre-calibration value of 23.87 (ft/day)^2 accrued if each observation group comprises the entirety of the calibration dataset.

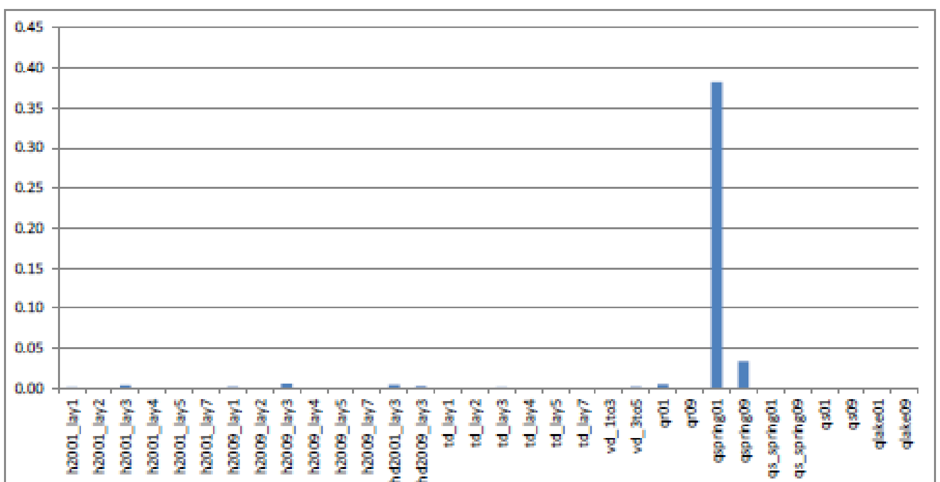


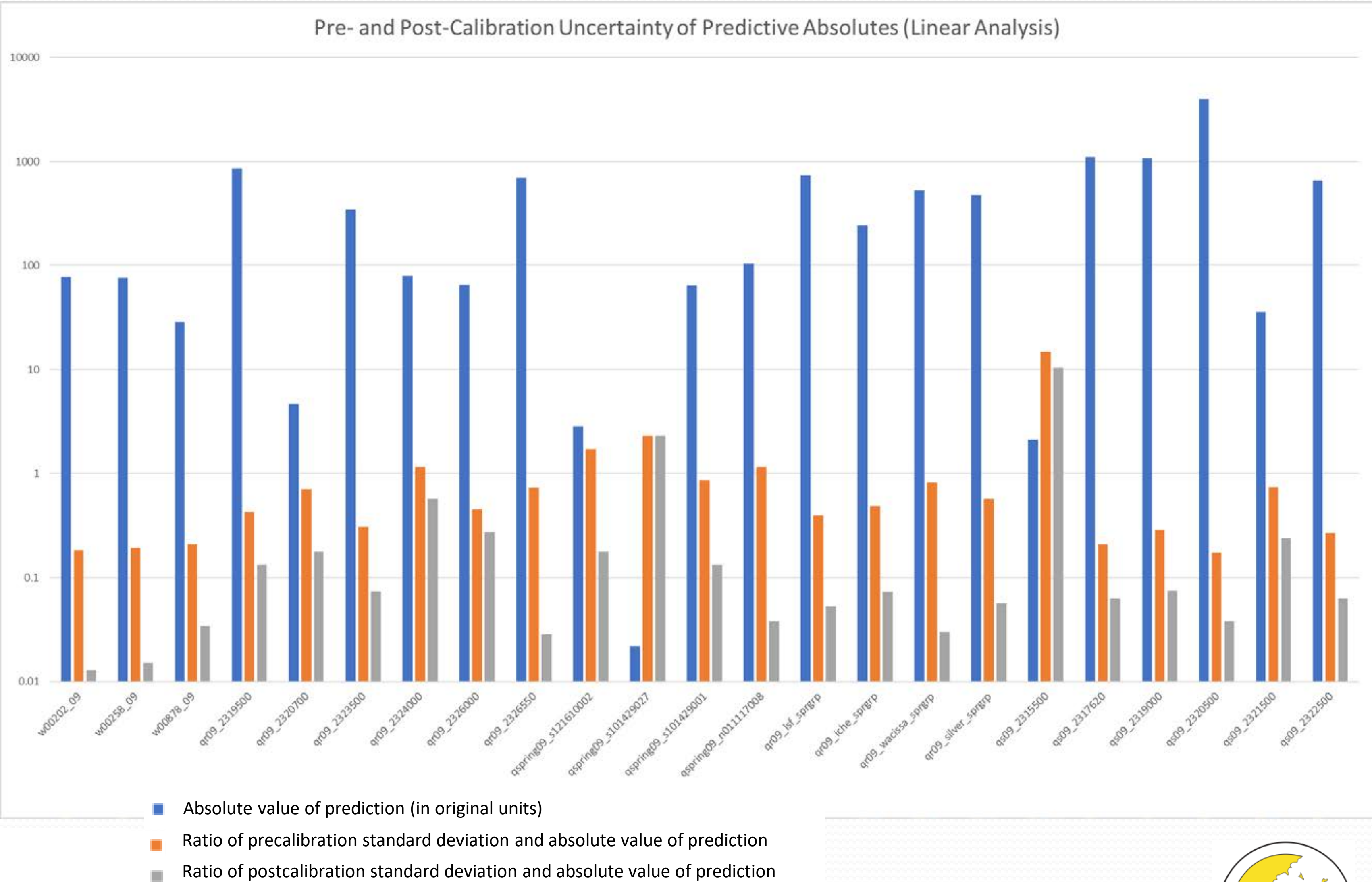
Figure 5.3b Increase in the uncertainty variance of prediction *qspring09_s12161002* from its post-calibration value of 0.257 (ft/day)^2 incurred if each observation group is removed from the calibration dataset.

