



Lake Superior North and Lake Superior South Basins

Watershed Model Development - Draft Report

Appendices A, B, and C

Prepared for
Minnesota Pollution Control Agency

Prepared by



One Park Drive, Suite 200 • PO Box 14409
Research Triangle Park, NC 27709

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Appendix A. Detailed Snow Calibration Results

WEATHER REGION 1

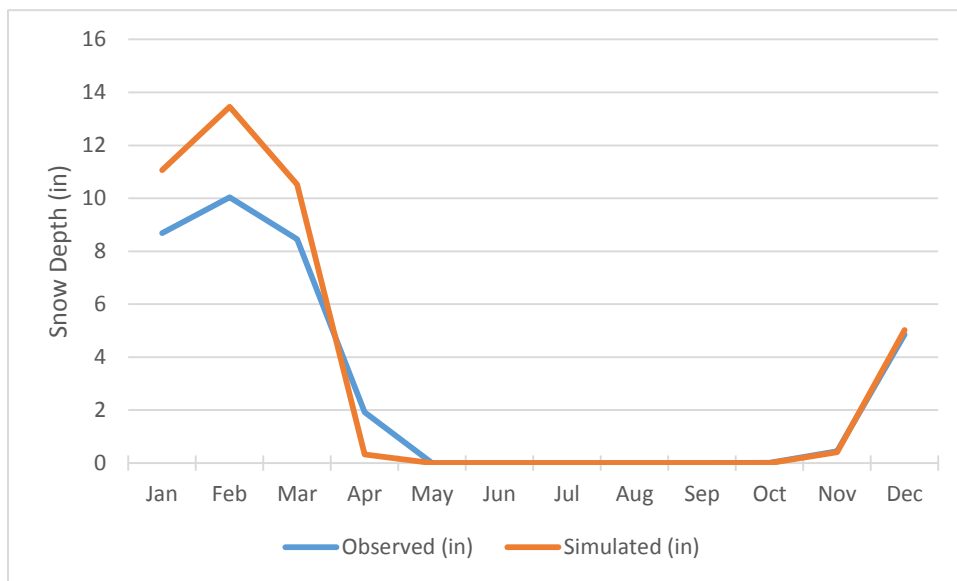


Figure 1. Mean monthly snow depth for weather region 1

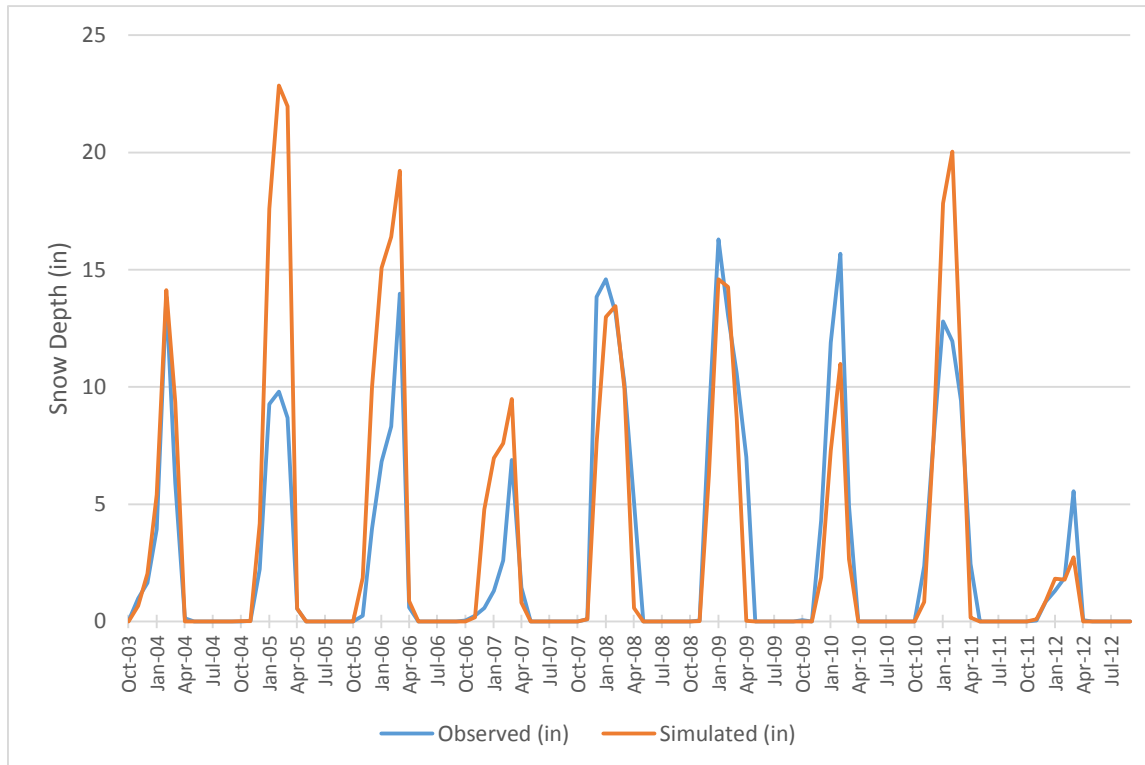


Figure 2. Mean monthly snow depth time-series for weather region 1

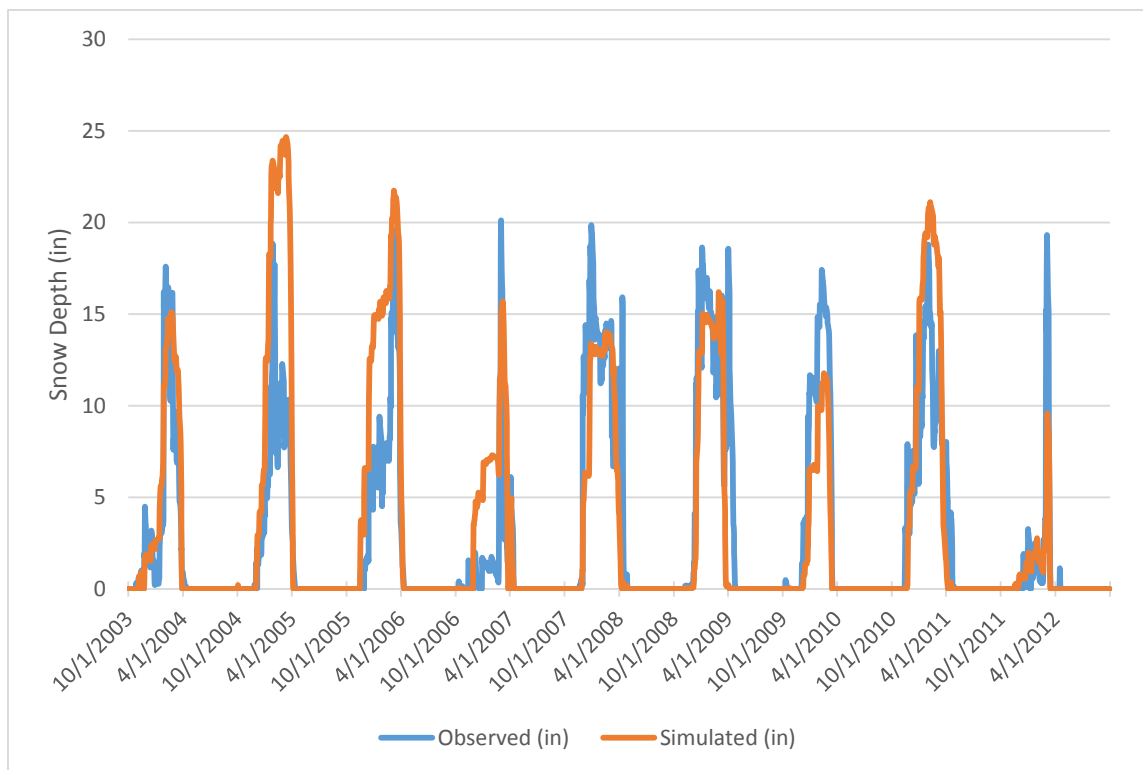


Figure 3. Mean daily snow depth time-series for weather region 1

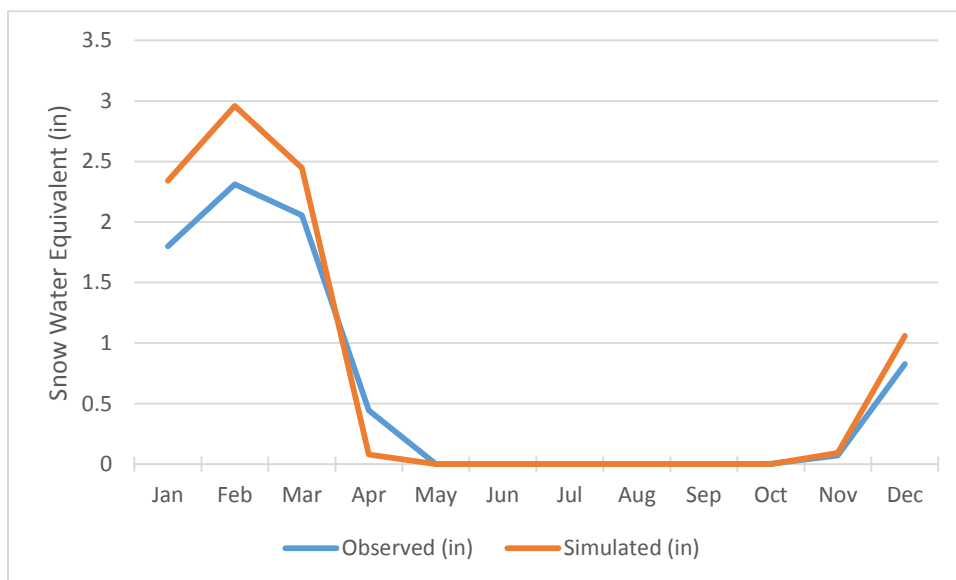


Figure 4. Mean monthly snow water equivalent for weather region 1

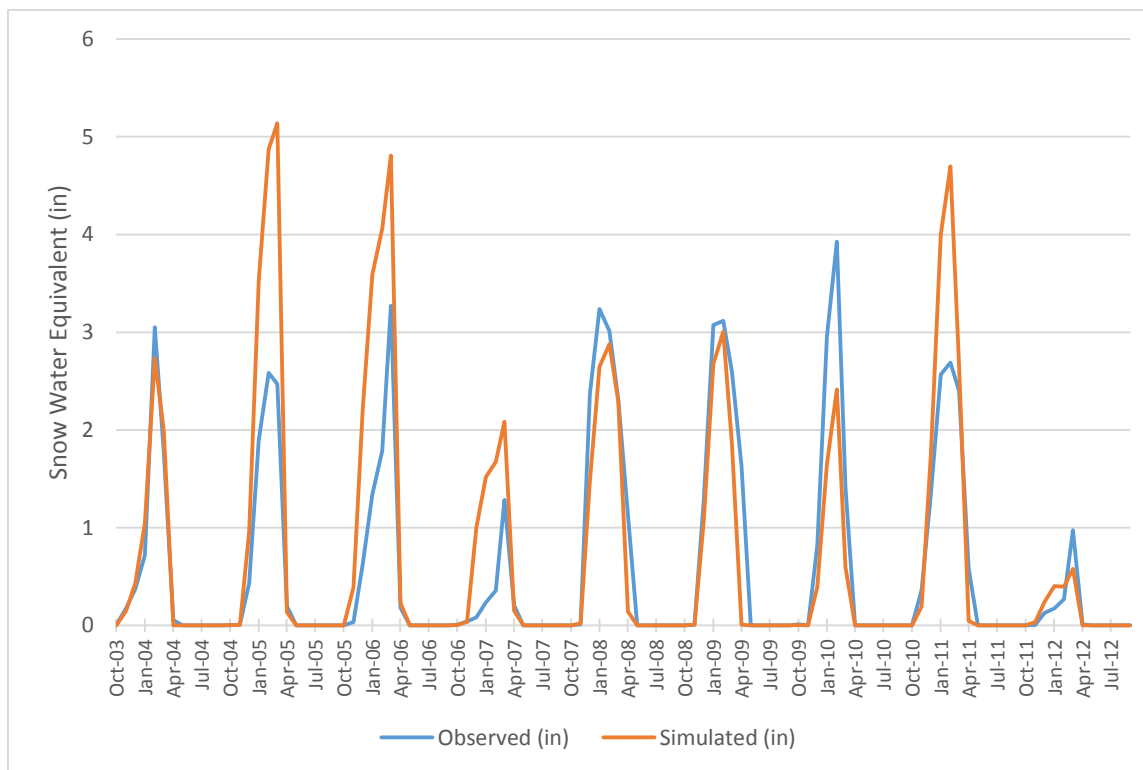


Figure 5. Mean monthly snow water equivalent time-series for weather region 1

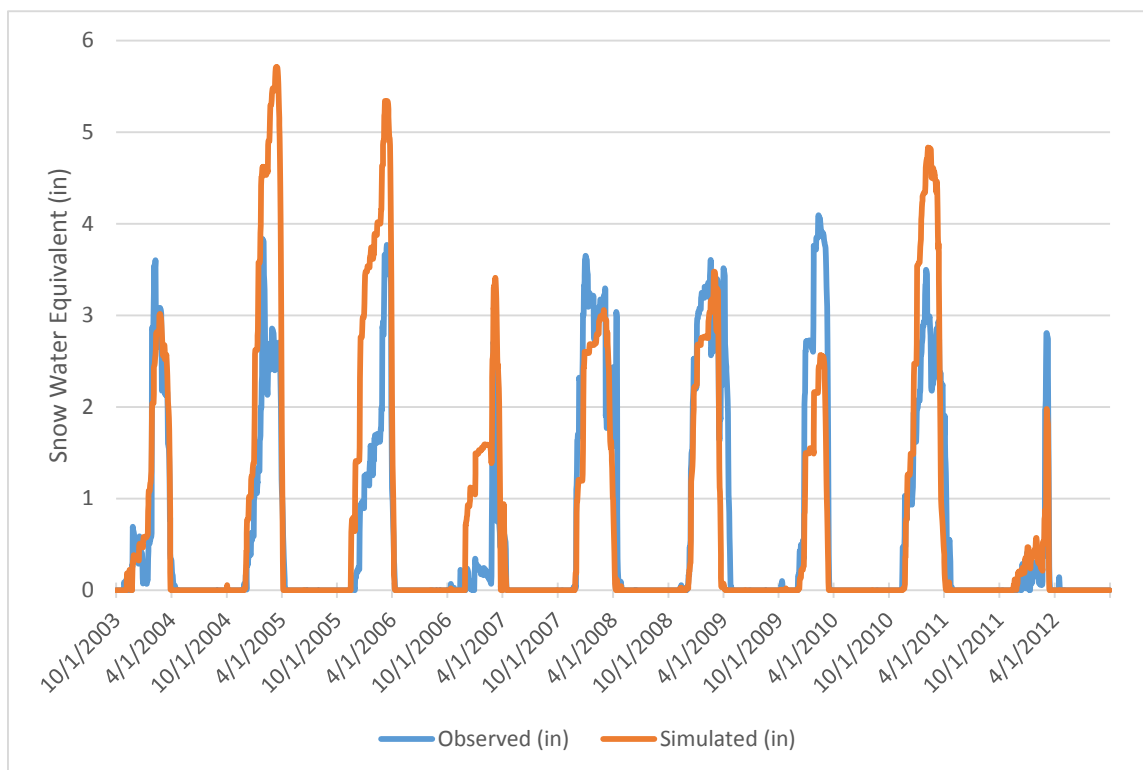


Figure 6. Mean daily snow water equivalent time-series for weather region 1

WEATHER REGION 2

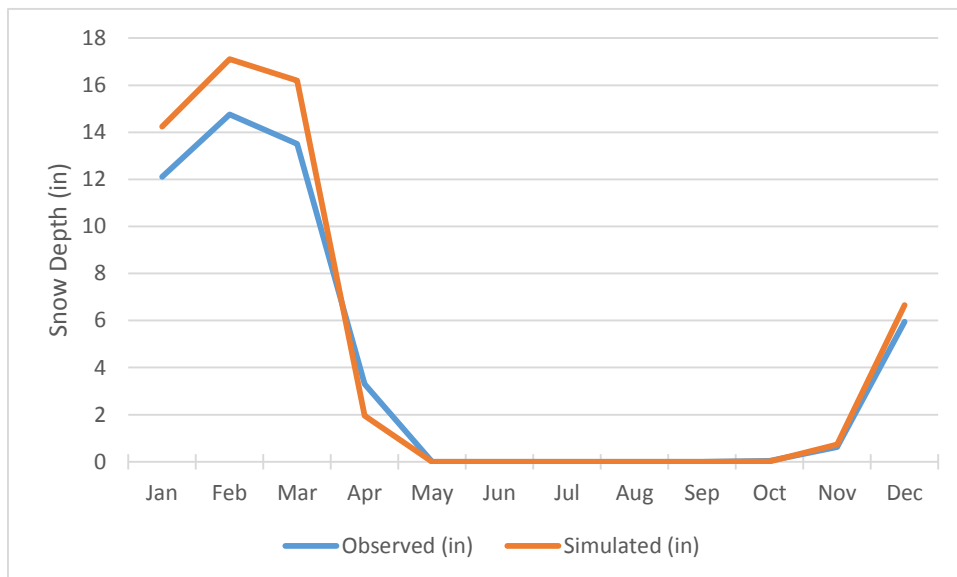


Figure 7. Mean monthly snow depth for weather region 2

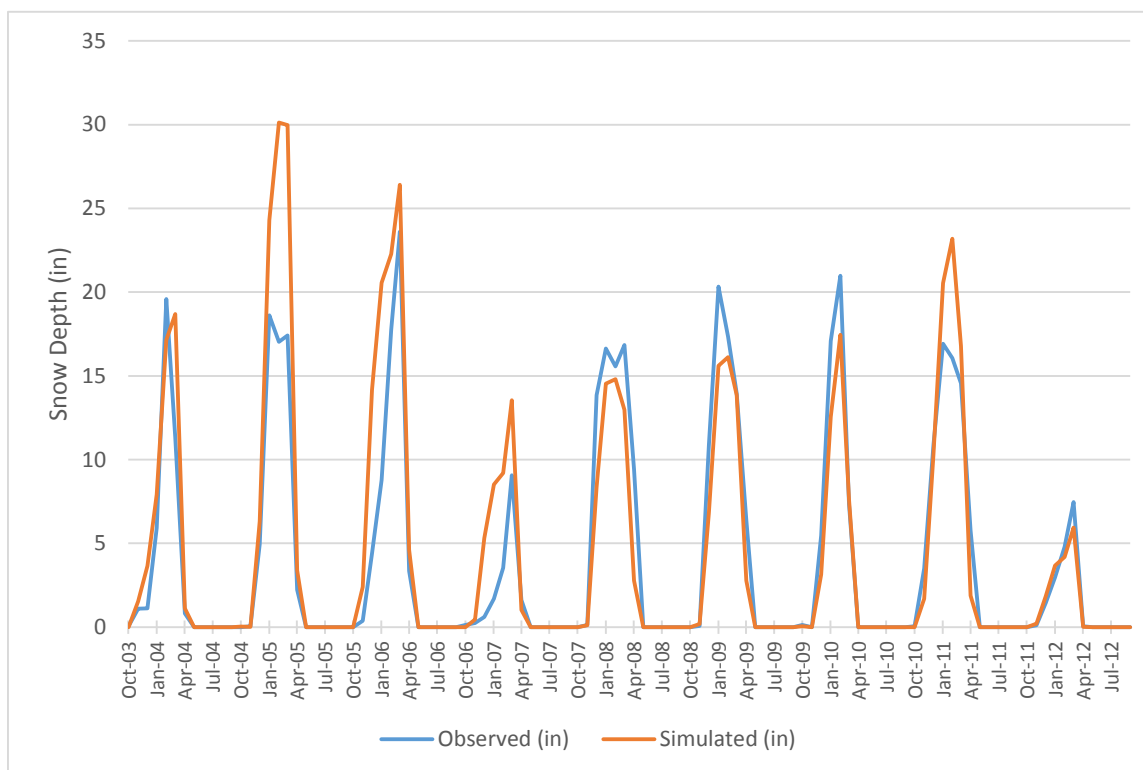


Figure 8. Mean monthly snow depth time-series for weather region 2

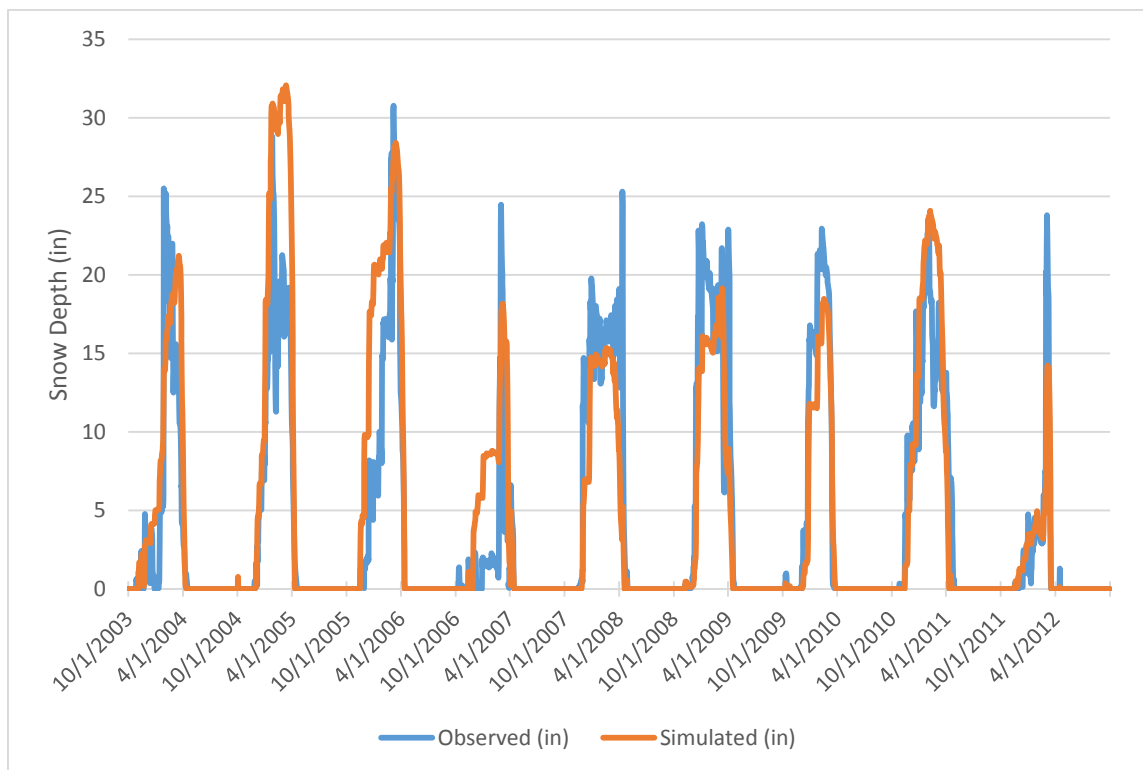


Figure 9. Mean daily snow depth time-series for weather region 2

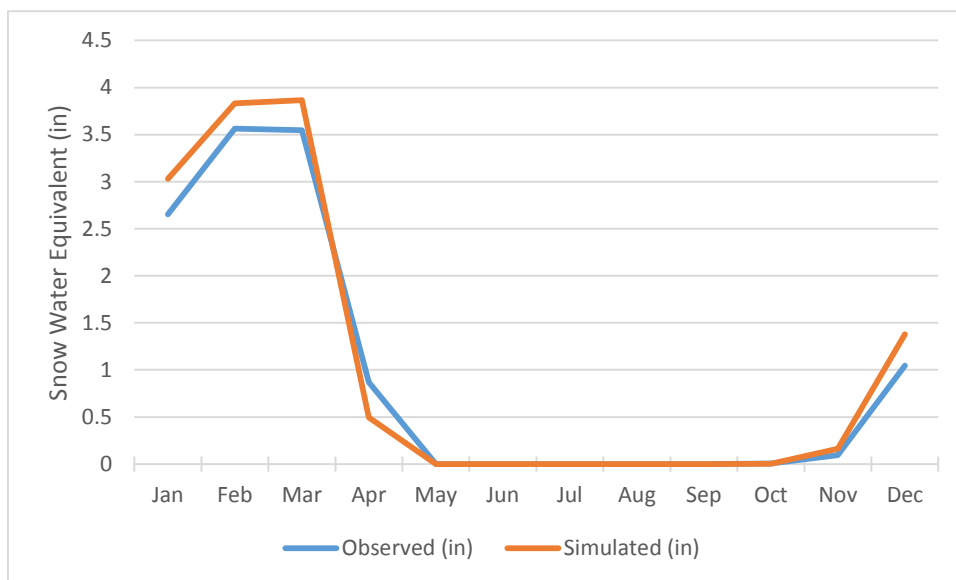


Figure 10. Mean monthly snow water equivalent for weather region 2

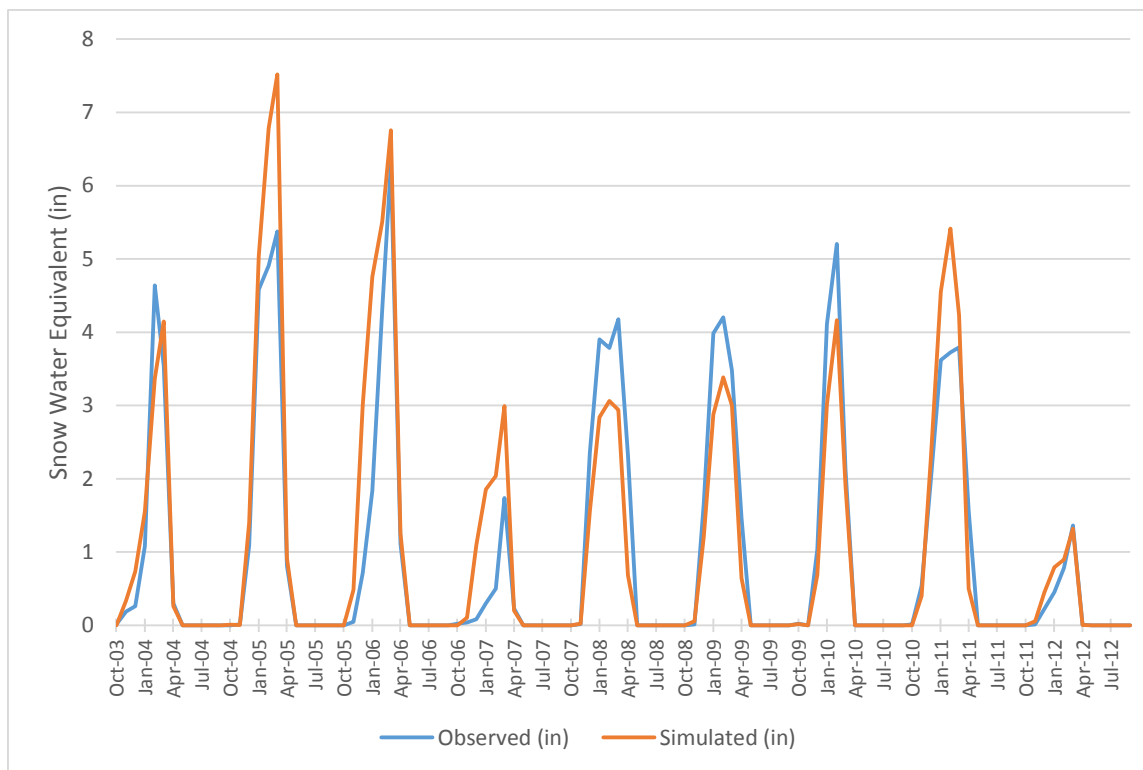


Figure 11. Mean monthly snow water equivalent time-series for weather region 2

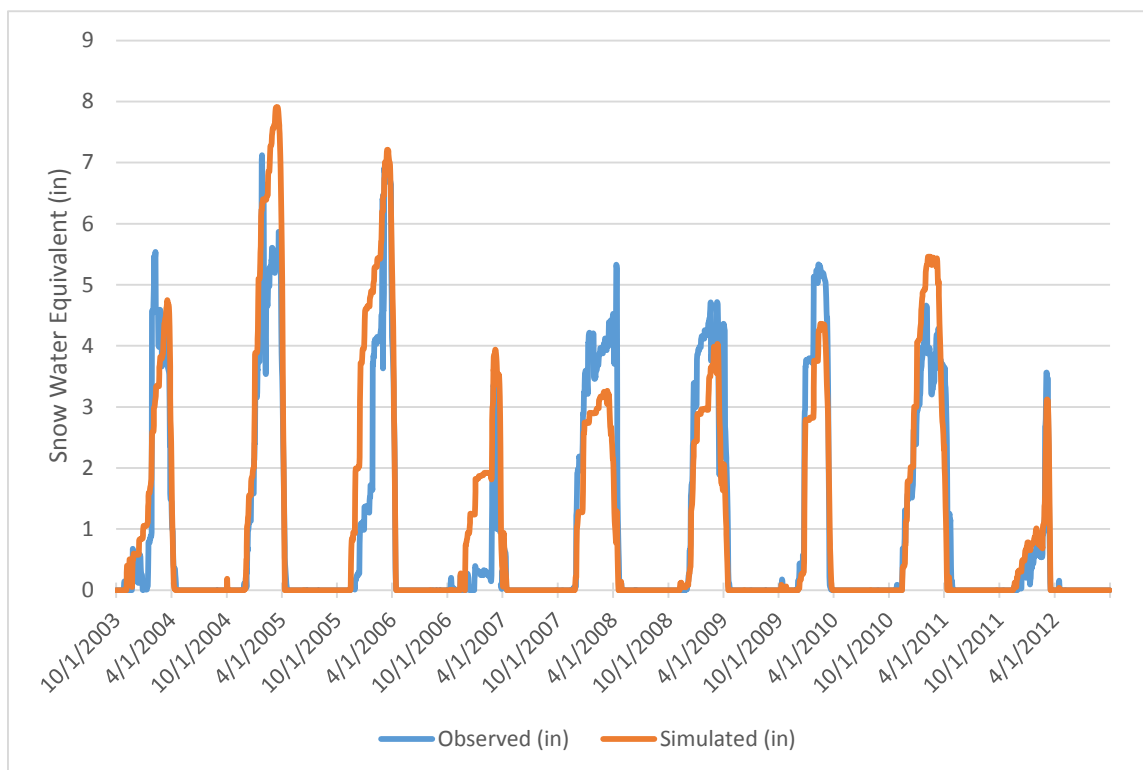


Figure 12. Mean daily snow water equivalent time-series for weather region 2

WEATHER REGION 3

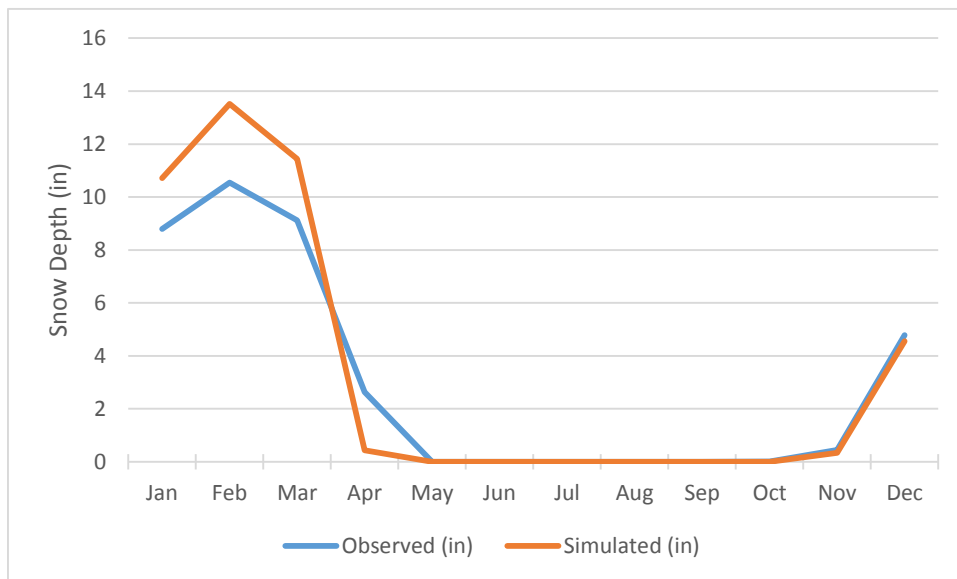


Figure 13. Mean monthly snow depth for weather region 3

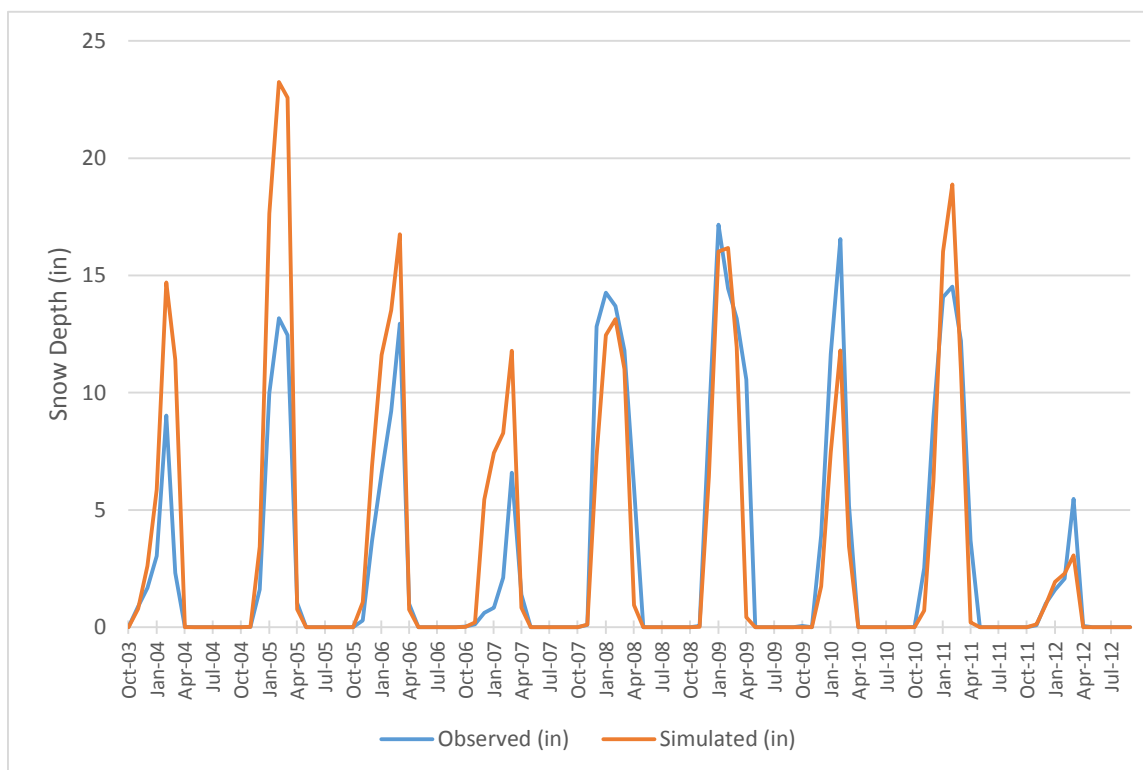


Figure 14. Mean monthly snow depth time-series for weather region 3

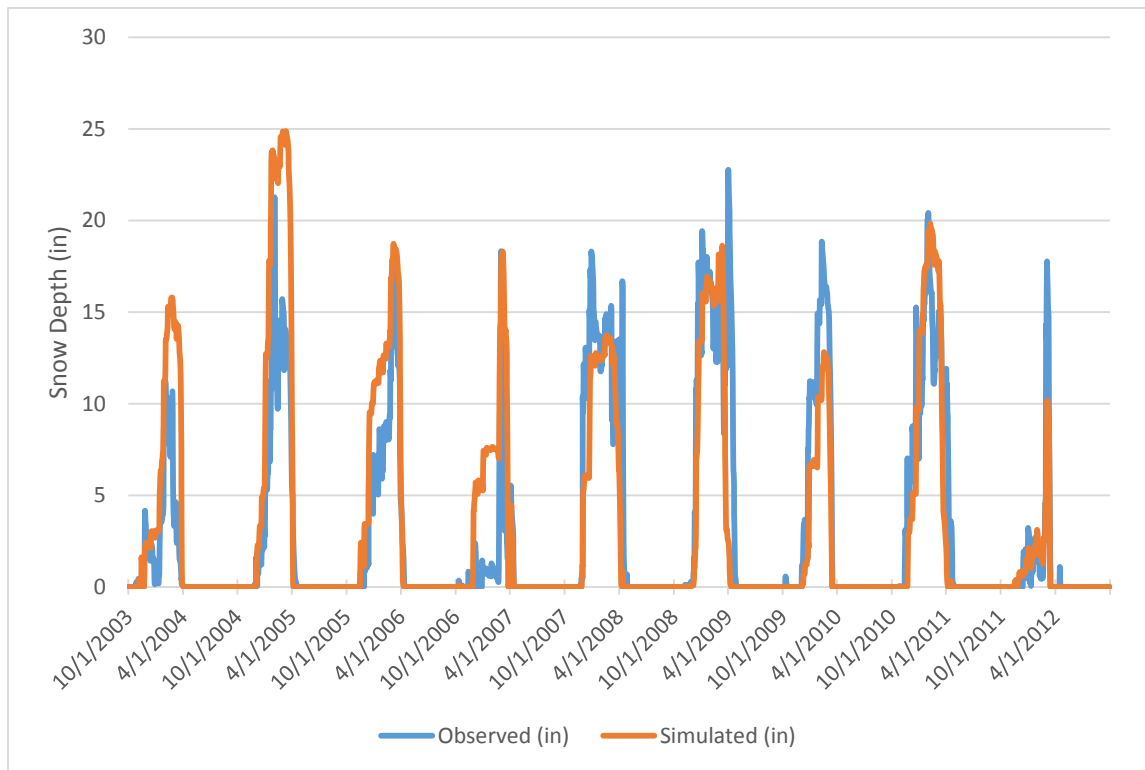


Figure 15. Mean daily snow depth time-series for weather region 3

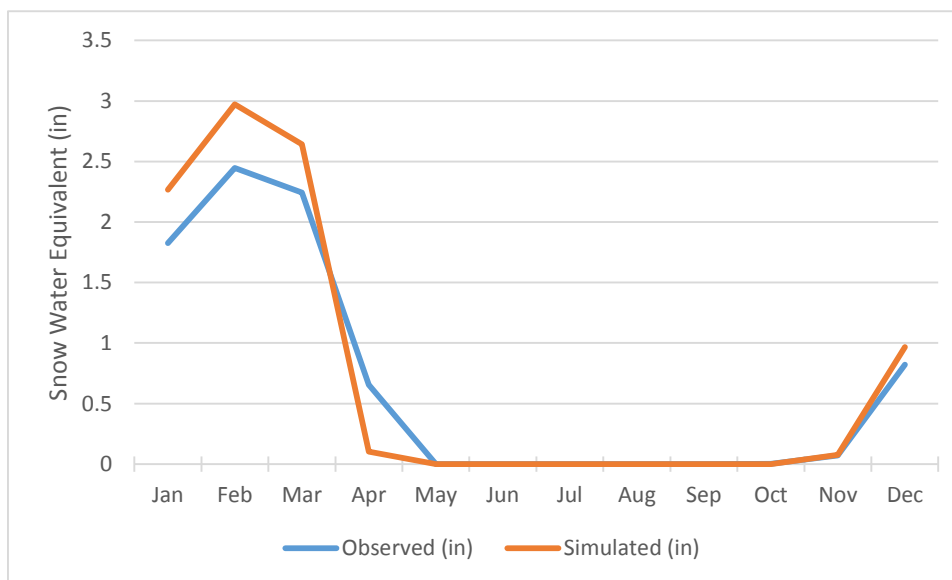


Figure 16. Mean monthly snow water equivalent for weather region 3

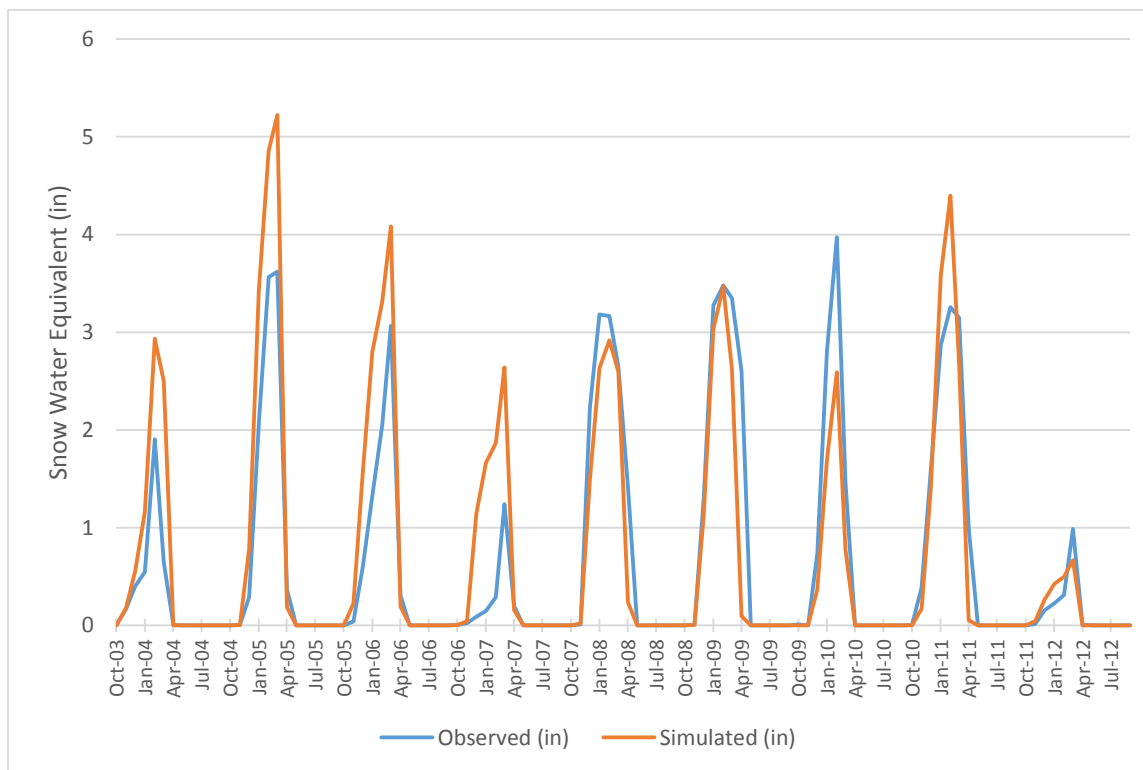


Figure 17. Mean monthly snow water equivalent time-series for weather region 3

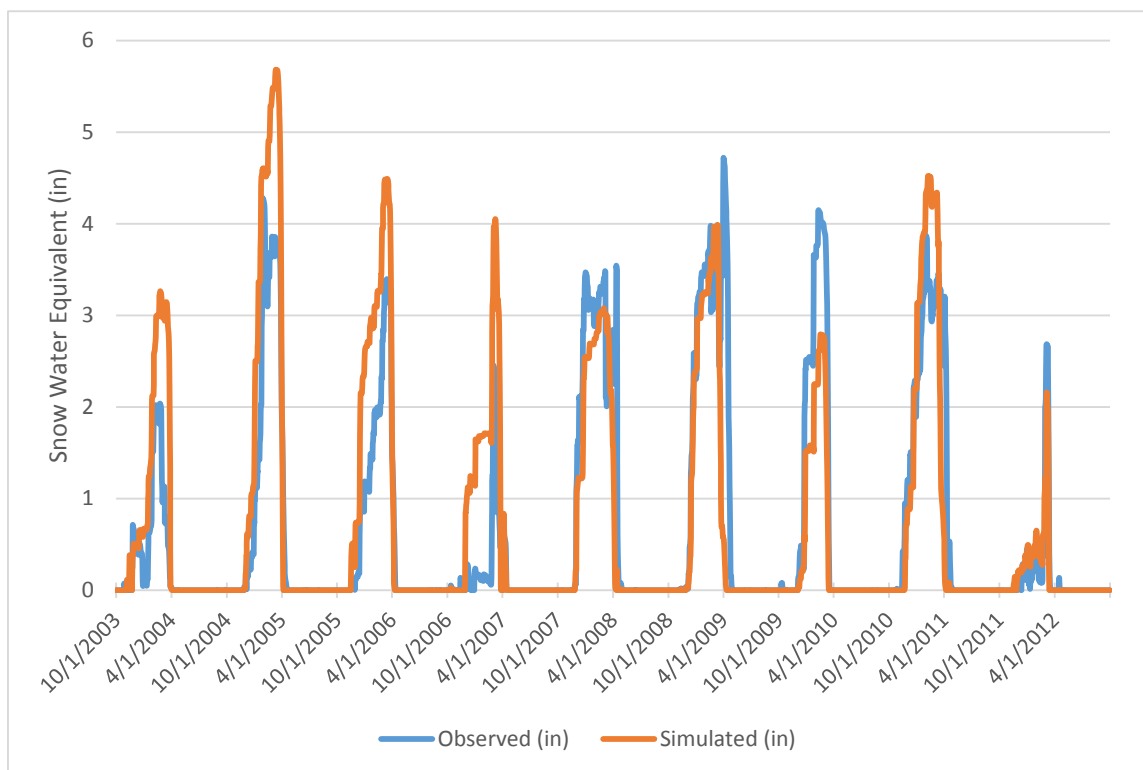


Figure 18. Mean daily snow water equivalent time-series for weather region 3

WEATHER REGION 4

