

**HOLISTIC WATERSHED MANAGEMENT FOR EXISTING AND FUTURE LAND
USE DEVELOPMENT ACTIVITIES: OPPORTUNITIES FOR ACTION FOR LOCAL
DECISION MAKERS: PHASE 1 – MODELING AND DEVELOPMENT OF FLOW
DURATION CURVES (FDC 1 PROJECT)**

**SUPPORT FOR SUTHEAST NEW ENGLAND PROGRAM (SNEP)
COMMUNICATIONS STRATEGY AND TECHNICAL ASSISTANCE**

TASK 6. APPENDIX A
JULY 26, 2021

Prepared for:

U.S. EPA Region 1



Prepared by:

Paradigm Environmental



Great Lakes Environmental Center



Blanket Purchase Agreement: BPA-68HE0118A0001-0003
Requisition Number: PR-R1-20-00322
Order: 68HE0121F0001

Calibration

WADING RIVER NEAR NORTON MA

Station ID: 01109000

10/01/2010 - 09/30/2020

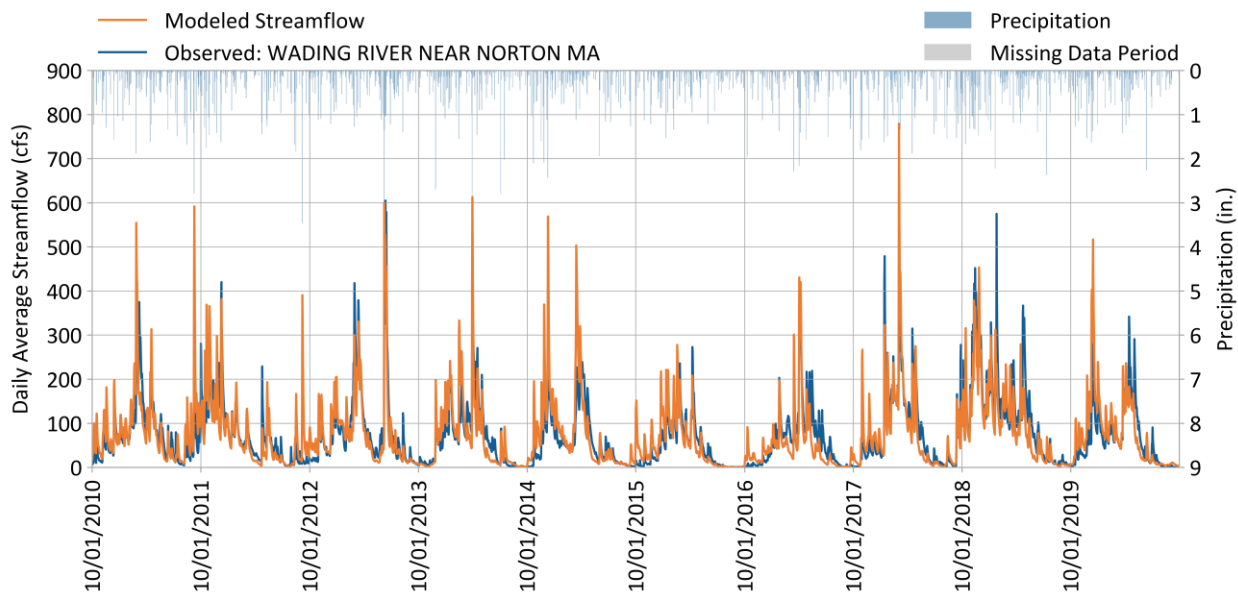


Figure 1. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. daily observed streamflow.

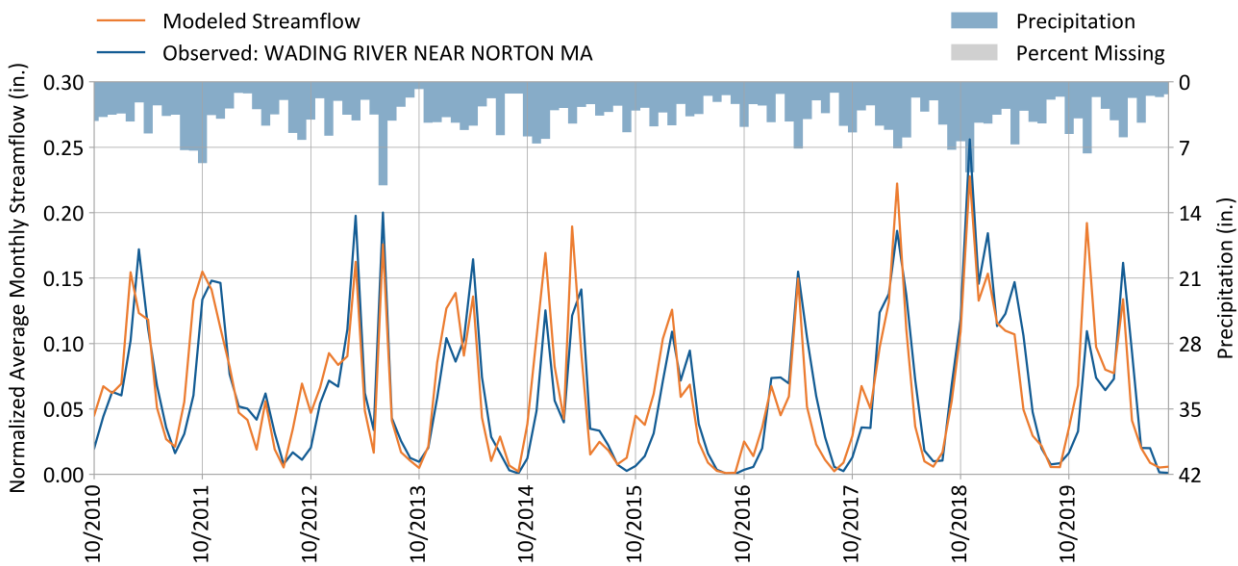


Figure 2. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed normalized monthly streamflow.