Assessing the information content of various observation groups

Source:
Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

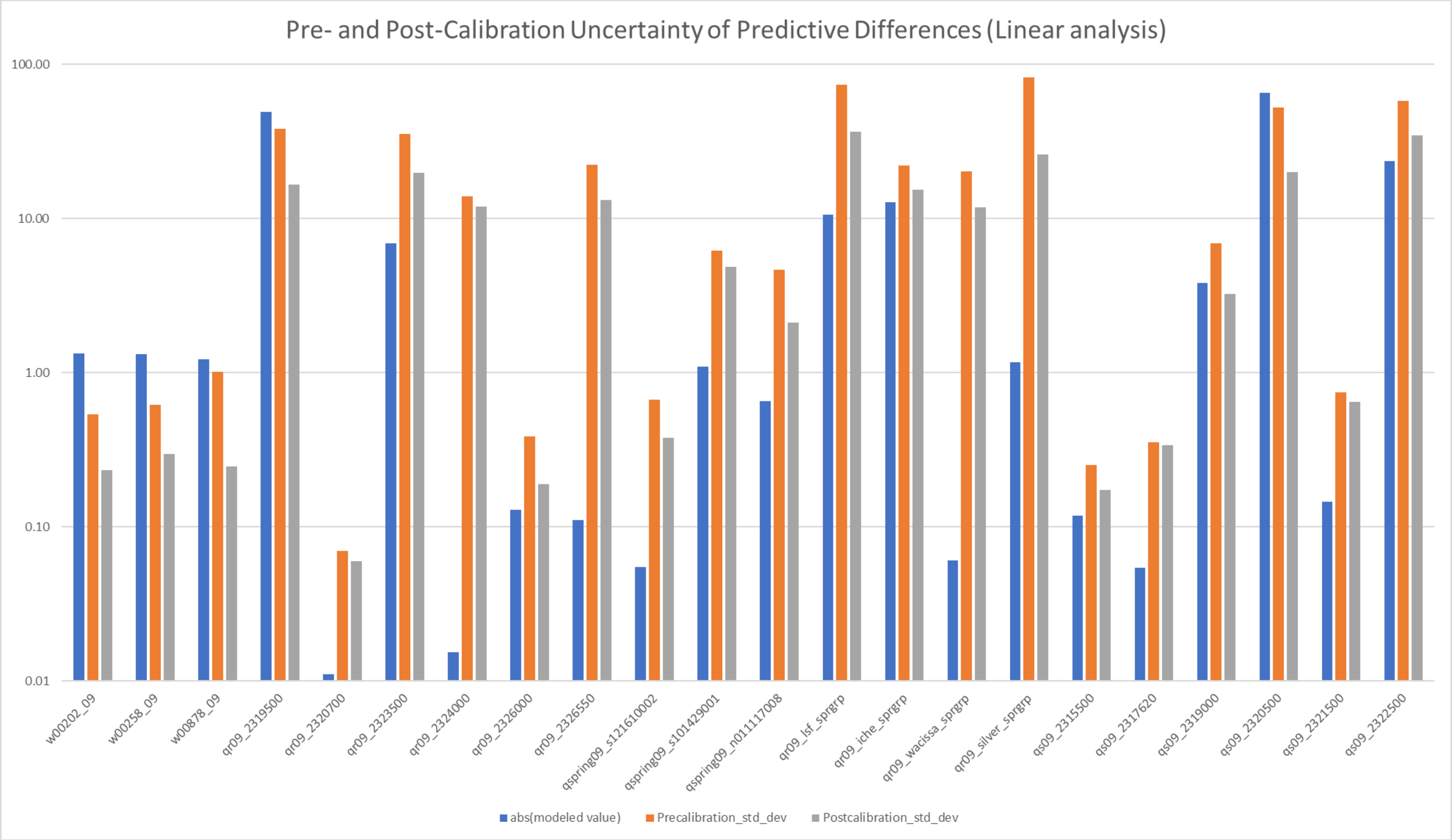
SUWANNEE RIVER WATER MANAGEMENT DISTRICT