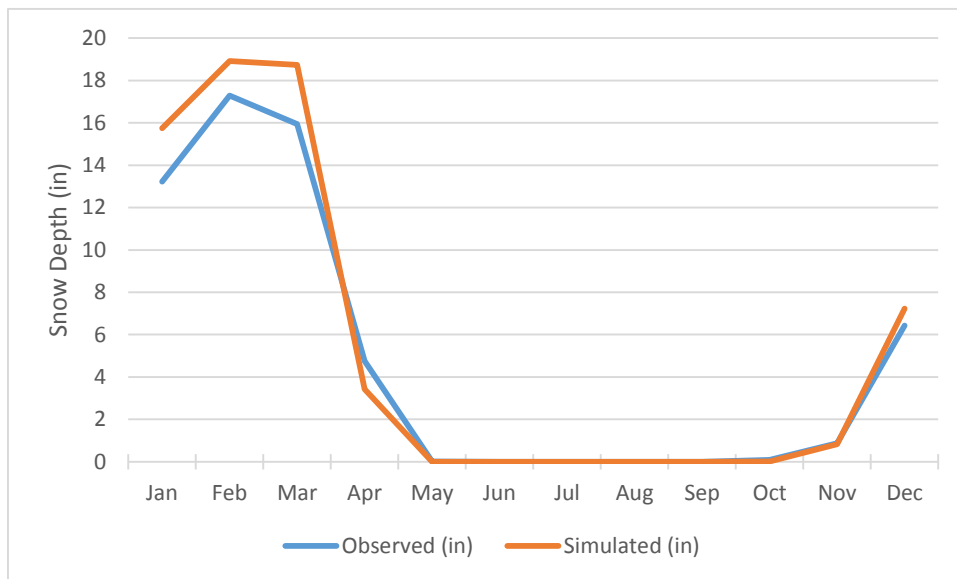


Figure 19. Mean monthly snow depth for weather region 4

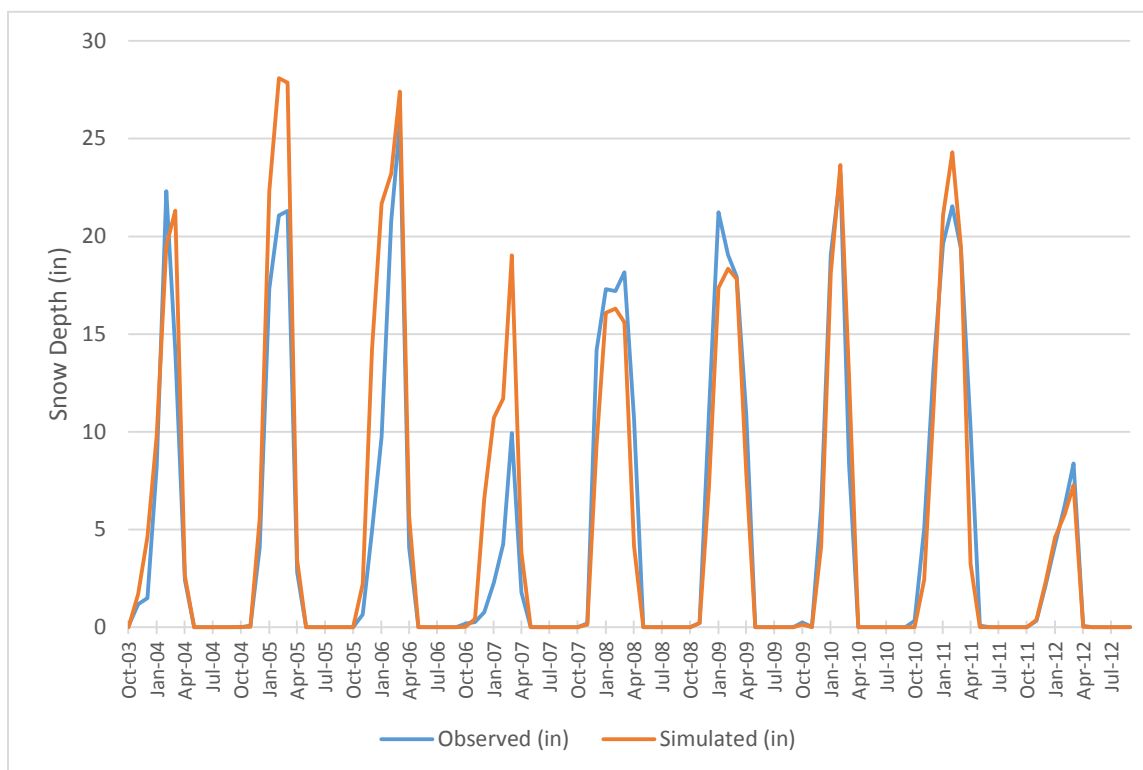


Figure 20. Mean monthly snow depth time-series for weather region 4

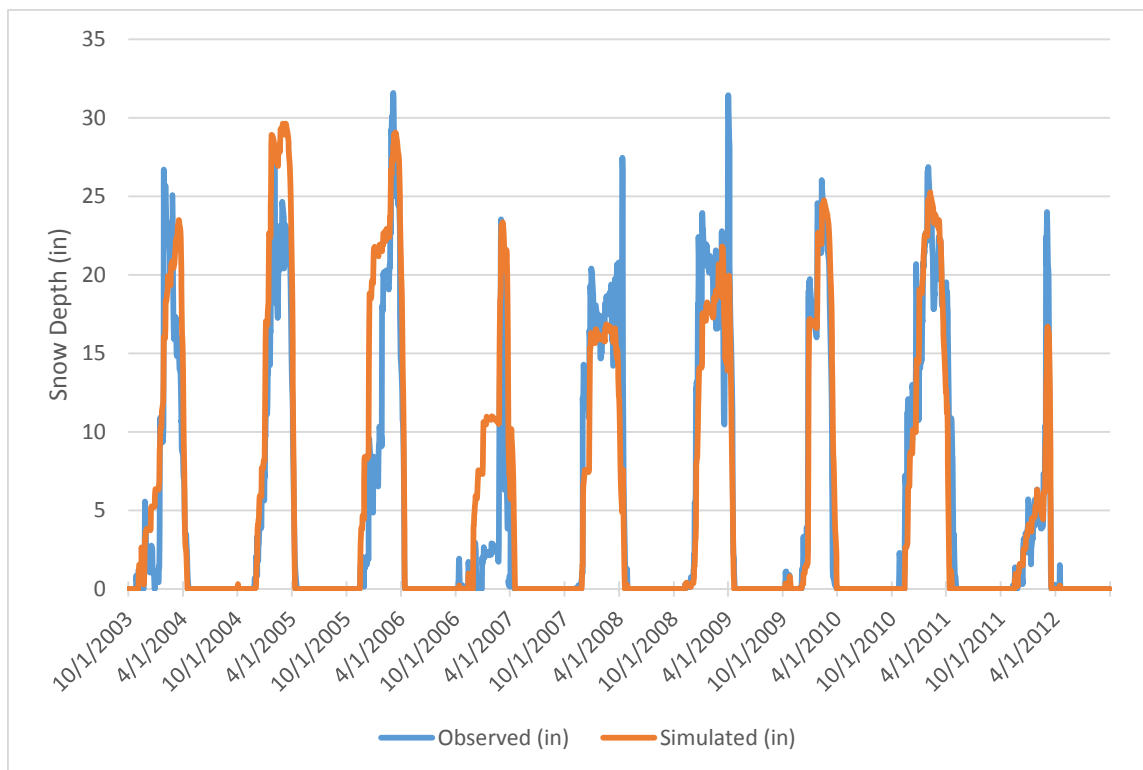


Figure 21. Mean daily snow depth time-series for weather region 4

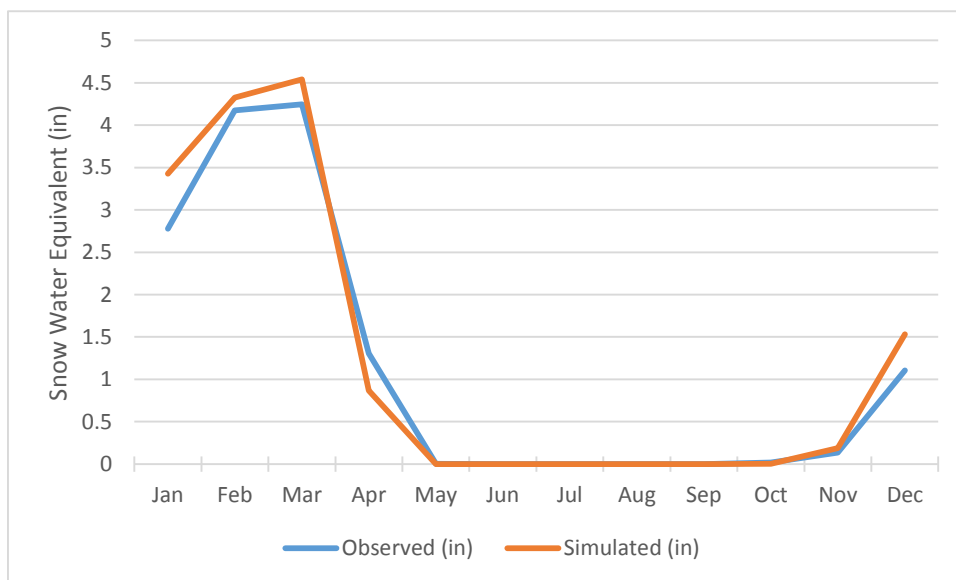


Figure 22. Mean monthly snow water equivalent for weather region 4

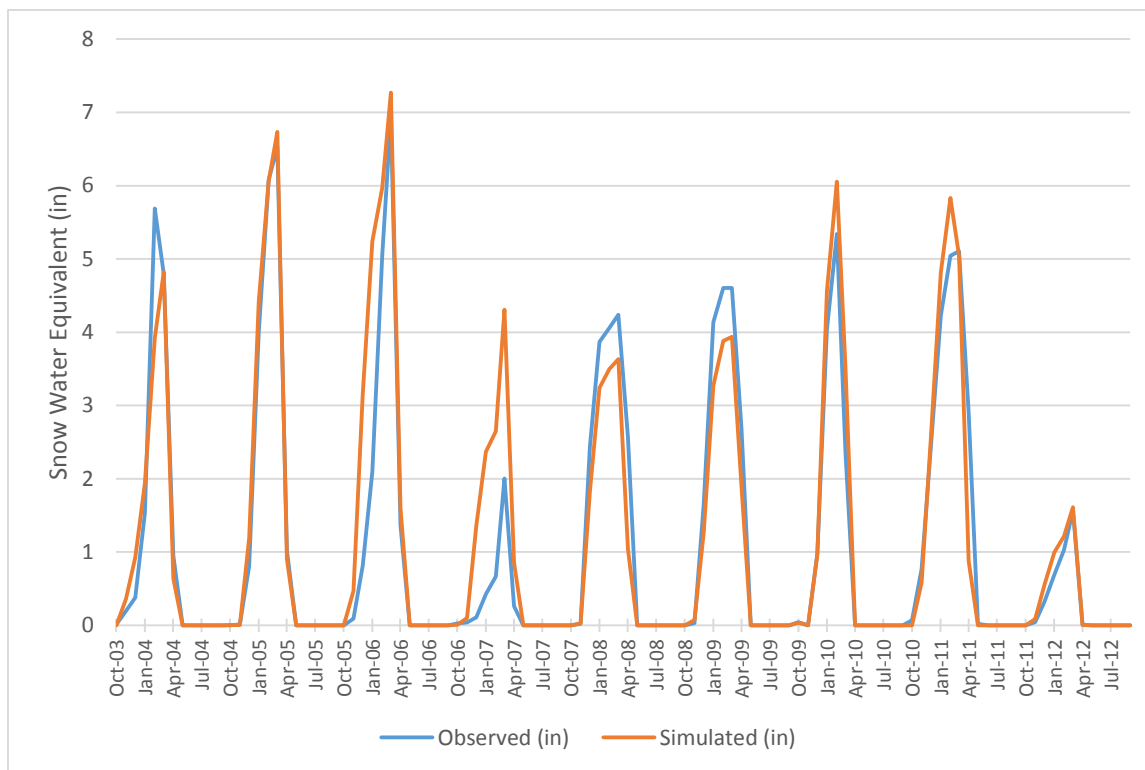


Figure 23. Mean monthly snow water equivalent time-series for weather region 4

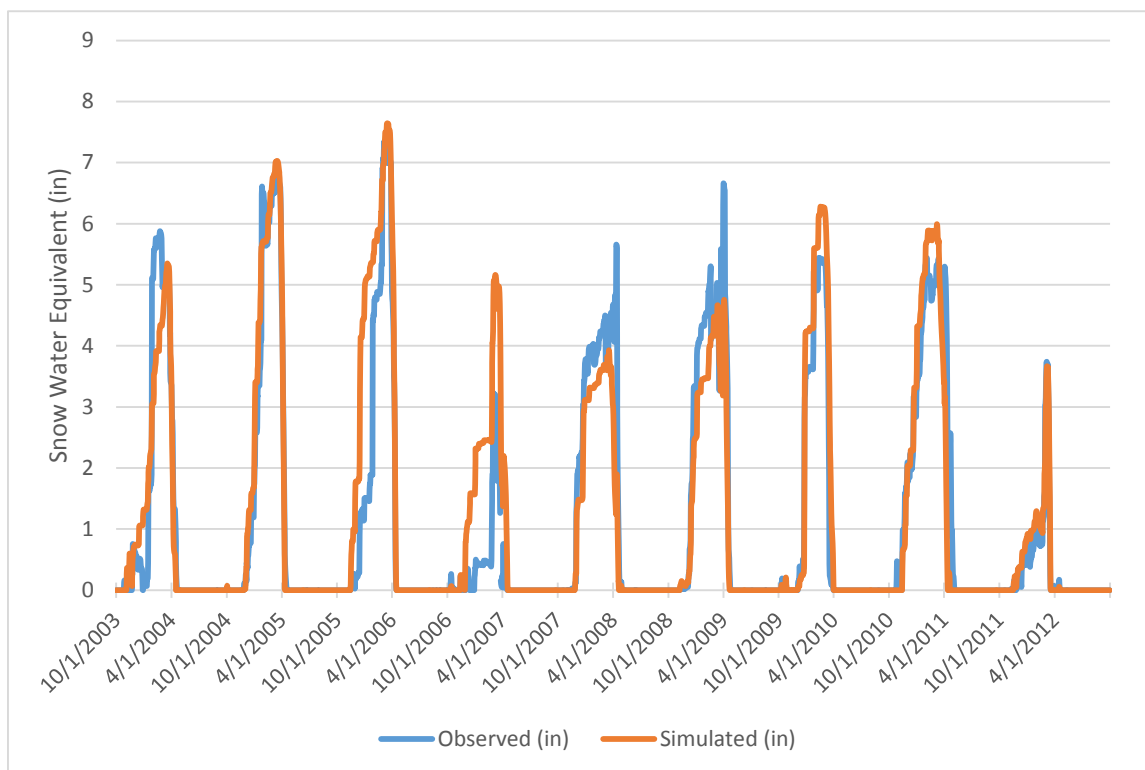


Figure 24. Mean daily snow water equivalent time-series for weather region 4

WEATHER REGION 5

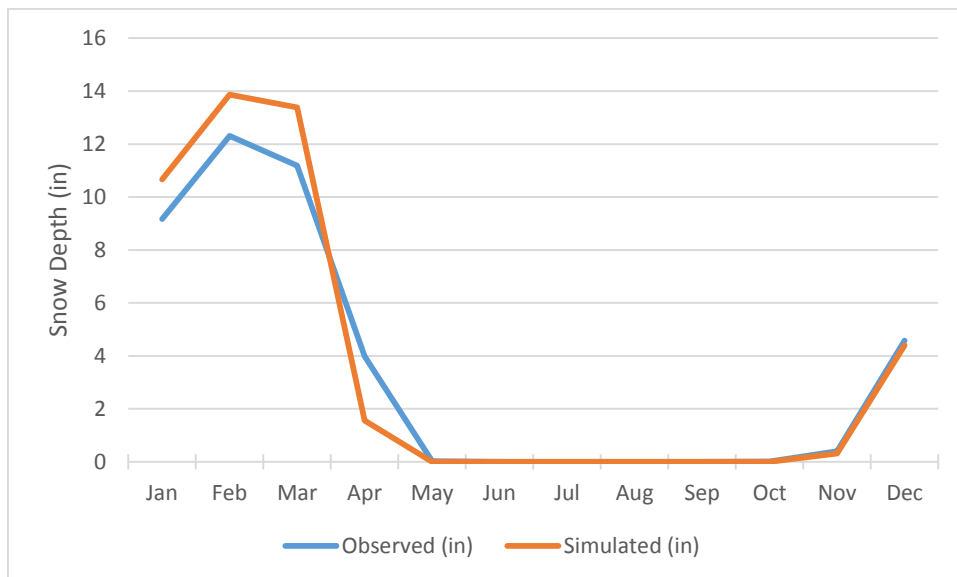


Figure 25. Mean monthly snow depth for weather region 5

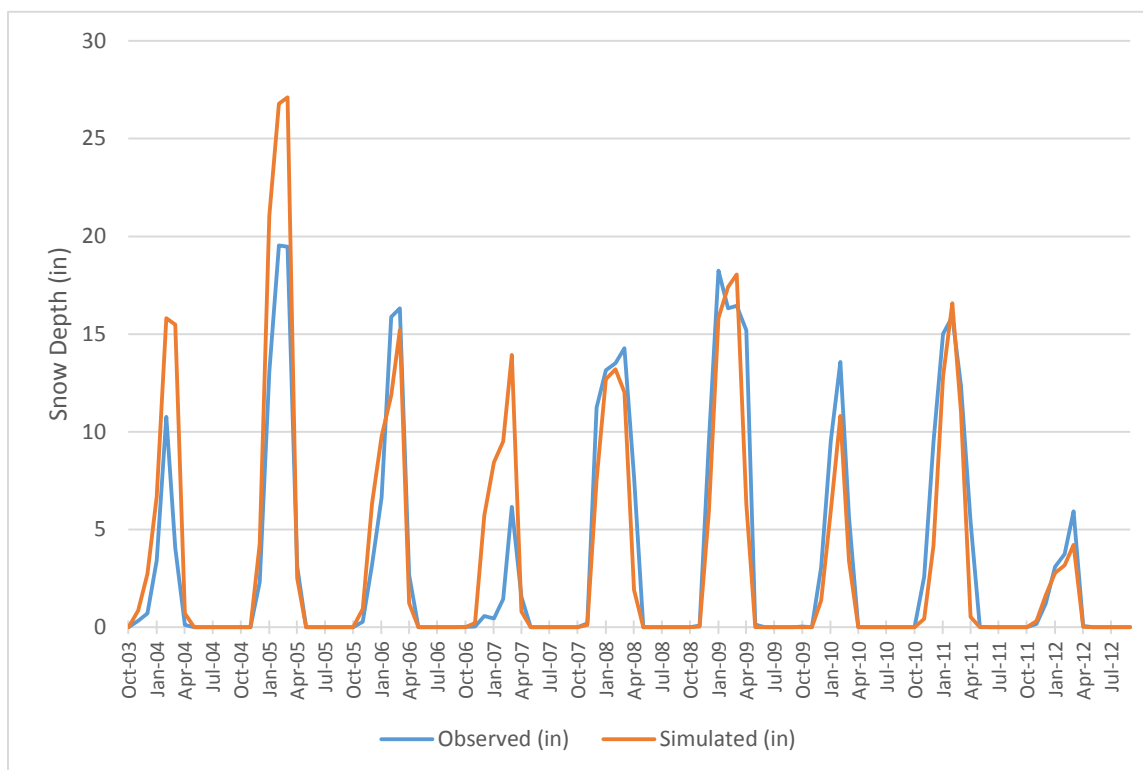


Figure 26. Mean monthly snow depth time-series for weather region 5

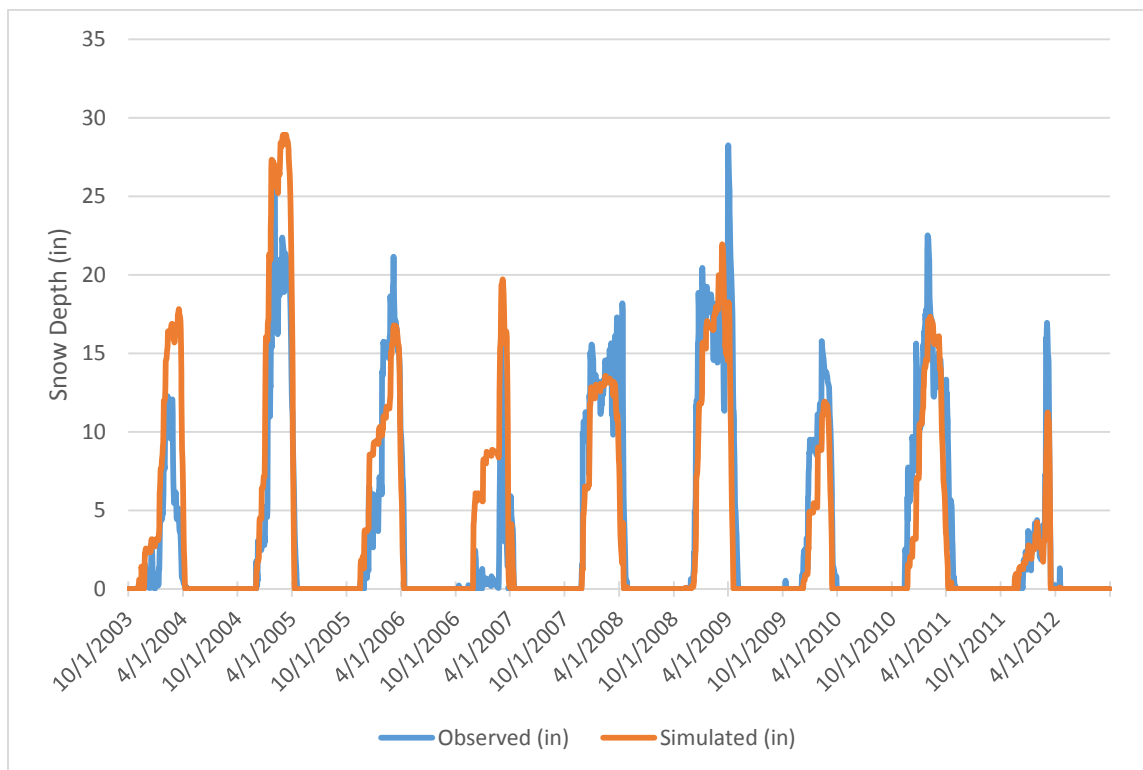


Figure 27. Mean daily snow depth time-series for weather region 5

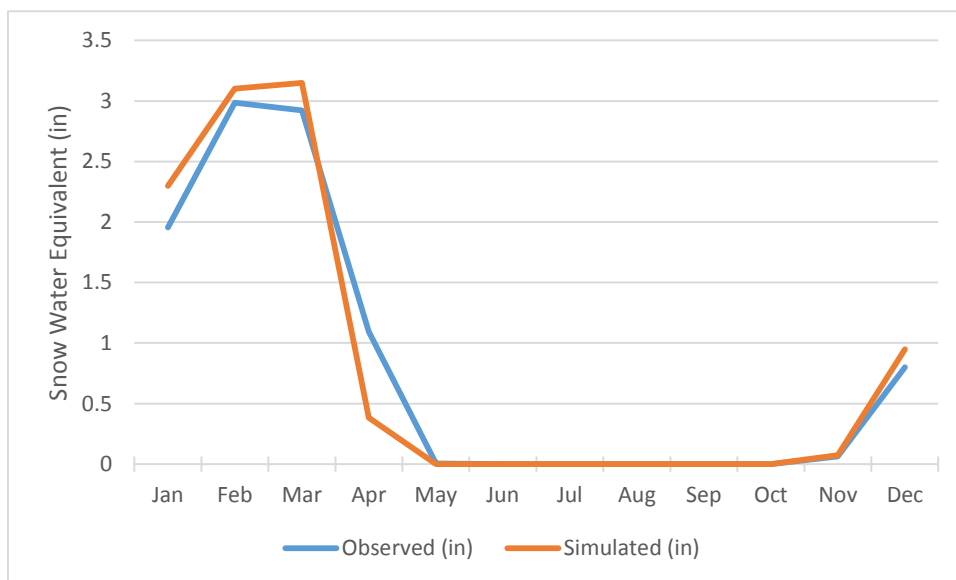


Figure 28. Mean monthly snow water equivalent for weather region 5

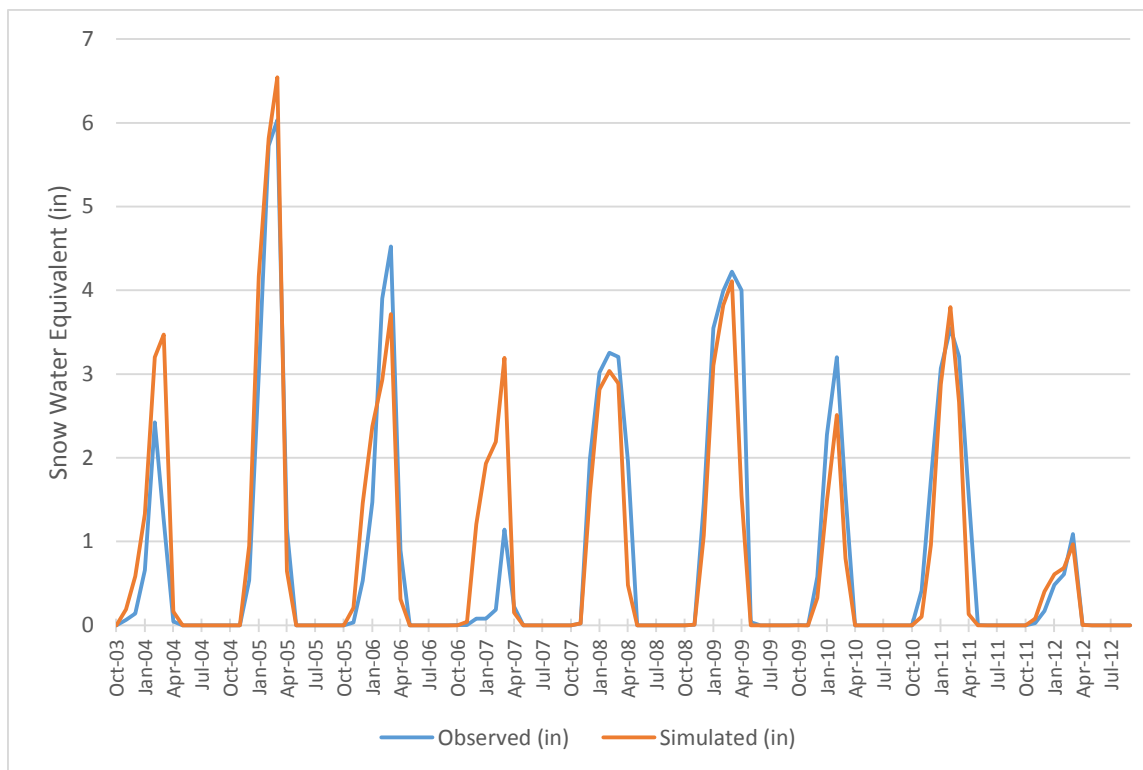


Figure 29. Mean monthly snow water equivalent time-series for weather region 5

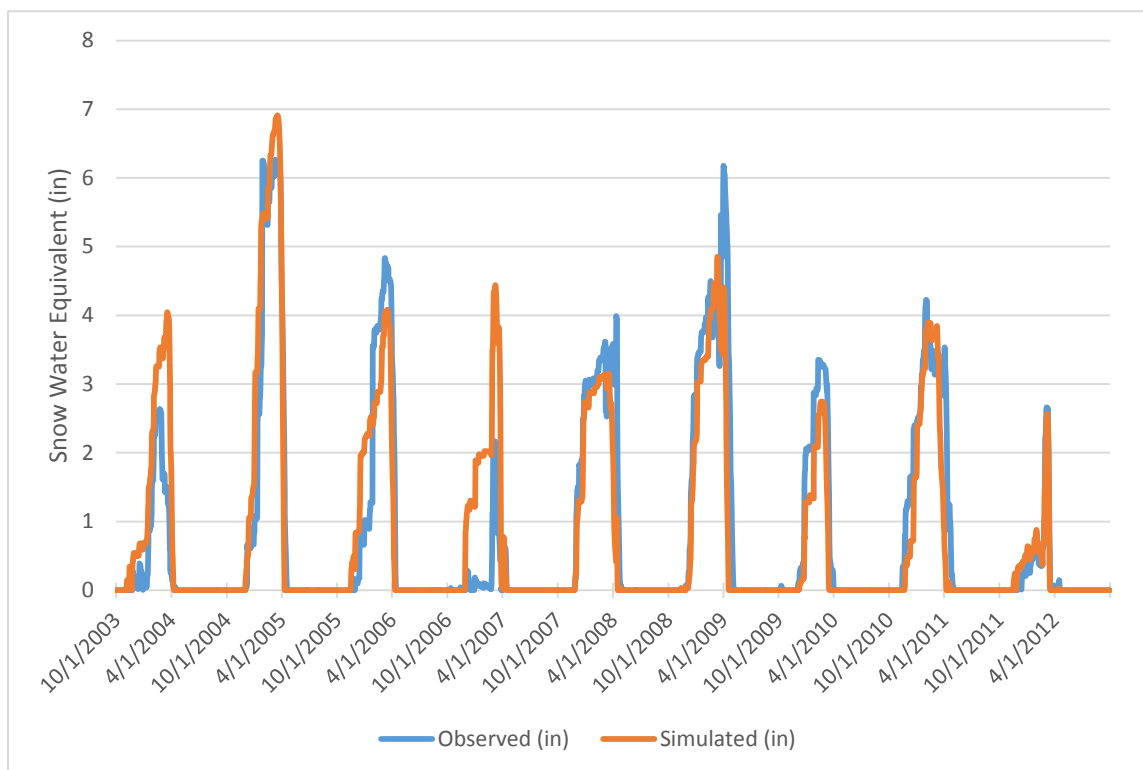


Figure 30. Mean daily snow water equivalent time-series for weather region 5

WEATHER REGION 6

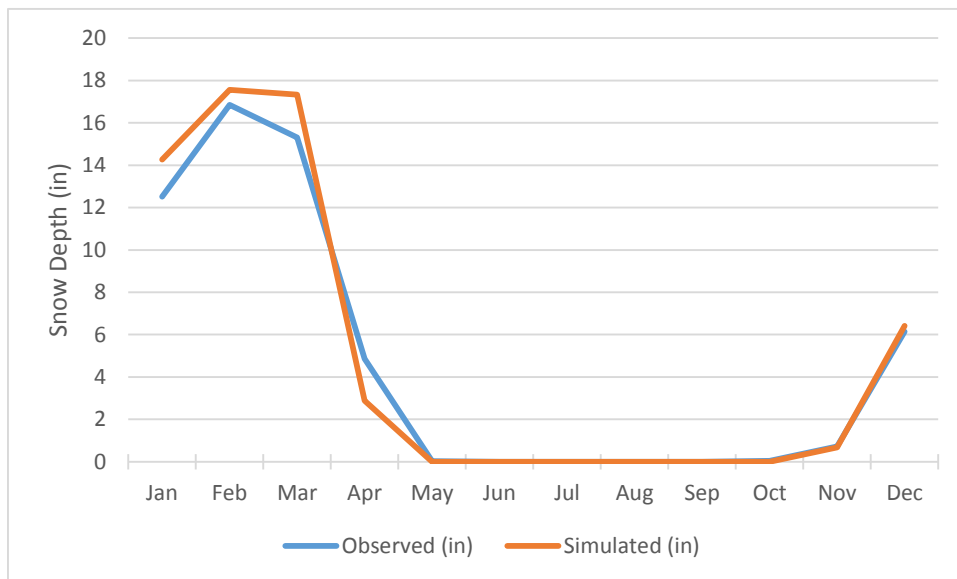


Figure 31. Mean monthly snow depth for weather region 6

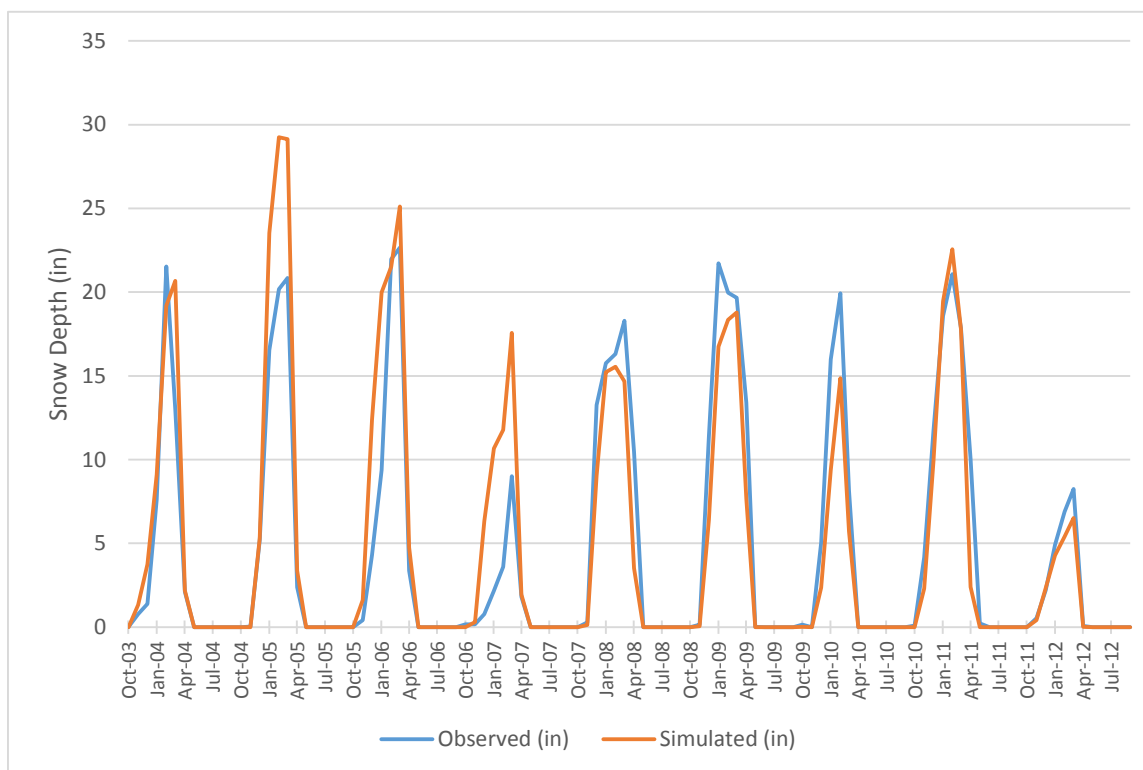


Figure 32. Mean monthly snow depth time-series for weather region 6

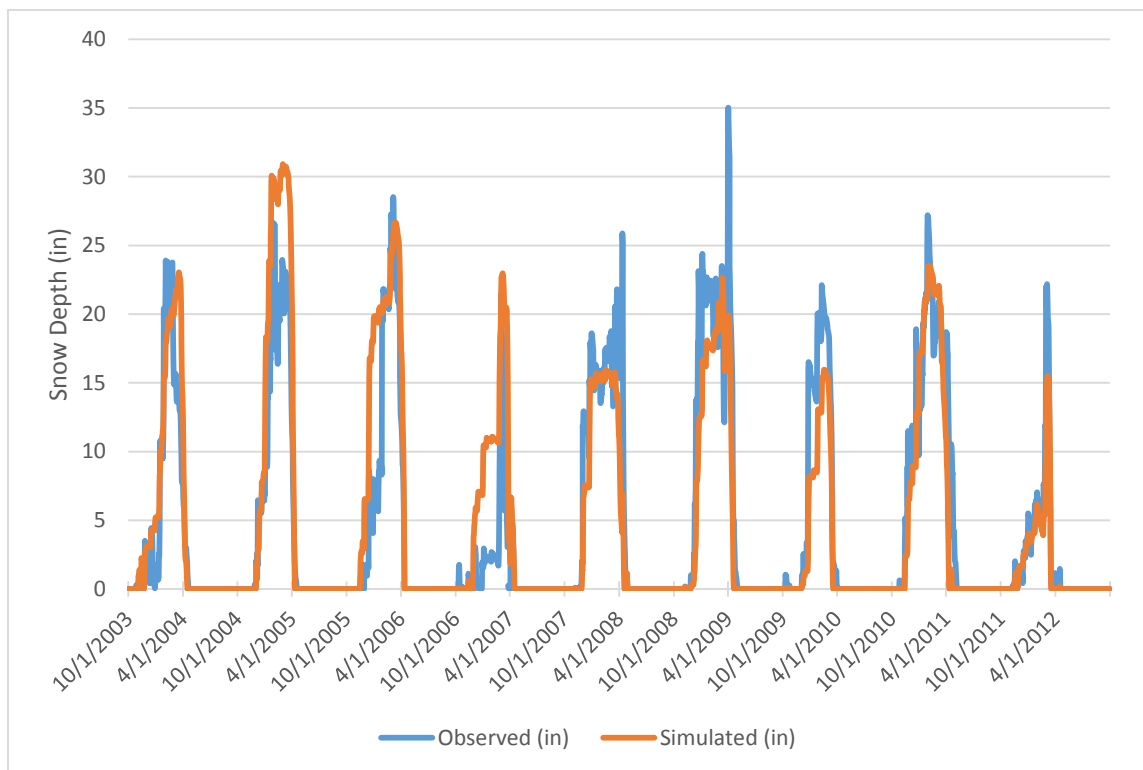


Figure 33. Mean daily snow depth time-series for weather region 6

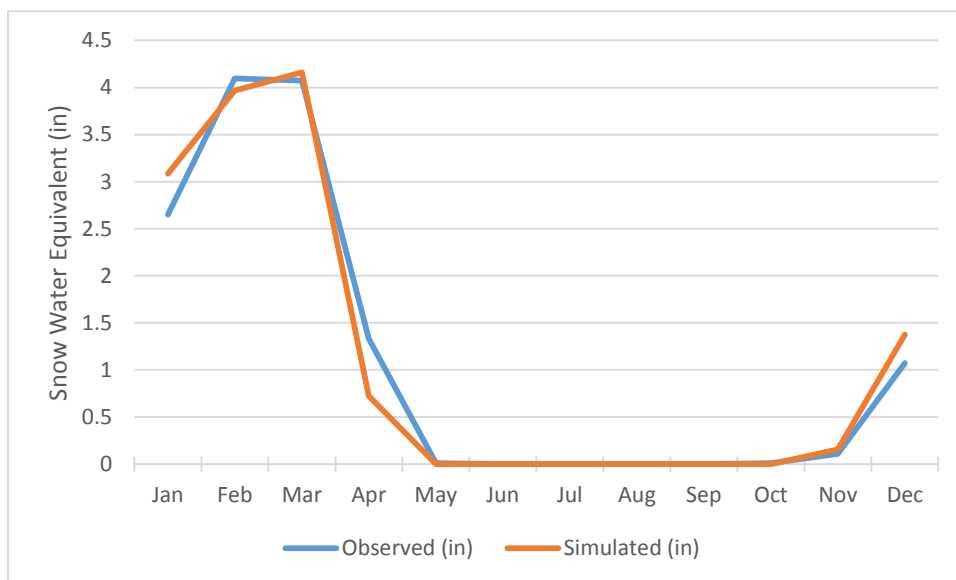


Figure 34. Mean monthly snow water equivalent for weather region 6

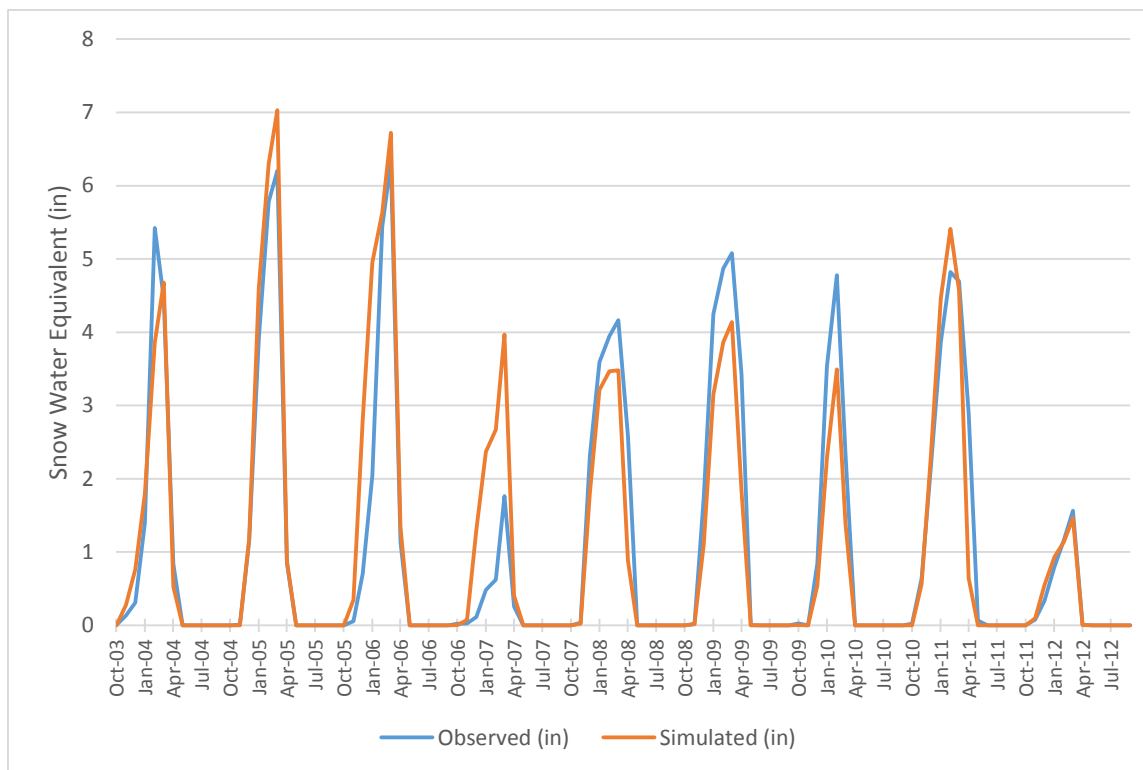


Figure 35. Mean monthly snow water equivalent time-series for weather region 6

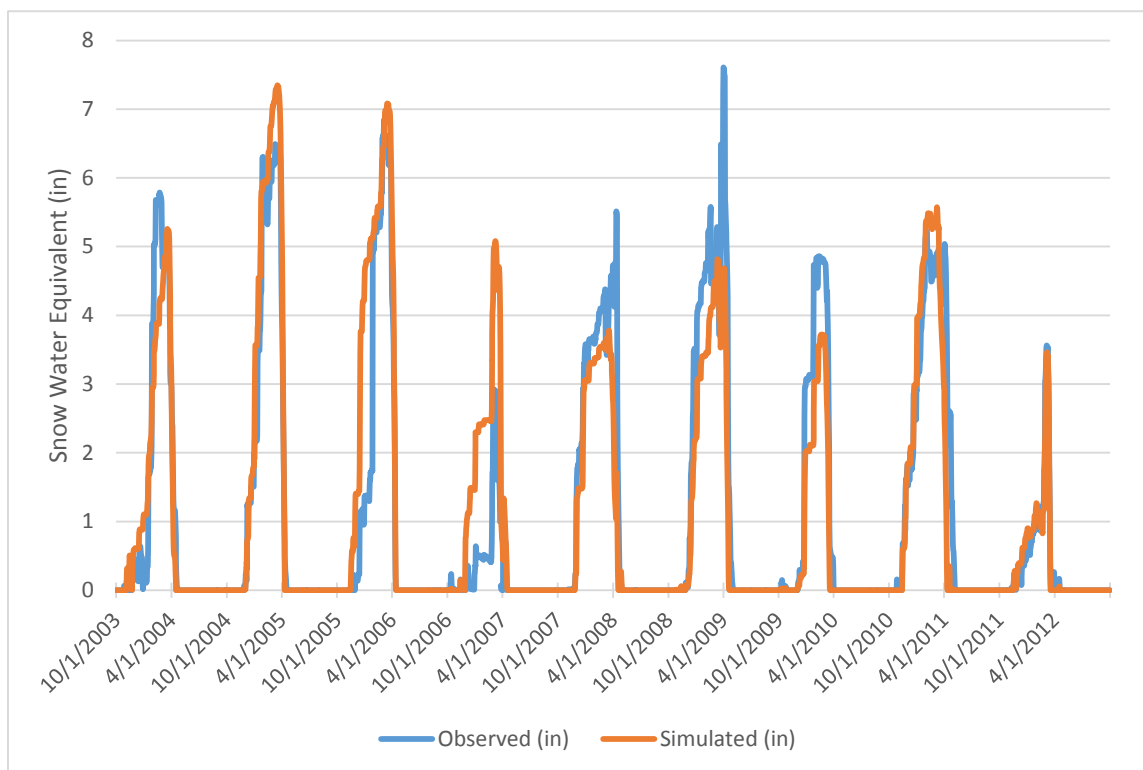


Figure 36. Mean daily snow water equivalent time-series for weather region 6

WEATHER REGION 7

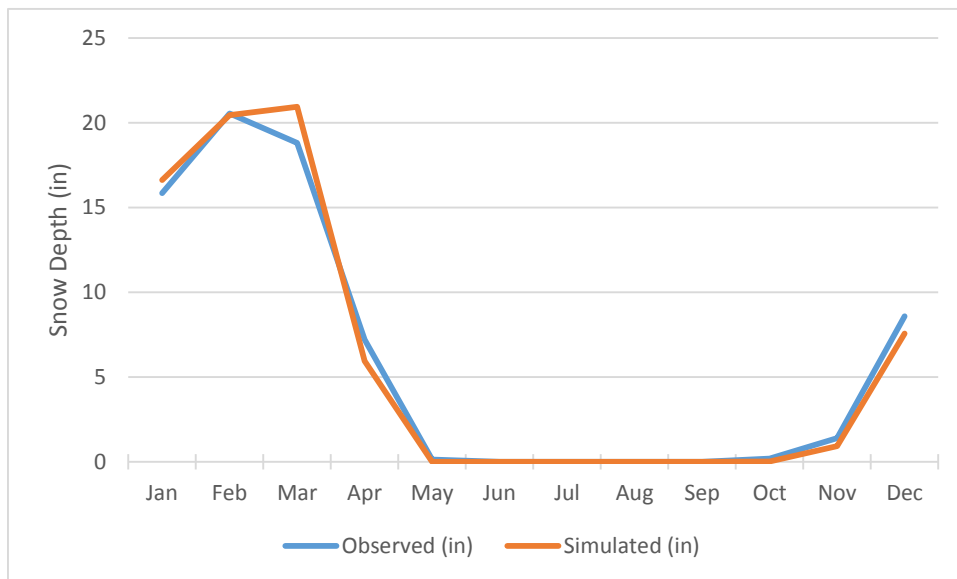


Figure 37. Mean monthly snow depth for weather region 7

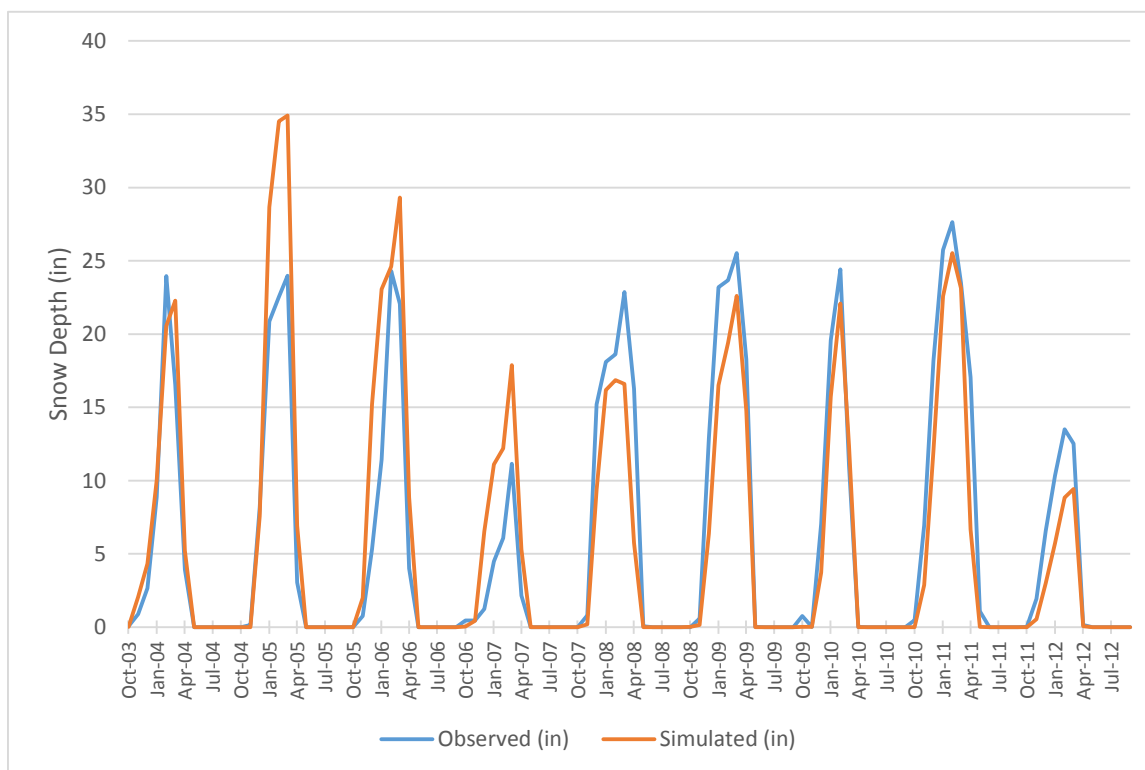


Figure 38. Mean monthly snow depth time-series for weather region 7

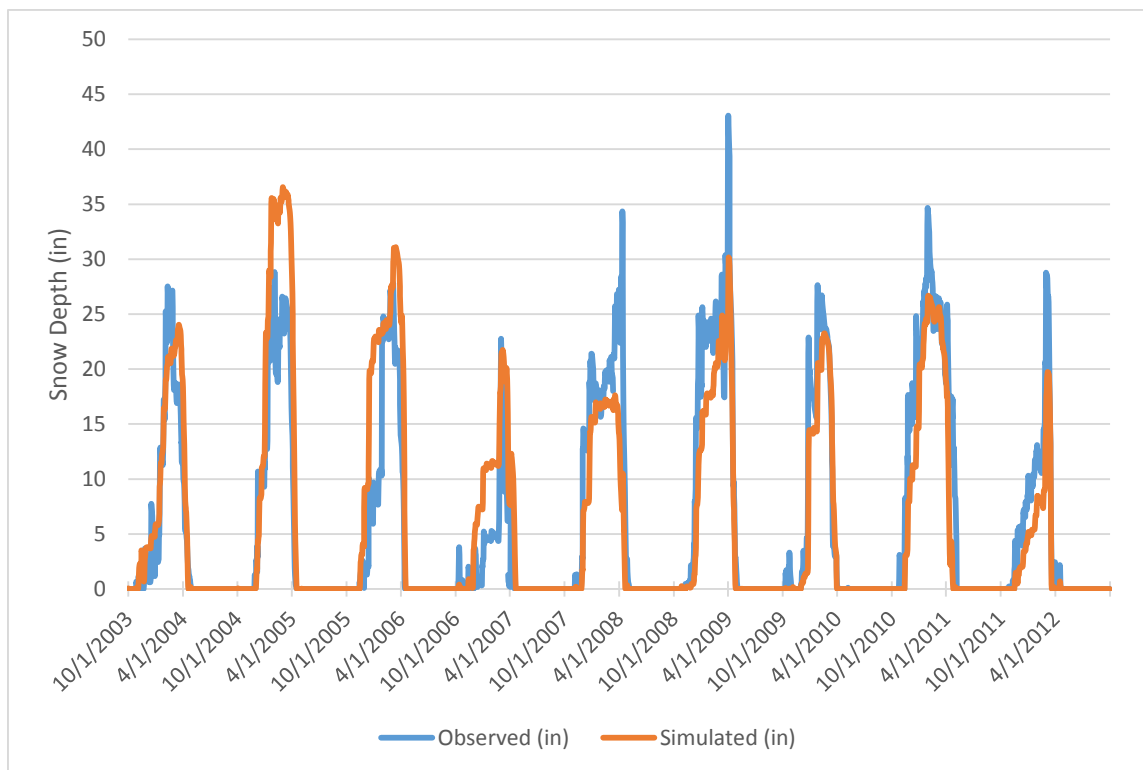


Figure 39. Mean daily snow depth time-series for weather region 7

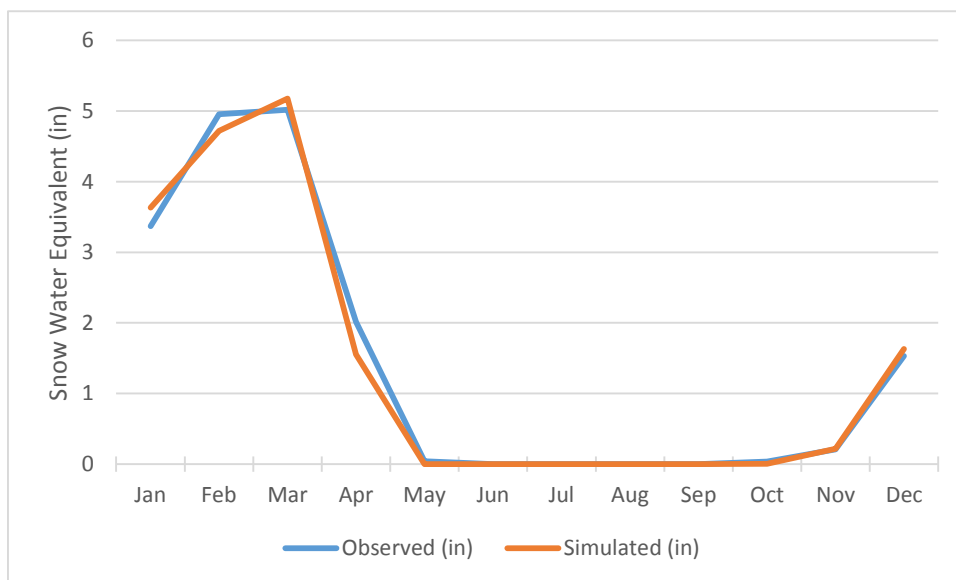


Figure 40. Mean monthly snow water equivalent for weather region 7