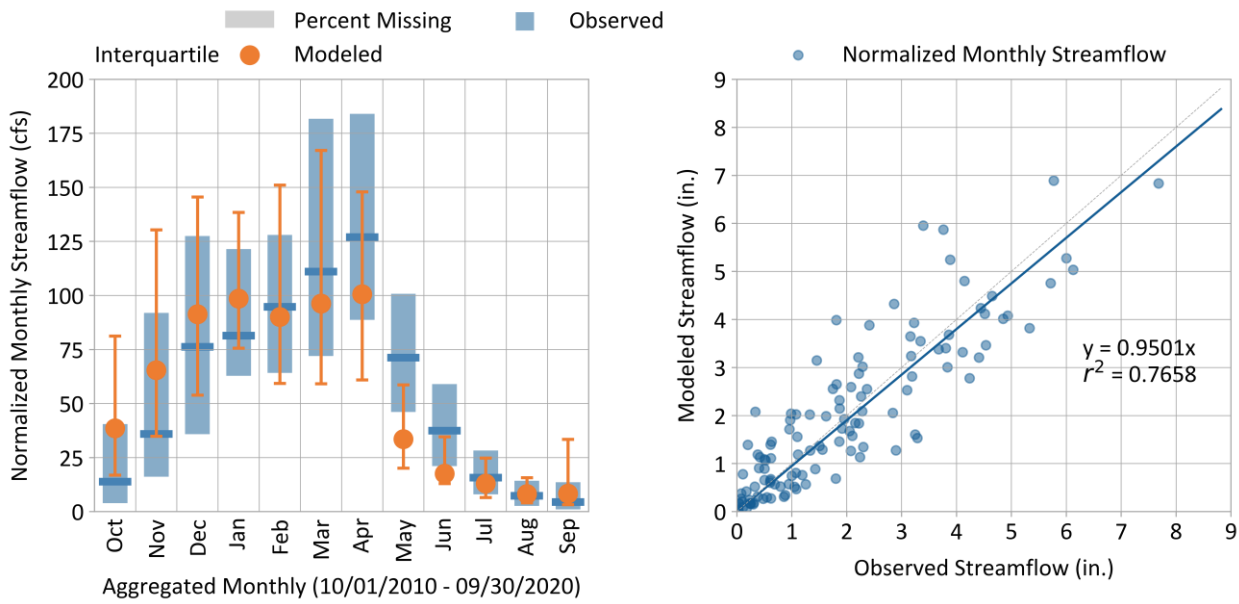


Figure 3. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed normalized monthly streamflow.

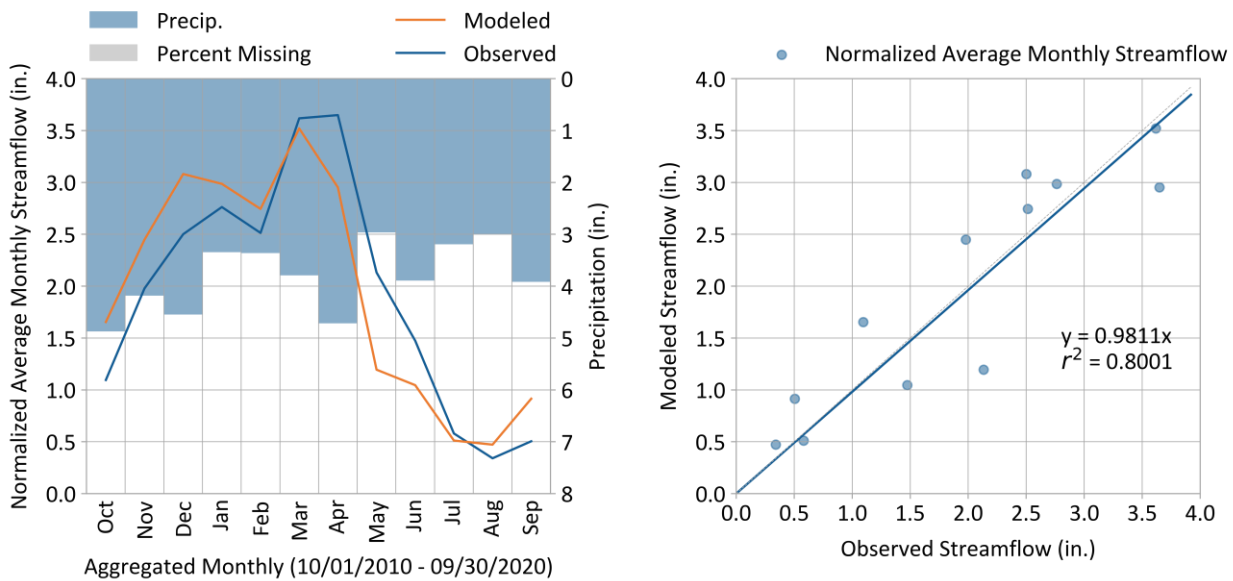


Figure 4. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Average normalized monthly streamflow.

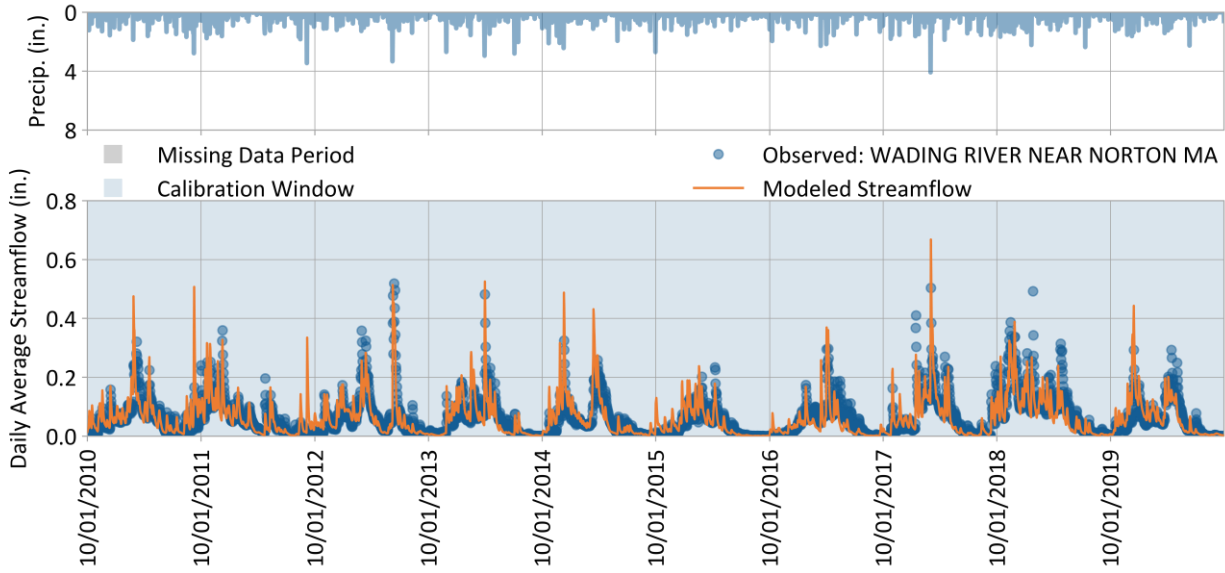


Figure 5. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed normalized daily streamflow.