NFSEG v1.0 Linear Analysis of Uncertainty:



Based on results from Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

NFSEG v1.0 Linear Analysis of Uncertainty:



- Absolute value of prediction (in original units)
- Precalibration standard deviation
- Postcalibration standard deviation

Based on results from Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)
Note that results for qspring09_s101429027 are not shown because the predicted change and uncertainty were less than or equal to 0.0001

NFSEG v1.0 Semi-linear Analysis of Uncertainty: Predictive Differences

Prediction	Value of predicted change from 2009 to 2035, calculated using ***k***	Linear analysis, postcalibration uncertainty standard deviation of predicted change from 2009 to 2035	Semi-linear, postcalibration uncertainty[3] standard deviation of predicted change from 2009 to 2035
w00202_09[1]	1.34	0.23	0.10
w00878_09[1]	-1.22	0.25	0.23
qr09_iche_sprgrp[2]	-12.82	15.36	0.34
qs09_2320500[2]	-65.38	20.01	0.77
qs09_2321500[2]	-0.15	0.65	0.00
qs09_2322500[2]	-23.69	34.51	0.72

Adapted from Watermark Numerical Computing, August 2016, Linear predictive uncertainty analysis applied to the NFSEG groundwater model (Appendix J of draft report documenting the development and calibration of the NFSEG groundwater model)

1. Values are in feet. Positive predictive changes mean drawdown.
2. Values are in cubic feet per second. Negative predictive changes mean reduction in flows.
3. Postcalibration uncertainty estimates from semi-linear analysis were estimated as half of the difference between the predicted change values that were calculated using $\underline{k} \pm \delta k$

NFSEG v1.0 Linear Analysis of Uncertainty: A Few Takeaways

- Explicit framework for quantifying uncertainty
- Like the underlying parameter and prediction estimates, estimates of uncertainty will always be approximations
- Informative ancillary results
- Identification of issues:
  - Solver convergence can affect results of important predictions
  - Linear analysis probably overstates uncertainty in some cases
  - Semi-linear analysis probably understates uncertainty in some cases
  - Nonlinear analysis logical next step

Plans for NFSEG 1.1 Uncertainty Analysis: Essential Aspects

- At a minimum, another linear and semi-linear analysis ....
- Plan to carry out nonlinear analysis if possible:
  - Generate a set of random parameter-field 'realizations'
  - Compute parameter uncertainty as the variance of individual parameters from the above set of parameter realizations
  - Compute prediction uncertainty by running the model once for each of the above random-parameter-field realizations
- Generate a few hundred parameter fields (about 200)
- Additional prediction locations (compared to NFSEG v1.0)

2010 Verification Simulation

2010 Verification Simulation

- 2010 was selected based on input from SJRWMD Water Supply Planning staff early on in model development
- Subsequently built input datasets to compile the 2010 simulation, including:
  - Recharge and applied irrigation
  - Water Use
  - Observation Datasets:
    - Groundwater levels, lake levels, spring flows, gaged river/stream flows

Peer Review Panel Discussion

Next Steps

Case 005 Updates

- Updated water use – 2001/2009
- Recharge updates
- Updated baseflow targets/ranges
- Upper and lower bound adjustments
  - Bubble high east
- Review and update observations as needed
- VHDs
  - Add synthetic targets: Layer 1-3, Layer 3-5
- Drainage improvements
- Re-weighting
- Covariance matrices pilot point regularization
- Temporal differences/test with consideration of eliminating them

August 24 Meeting

- Case 5 results

Public Comments