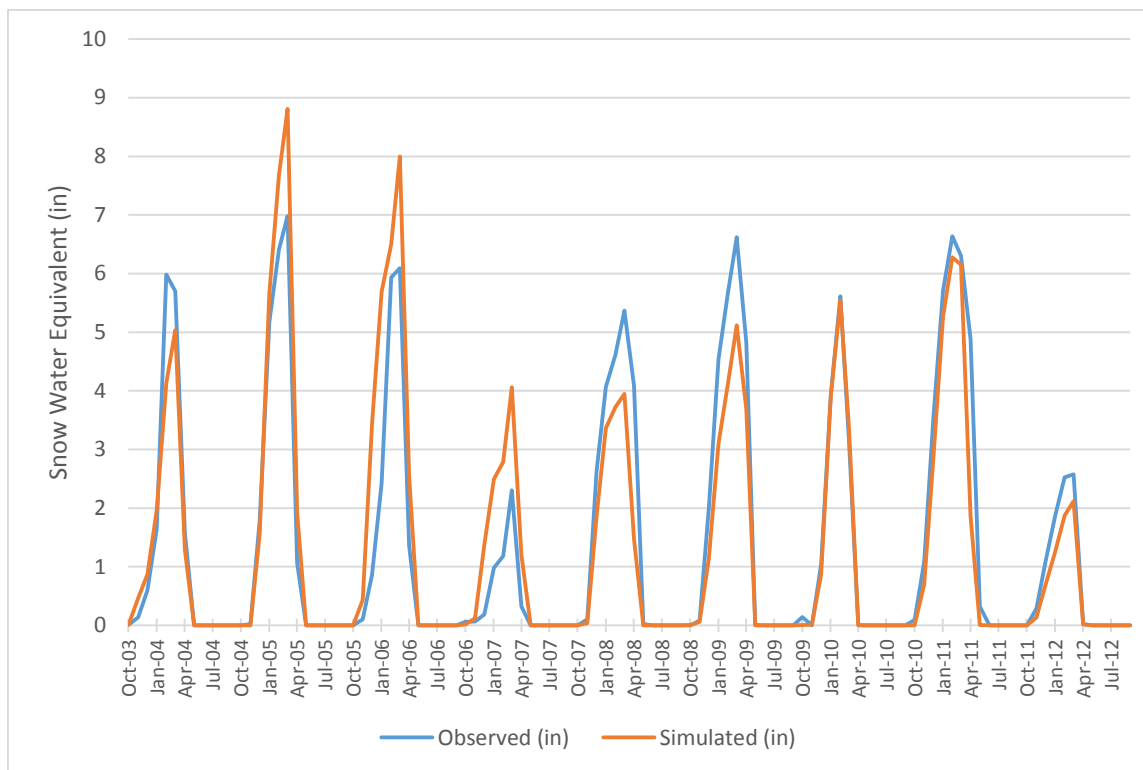


Figure 41. Mean monthly snow water equivalent time-series for weather region 7

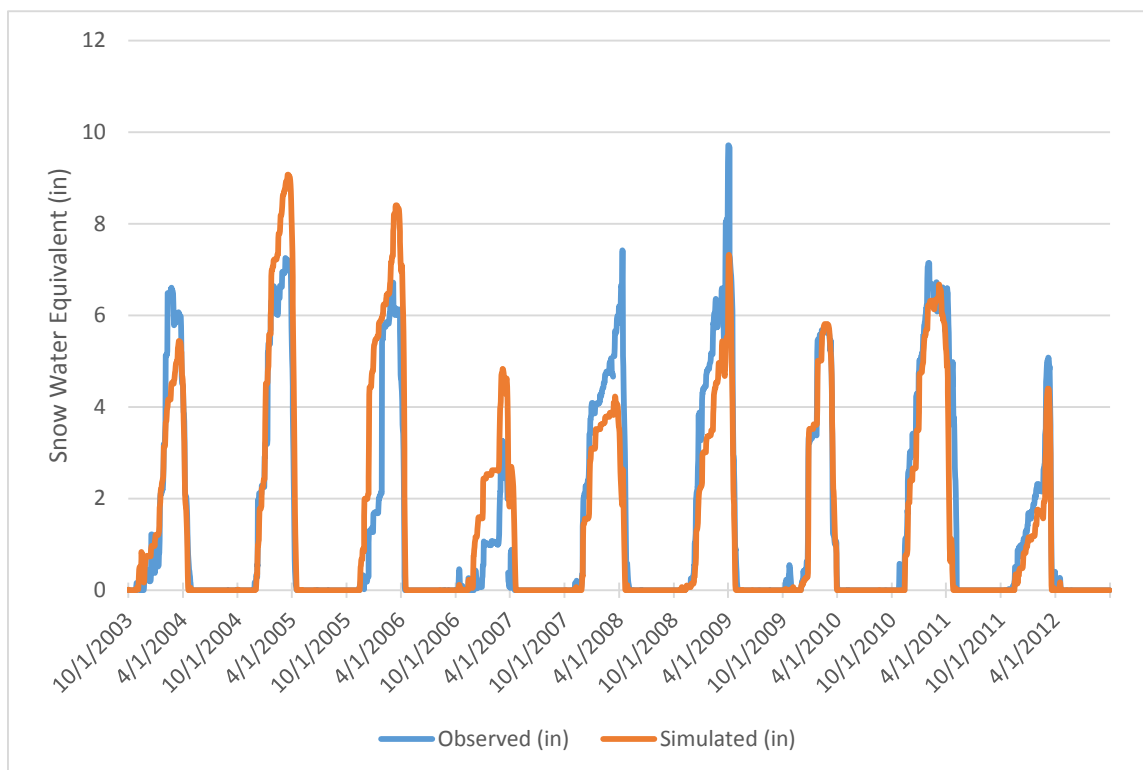


Figure 42. Mean daily snow water equivalent time-series for weather region 7

WEATHER REGION 8

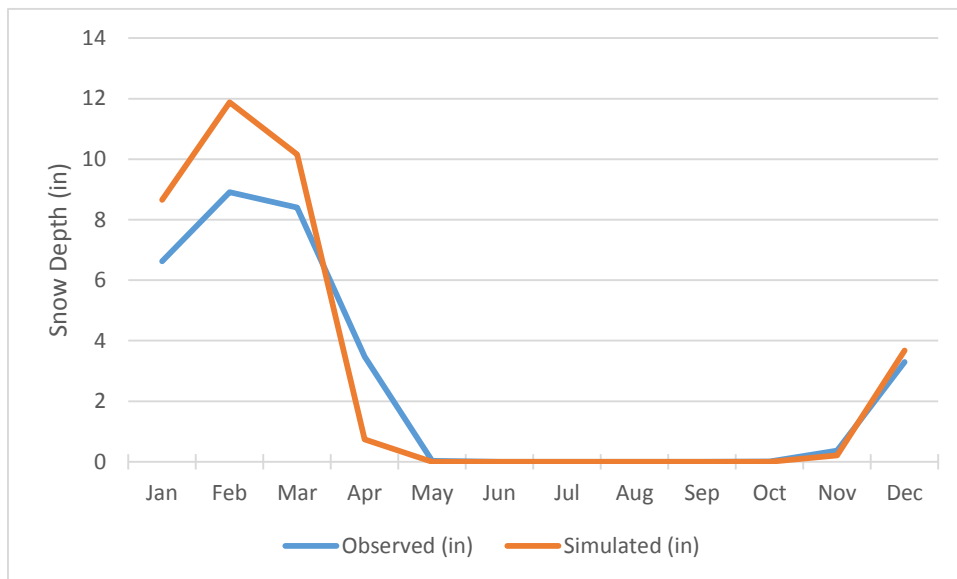


Figure 43. Mean monthly snow depth for weather region 8

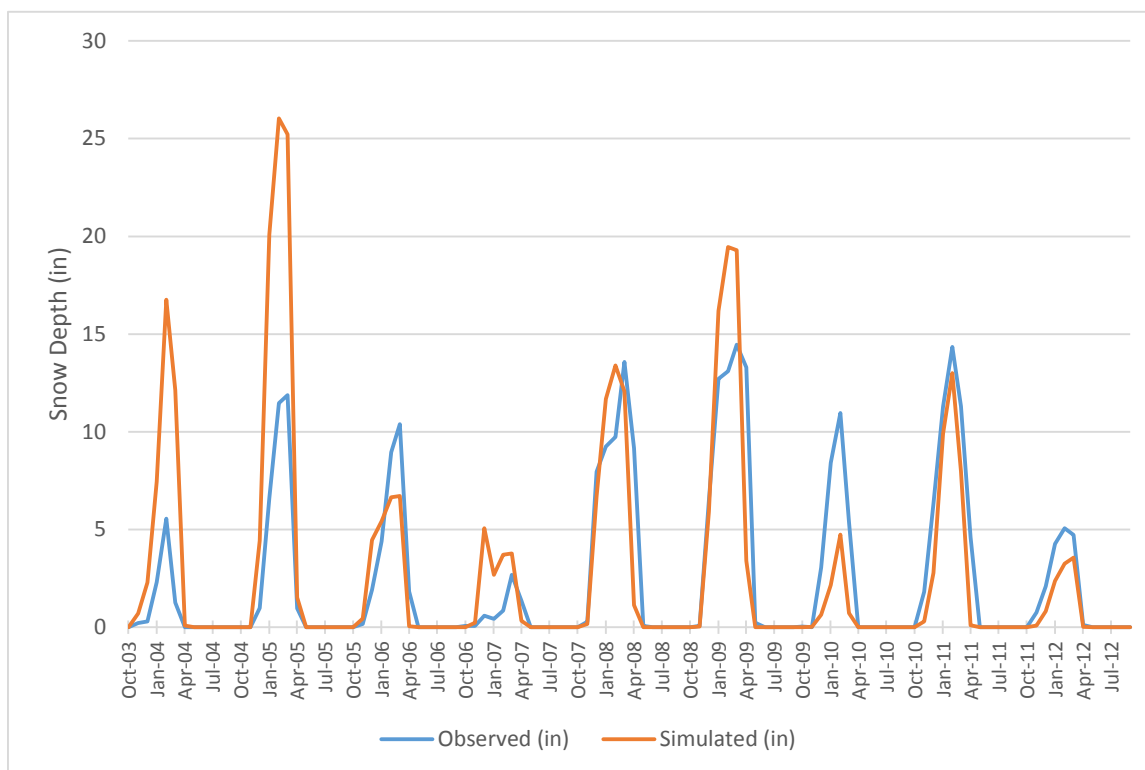


Figure 44. Mean monthly snow depth time-series for weather region 8

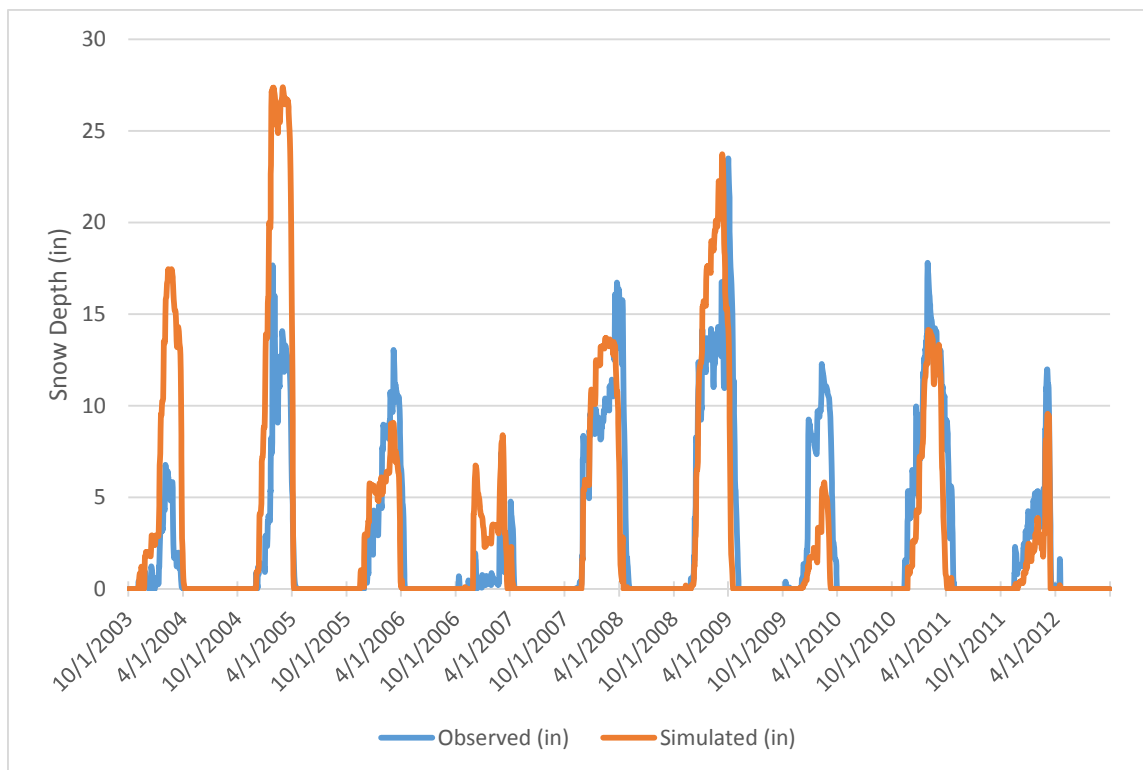


Figure 45. Mean daily snow depth time-series for weather region 8

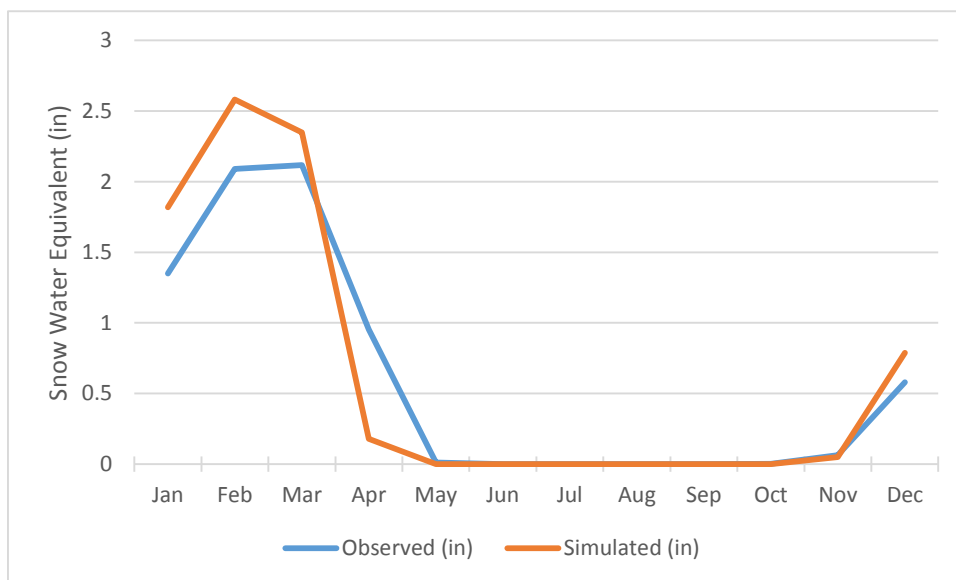


Figure 46. Mean monthly snow water equivalent for weather region 8

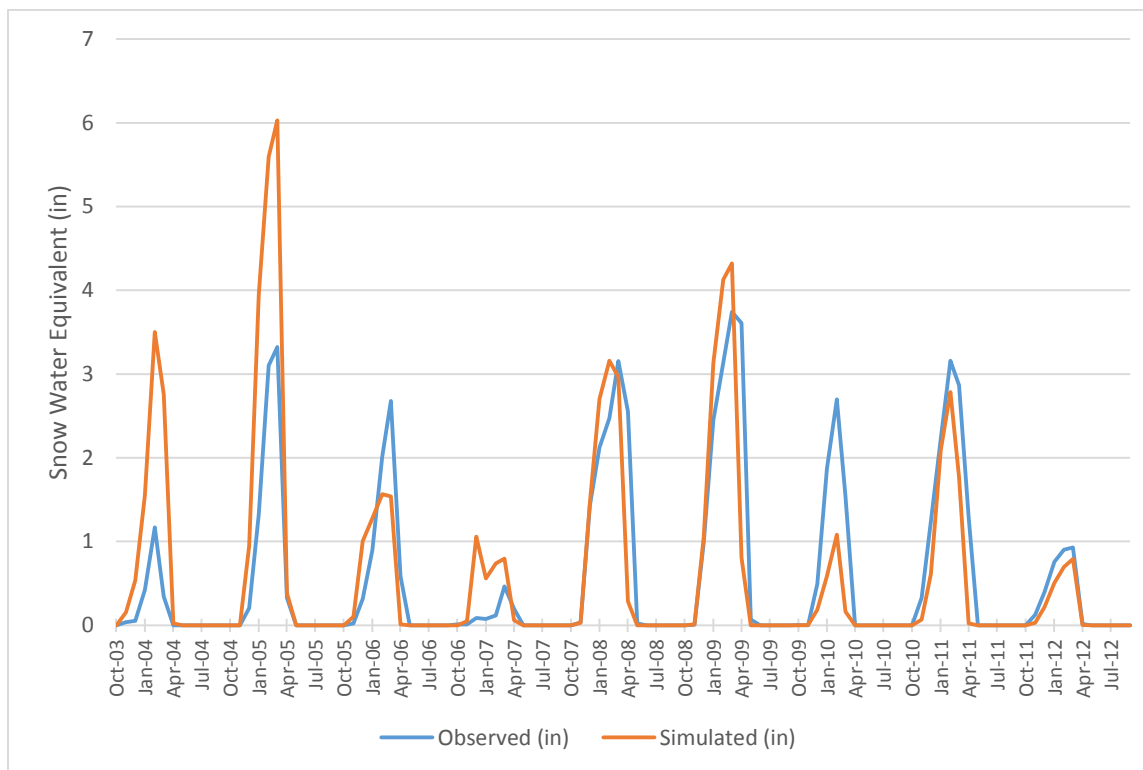


Figure 47. Mean monthly snow water equivalent time-series for weather region 8

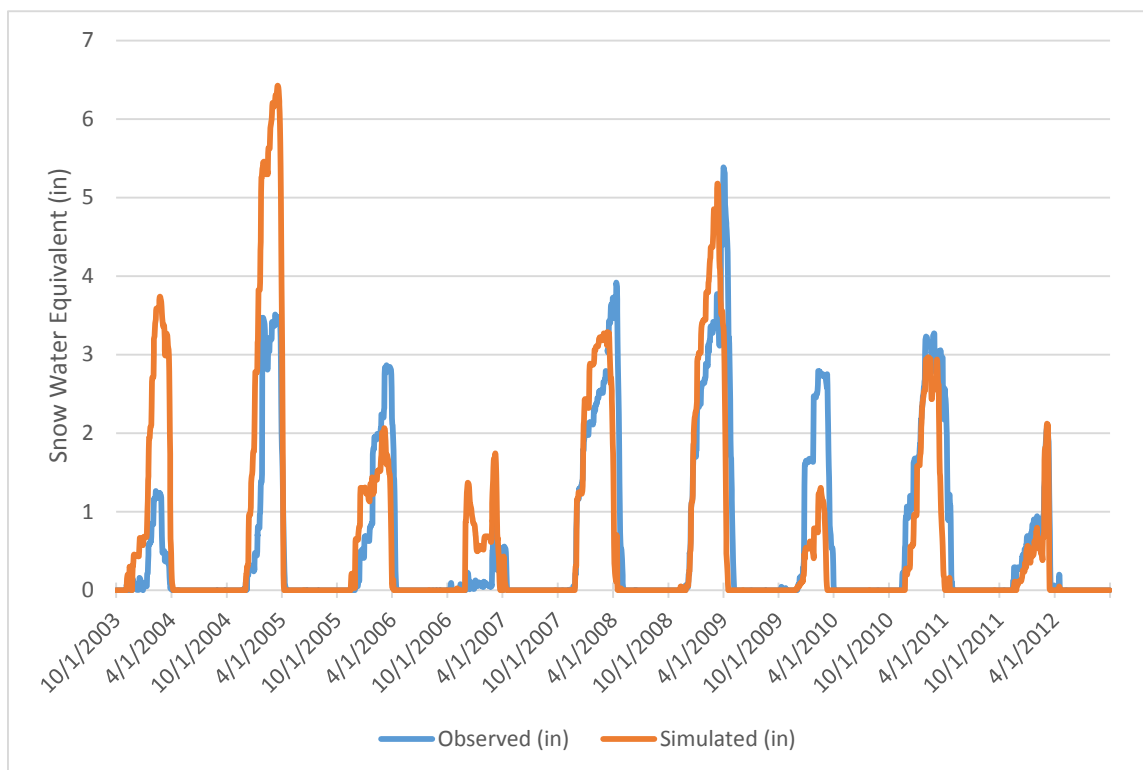


Figure 48. Mean daily snow water equivalent time-series for weather region 8

WEATHER REGION 9

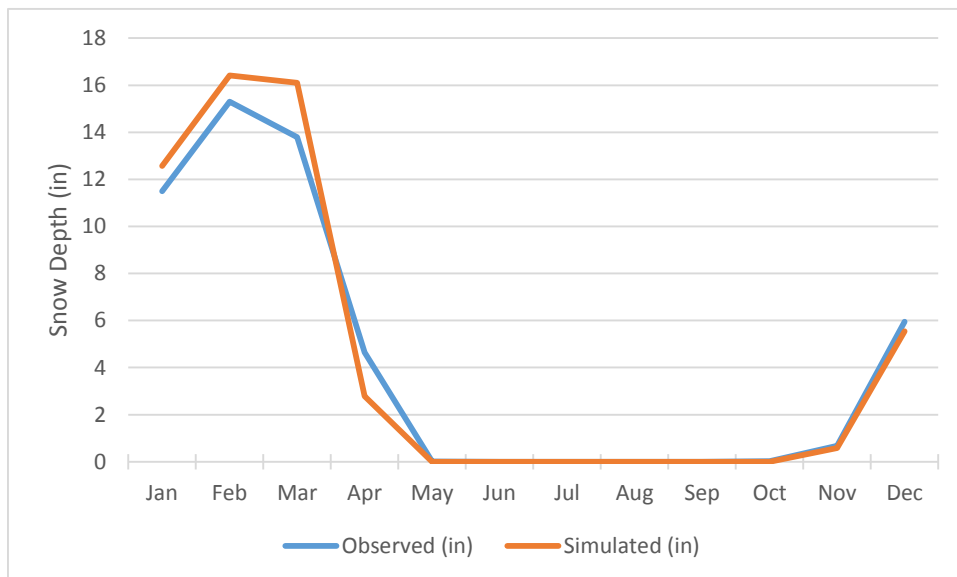


Figure 49. Mean monthly snow depth for weather region 9

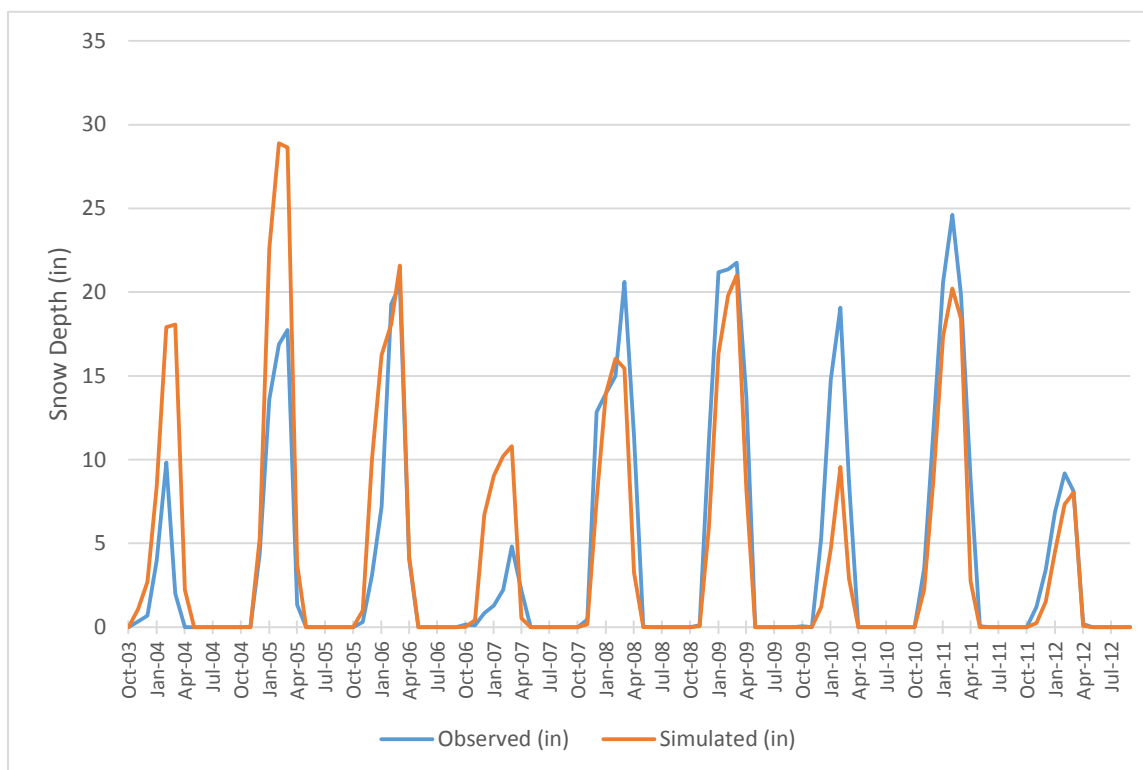


Figure 50. Mean monthly snow depth time-series for weather region 9

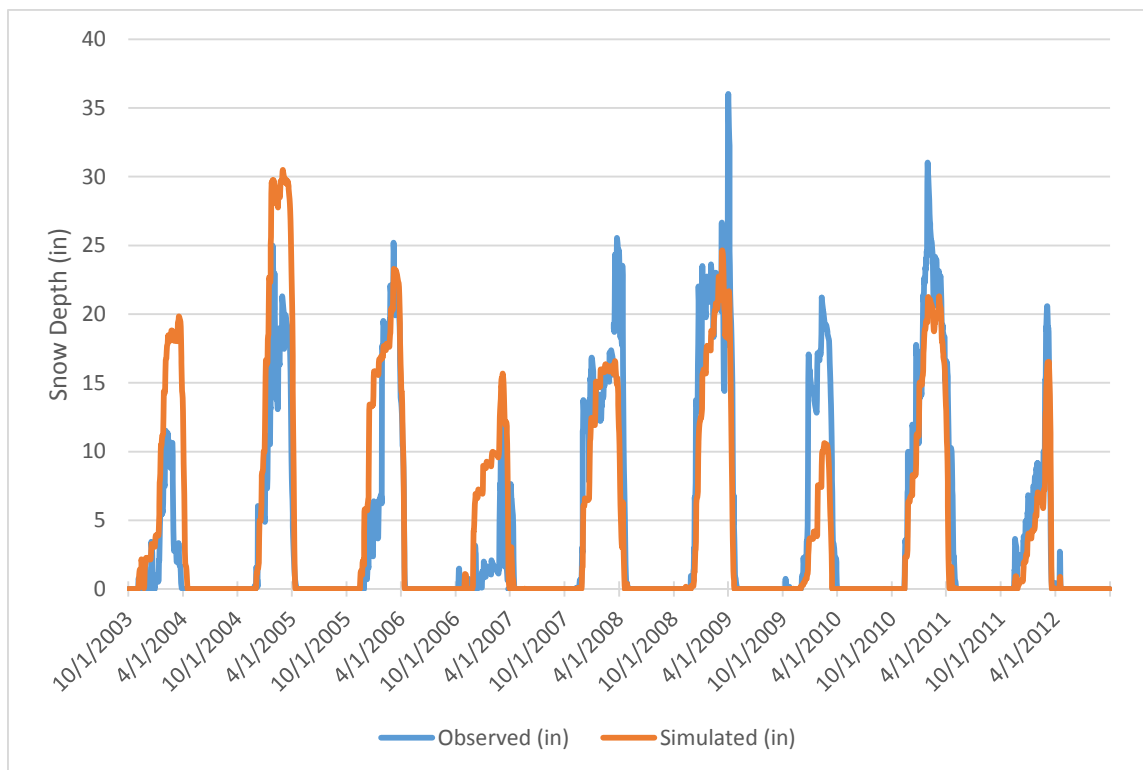


Figure 51. Mean daily snow depth time-series for weather region 9

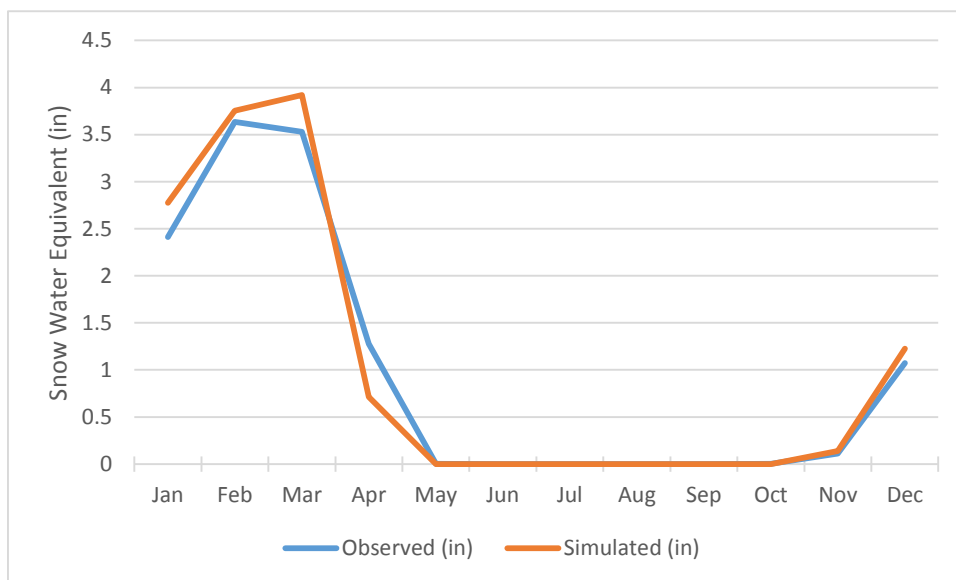


Figure 52. Mean monthly snow water equivalent for weather region 9

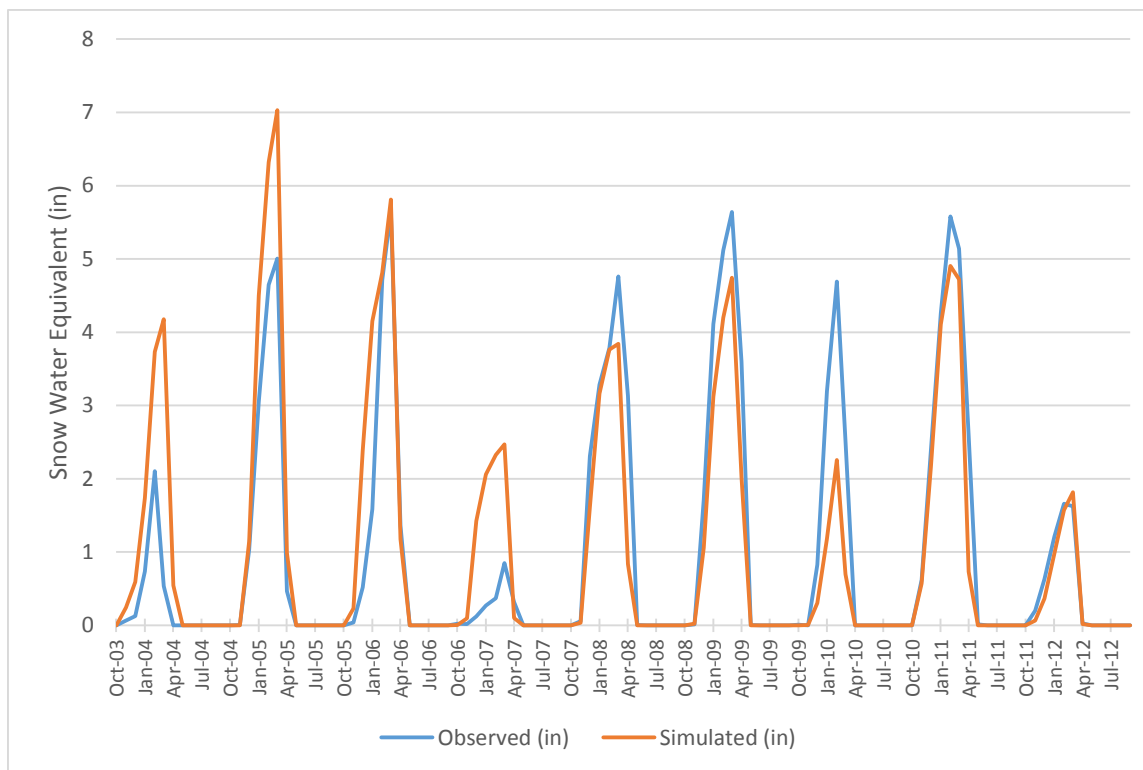


Figure 53. Mean monthly snow water equivalent time-series for weather region 9

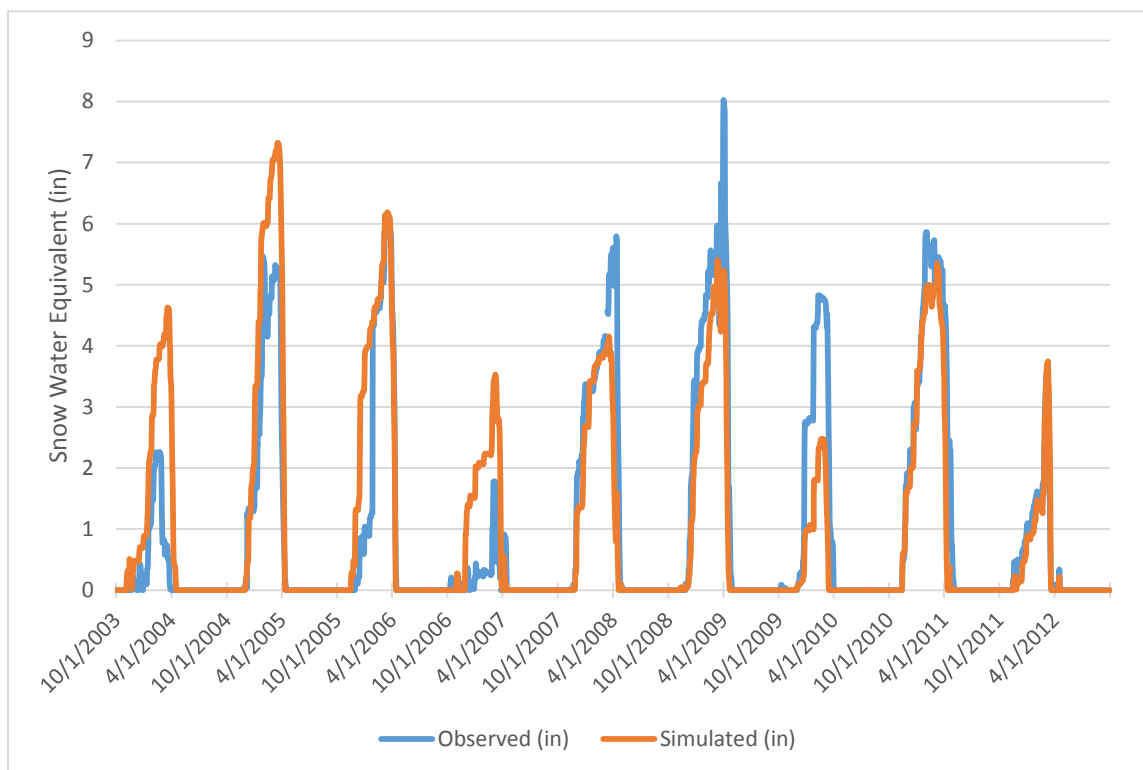


Figure 54. Mean daily snow water equivalent time-series for weather region 9

WEATHER REGION 10

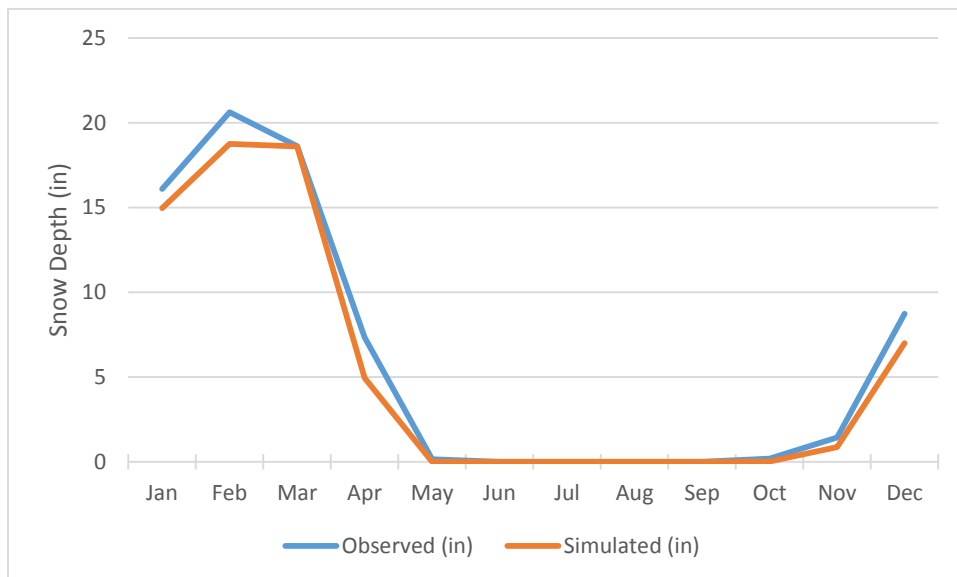


Figure 55. Mean monthly snow depth for weather region 10

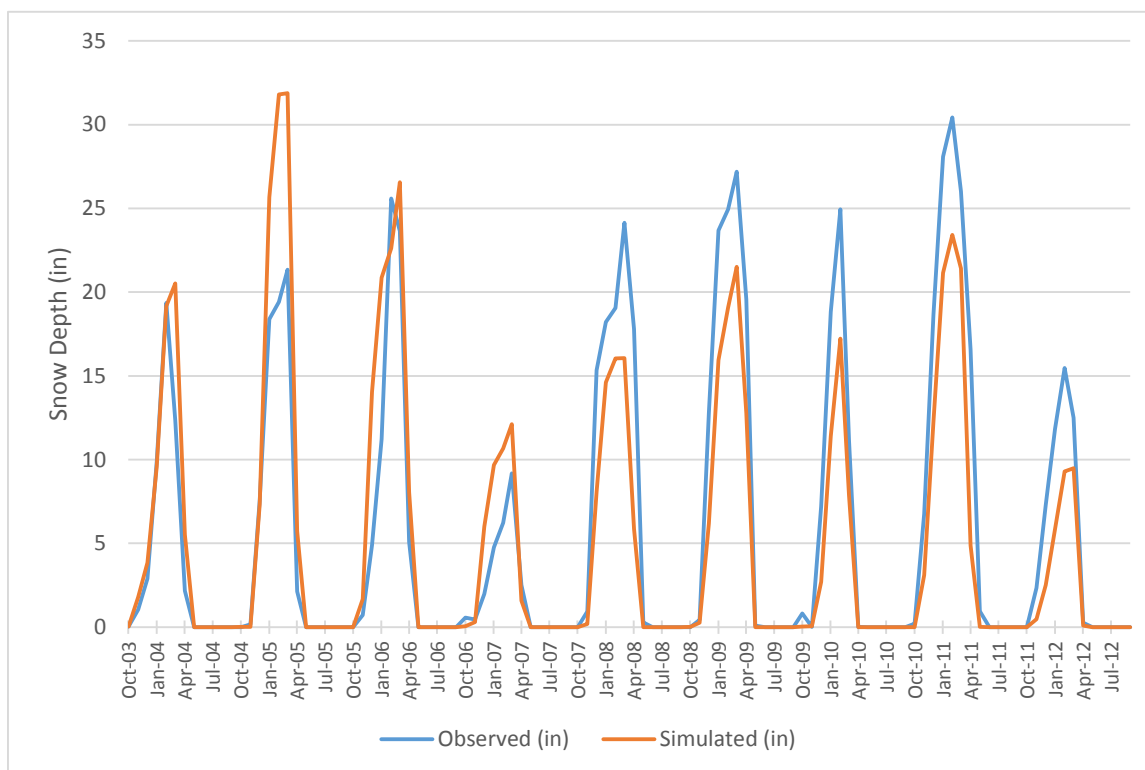


Figure 56. Mean monthly snow depth time-series for weather region 10

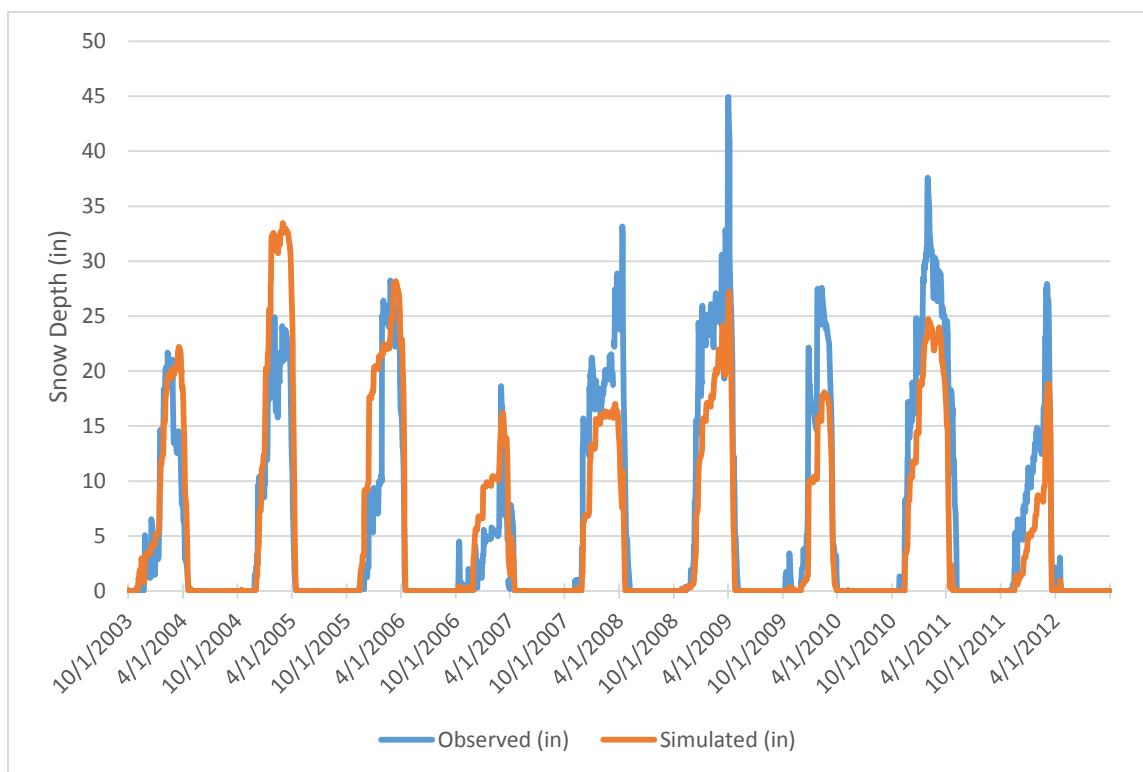


Figure 57. Mean daily snow depth time-series for weather region 10

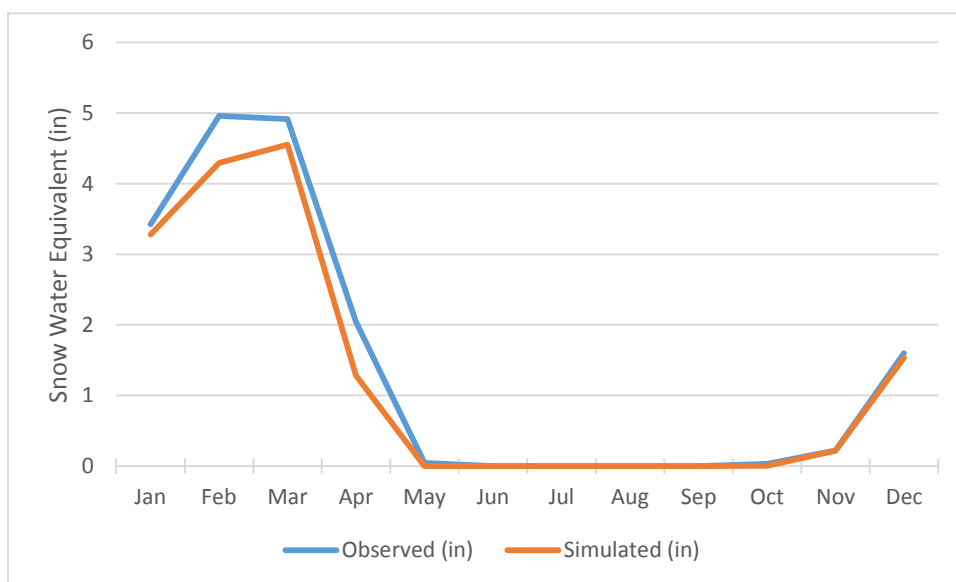


Figure 58. Mean monthly snow water equivalent for weather region 10

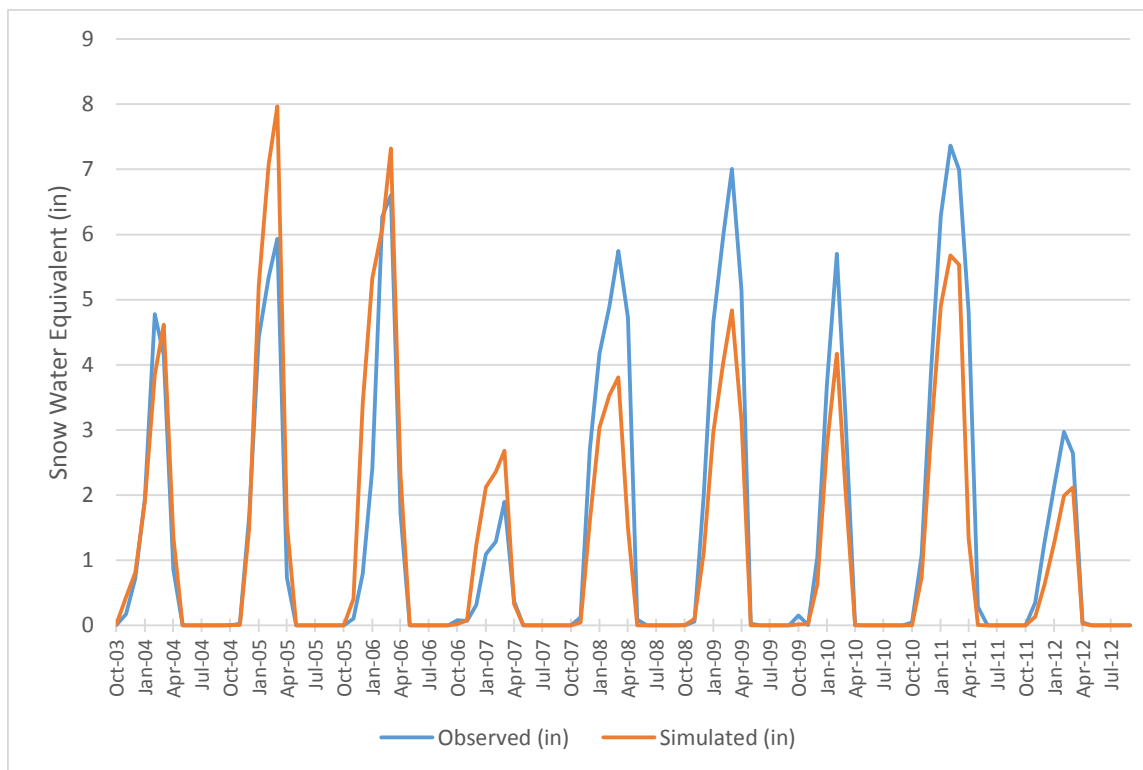


Figure 59. Mean monthly snow water equivalent time-series for weather region 10

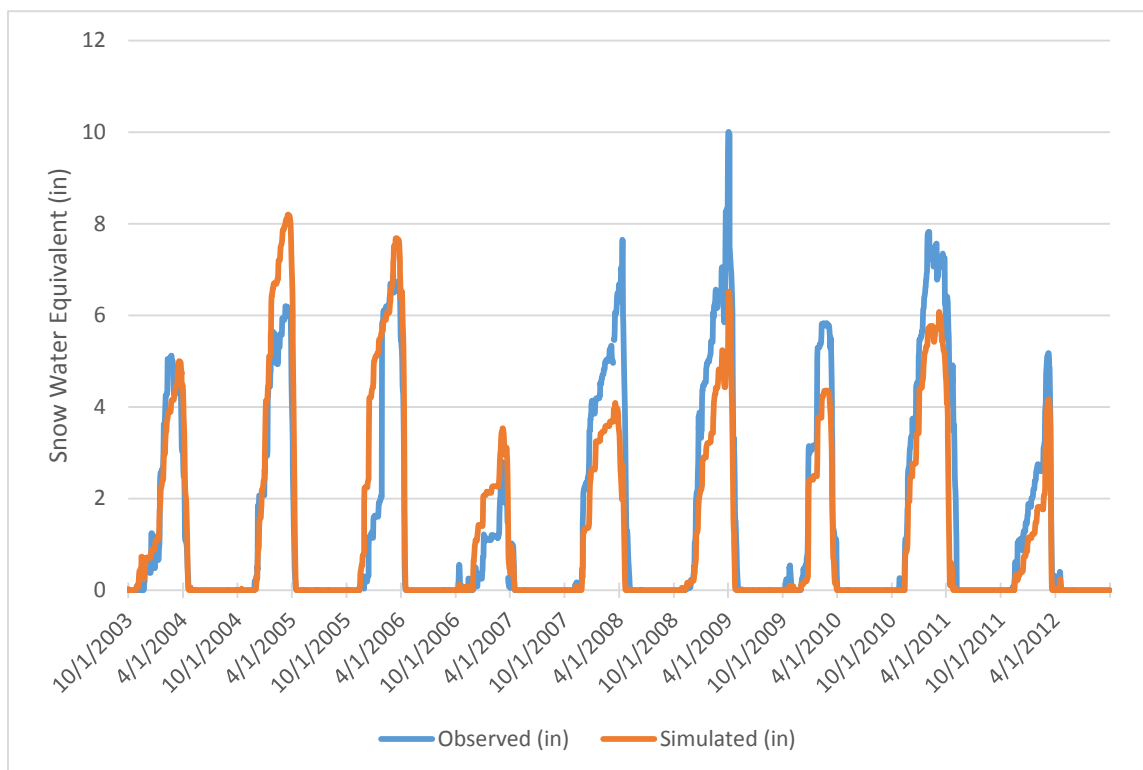


Figure 60. Mean daily snow water equivalent time-series for weather region 10

WEATHER REGION 11

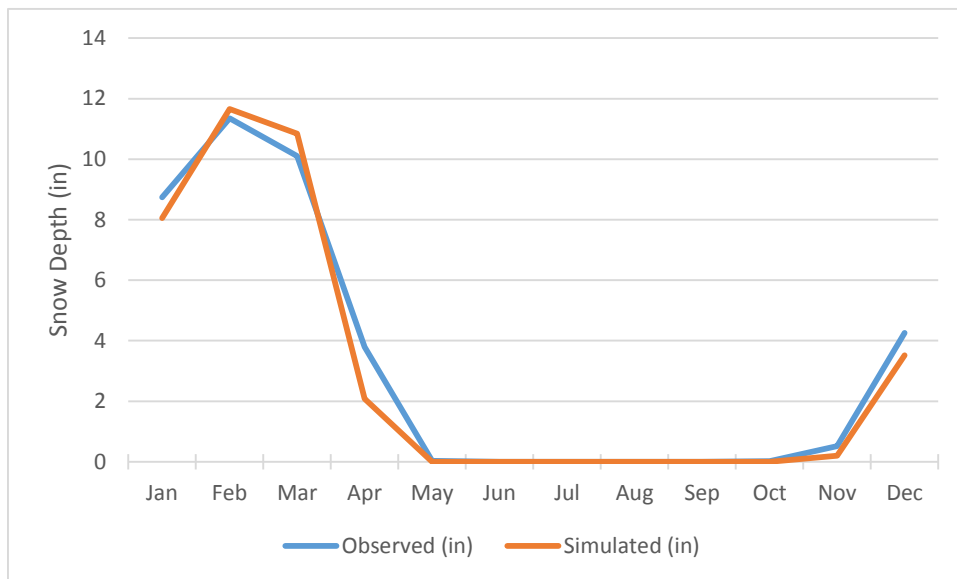


Figure 61. Mean monthly snow depth for weather region 11