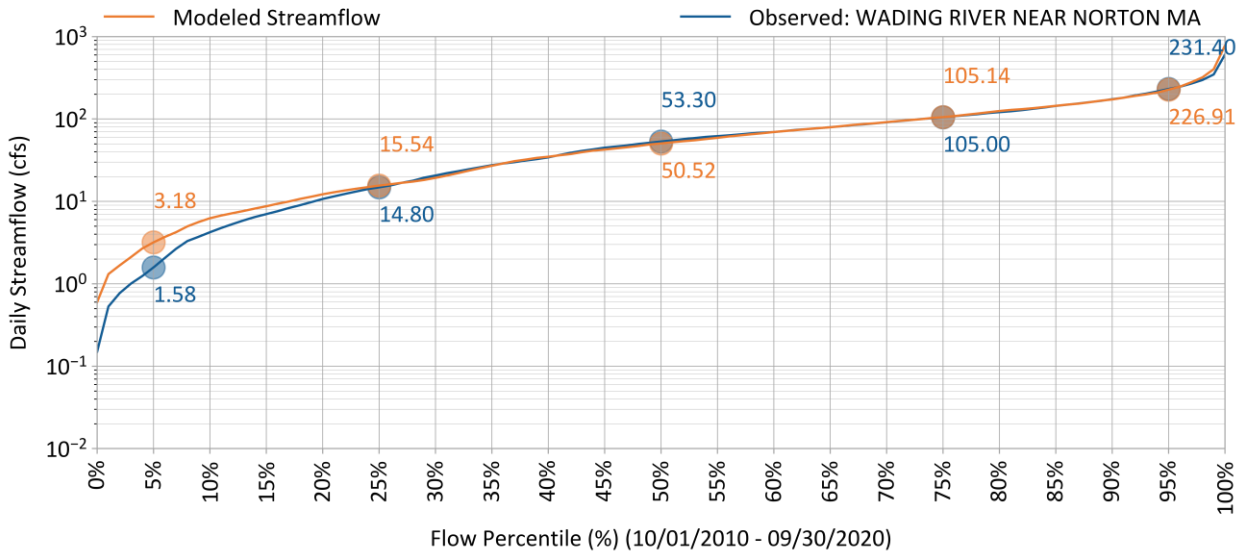


Figure 6. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed streamflow duration curves.

Table 1. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Percent bias statistical metric for predicted vs observed volumes.

Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)					
Calibration Metrics (10/01/2010 - 09/30/2020)	Percent Bias (PBIAS)				
	All Seasons	Winter	Spring	Summer	Fall
All Conditions	-1.6%	-4.0%	28.4%	-33.2%	-28.9%
Highest 10% of Daily Flow Rates	7.5%	4.0%	18.4%	4.0%	-0.2%
Lowest 50% of Daily Flow Rates	-33.5%	-11.7%	42.2%	-43.8%	-110.4%
Days Categorized as Storm Flow	-7.9%	-8.5%	23.5%	-31.1%	-33.9%
Days Categorized as Baseflow	4.7%	0.7%	32.3%	-35.3%	-22.2%

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
Percent Bias (PBIAS)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	<5%	5% - 10%	10% - 15%	>15%	Moriasi et al. (2015)
	Seasonal Flows		<10%	10% - 15%	15% - 25%	>25%	
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates						
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Table 2. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: R² statistical metric for predicted vs observed volumes.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2010 - 09/30/2020)		R-Squared (R²)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		0.72	0.63	0.83	0.44	0.78
Highest 10% of Daily Flow Rates		0.38	0.28	0.61	0.39	0.42
Lowest 50% of Daily Flow Rates		0.25	0.29	0.3	0.22	0.47
Days Categorized as Storm Flow		0.71	0.6	0.83	0.41	0.78
Days Categorized as Baseflow		0.75	0.66	0.82	0.51	0.82

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
R-Squared (R ²)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	>0.85	0.75 - 0.85	0.60 - 0.75	≤0.60	Moriasi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates		>0.75	0.60 - 0.75	0.50 - 0.60	≤0.50	
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Table 3. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Nash-Sutcliffe efficiency statistical metric for predicted vs observed flow rates.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2010 - 09/30/2020)		Nash-Sutcliffe Efficiency (E)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		0.68	0.5	0.71	-0.58	0.69
Highest 10% of Daily Flow Rates		-0.38	-0.62	0.01	-46.92	-0.19
Lowest 50% of Daily Flow Rates		-1.56	-3.94	-0.65	-3.6	-3.38
Days Categorized as Storm Flow		0.63	0.44	0.74	-0.75	0.64
Days Categorized as Baseflow		0.74	0.59	0.66	-0.34	0.78

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
Nash-Sutcliffe Efficiency (E)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	>0.80	0.70 - 0.80	0.50 - 0.70	≤0.50	Moriasi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates		>0.70	0.50 - 0.70	0.40 - 0.50	≤0.40	
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Validation

WADING RIVER NEAR NORTON MA

Station ID: 01109000

10/01/2000 - 09/30/2010

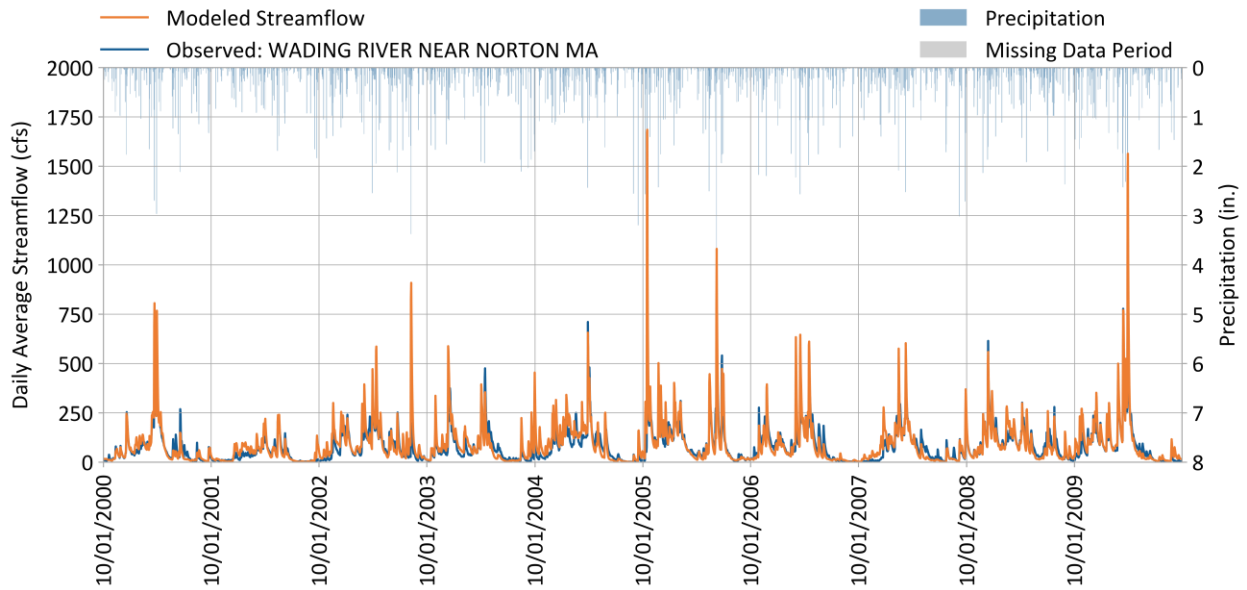


Figure 7. WADING RIVER NEAR NORTON MA (01109000) - Hydrology validation: Simulated vs. daily observed streamflow.

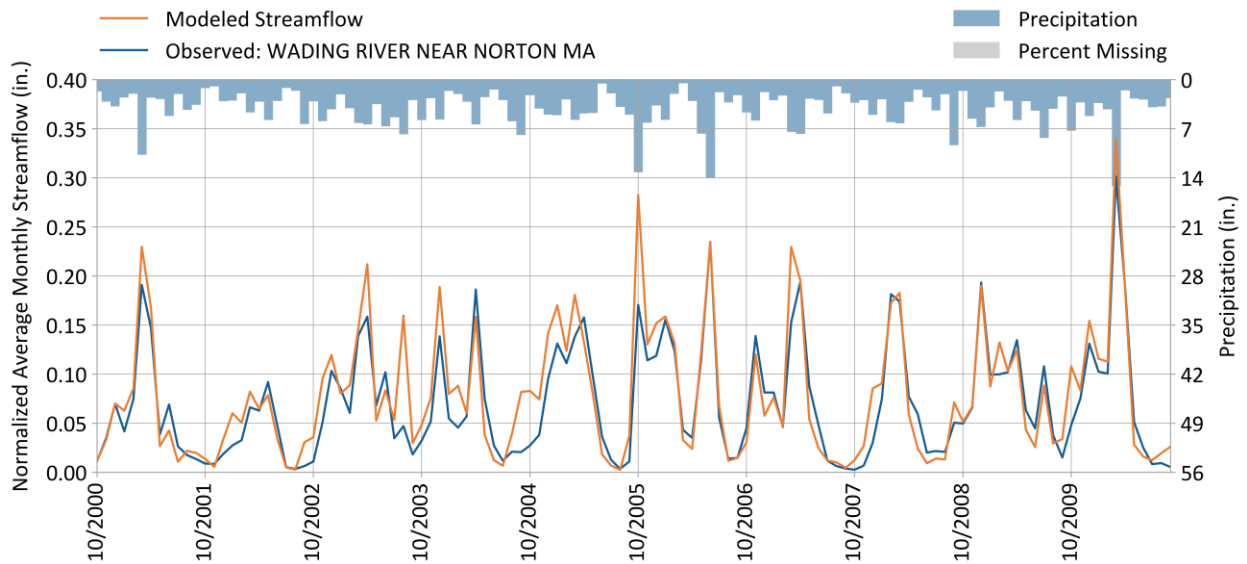


Figure 8. WADING RIVER NEAR NORTON MA (01109000) - Hydrology validation: Simulated vs. observed normalized monthly streamflow.

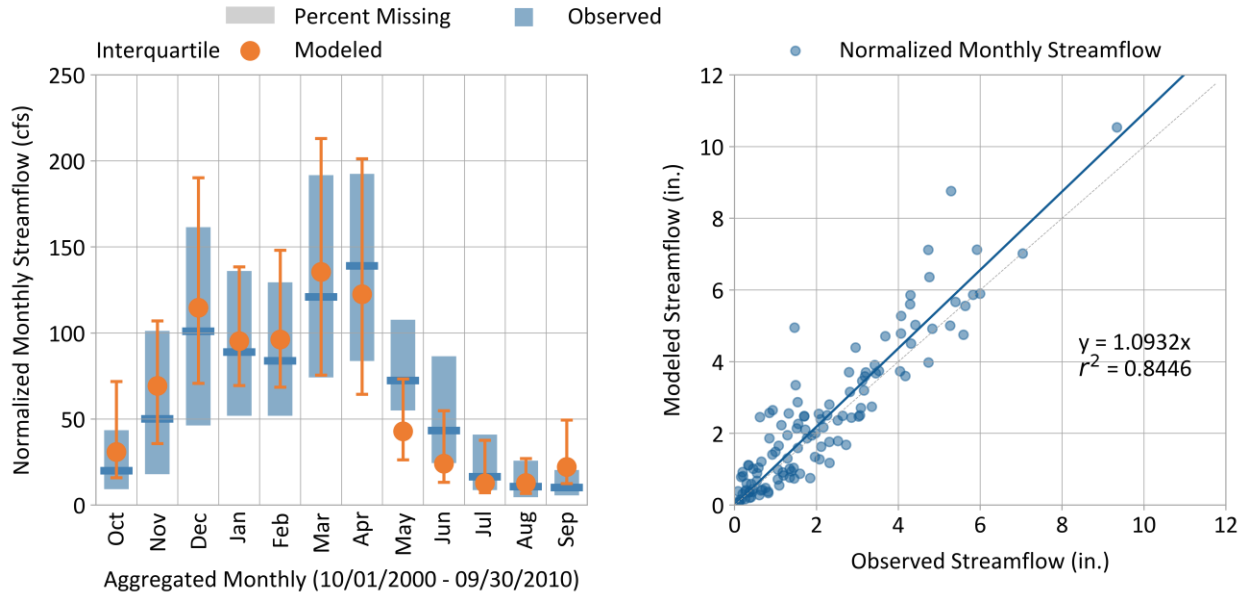


Figure 9. WADING RIVER NEAR NORTON MA (01109000) - Hydrology validation: Simulated vs. observed normalized monthly streamflow.