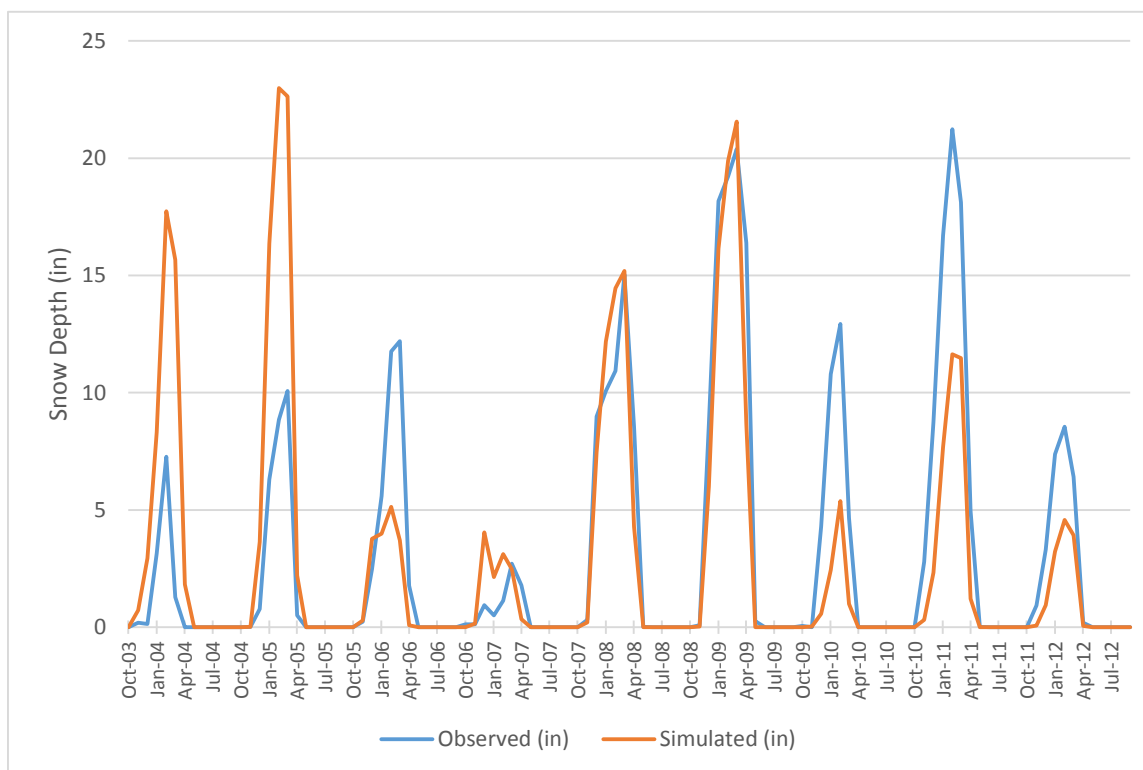


Figure 62. Mean monthly snow depth time-series for weather region 11

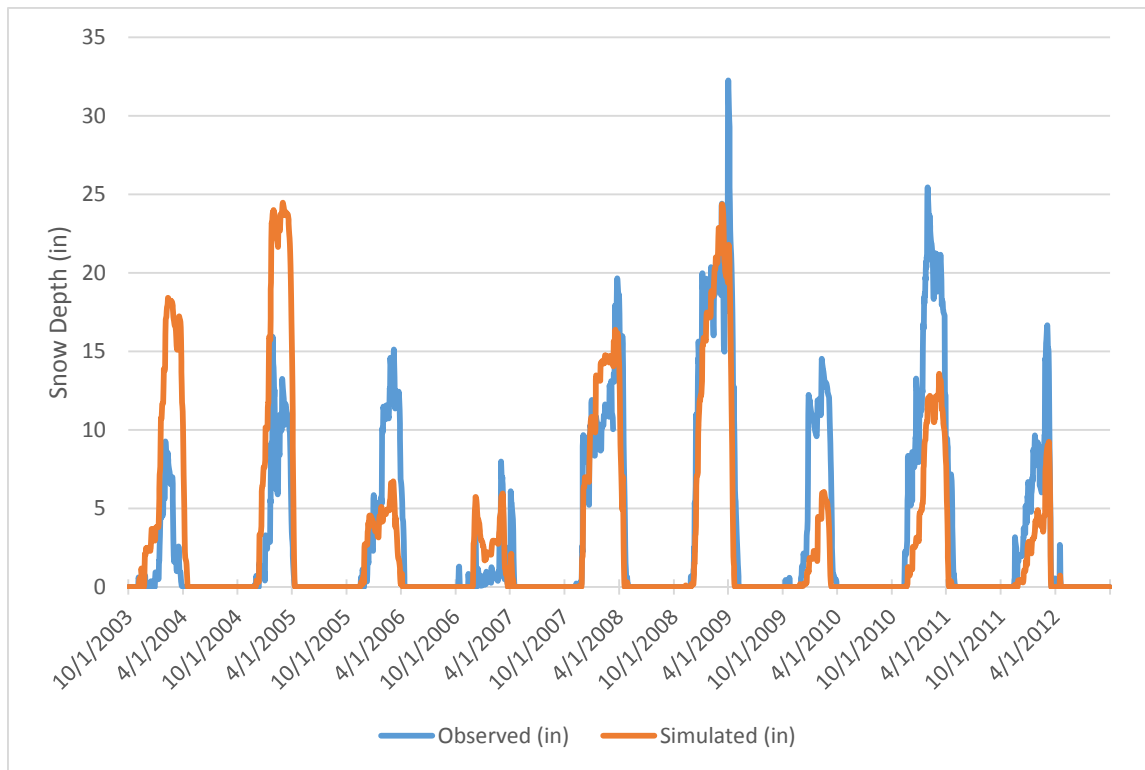


Figure 63. Mean daily snow depth time-series for weather region 11

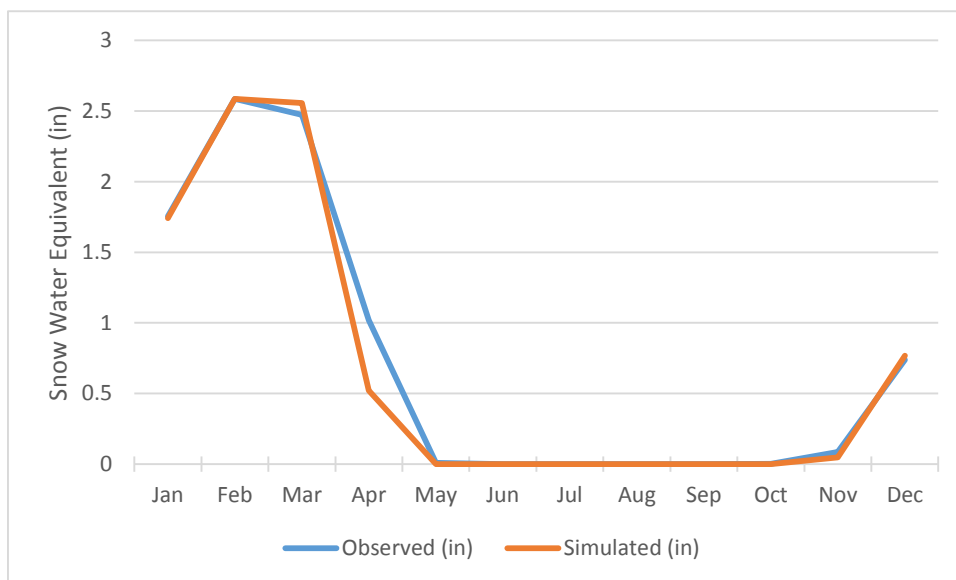


Figure 64. Mean monthly snow water equivalent for weather region 11

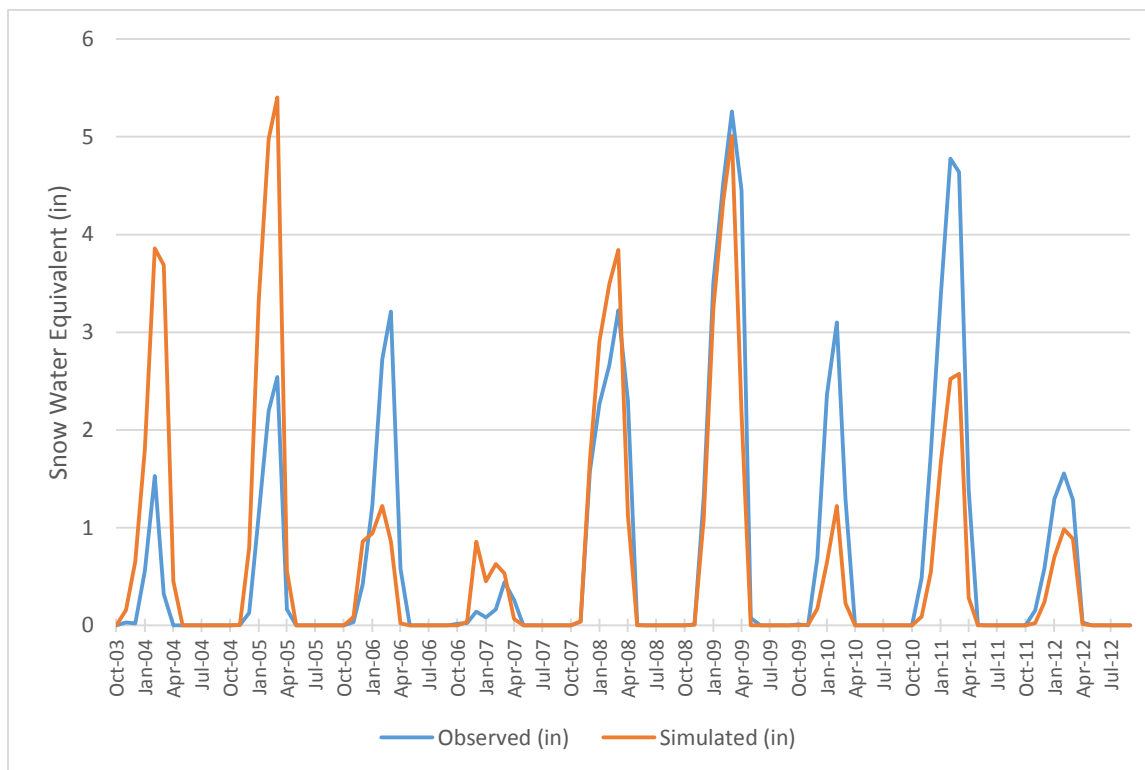


Figure 65. Mean monthly snow water equivalent time-series for weather region 11

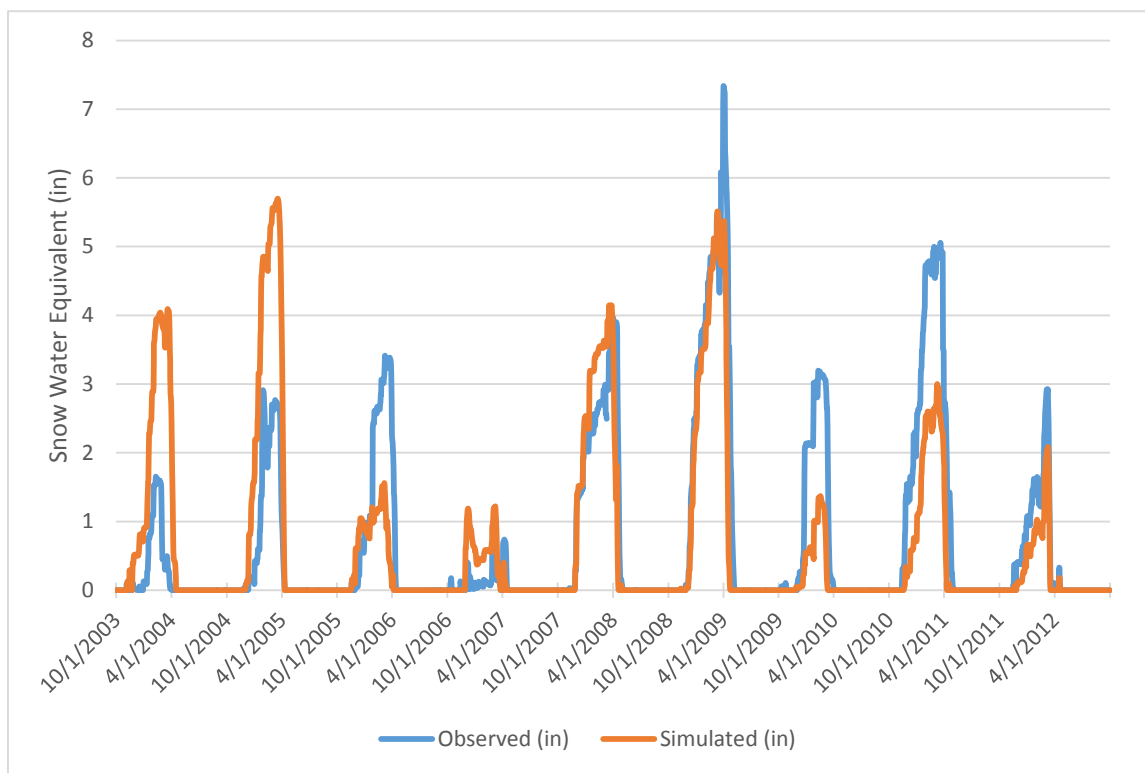


Figure 66. Mean daily snow water equivalent time-series for weather region 11

WEATHER REGION 12

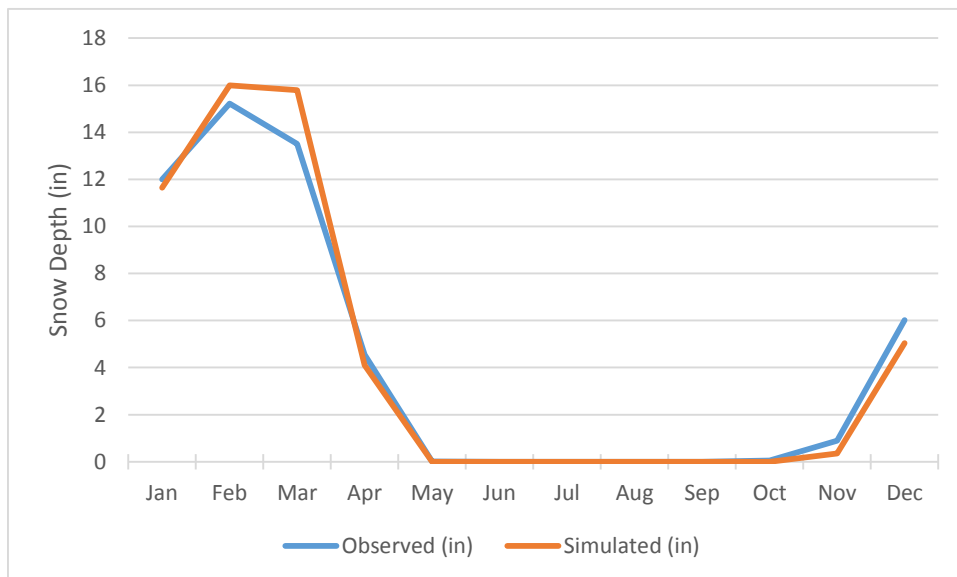


Figure 67. Mean monthly snow depth for weather region 12

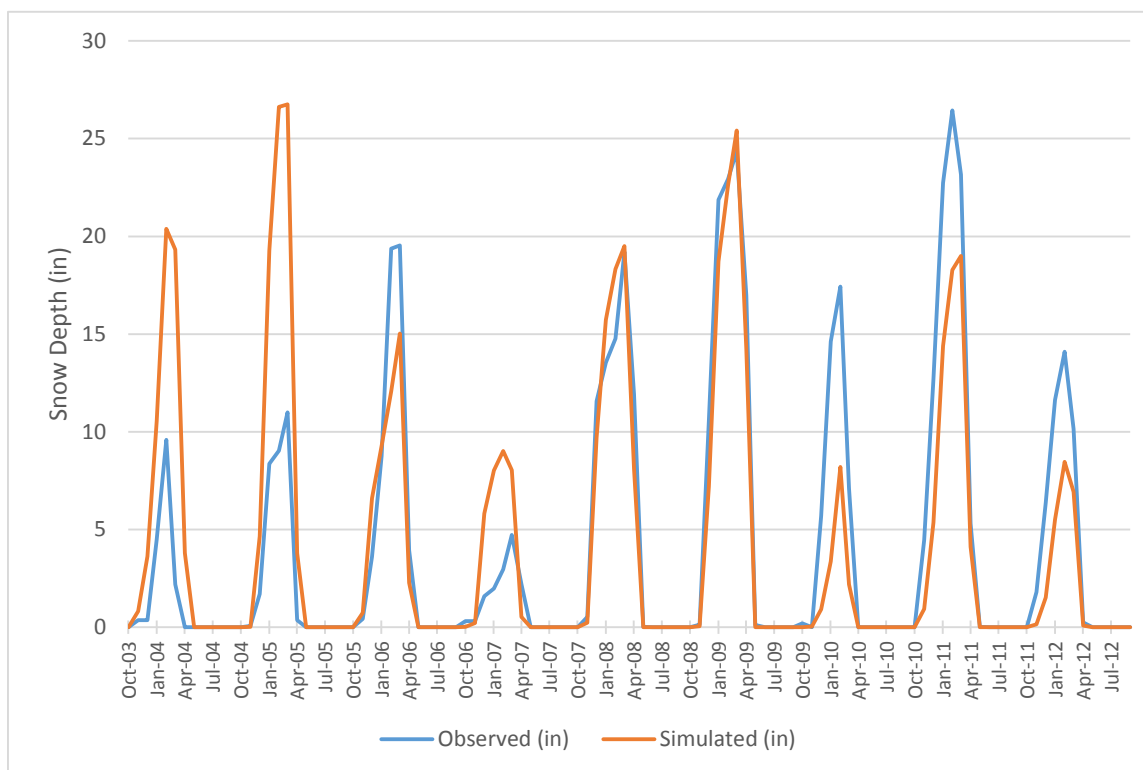


Figure 68. Mean monthly snow depth time-series for weather region 12

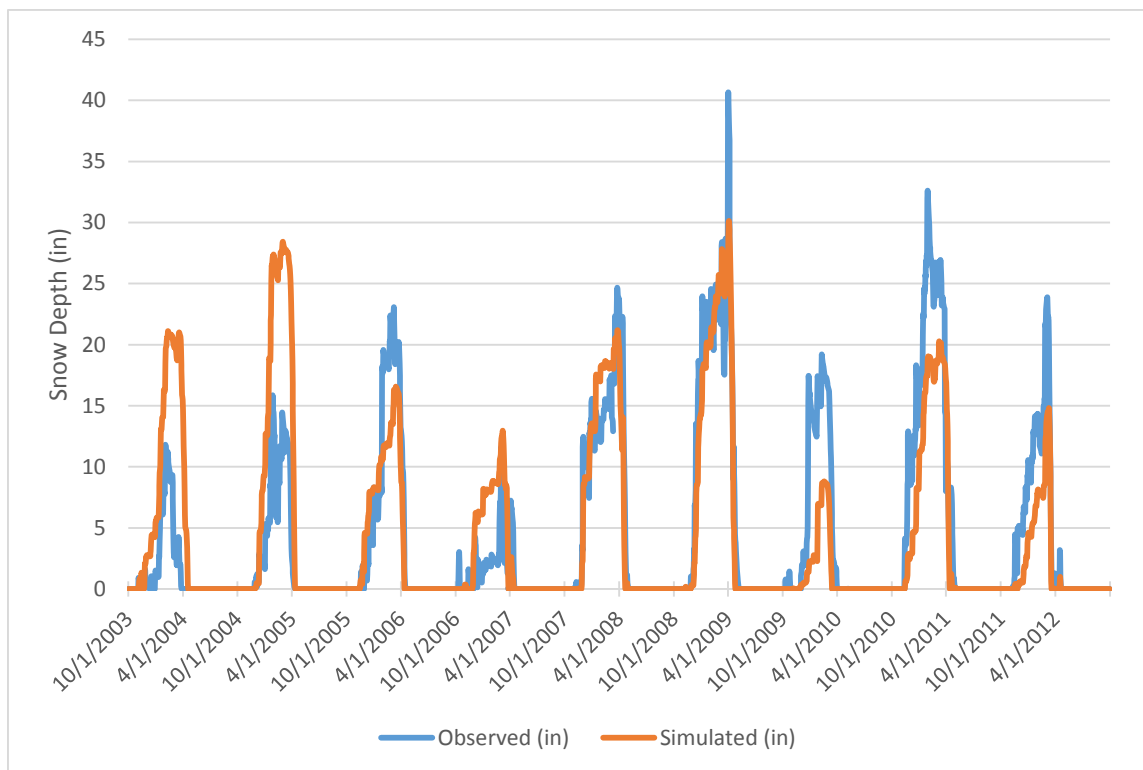


Figure 69. Mean daily snow depth time-series for weather region 12

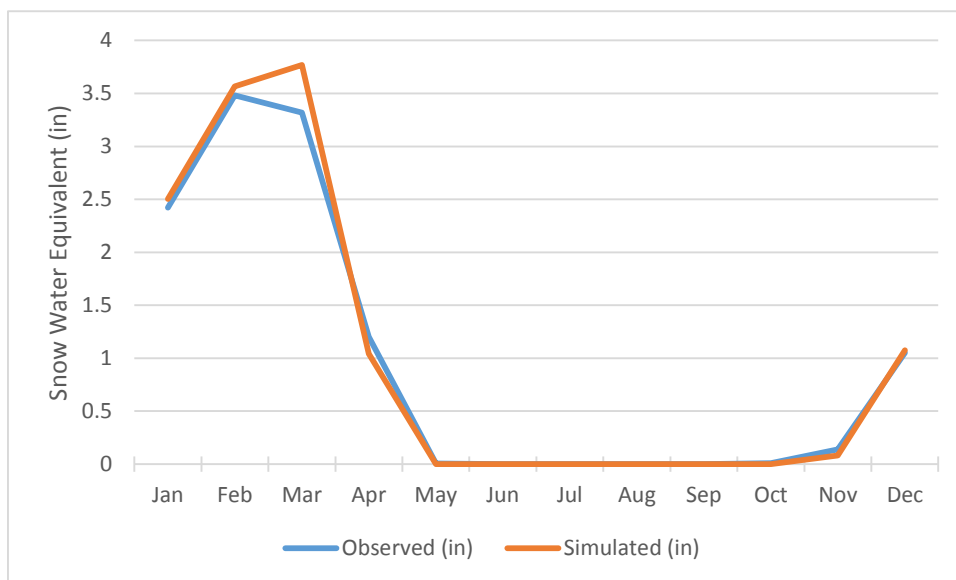


Figure 70. Mean monthly snow water equivalent for weather region 12

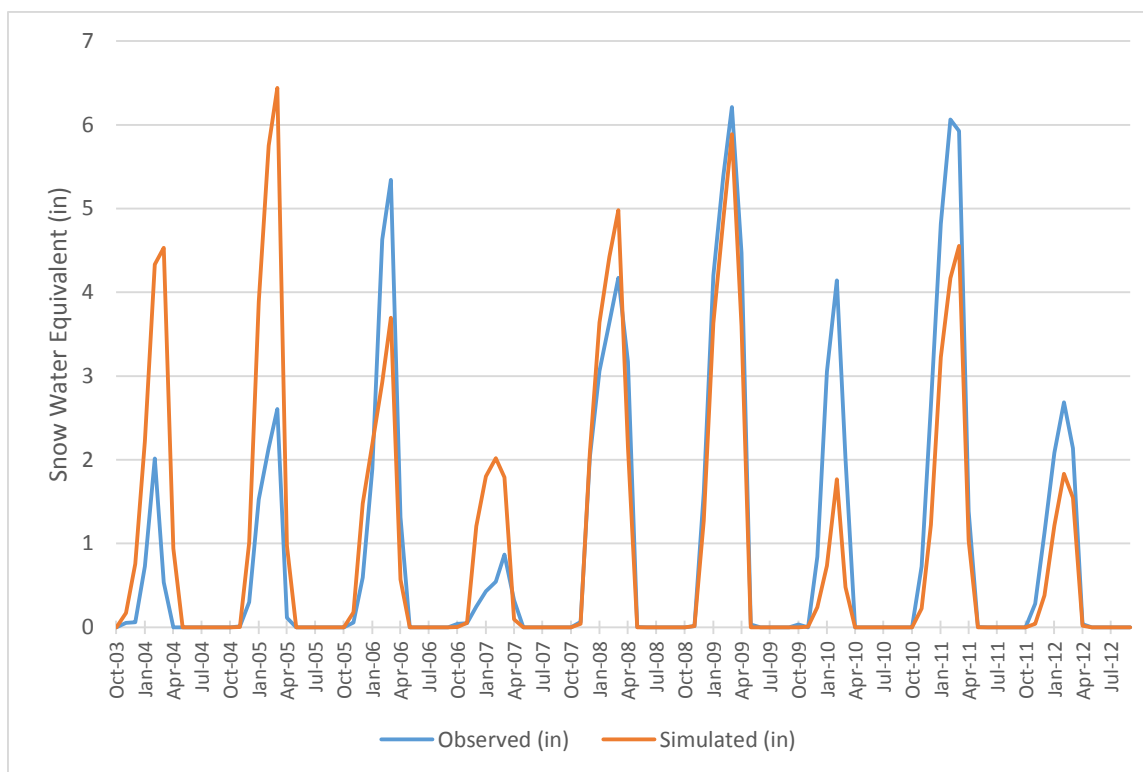


Figure 71. Mean monthly snow water equivalent time-series for weather region 12

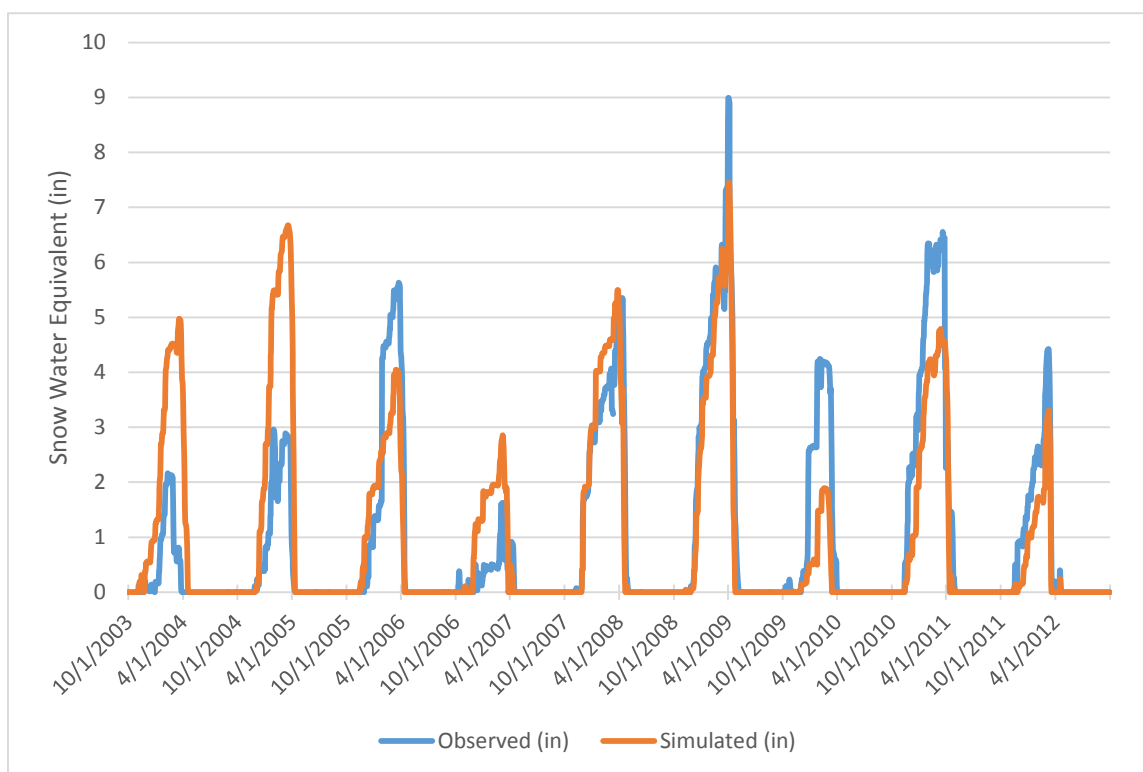


Figure 72. Mean daily snow water equivalent time-series for weather region 12

WEATHER REGION 13

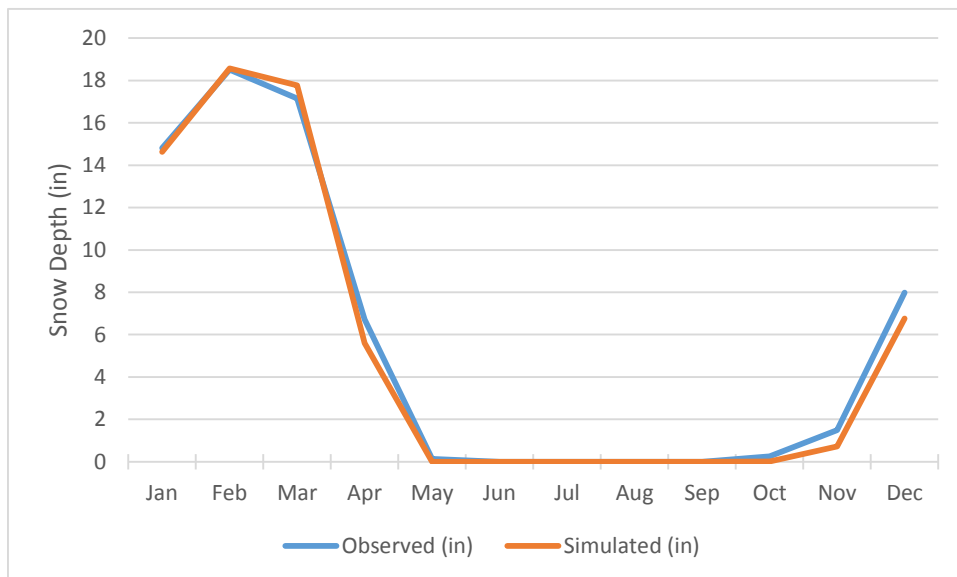


Figure 73. Mean monthly snow depth for weather region 13

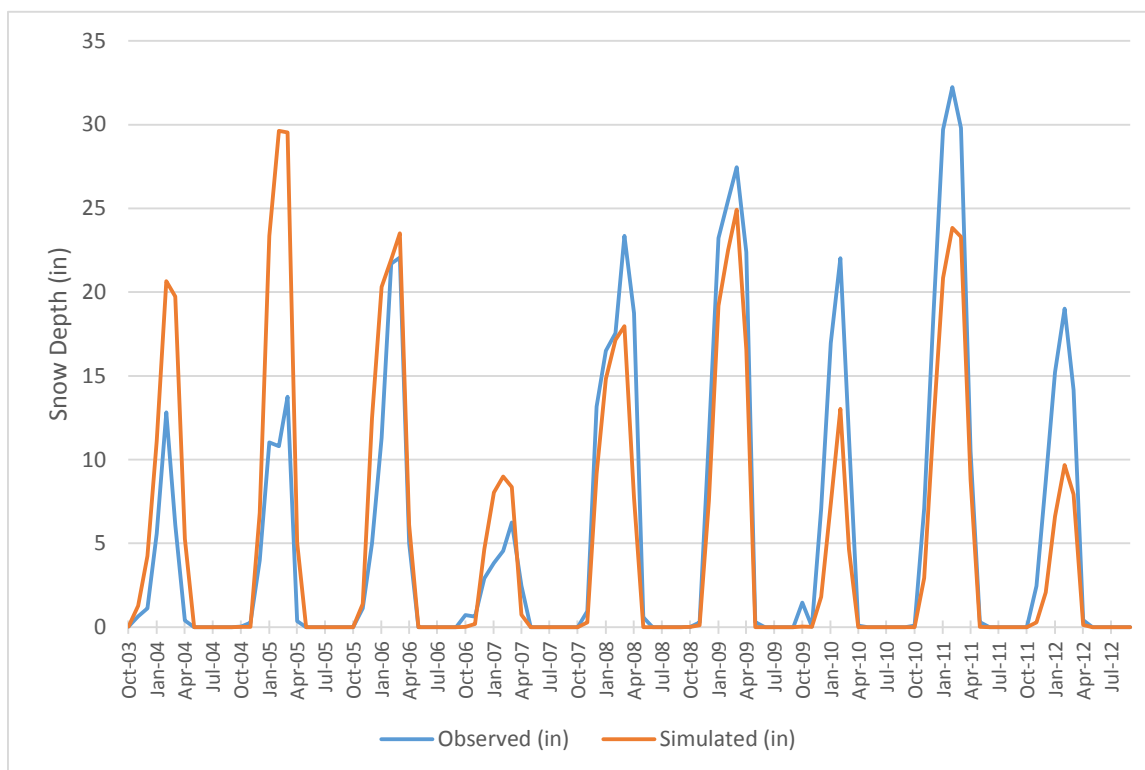


Figure 74. Mean monthly snow depth time-series for weather region 13

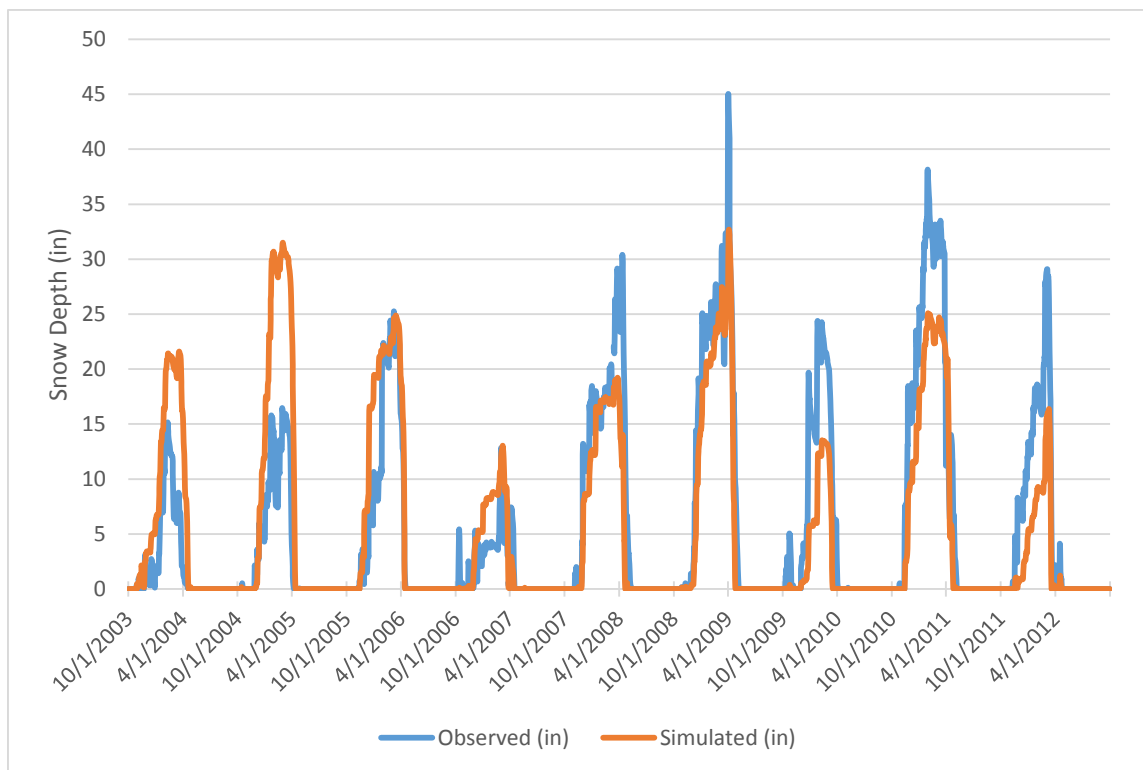


Figure 75. Mean daily snow depth time-series for weather region 13

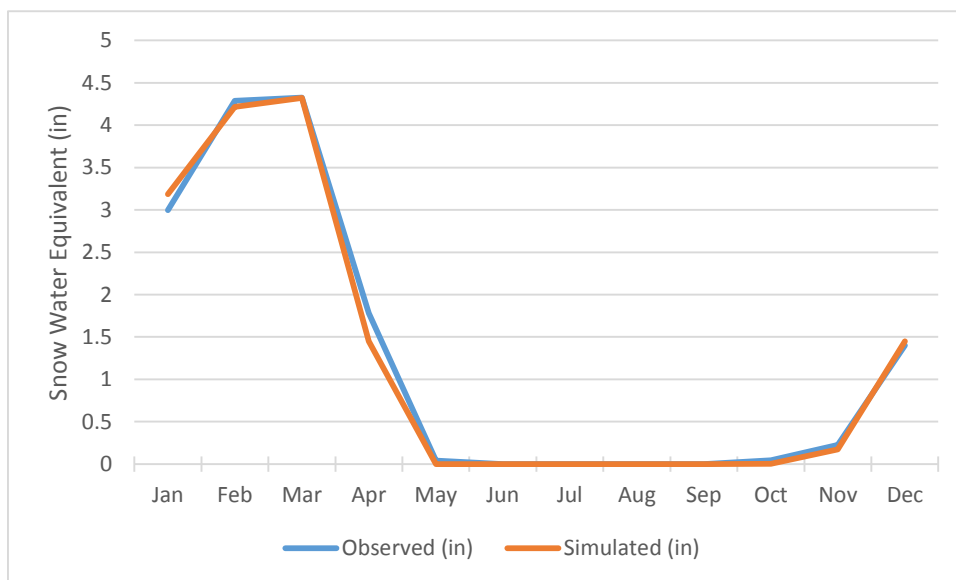


Figure 76. Mean monthly snow water equivalent for weather region 13

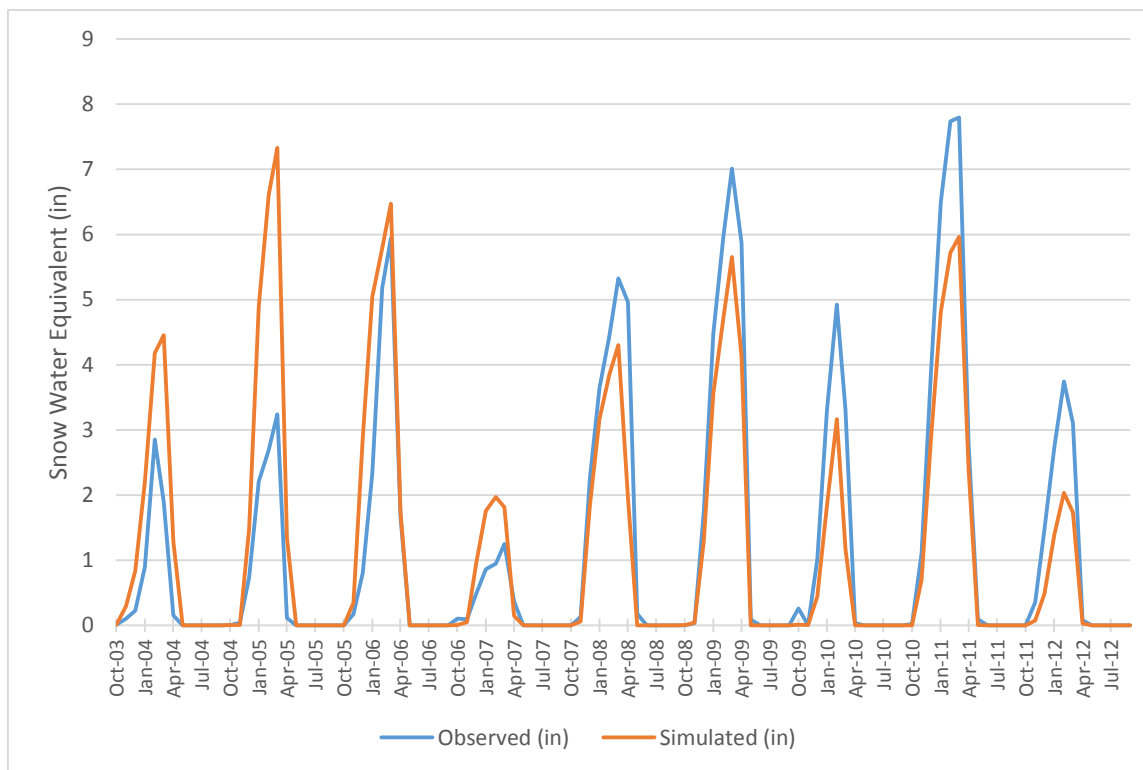


Figure 77. Mean monthly snow water equivalent time-series for weather region 13

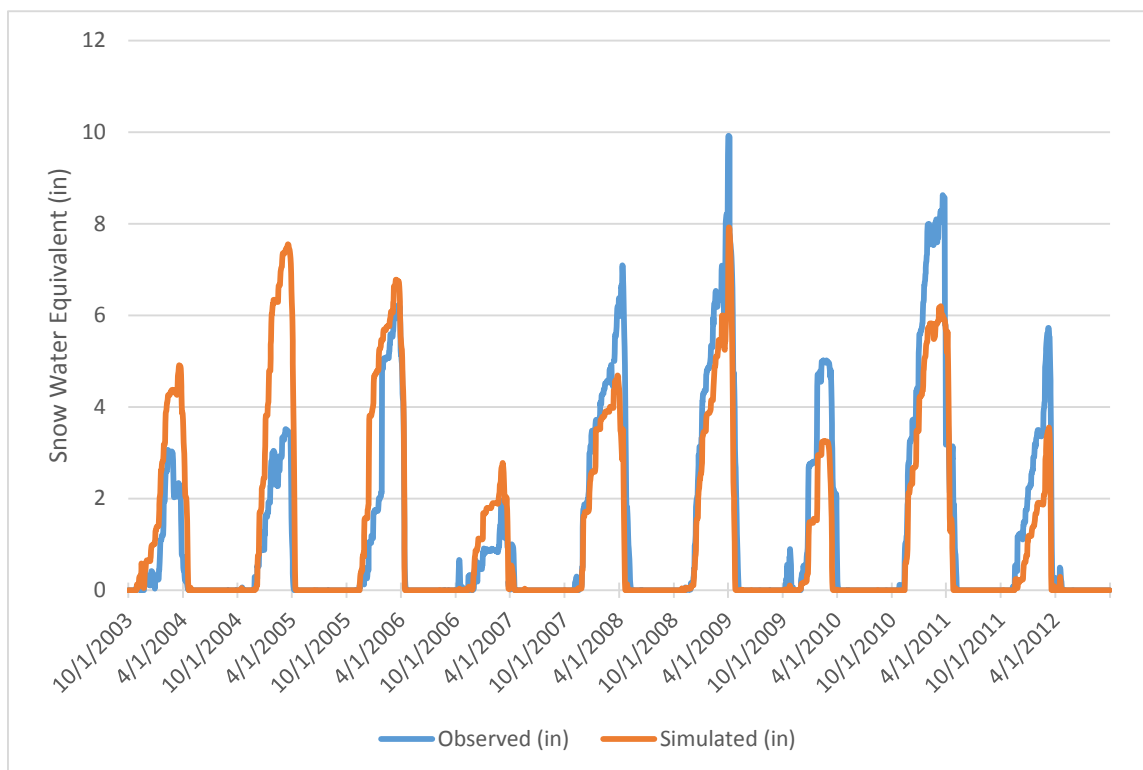


Figure 78. Mean daily snow water equivalent time-series for weather region 13

WEATHER REGION 14

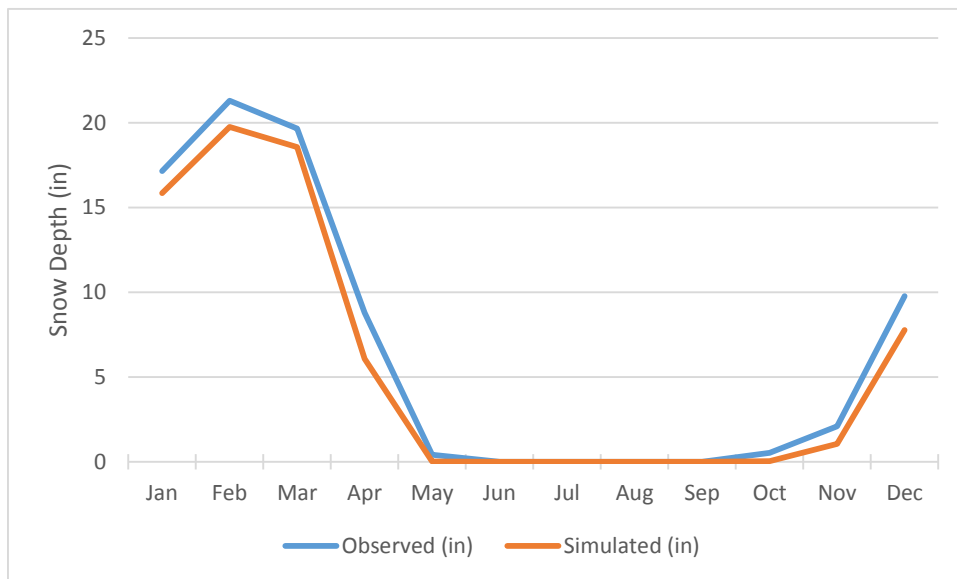


Figure 79. Mean monthly snow depth for weather region 14

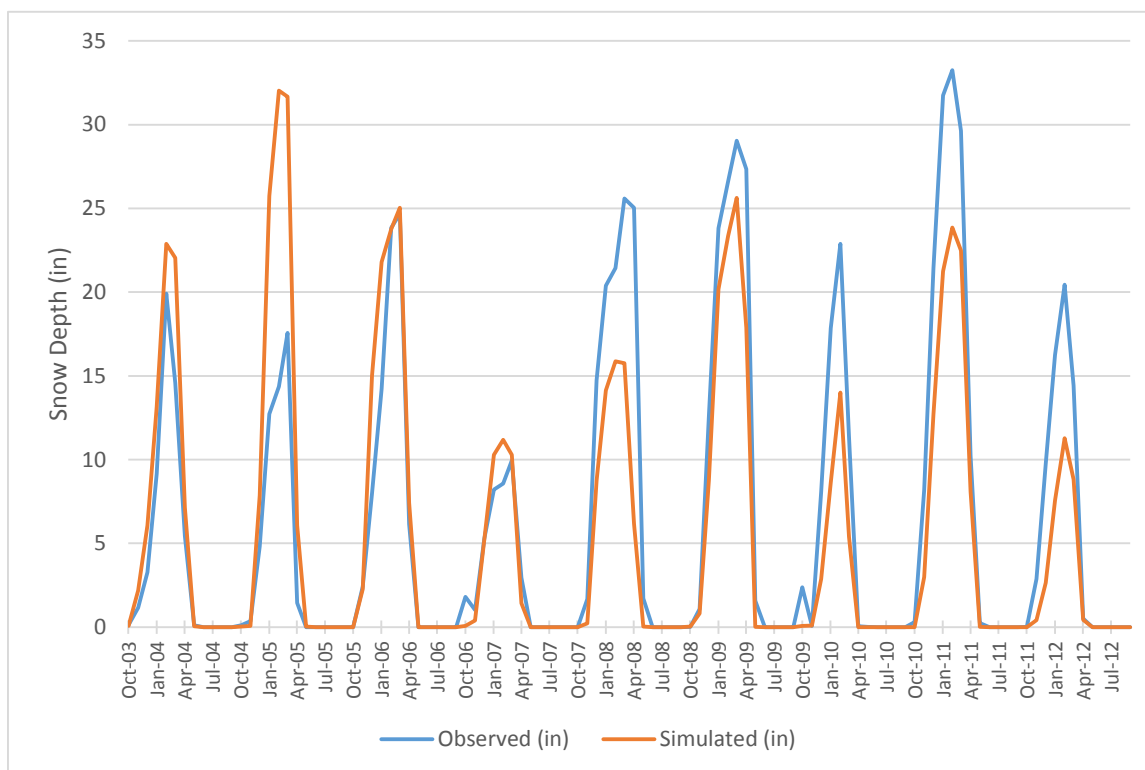


Figure 80. Mean monthly snow depth time-series for weather region 14

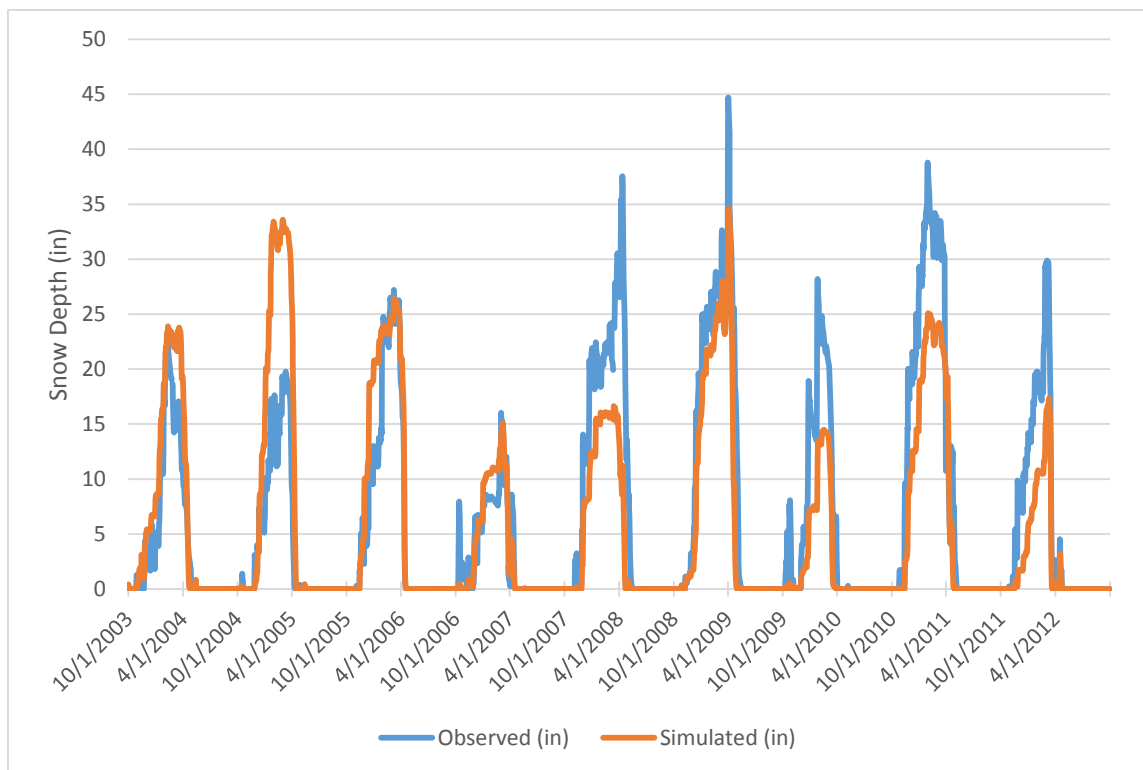


Figure 81. Mean daily snow depth time-series for weather region 14

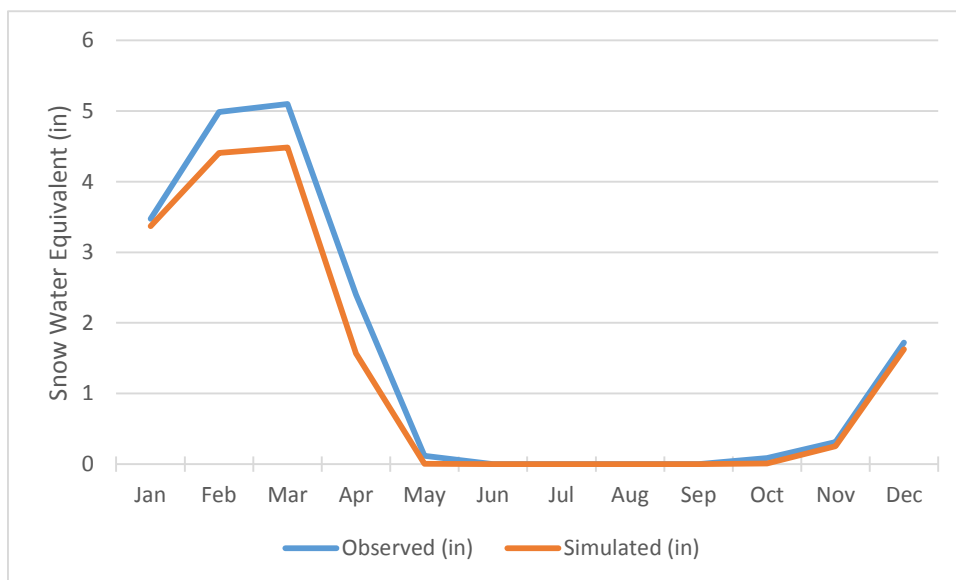


Figure 82. Mean monthly snow water equivalent for weather region 14

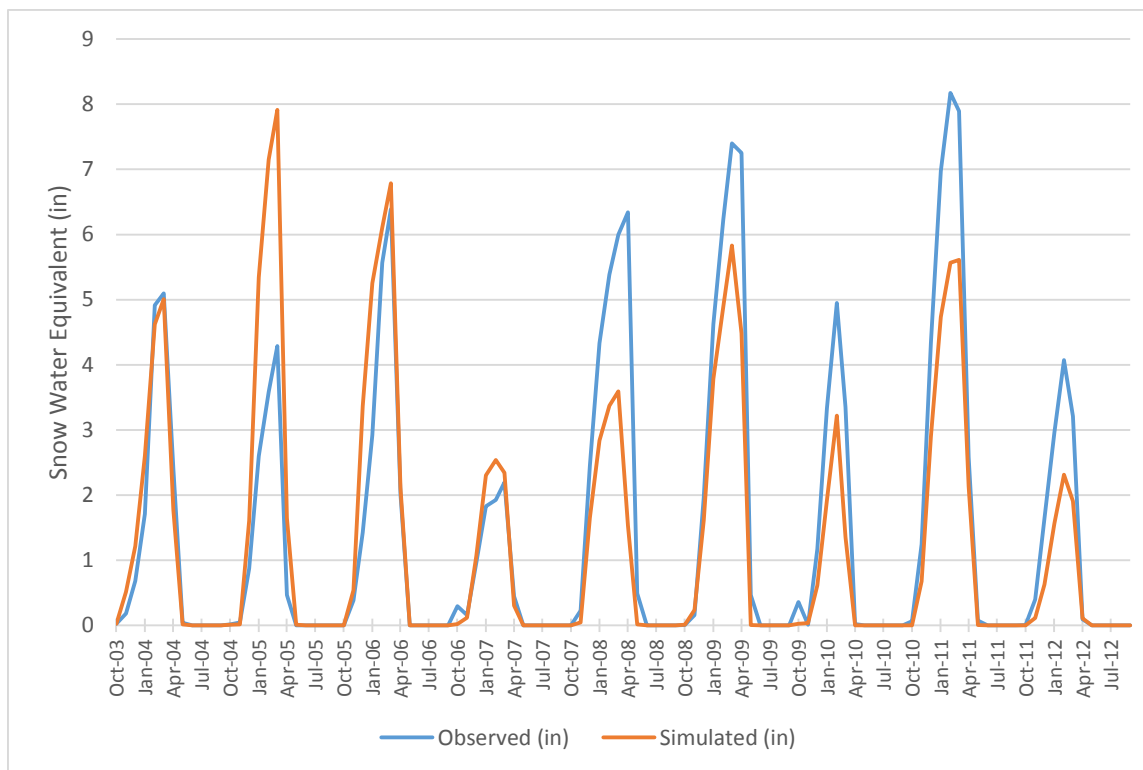