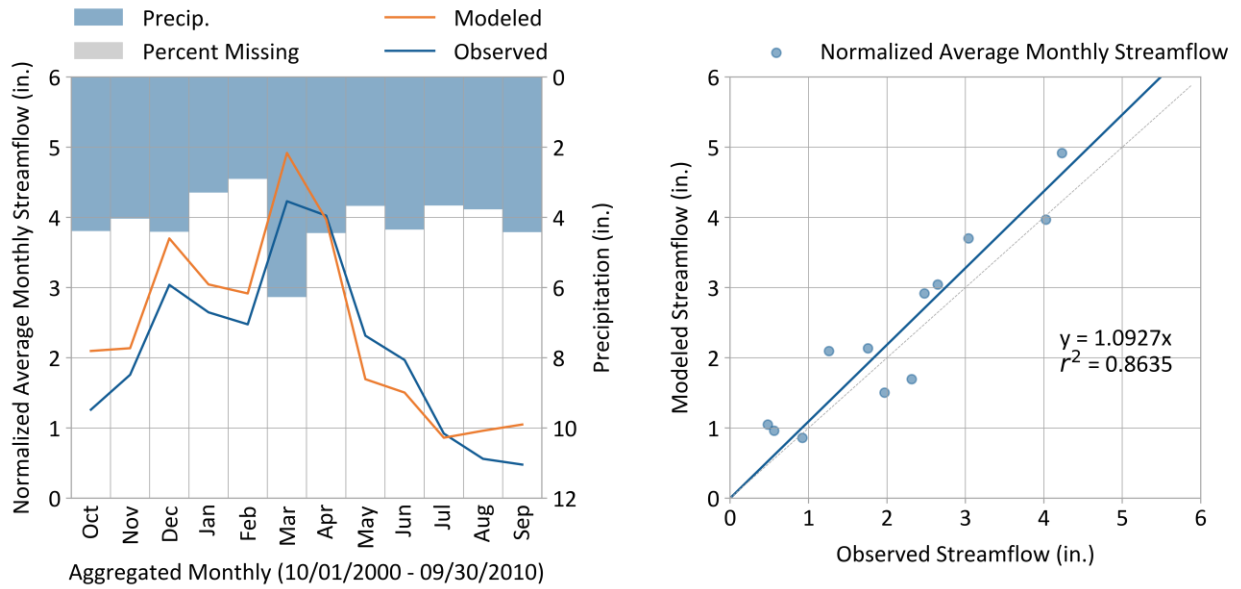


Figure 10. WADING RIVER NEAR NORTON MA (01109000) - Hydrology validation: Average normalized monthly streamflow.

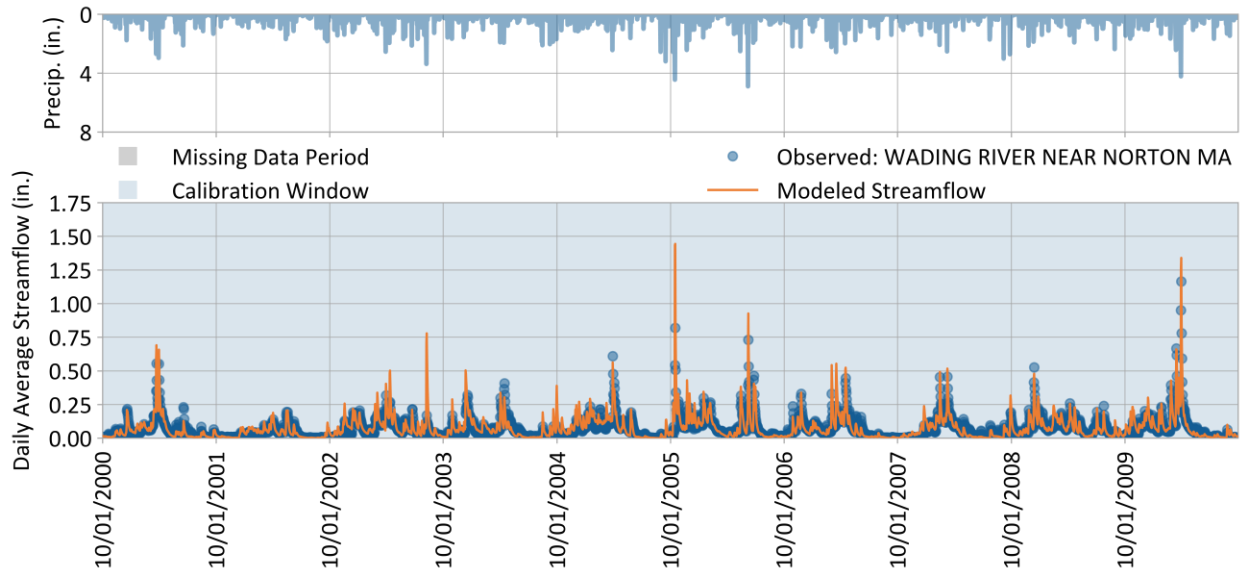


Figure 11. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed normalized daily streamflow.

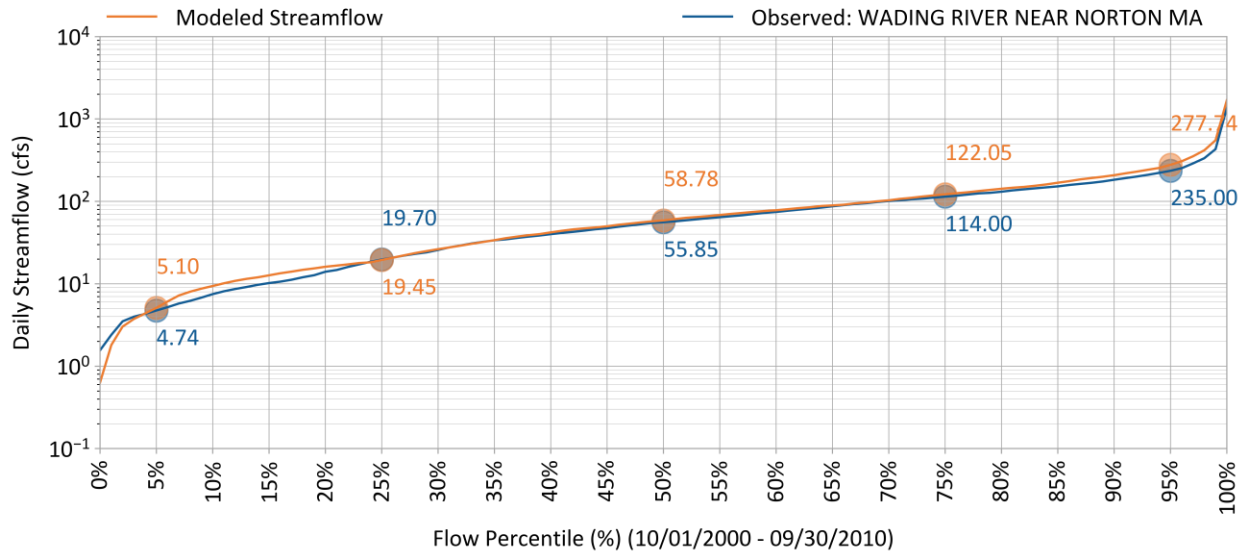


Figure 12. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed streamflow duration curves.