Figure 83. Mean monthly snow water equivalent time-series for weather region 14

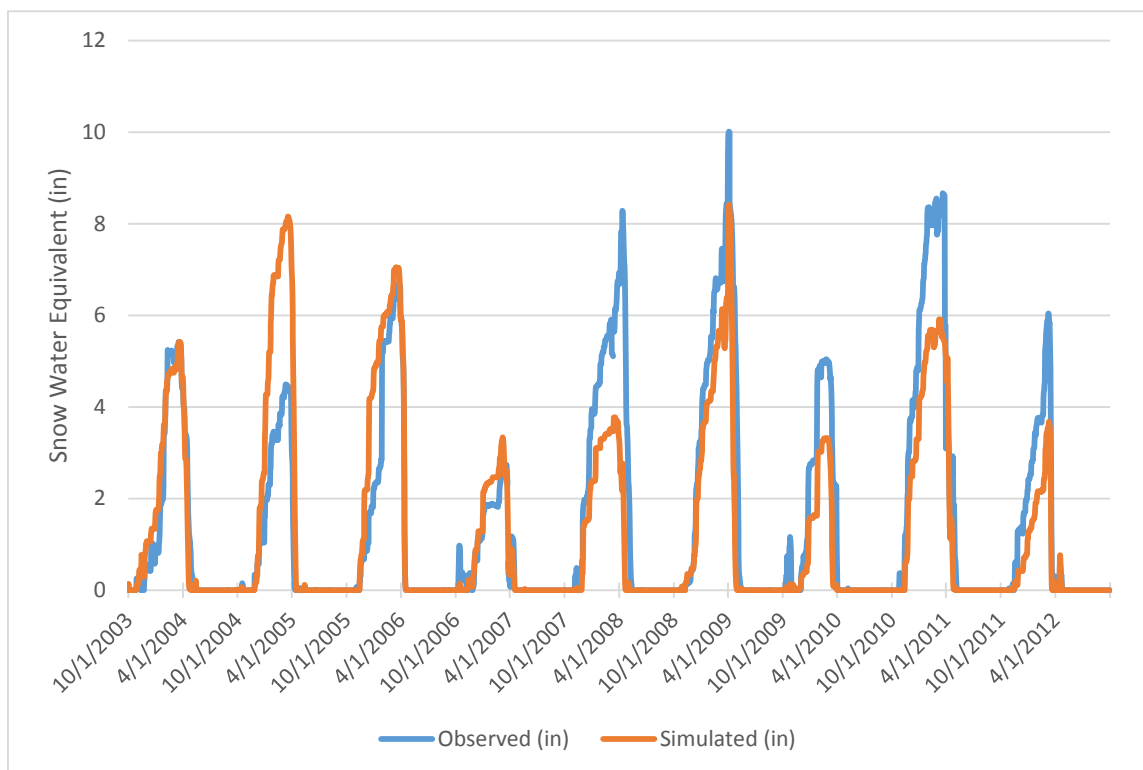


Figure 84. Mean daily snow water equivalent time-series for weather region 14

WEATHER REGION 15

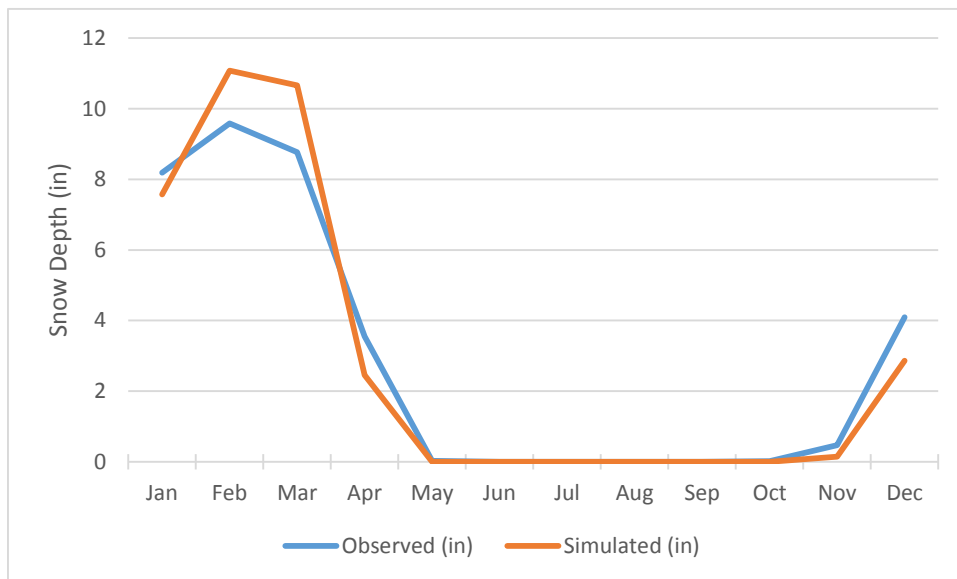


Figure 85. Mean monthly snow depth for weather region 15

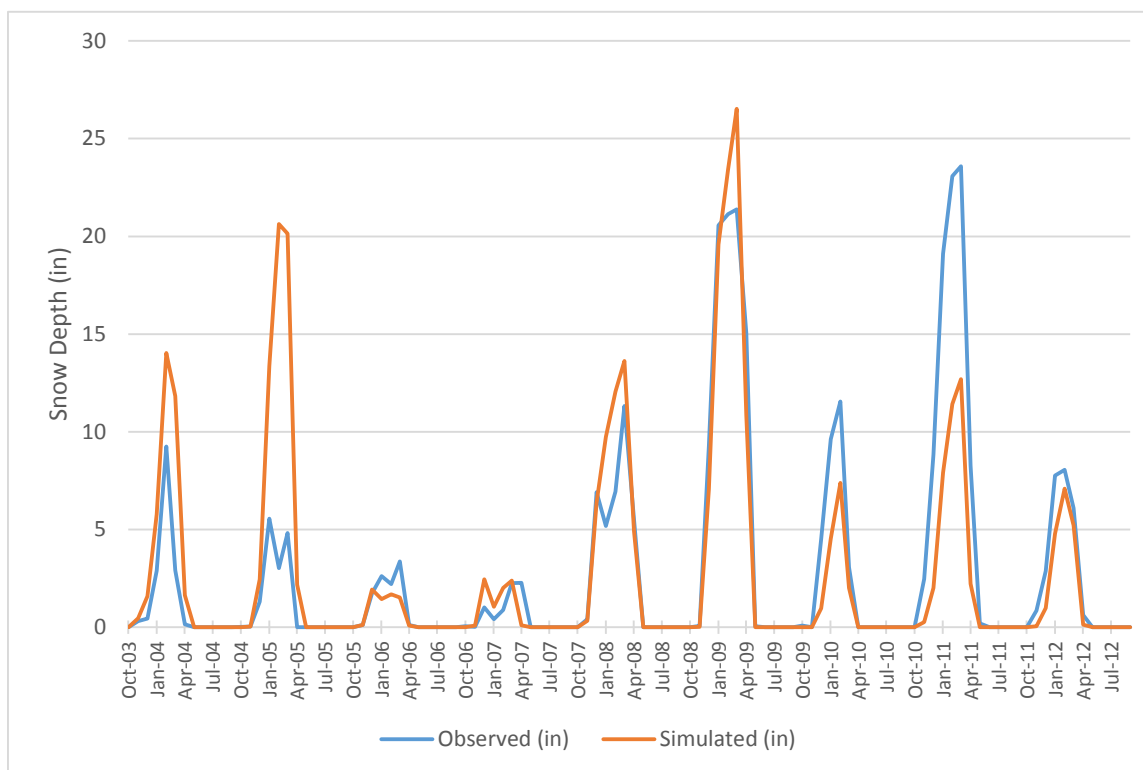


Figure 86. Mean monthly snow depth time-series for weather region 15

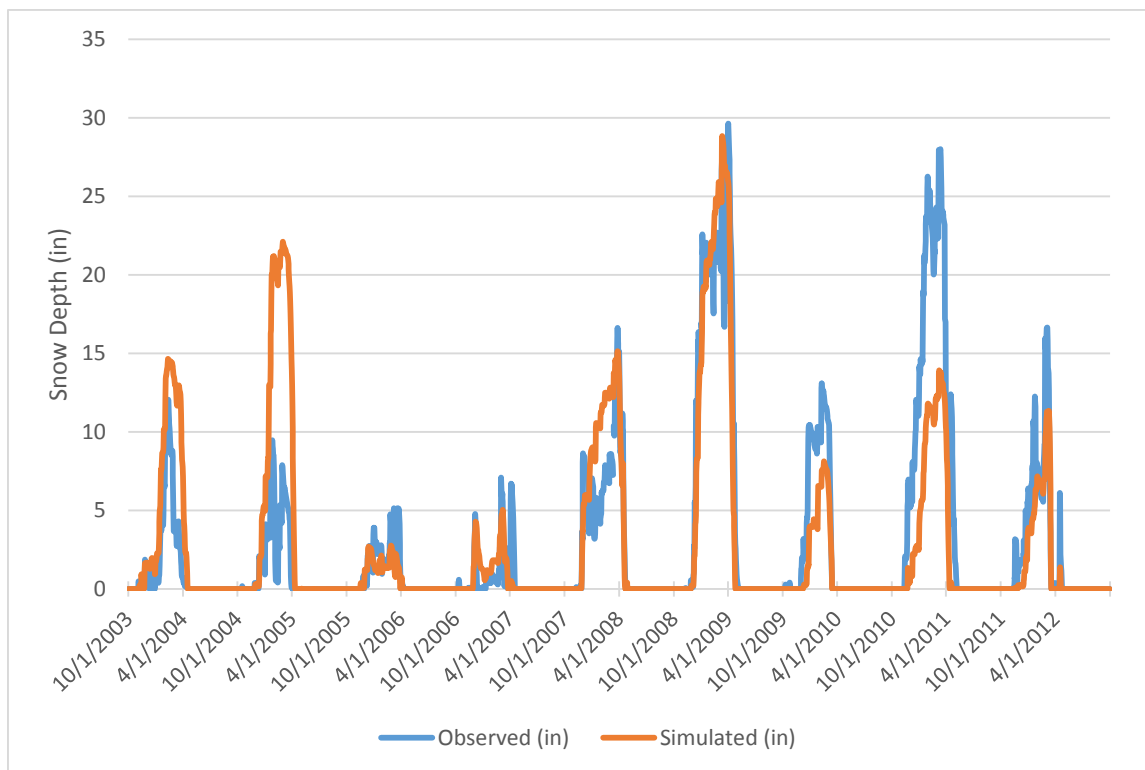


Figure 87. Mean daily snow depth time-series for weather region 15

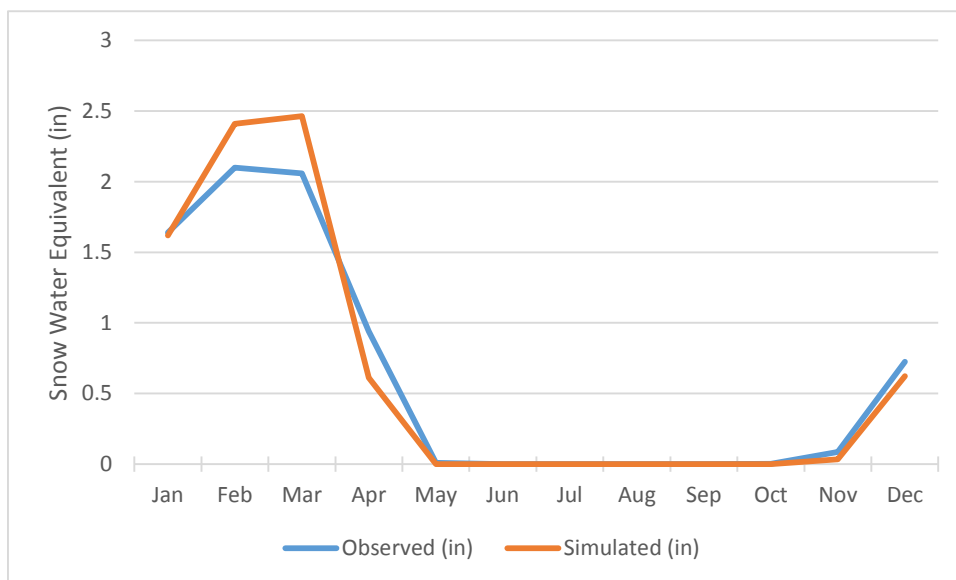


Figure 88. Mean monthly snow water equivalent for weather region 15

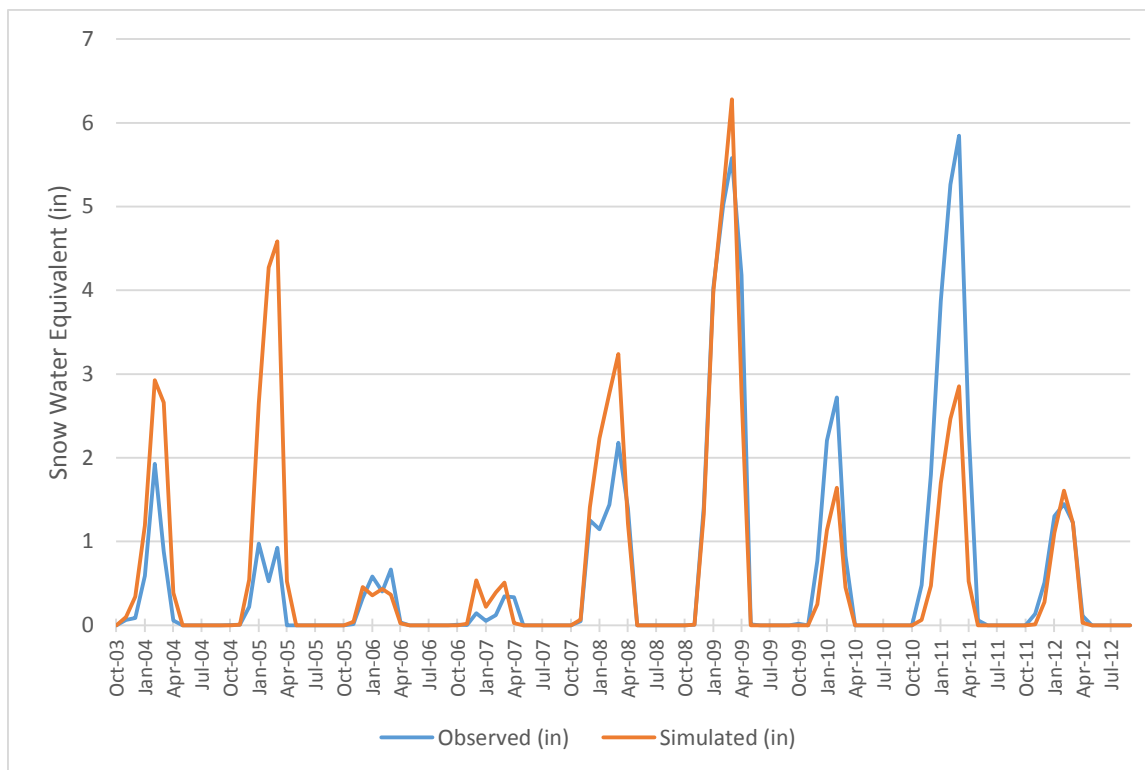


Figure 89. Mean monthly snow water equivalent time-series for weather region 15

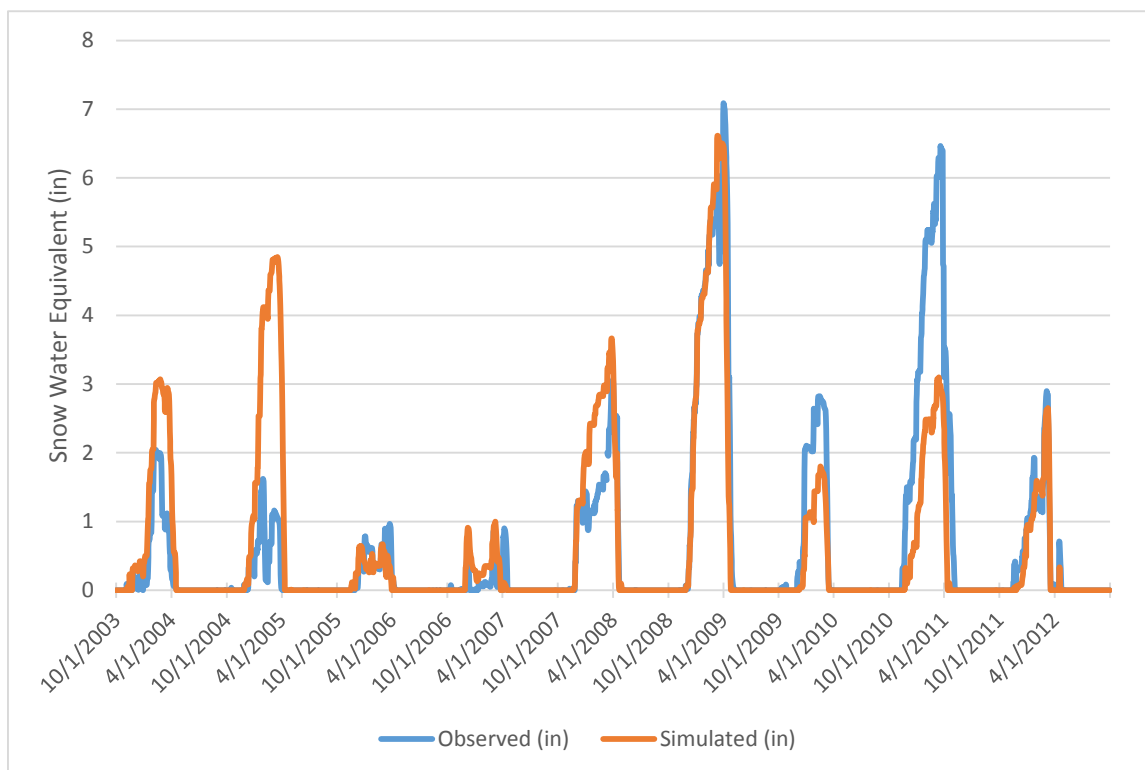


Figure 90. Mean daily snow water equivalent time-series for weather region 15

WEATHER REGION 16

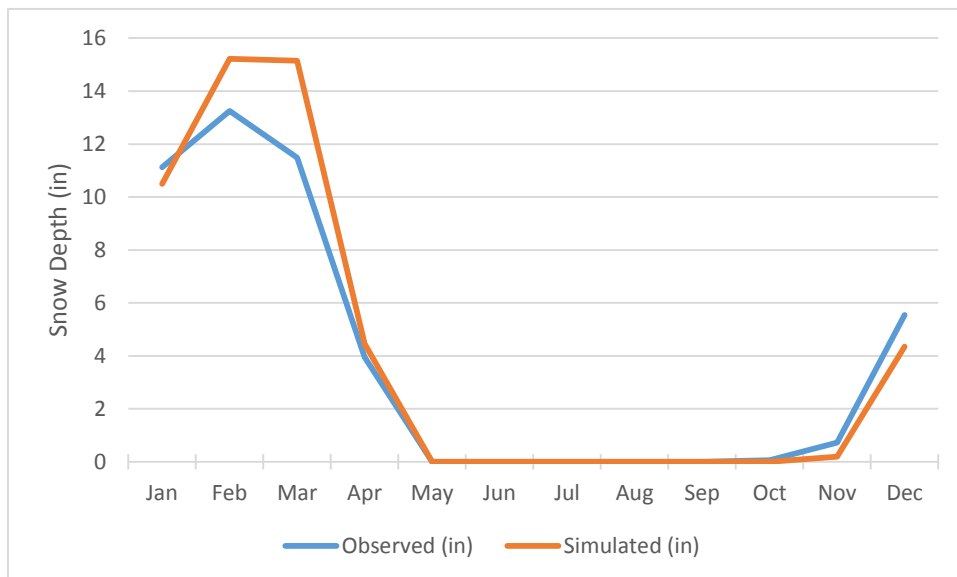


Figure 91. Mean monthly snow depth for weather region 16

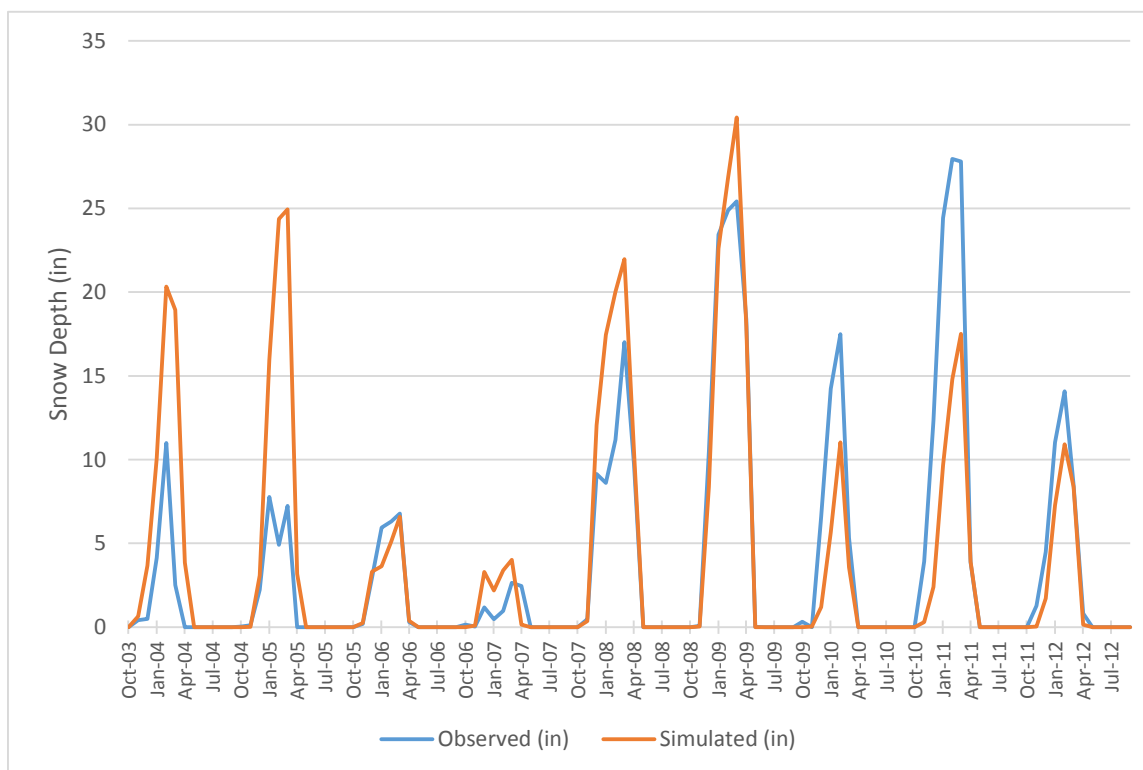


Figure 92. Mean monthly snow depth time-series for weather region 16

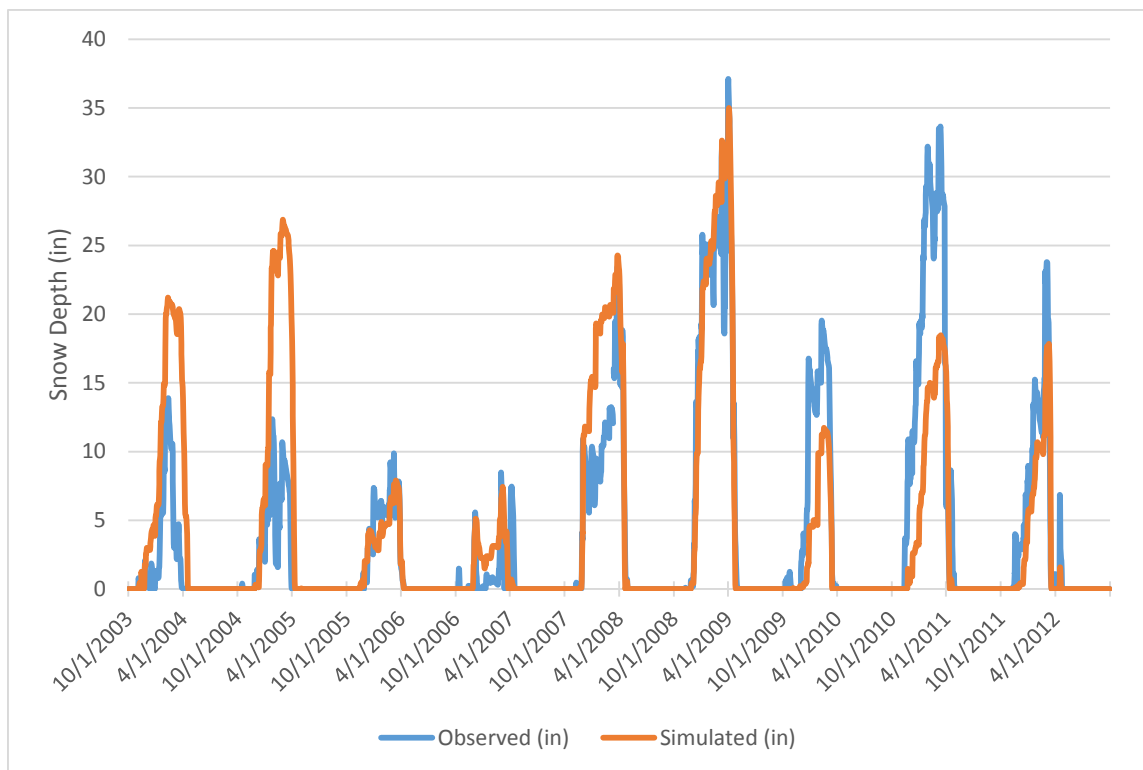


Figure 93. Mean daily snow depth time-series for weather region 16

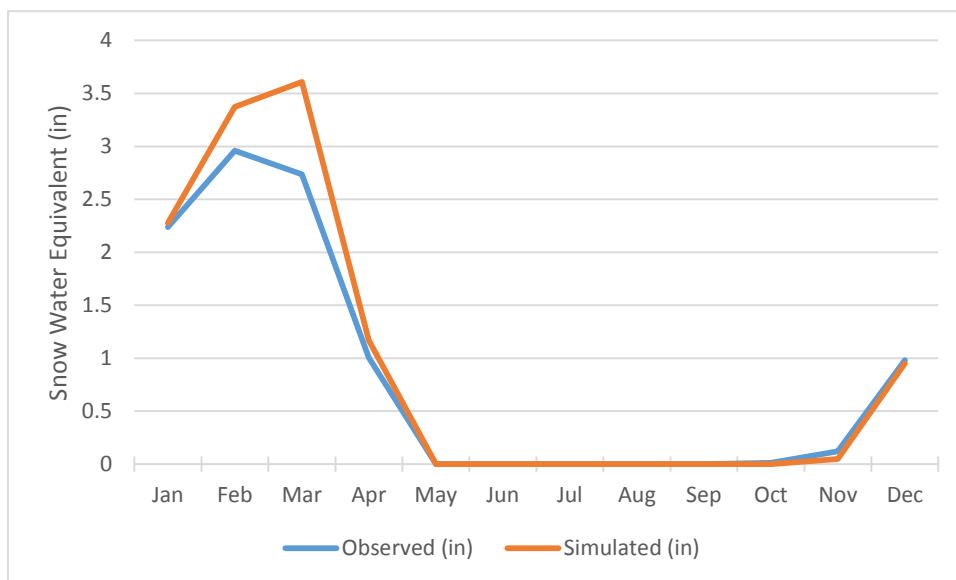


Figure 94. Mean monthly snow water equivalent for weather region 16

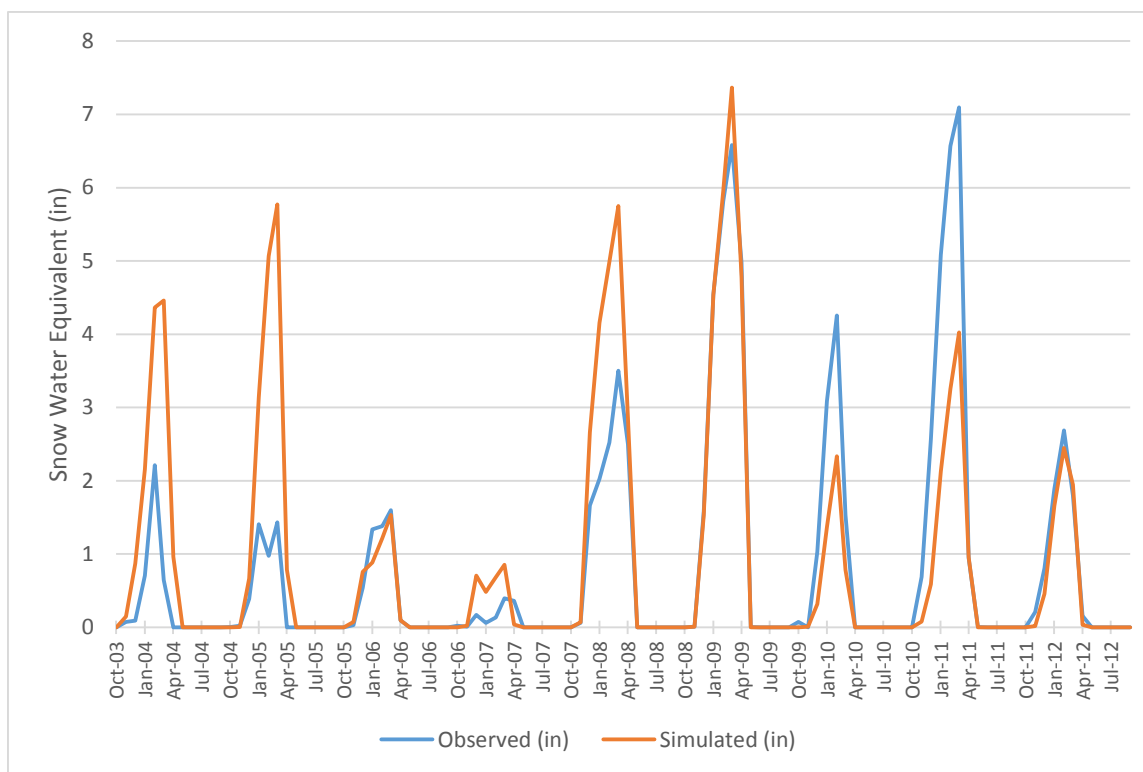


Figure 95. Mean monthly snow water equivalent time-series for weather region 16

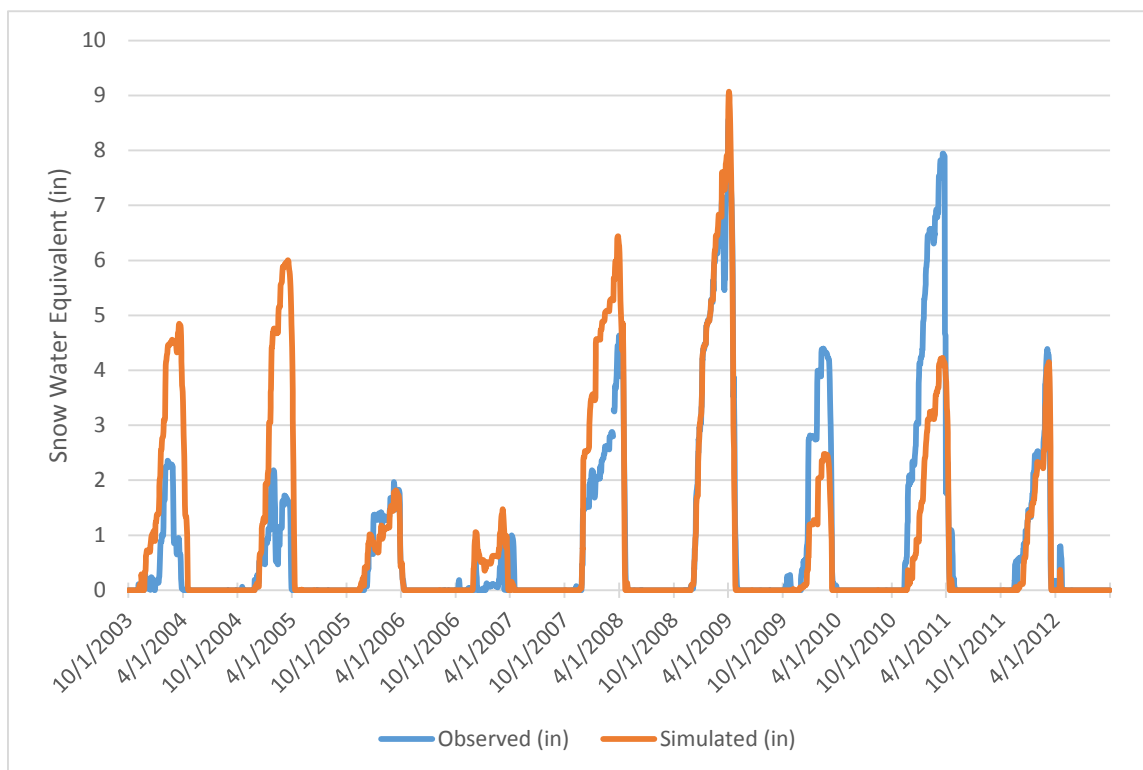


Figure 96. Mean daily snow water equivalent time-series for weather region 16

WEATHER REGION 17

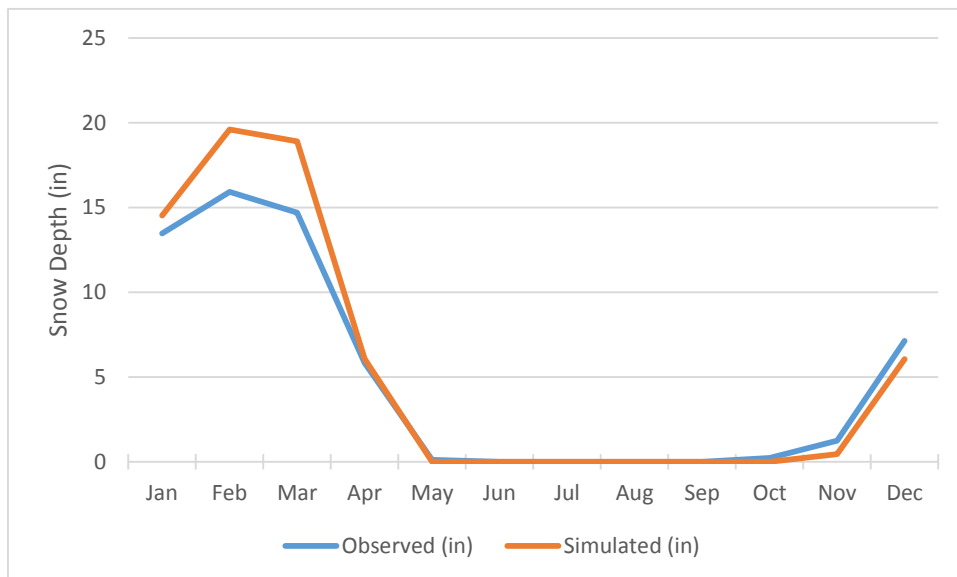


Figure 97. Mean monthly snow depth for weather region 17

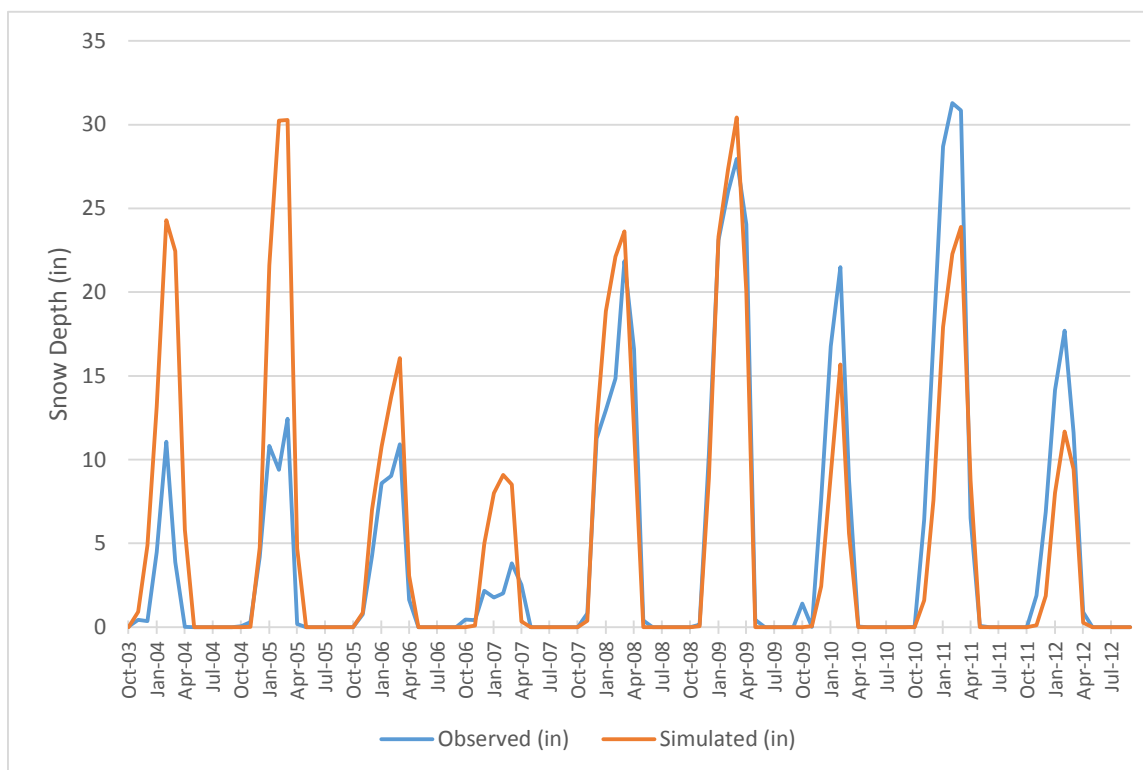


Figure 98. Mean monthly snow depth time-series for weather region 17

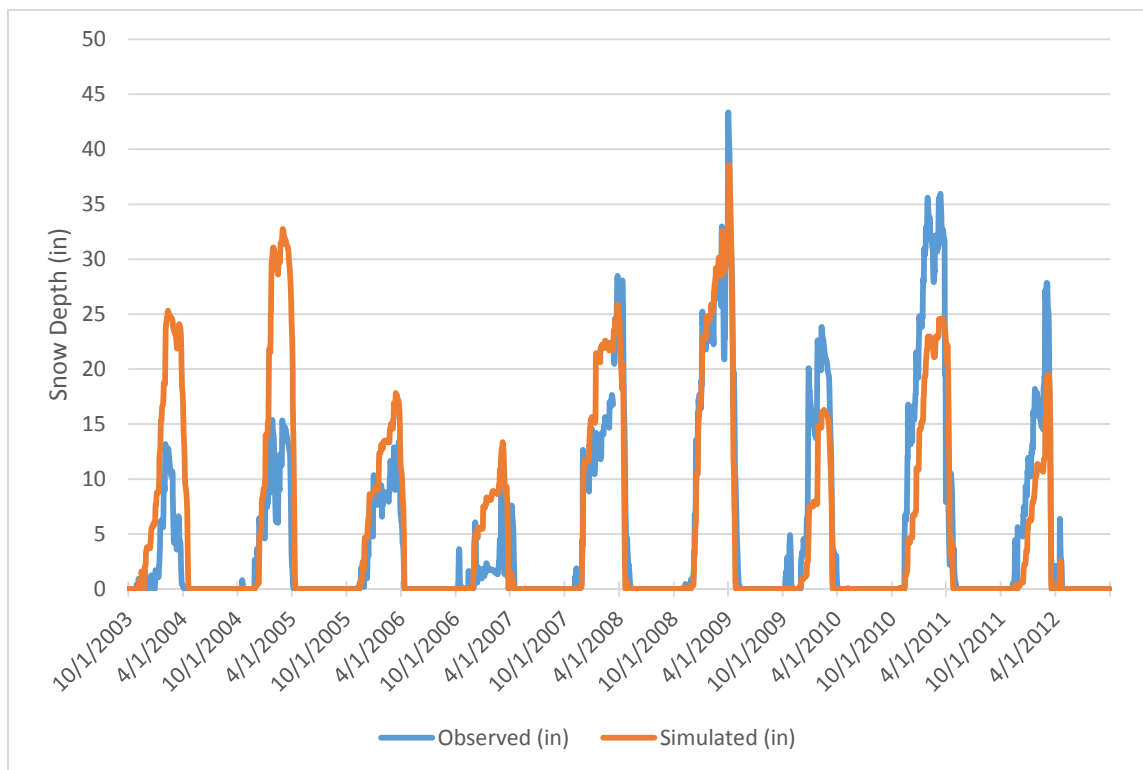


Figure 99. Mean daily snow depth time-series for weather region 17

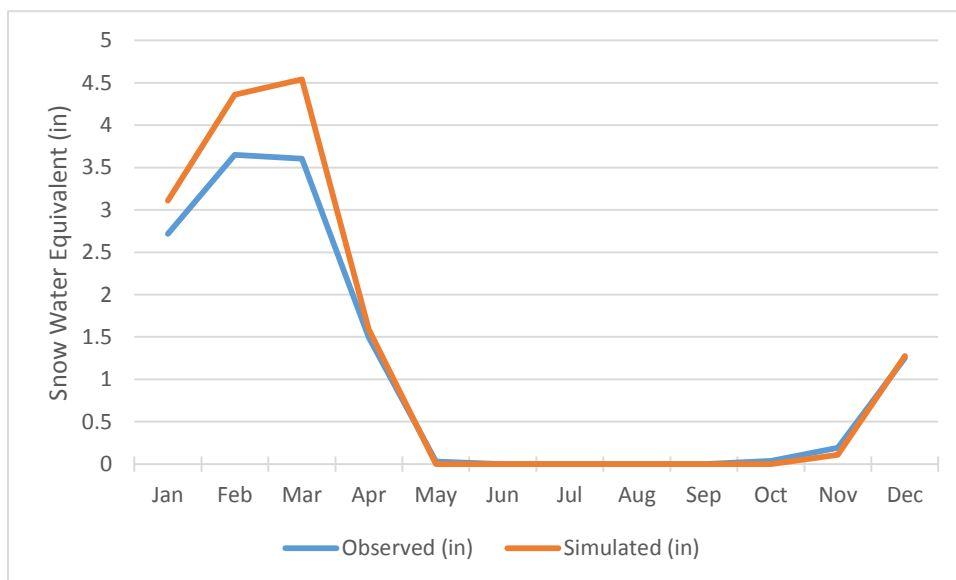


Figure 100. Mean monthly snow water equivalent for weather region 17

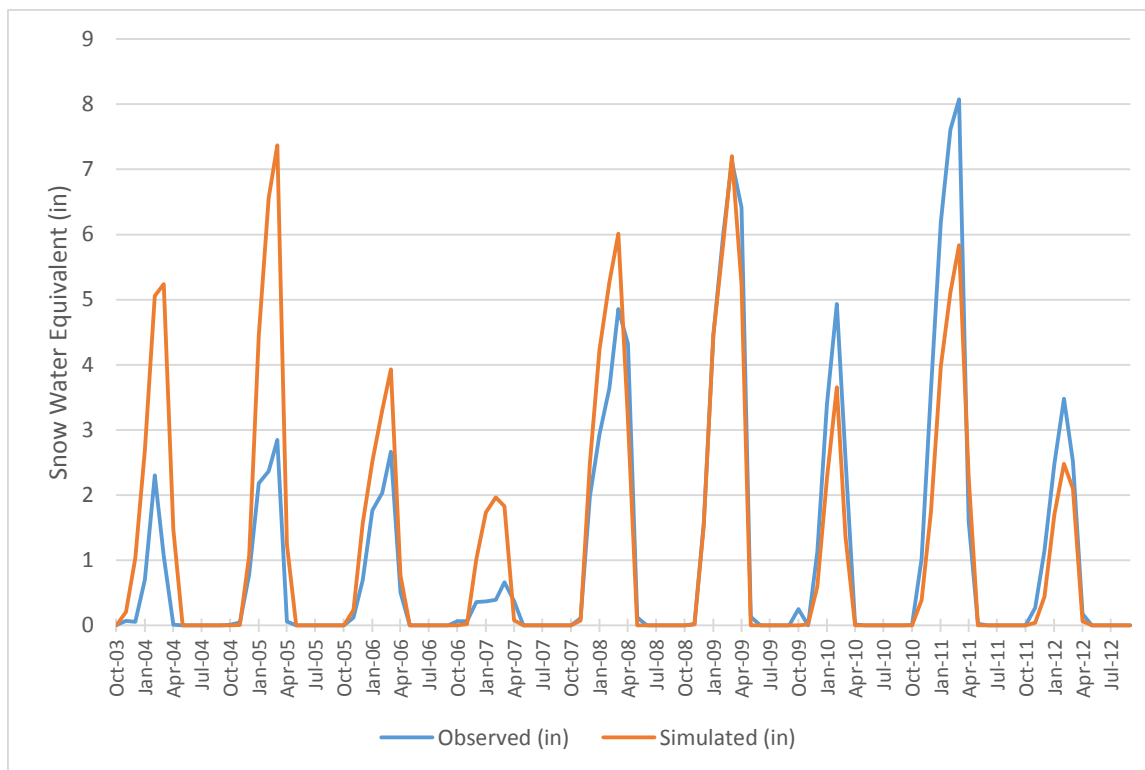


Figure 101. Mean monthly snow water equivalent time-series for weather region 17

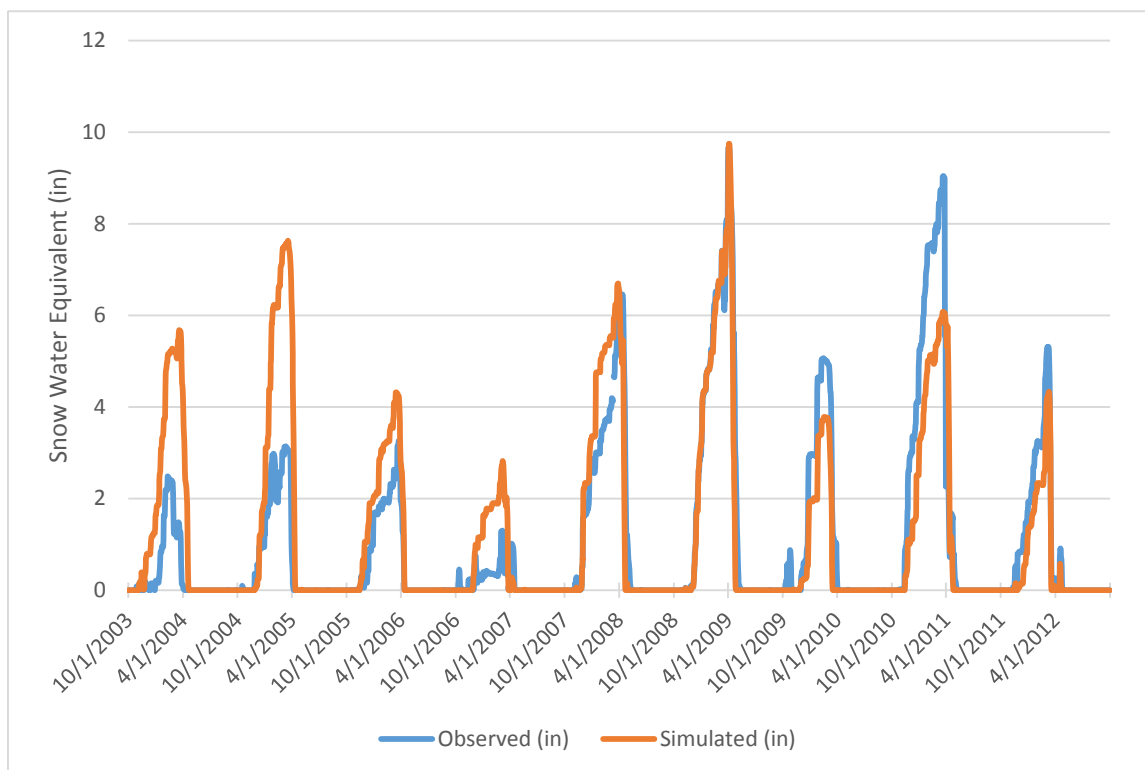


Figure 102. Mean daily snow water equivalent time-series for weather region 17

WEATHER REGION 18

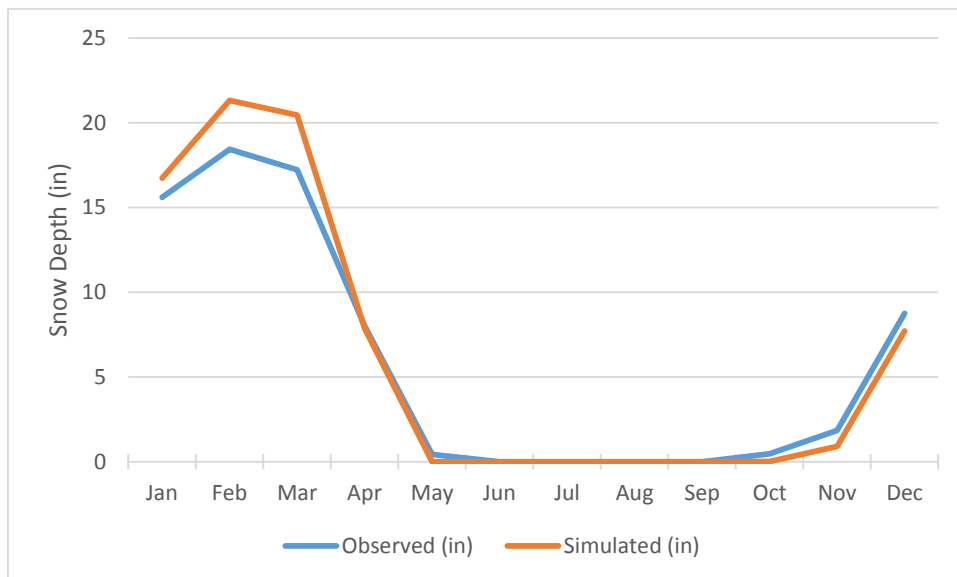


Figure 103. Mean monthly snow depth for weather region 18

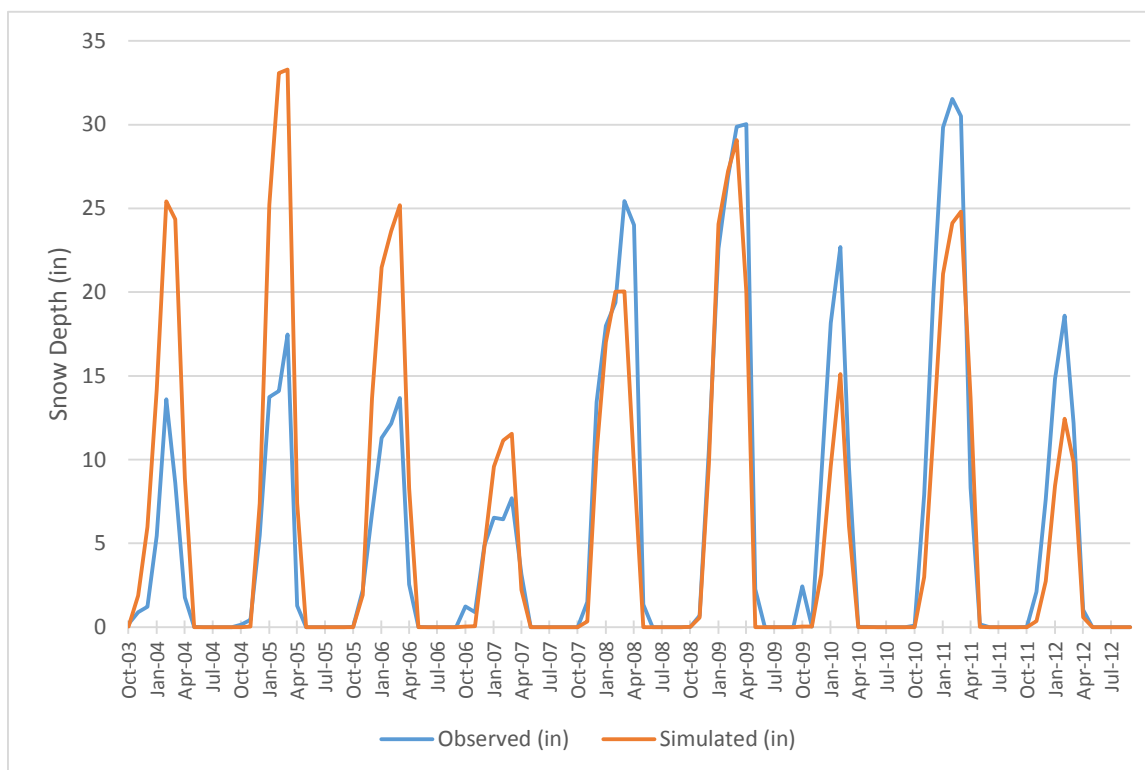


Figure 104. Mean monthly snow depth time-series for weather region 18

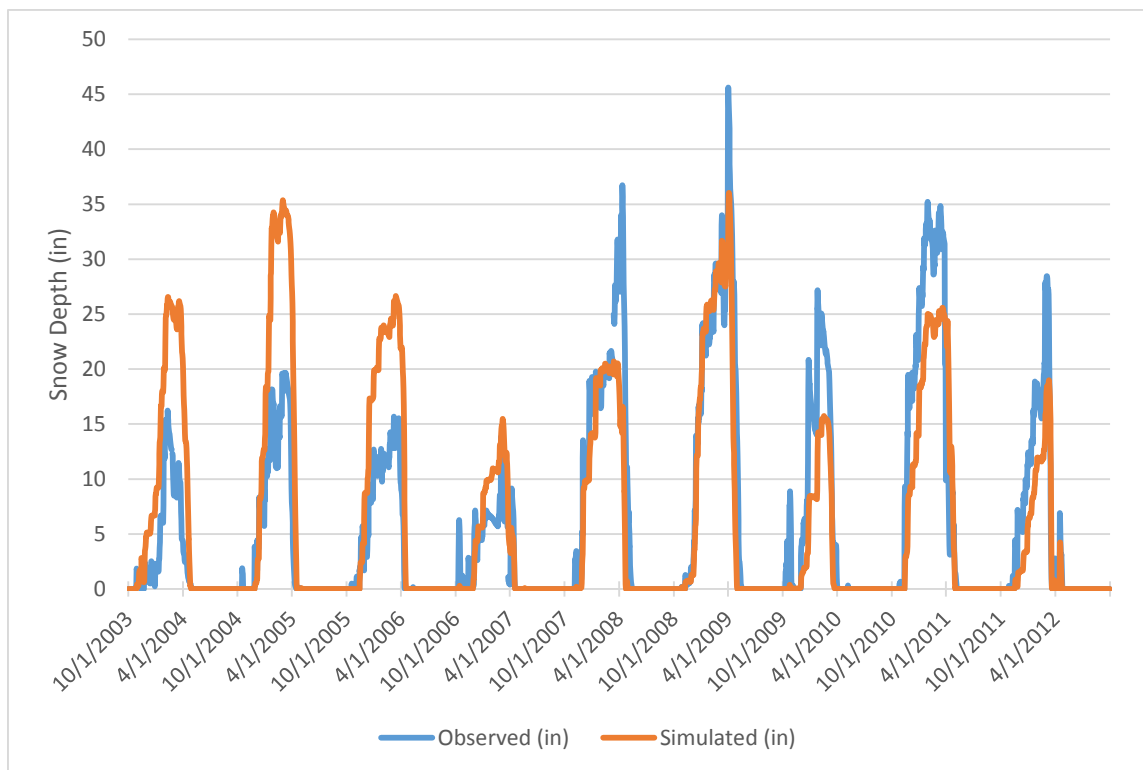


Figure 105. Mean daily snow depth time-series for weather region 18

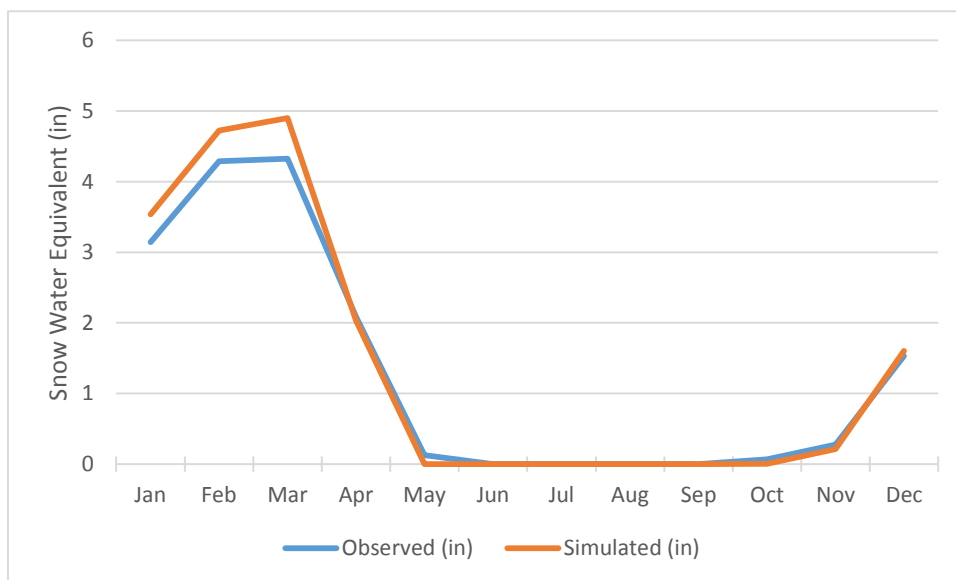


Figure 106. Mean monthly snow water equivalent for weather region 18

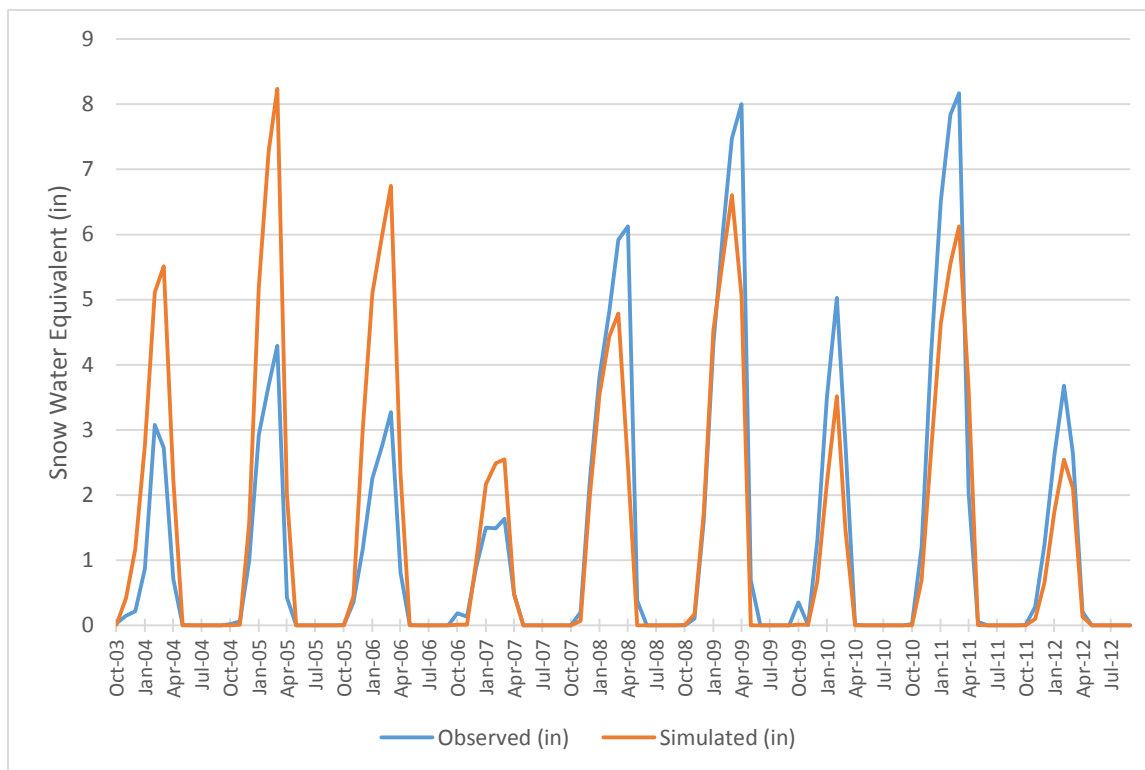


Figure 107. Mean monthly snow water equivalent time-series for weather region 18

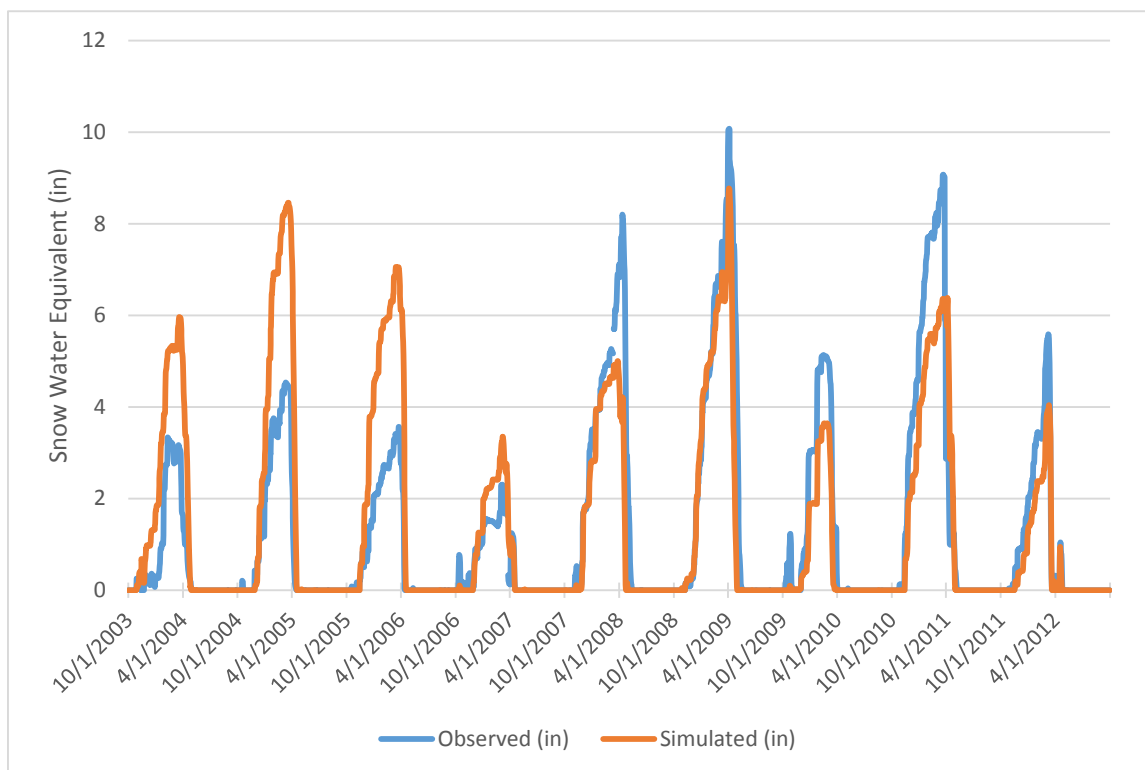


Figure 108. Mean daily snow water equivalent time-series for weather region 18

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Appendix B. Detailed Flow Calibration Results

EAST BRANCH AMITY CREEK AT DULUTH (HYDSTRA 02037005)

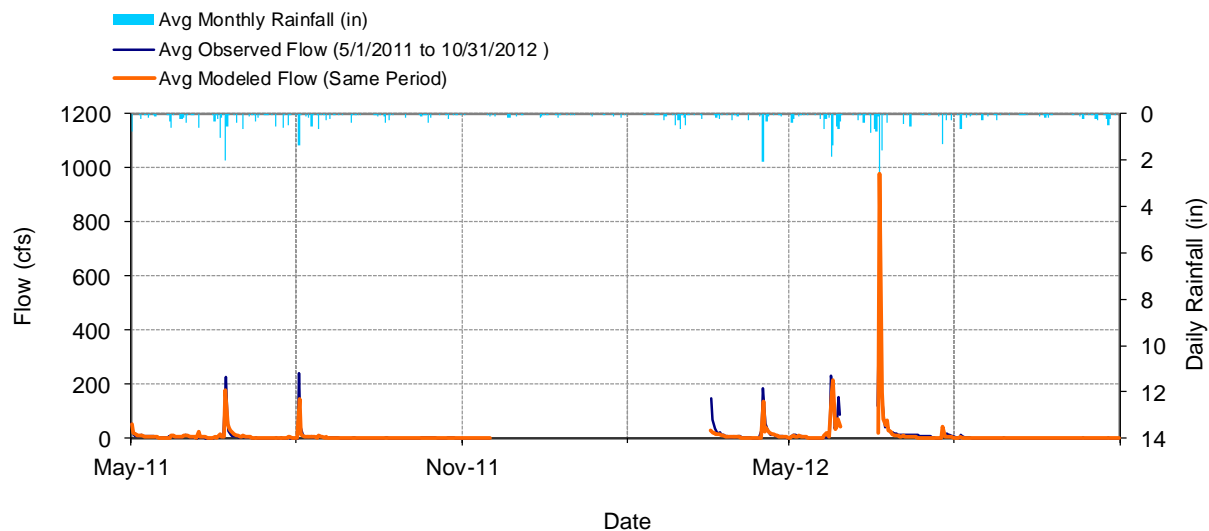


Figure 109. Mean daily flow at East Branch Amity Creek at Duluth

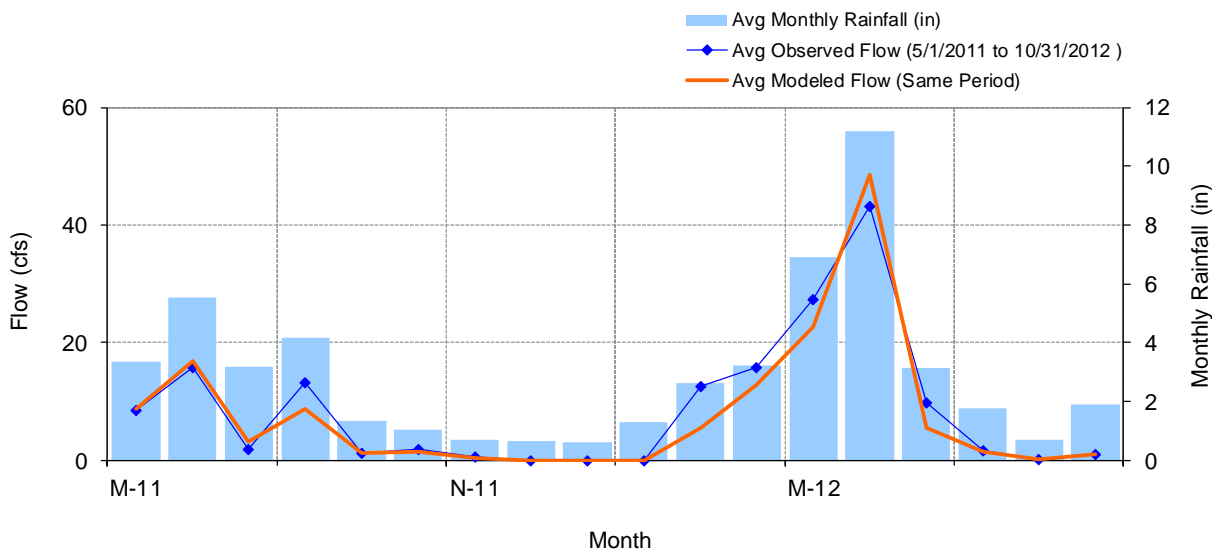


Figure 110. Mean monthly flow at East Branch Amity Creek at Duluth

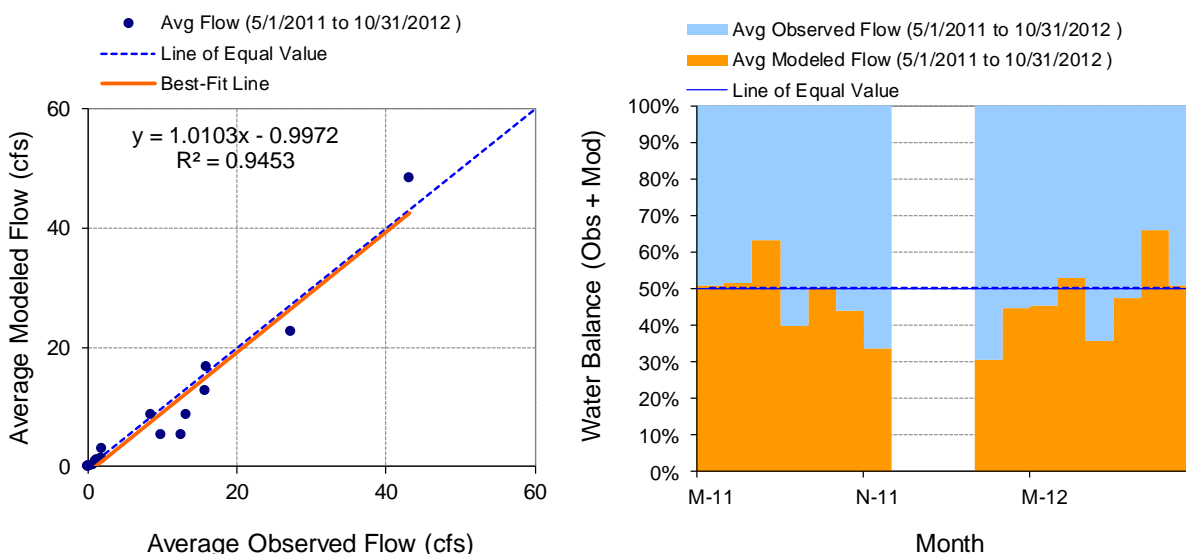


Figure 111. Monthly flow regression and temporal variation at East Branch Amity Creek at Duluth

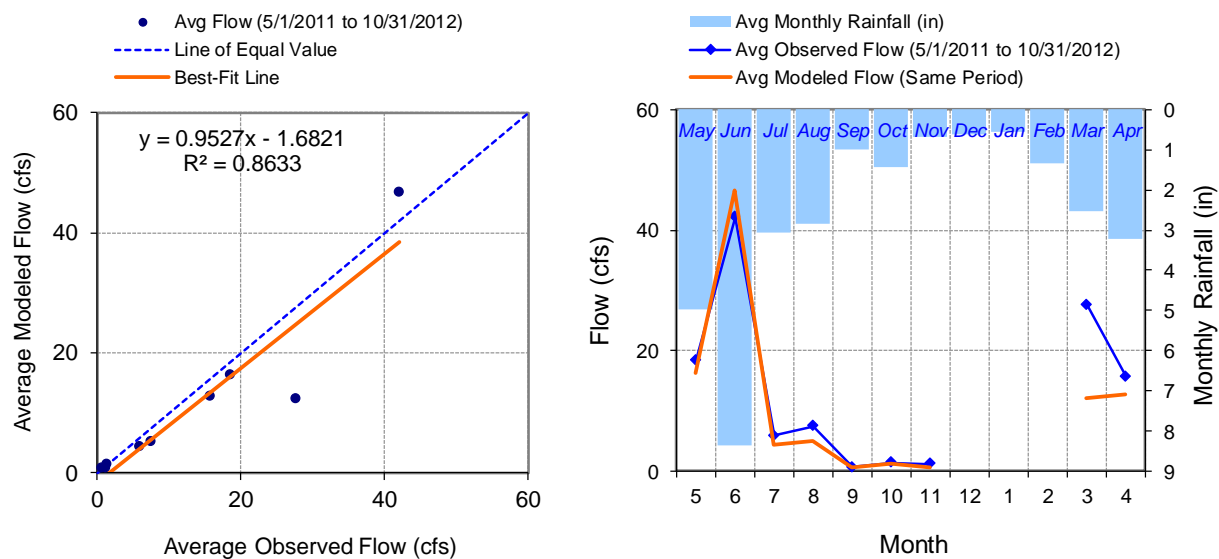


Figure 112. Seasonal regression and temporal aggregate at East Branch Amity Creek at Duluth

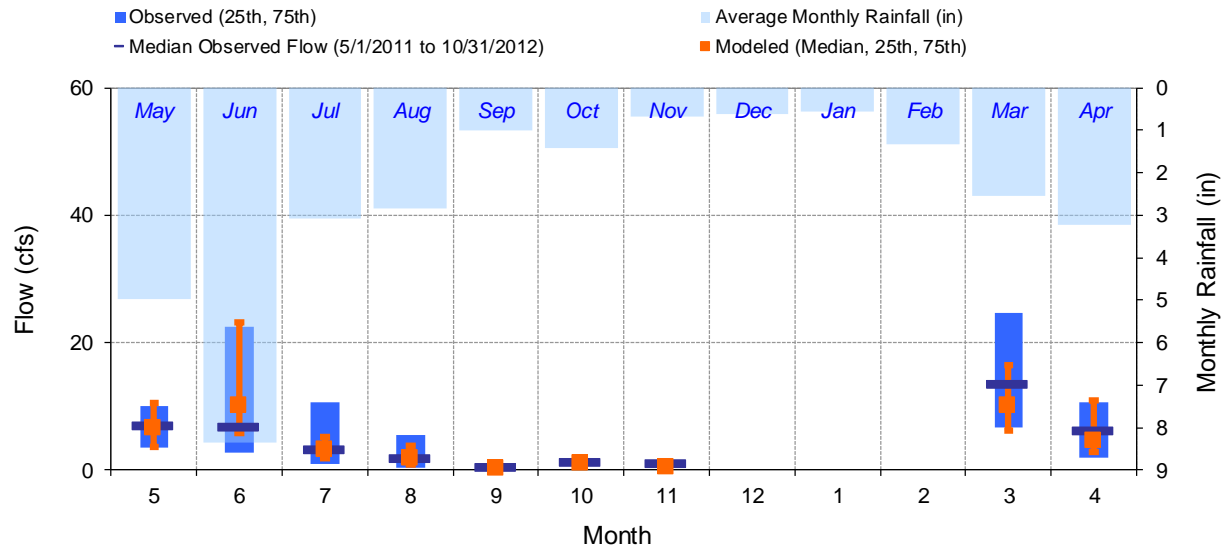


Figure 113. Seasonal medians and ranges at East Branch Amity Creek at Duluth

Table 1. Seasonal summary at East Branch Amity Creek at Duluth

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
May	18.46	6.90	3.58	10.00	16.22	6.54	3.69	10.56
Jun	42.11	6.85	2.75	22.50	46.62	10.15	5.79	23.14
Jul	5.84	3.25	0.91	10.75	4.29	3.15	1.95	5.26
Aug	7.39	1.80	0.33	5.50	5.06	1.80	0.83	3.74
Sep	0.61	0.44	0.08	1.03	0.65	0.31	0.14	1.02
Oct	1.38	1.30	1.10	1.60	1.21	0.99	0.52	1.68
Nov	1.13	1.10	1.10	1.20	0.57	0.53	0.40	0.77
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	27.61	13.50	6.65	24.75	12.11	10.20	6.30	16.41
Apr	15.73	6.30	1.93	10.75	12.69	4.60	2.85	10.88

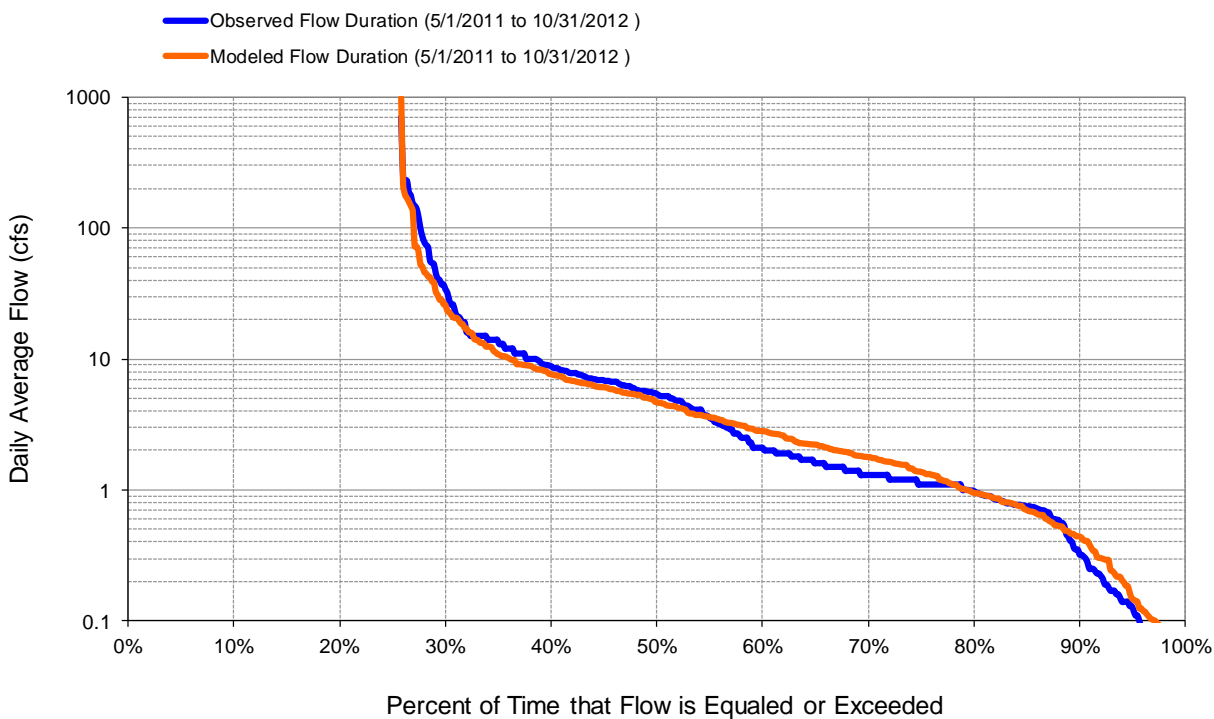


Figure 114. Flow exceedance at East Branch Amity Creek at Duluth

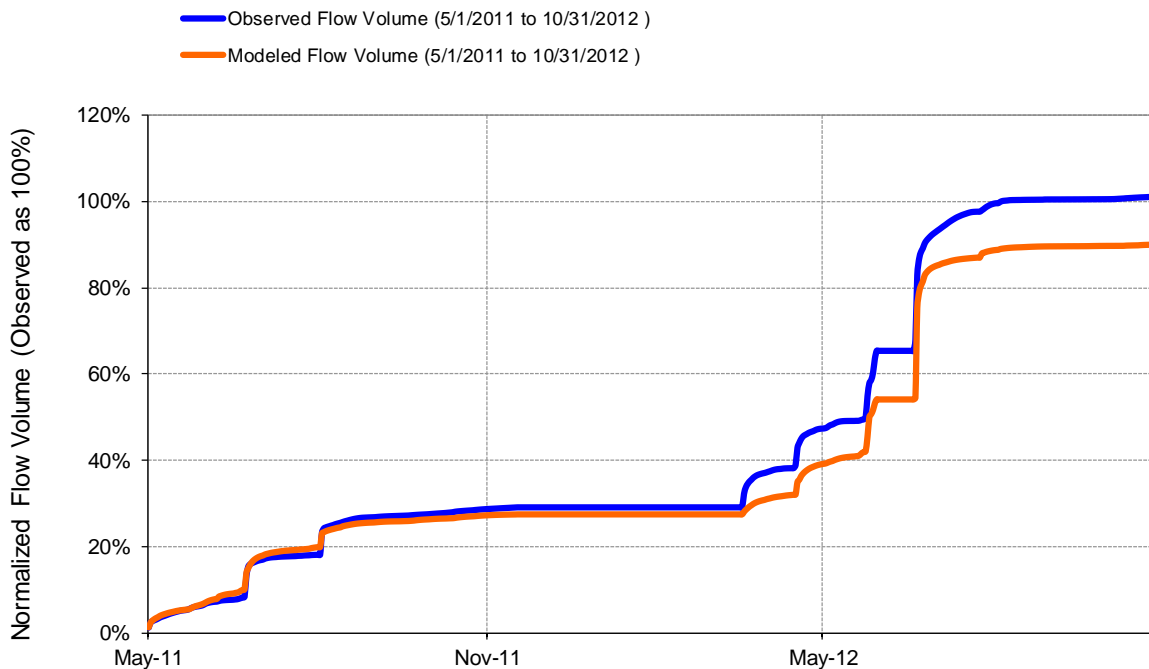


Figure 115. Flow accumulation at East Branch Amity Creek at Duluth

Table 2. Summary statistics at East Branch Amity Creek at Duluth

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 110 1.51-Year Analysis Period: 5/1/2011 - 10/31/2012 Flow volumes are (inches/year) for upstream drainage area		East Branch Amity Creek at Duluth, 1.8 mi DS of CSAH Manually Entered Data Drainage Area (sq-mi): 8.12	