Table 4. WADING RIVER NEAR NORTON MA (01109000) - Hydrology validation: Percent bias statistical metric for predicted vs observed volumes.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2000 - 09/30/2010)		Percent Bias (PBIAS)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		-12.4%	-16.3%	13.7%	-46.5%	-31.0%
Highest 10% of Daily Flow Rates		-13.5%	-13.7%	-5.4%	-73.3%	-20.9%
Lowest 50% of Daily Flow Rates		-35.6%	-47.0%	42.5%	-51.1%	-80.6%
Days Categorized as Storm Flow		-19.9%	-20.7%	9.0%	-56.6%	-40.7%
Days Categorized as Baseflow		-5.3%	-11.2%	17.0%	-38.1%	-21.0%

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
Percent Bias (PBIAS)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	<5%	5% - 10%	10% - 15%	>15%	Moriassi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates		<10%	10% - 15%	15% - 25%	>25%	
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Table 5. WADING RIVER NEAR NORTON MA (01109000) - Hydrology validation: R² statistical metric for predicted vs observed volumes.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2000 - 09/30/2010)		R-Squared (R²)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		0.81	0.88	0.9	0.49	0.77
Highest 10% of Daily Flow Rates		0.73	0.85	0.79	0.14	0.73
Lowest 50% of Daily Flow Rates		0.32	0.1	0.54	0.33	0.44
Days Categorized as Storm Flow		0.81	0.9	0.89	0.48	0.79
Days Categorized as Baseflow		0.82	0.82	0.92	0.52	0.78

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
R-Squared (R ²)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	>0.85	0.75 - 0.85	0.60 - 0.75	≤0.60	Moriassi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates		>0.75	0.60 - 0.75	0.50 - 0.60	≤0.50	
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Table 6. WADING RIVER NEAR NORTON MA (01109000) - Hydrology validation: Nash-Sutcliffe efficiency statistical metric for predicted vs observed flow rates.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2000 - 09/30/2010)		Nash-Sutcliffe Efficiency (E)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		0.66	0.78	0.82	-1.5	0.38
Highest 10% of Daily Flow Rates		0.23	0.65	0.53	-107.61	-1.09
Lowest 50% of Daily Flow Rates		-1.47	-7.7	-0.72	-2.39	-3.04
Days Categorized as Storm Flow		0.6	0.78	0.79	-2.28	0.24
Days Categorized as Baseflow		0.76	0.74	0.84	-0.56	0.65

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
Nash-Sutcliffe Efficiency (E)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	>0.80	0.70 - 0.80	0.50 - 0.70	≤0.50	Moriassi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates		>0.70	0.50 - 0.70	0.40 - 0.50	≤0.40	
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Baseline Simulation Period

WADING RIVER NEAR NORTON MA
Station ID: 01109000
10/01/2000 - 09/30/2020

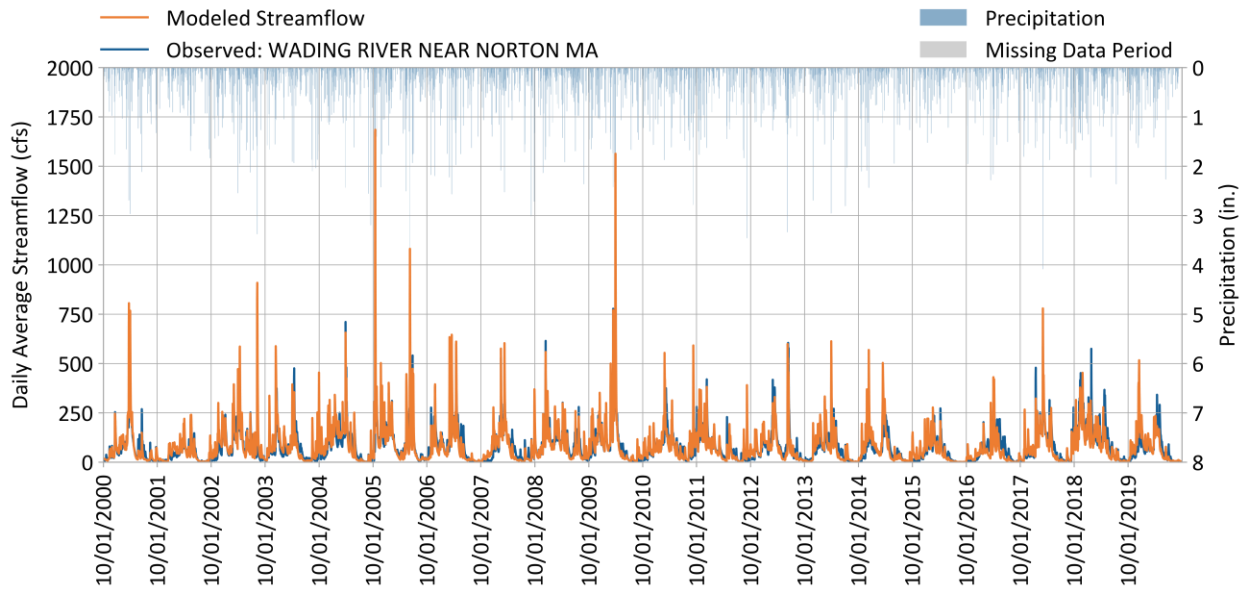


Figure 13. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. daily observed streamflow.

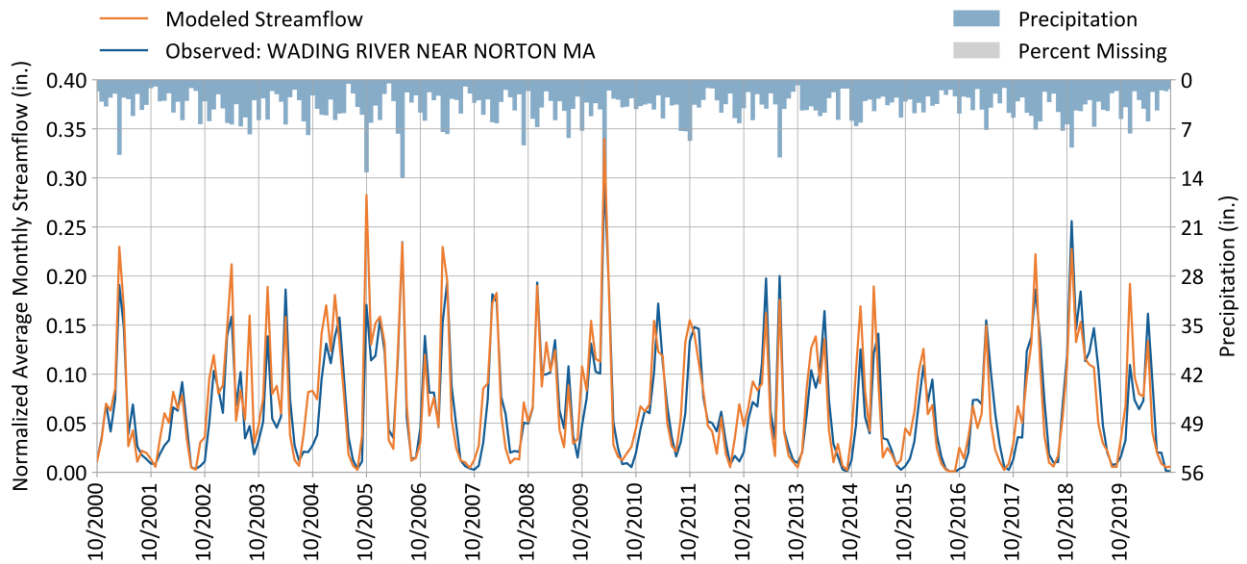


Figure 14. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed normalized monthly streamflow.