Total Simulated In-stream Flow:	12.73	Total Observed In-stream Flow:	14.28
Total of simulated highest 10% flows:	9.26	Total of Observed highest 10% flows:	10.62
Total of Simulated lowest 50% flows:	0.63	Total of Observed Lowest 50% flows:	0.53
Simulated Summer Flow Volume (months 7-9):	1.88	Observed Summer Flow Volume (7-9):	2.61
Simulated Fall Flow Volume (months 10-12):	0.26	Observed Fall Flow Volume (10-12):	0.32
Simulated Winter Flow Volume (months 1-3):	0.52	Observed Winter Flow Volume (1-3):	1.18
Simulated Spring Flow Volume (months 4-6):	10.07	Observed Spring Flow Volume (4-6):	10.18
Total Simulated Storm Volume:	7.23	Total Observed Storm Volume:	7.50
Simulated Summer Storm Volume (7-9):	0.81	Observed Summer Storm Volume (7-9):	1.17
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-10.87	10	
Error in 50% lowest flows:	20.75	10	
Error in 10% highest flows:	-12.88	15	
Seasonal volume error - Summer:	-27.75	30	
Seasonal volume error - Fall:	-18.62	30	
Seasonal volume error - Winter:	-56.14	30	
Seasonal volume error - Spring:	-1.08	30	
Error in storm volumes:	-3.55	20	
Error in summer storm volumes:	-31.43	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.820	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.678		
Monthly NSE	0.930		

AMITY CREEK AT DULUTH (HYDSTRA 02038001)

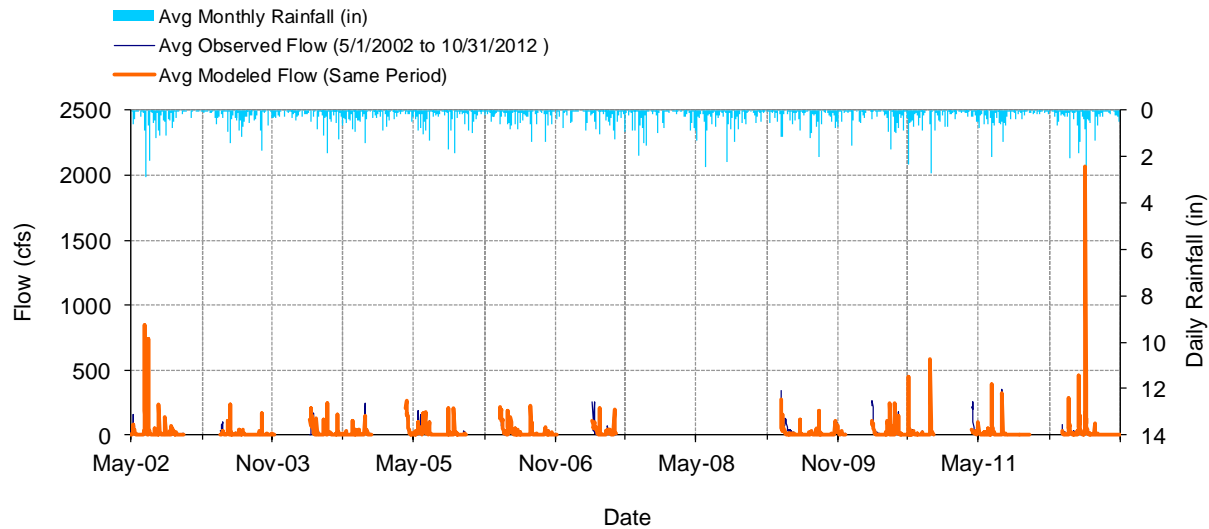


Figure 116. Mean daily flow at Amity Creek at Duluth

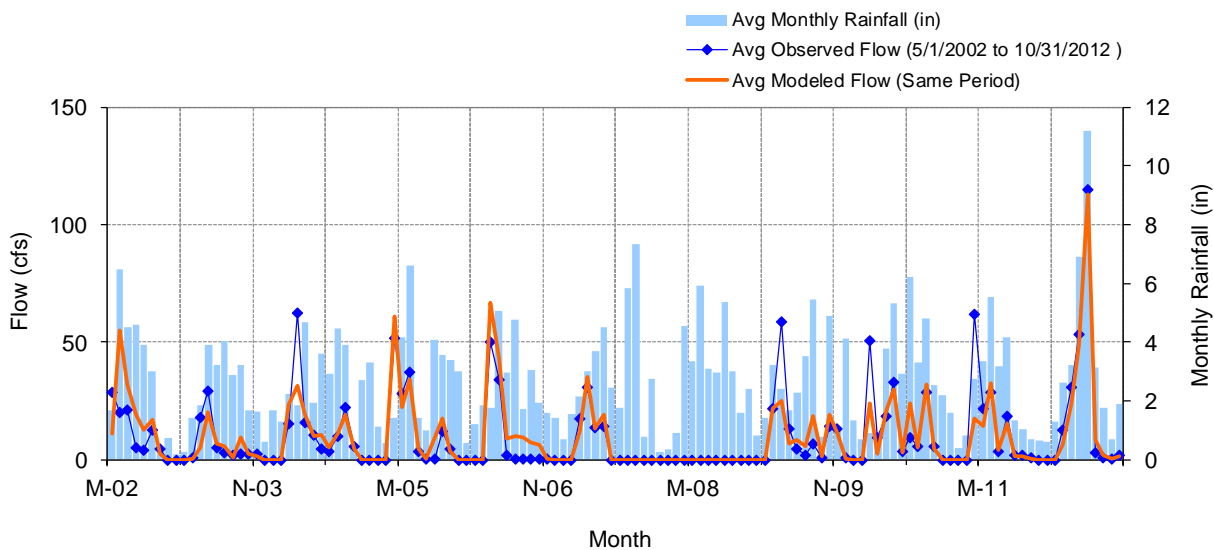


Figure 117. Mean monthly flow at Amity Creek at Duluth

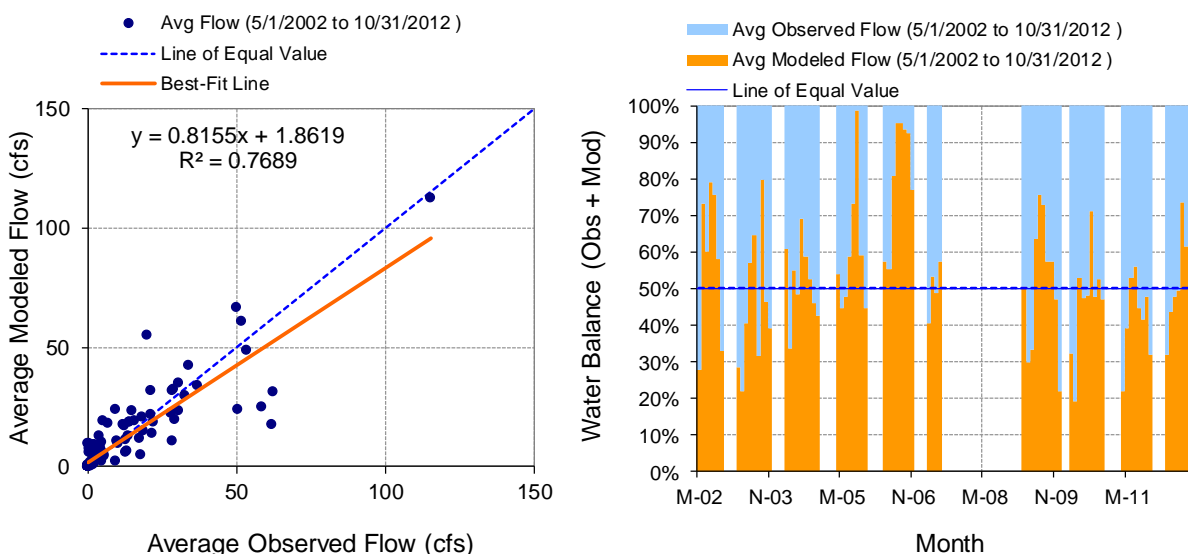


Figure 118. Monthly flow regression and temporal variation at Amity Creek at Duluth

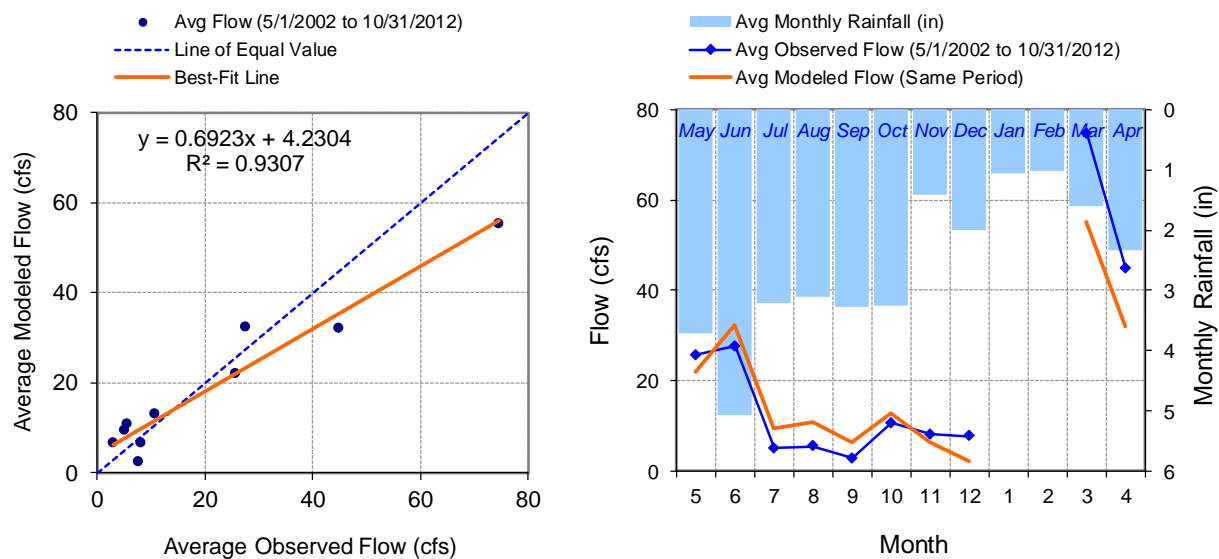


Figure 119. Seasonal regression and temporal aggregate at Amity Creek at Duluth

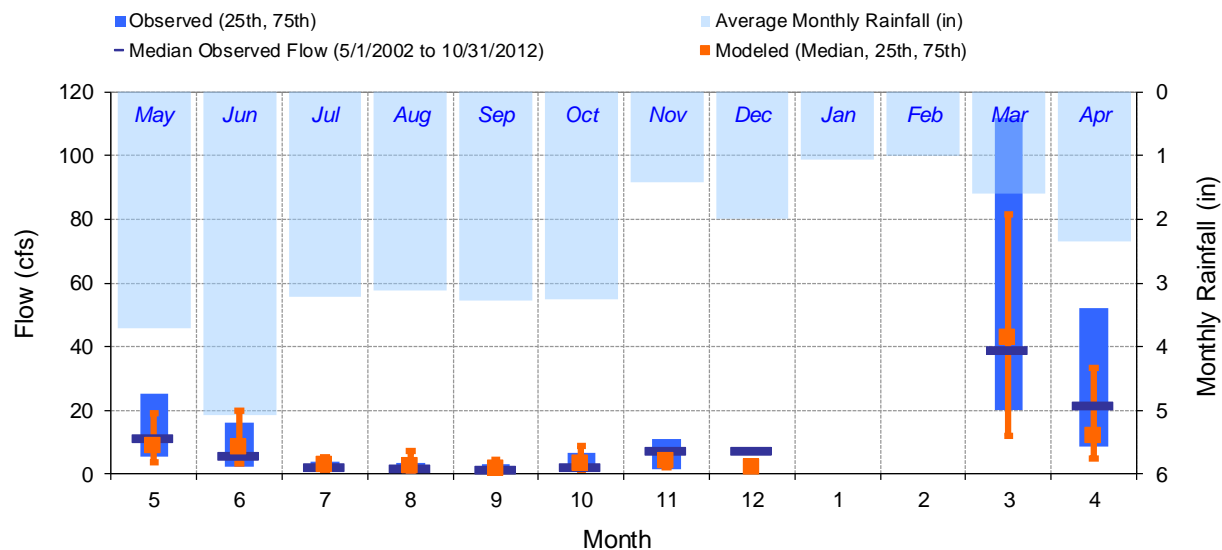


Figure 120. Seasonal medians and ranges at Amity Creek at Duluth

Table 3. Seasonal summary at Amity Creek at Duluth

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
May	25.67	11.32	5.54	25.23	21.84	8.79	3.91	19.01
Jun	27.59	5.71	2.53	16.00	32.34	8.48	3.27	20.02
Jul	4.99	2.02	1.09	3.83	9.39	2.81	1.29	5.38
Aug	5.42	1.83	0.48	3.69	10.72	2.44	0.96	7.42
Sep	2.83	1.40	0.38	3.05	6.43	1.72	0.30	4.38
Oct	10.66	2.30	1.35	6.50	12.86	3.49	1.30	8.91
Nov	8.11	7.10	1.50	11.00	6.39	4.02	2.01	6.78
Dec	7.73	7.40	7.08	8.05	2.16	2.14	1.96	2.34
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	74.68	39.00	20.00	111.71	55.21	42.93	11.98	81.51
Apr	44.78	21.50	8.55	51.93	32.04	12.03	5.06	33.36