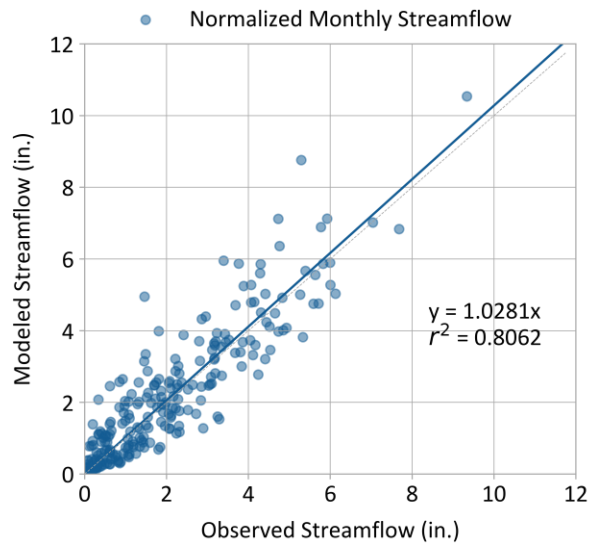
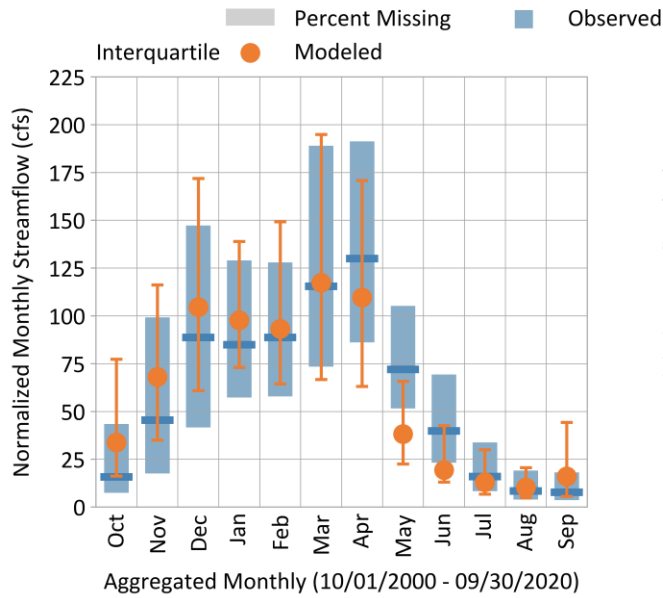


Figure 15. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed normalized monthly streamflow.

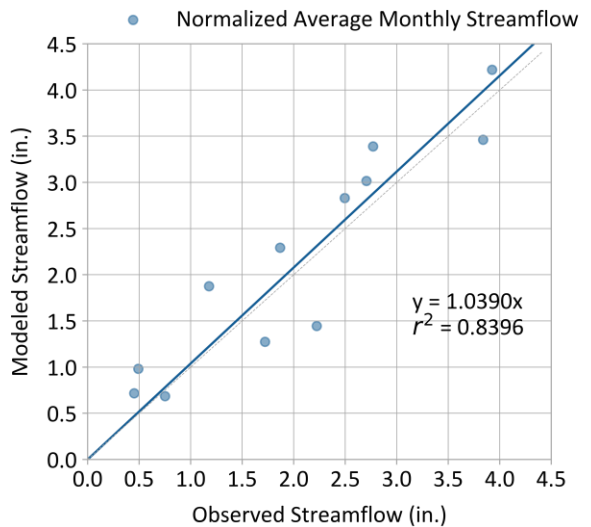
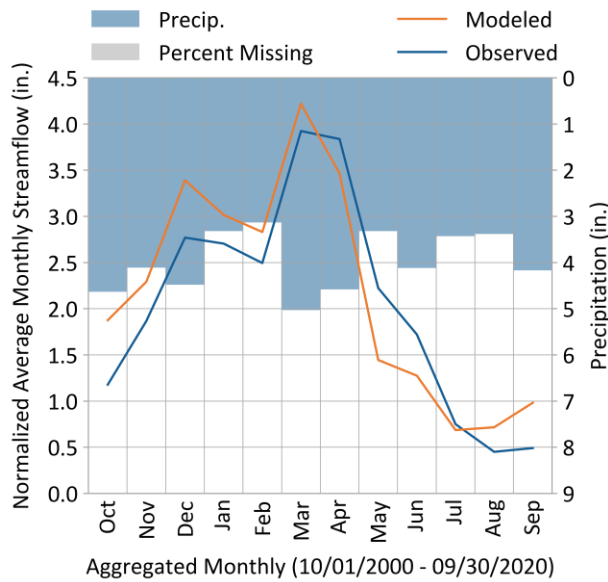


Figure 16. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Average normalized monthly streamflow.

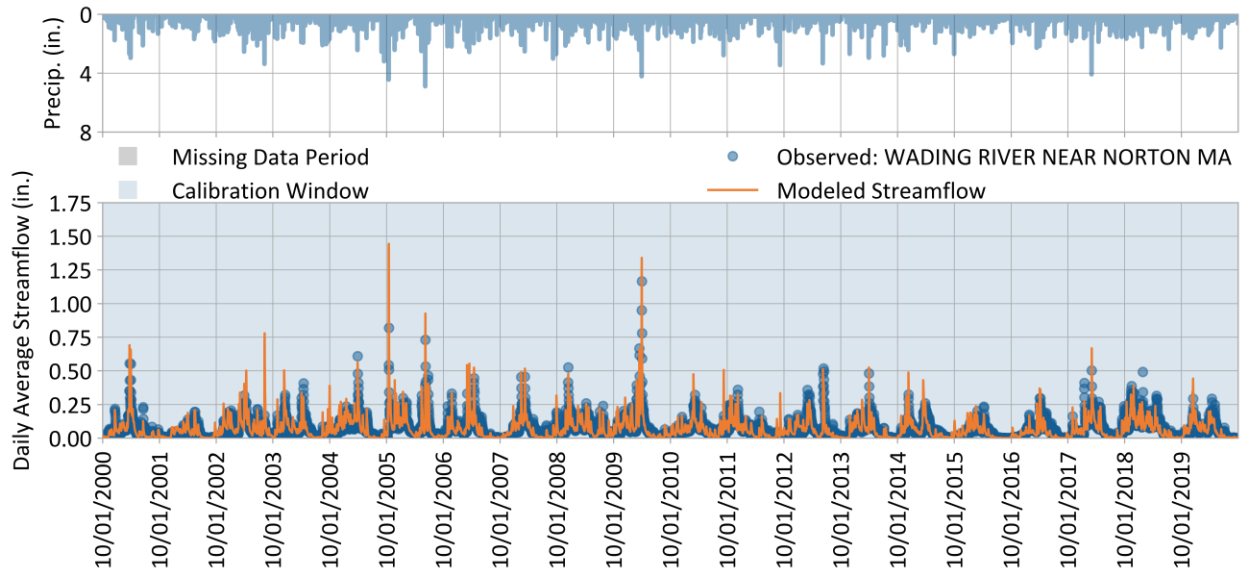


Figure 17. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed normalized daily streamflow.

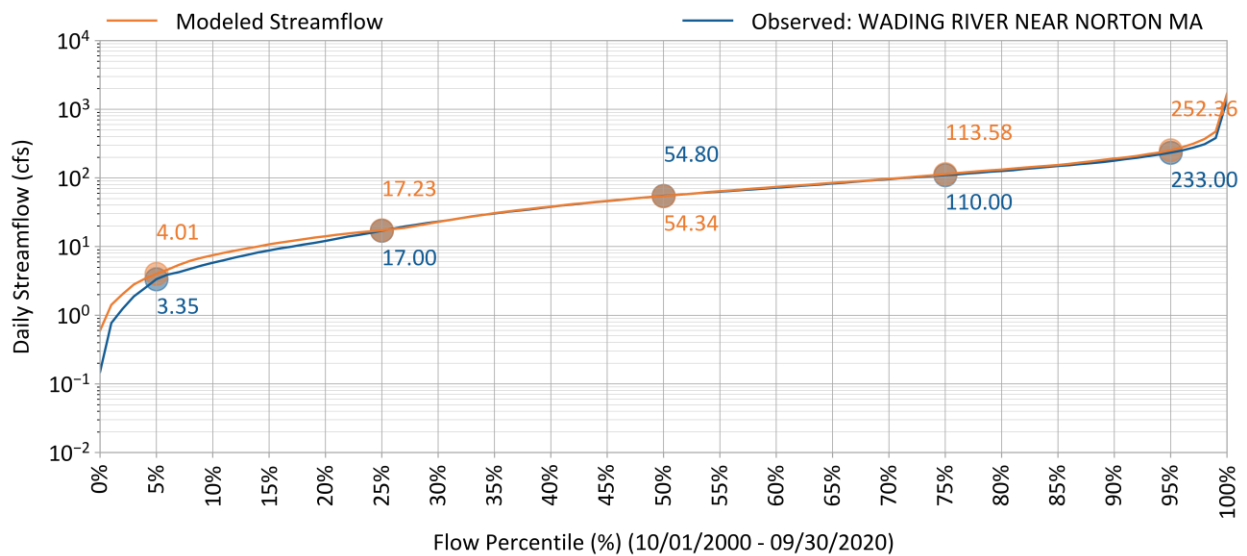


Figure 18. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Simulated vs. observed streamflow duration curves.

Table 7. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Percent bias statistical metric for predicted vs observed volumes.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2000 - 09/30/2020)		Percent Bias (PBIAS)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		-7.3%	-10.3%	20.6%	-40.9%	-30.0%
Highest 10% of Daily Flow Rates		-3.7%	-5.6%	5.2%	-40.8%	-10.4%
Lowest 50% of Daily Flow Rates		-34.4%	-33.0%	42.5%	-47.7%	-94.5%
Days Categorized as Storm Flow		-14.1%	-14.9%	16.0%	-45.3%	-37.3%
Days Categorized as Baseflow		-0.6%	-5.2%	24.0%	-37.0%	-21.6%

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
Percent Bias (PBIAS)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	<5%	5% - 10%	10% - 15%	>15%	Moriiasi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates		<10%	10% - 15%	15% - 25%	>25%	
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Table 8. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: R² statistical metric for predicted vs observed volumes.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2000 - 09/30/2020)		R-Squared (R²)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		0.77	0.79	0.86	0.47	0.76
Highest 10% of Daily Flow Rates		0.64	0.71	0.74	0.17	0.63
Lowest 50% of Daily Flow Rates		0.29	0.09	0.4	0.28	0.46
Days Categorized as Storm Flow		0.77	0.8	0.86	0.45	0.76
Days Categorized as Baseflow		0.78	0.75	0.87	0.52	0.79

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
R-Squared (R ²)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	>0.85	0.75 - 0.85	0.60 - 0.75	≤0.60	Moriiasi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates		>0.75	0.60 - 0.75	0.50 - 0.60	≤0.50	
	Days Categorized as Storm Flow						
Days Categorized as Baseflow							

Table 9. WADING RIVER NEAR NORTON MA (01109000) - Hydrology calibration: Nash-Sutcliffe efficiency statistical metric for predicted vs observed flow rates.

		Observed vs Simulated Calibration Performance for Flow Rates (Simulated vs Observed Flow Rates for Condition-Season across Simulation)				
Calibration Metrics (10/01/2000 - 09/30/2020)		Nash-Sutcliffe Efficiency (E)				
		All Seasons	Winter	Spring	Summer	Fall
All Conditions		0.67	0.69	0.78	-1.1	0.53
Highest 10% of Daily Flow Rates		0.11	0.44	0.4	-68.53	-0.85
Lowest 50% of Daily Flow Rates		-1.46	-6.31	-0.66	-2.88	-3.09
Days Categorized as Storm Flow		0.61	0.68	0.77	-1.59	0.42
Days Categorized as Baseflow		0.75	0.68	0.77	-0.46	0.71

Performance Metric	Hydrological Condition	Comparison Type	Performance Threshold for Hydrology Simulation				Reference
			Very Good	Good	Satisfactory	Unsatisfactory	
Nash-Sutcliffe Efficiency (E)	All Conditions	Compare All Observed vs Simulated Daily Flow Rates that Occur During Selected Season-Conditions	>0.80	0.70 - 0.80	0.50 - 0.70	≤0.50	Moriasi et al. (2015)
	Seasonal Flows						
	Highest 10% of Daily Flow Rates						
	Lowest 50% of Daily Flow Rates						
	Days Categorized as Storm Flow						
	Days Categorized as Baseflow						