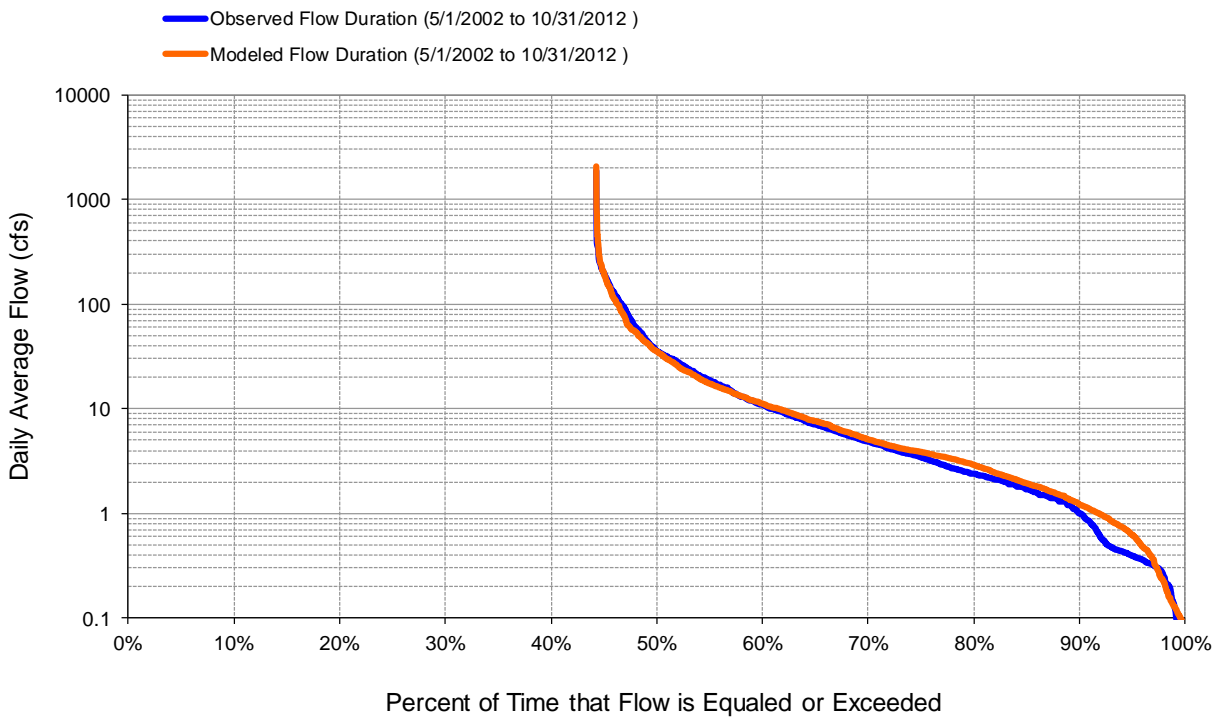


Figure 121. Flow exceedance at Amity Creek at Duluth

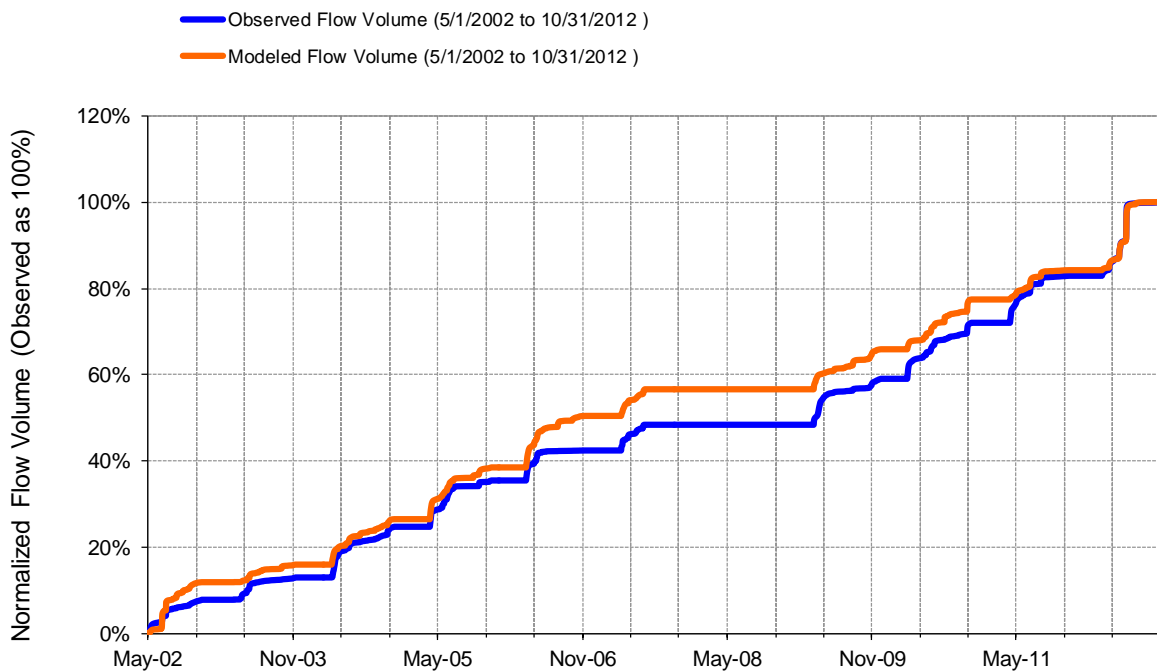


Figure 122. Flow accumulation at Amity Creek at Duluth

Table 4. Summary statistics at Amity Creek at Duluth

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 10 10.51-Year Analysis Period: 5/1/2002 - 10/31/2012 Flow volumes are (inches/year) for upstream drainage area		Amity Creek at Duluth, Occidental Blvd. Manually Entered Data Drainage Area (sq-mi): 16.7	
Total Simulated In-stream Flow:	8.20	Total Observed In-stream Flow:	8.19
Total of simulated highest 10% flows:	5.43	Total of Observed highest 10% flows:	5.45
Total of Simulated lowest 50% flows:	0.45	Total of Observed Lowest 50% flows:	0.38
Simulated Summer Flow Volume (months 7-9):	1.53	Observed Summer Flow Volume (7-9):	0.77
Simulated Fall Flow Volume (months 10-12):	0.95	Observed Fall Flow Volume (10-12):	0.87
Simulated Winter Flow Volume (months 1-3):	0.57	Observed Winter Flow Volume (1-3):	0.78
Simulated Spring Flow Volume (months 4-6):	5.15	Observed Spring Flow Volume (4-6):	5.78
Total Simulated Storm Volume:	4.04	Total Observed Storm Volume:	3.49
Simulated Summer Storm Volume (7-9):	0.95	Observed Summer Storm Volume (7-9):	0.40
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	0.13	10	
Error in 50% lowest flows:	17.69	10	
Error in 10% highest flows:	-0.42	15	
Seasonal volume error - Summer:	100.29	30	
Seasonal volume error - Fall:	8.69	30	
Seasonal volume error - Winter:	-26.07	30	
Seasonal volume error - Spring:	-10.92	30	
Error in storm volumes:	15.95	20	
Error in summer storm volumes:	140.35	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.653	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.488		
Monthly NSE	0.712		

TALMADGE RIVER NEAR DULUTH (HYDSTRA 02035001)

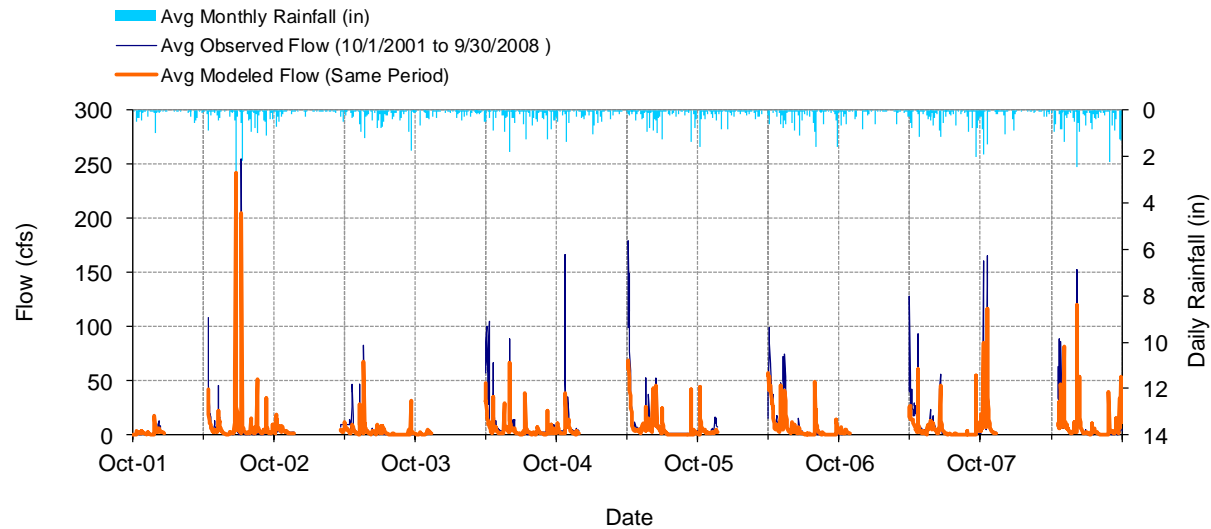


Figure 123. Mean daily flow at Talmadge River near Duluth

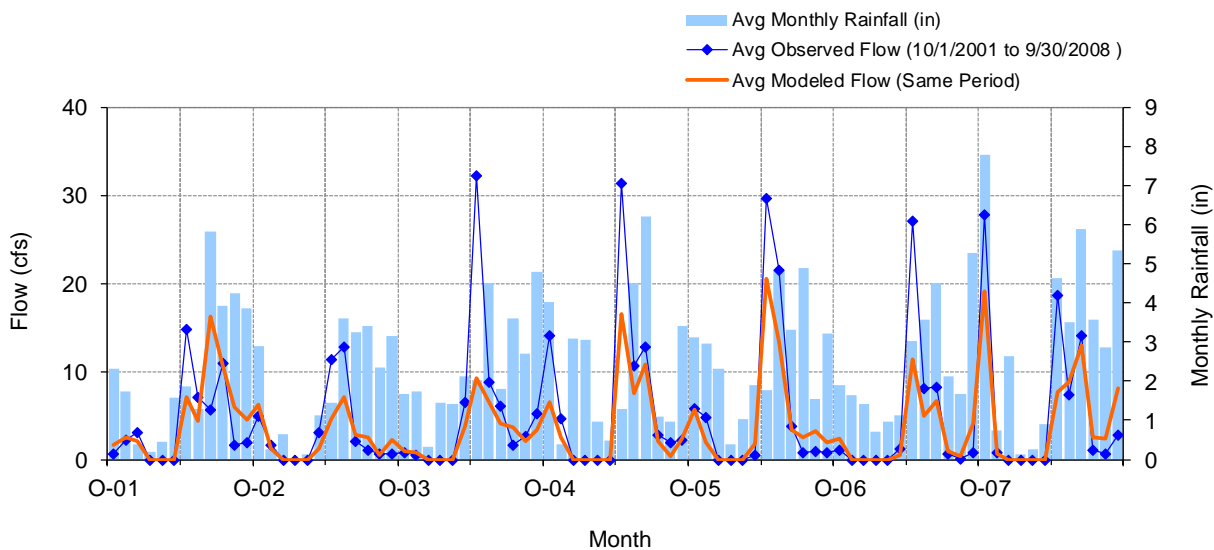


Figure 124. Mean monthly flow at Talmadge River near Duluth

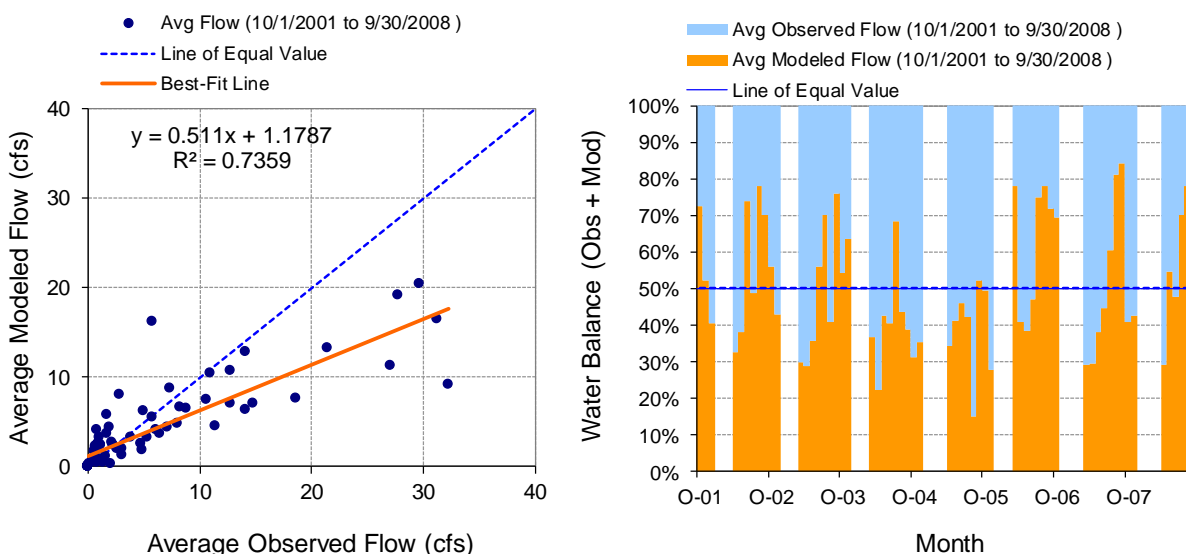


Figure 125. Monthly flow regression and temporal variation at Talmadge River near Duluth

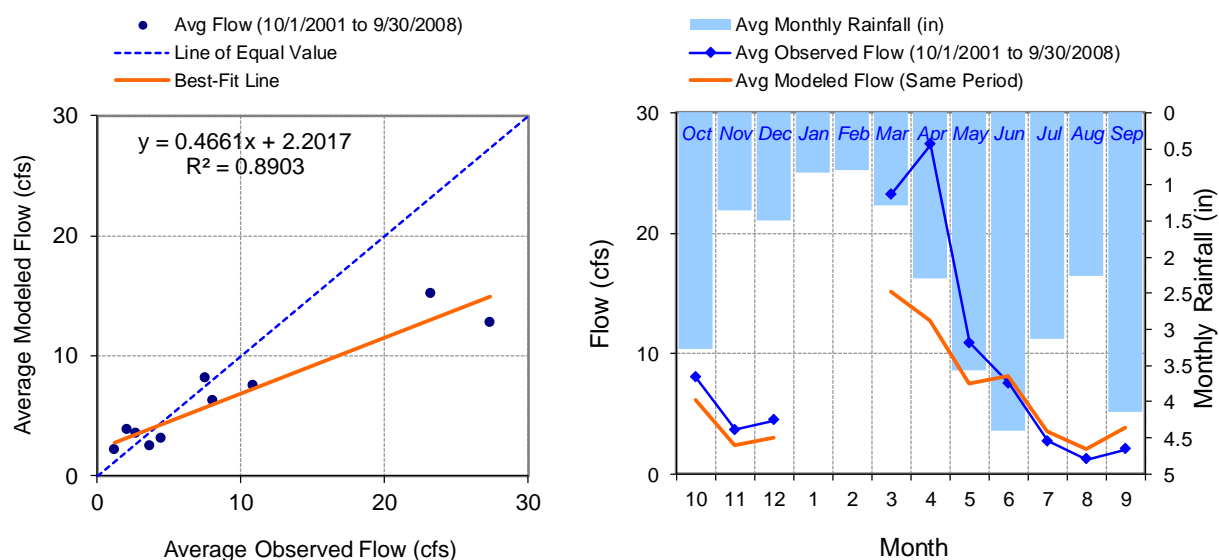


Figure 126. Seasonal regression and temporal aggregate at Talmadge River near Duluth

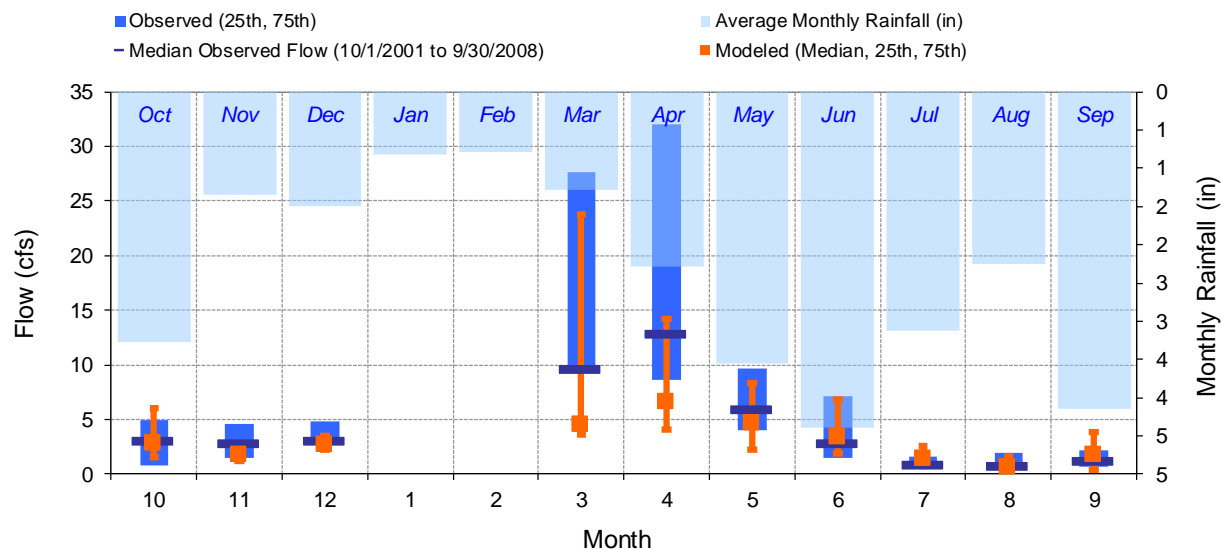


Figure 127. Seasonal medians and ranges at Talmadge River near Duluth

Table 5. Seasonal summary at Talmadge River near Duluth

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	8.01	3.03	0.82	4.98	6.18	2.80	1.49	6.09
Nov	3.68	2.77	1.47	4.65	2.39	1.81	1.24	2.72
Dec	4.44	3.04	2.87	4.87	3.02	2.67	2.19	3.52
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	23.24	9.58	9.58	27.66	15.12	4.54	3.67	23.78
Apr	27.35	12.85	8.68	32.00	12.74	6.61	4.11	14.19
May	10.86	5.90	4.04	9.64	7.50	4.64	2.26	8.32
Jun	7.51	2.86	1.50	7.15	8.10	3.44	1.84	6.88
Jul	2.72	0.88	0.62	1.61	3.52	1.45	0.75	2.60
Aug	1.23	0.70	0.59	1.95	2.10	0.64	0.29	1.69
Sep	2.05	1.20	0.64	2.13	3.81	1.78	0.35	3.85

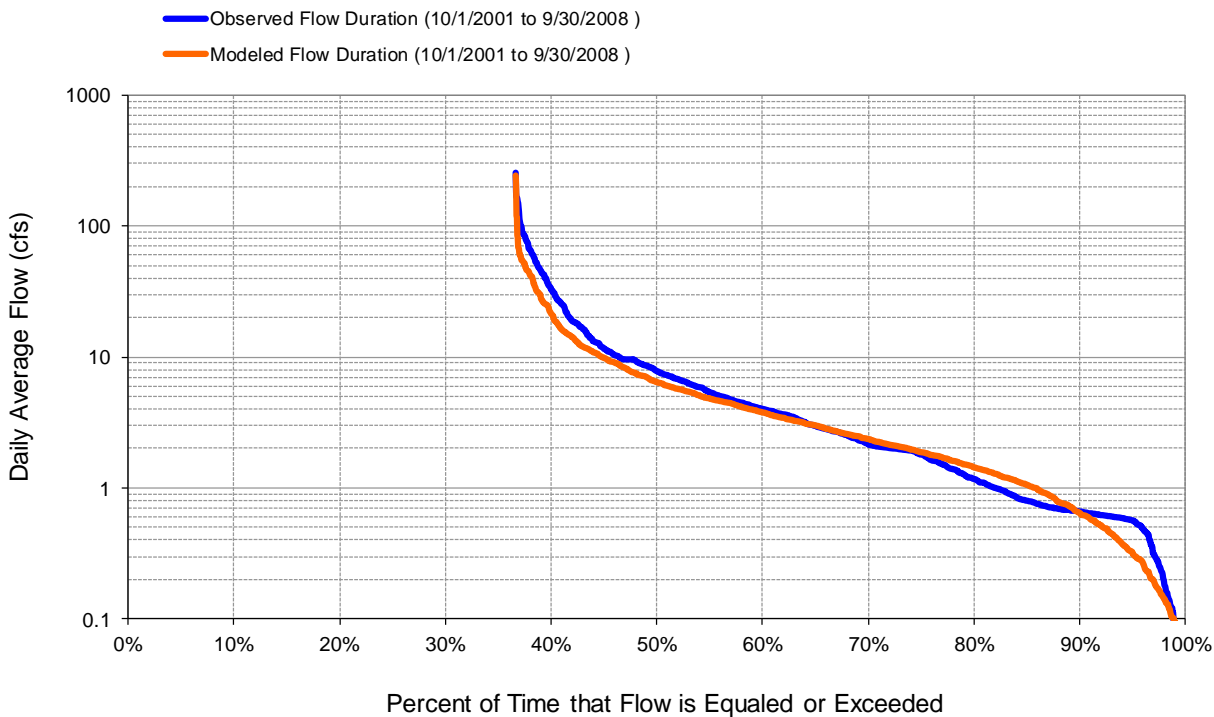


Figure 128. Flow exceedance at Talmadge River near Duluth

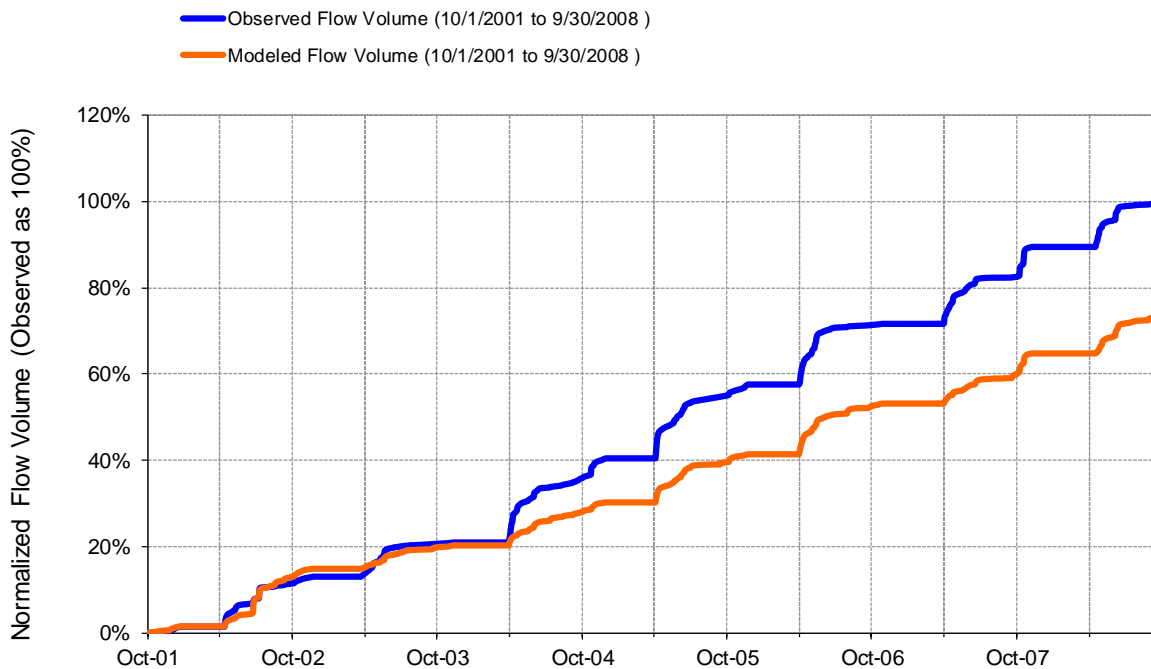


Figure 129. Flow accumulation at Talmadge River near Duluth

Table 6. Summary statistics at Talmadge River near Duluth

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 20 7-Year Analysis Period: 10/1/2001 - 9/30/2008 Flow volumes are (inches/year) for upstream drainage area		Talmadge River near Duluth, CR281 Manually Entered Data Drainage Area (sq-mi): 5.38	
Total Simulated In-stream Flow:	9.43	Total Observed In-stream Flow:	12.60
Total of simulated highest 10% flows:	5.05	Total of Observed highest 10% flows:	7.77
Total of Simulated lowest 50% flows:	0.93	Total of Observed Lowest 50% flows:	0.86
Simulated Summer Flow Volume (months 7-9):	1.99	Observed Summer Flow Volume (7-9):	1.27
Simulated Fall Flow Volume (months 10-12):	1.64	Observed Fall Flow Volume (10-12):	2.21
Simulated Winter Flow Volume (months 1-3):	0.22	Observed Winter Flow Volume (1-3):	0.34
Simulated Spring Flow Volume (months 4-6):	5.56	Observed Spring Flow Volume (4-6):	8.77
Total Simulated Storm Volume:	3.47	Total Observed Storm Volume:	4.61
Simulated Summer Storm Volume (7-9):	0.98	Observed Summer Storm Volume (7-9):	0.51
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-25.18	10	
Error in 50% lowest flows:	7.85	10	
Error in 10% highest flows:	-35.04	15	
Seasonal volume error - Summer:	56.66	30	
Seasonal volume error - Fall:	-25.56	30	
Seasonal volume error - Winter:	-34.96	30	
Seasonal volume error - Spring:	-36.58	30	
Error in storm volumes:	-24.82	20	
Error in summer storm volumes:	92.07	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.533	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.502		
Monthly NSE	0.569		

SUCKER RIVER NEAR PALMERS (HYDSTRA 02031001)

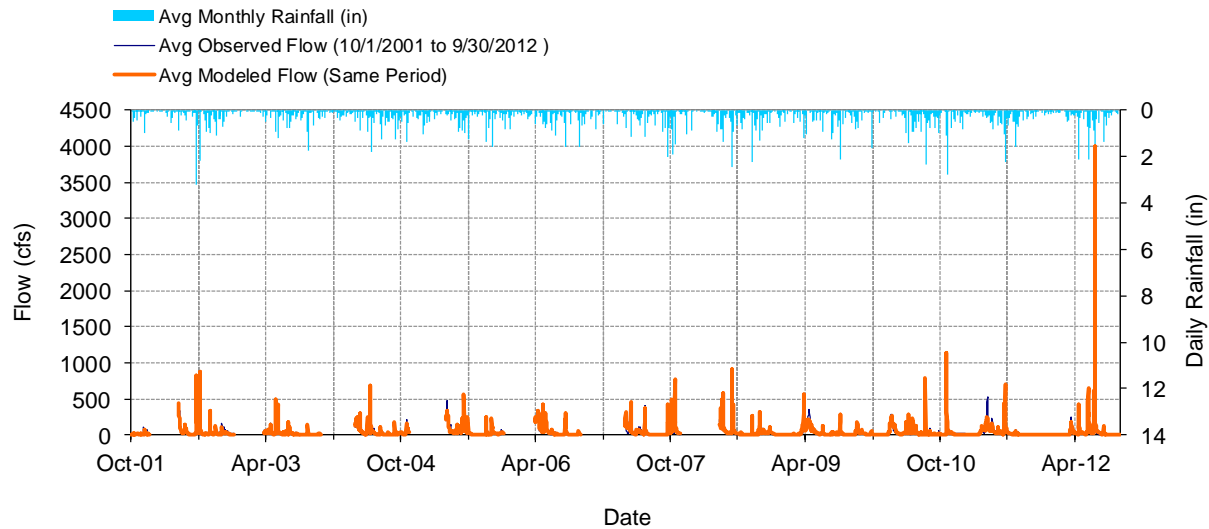


Figure 130. Mean daily flow at Sucker River near Palmers

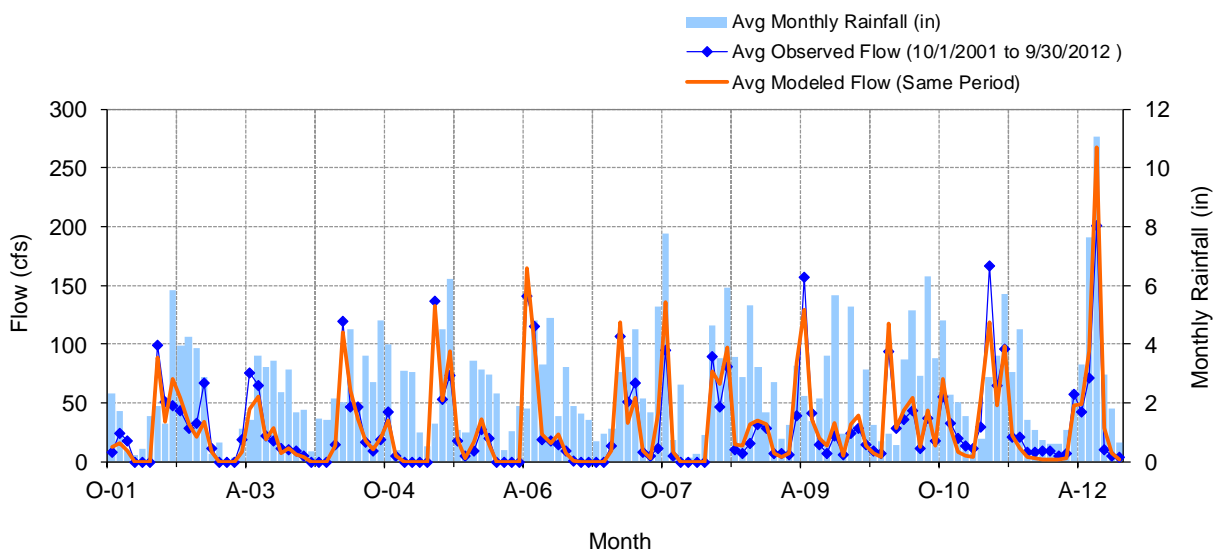


Figure 131. Mean monthly flow at Sucker River near Palmers

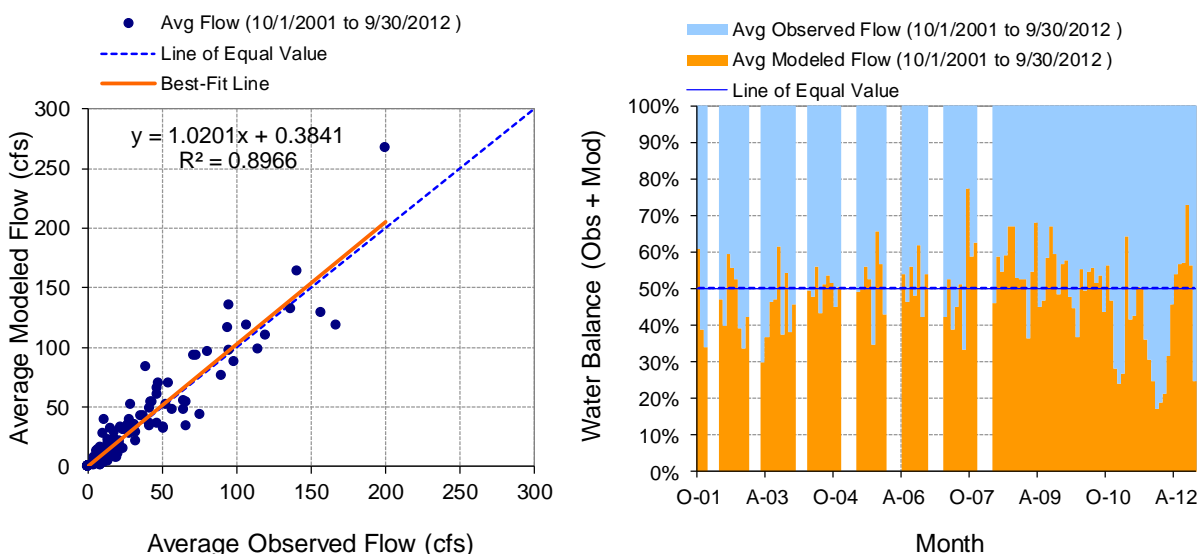


Figure 132. Monthly flow regression and temporal variation at Sucker River near Palmers

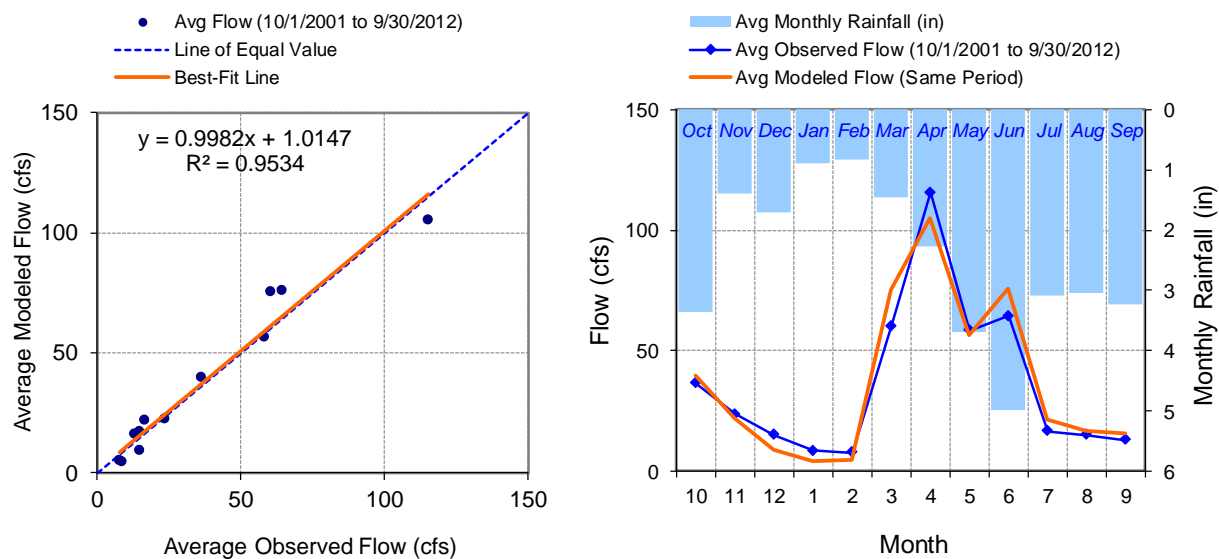


Figure 133. Seasonal regression and temporal aggregate at Sucker River near Palmers

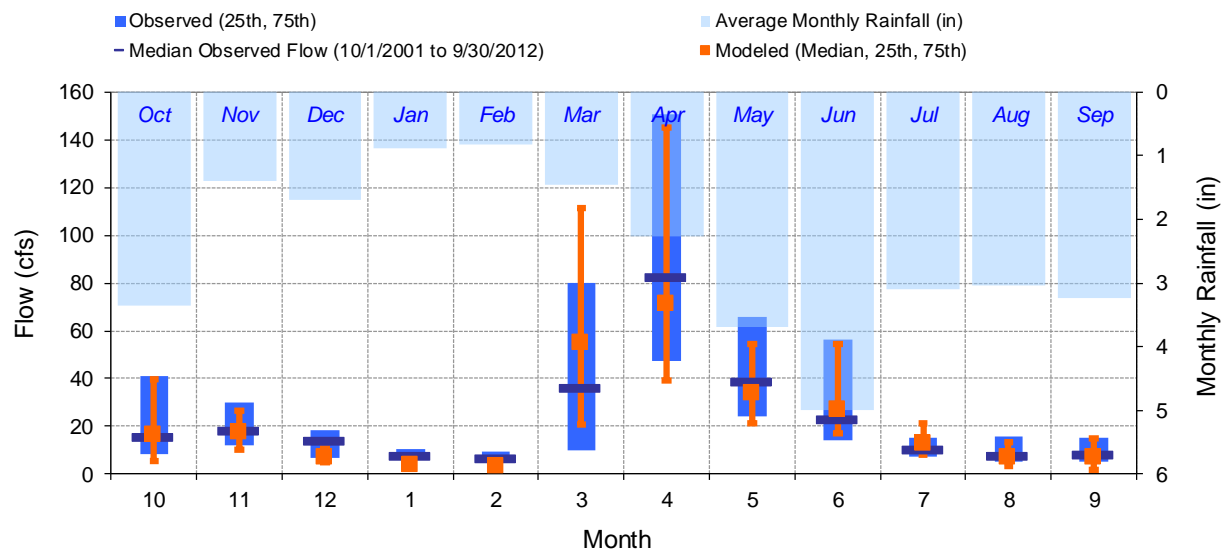


Figure 134. Seasonal medians and ranges at Sucker River near Palmers

Table 7. Seasonal summary at Sucker River near Palmers

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	36.46	15.61	8.65	41.05	39.50	16.31	5.56	39.54
Nov	23.49	18.00	12.32	29.99	21.86	17.59	10.28	26.45
Dec	14.91	14.00	7.00	18.40	8.77	7.04	5.17	10.65
Jan	8.48	7.80	6.18	10.54	4.14	3.95	2.77	4.97
Feb	7.62	6.50	5.30	9.60	4.59	3.41	2.96	5.08
Mar	60.19	36.00	10.00	80.00	75.39	55.07	20.87	111.24
Apr	115.47	82.61	47.40	150.73	105.07	71.44	39.37	145.26
May	58.30	38.52	24.00	65.85	56.34	33.69	21.42	54.41
Jun	64.44	22.89	13.96	56.57	75.74	27.28	16.90	54.66
Jul	16.58	10.00	7.30	15.26	21.41	13.00	8.11	21.12
Aug	14.93	7.83	5.30	16.00	16.77	7.08	3.39	13.59
Sep	12.92	8.23	5.31	15.16	15.61	7.00	2.02	15.04

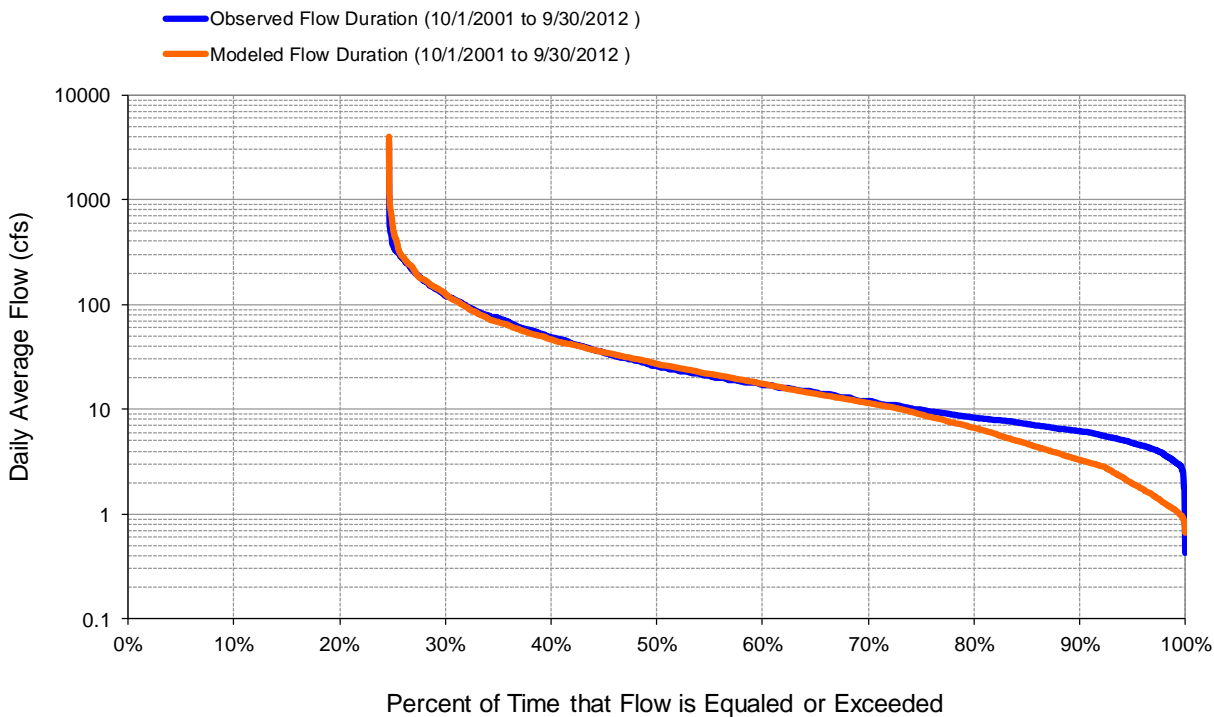


Figure 135. Flow exceedance at Sucker River near Palmers

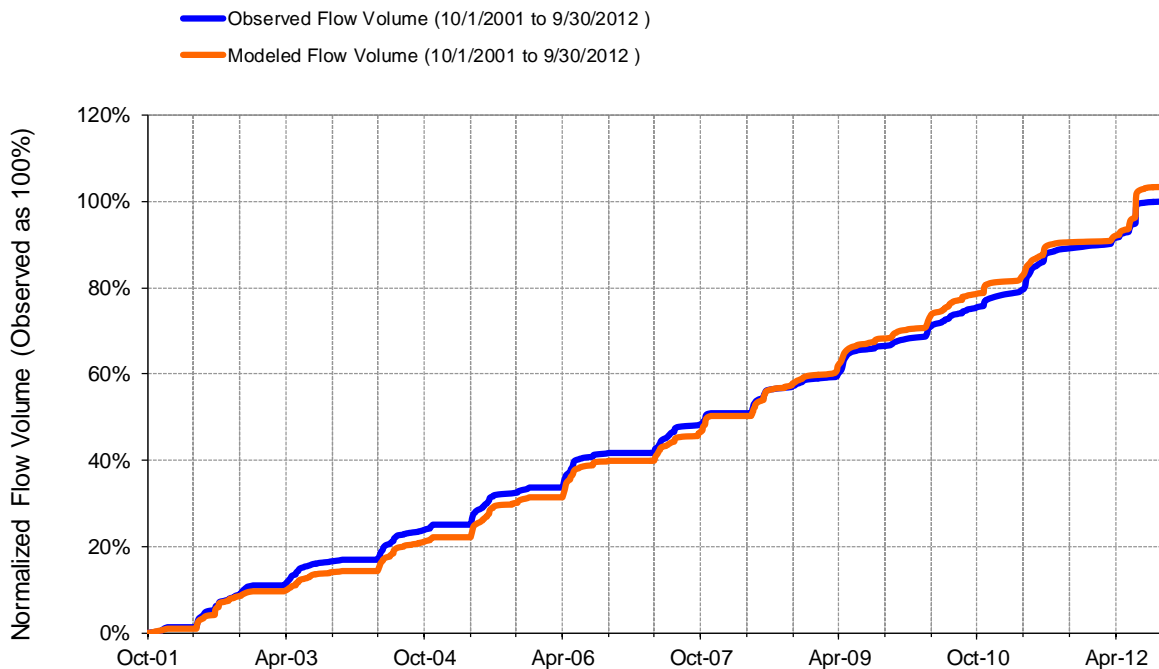


Figure 136. Flow accumulation at Sucker River near Palmers

Table 8. Summary statistics at Sucker River near Palmers

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 30 11-Year Analysis Period: 10/1/2001 - 9/30/2012 Flow volumes are (inches/year) for upstream drainage area Run 6h		Sucker River - 02031001 Manually Entered Data Drainage Area (sq-mi): 39.1	
Total Simulated In-stream Flow:	10.70	Total Observed In-stream Flow:	10.35
Total of simulated highest 10% flows:	5.92	Total of Observed highest 10% flows:	5.28
Total of Simulated lowest 50% flows:	0.91	Total of Observed Lowest 50% flows:	1.13
Simulated Summer Flow Volume (months 7-9):	1.57	Observed Summer Flow Volume (7-9):	1.30
Simulated Fall Flow Volume (months 10-12):	1.58	Observed Fall Flow Volume (10-12):	1.60
Simulated Winter Flow Volume (months 1-3):	0.98	Observed Winter Flow Volume (1-3):	0.88
Simulated Spring Flow Volume (months 4-6):	6.57	Observed Spring Flow Volume (4-6):	6.57
Total Simulated Storm Volume:	4.58	Total Observed Storm Volume:	3.94
Simulated Summer Storm Volume (7-9):	0.77	Observed Summer Storm Volume (7-9):	0.51
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	3.35	10	
Error in 50% lowest flows:	-19.39	10	
Error in 10% highest flows:	12.11	15	
Seasonal volume error - Summer:	21.08	30	
Seasonal volume error - Fall:	-1.44	30	
Seasonal volume error - Winter:	11.82	30	
Seasonal volume error - Spring:	-0.11	30	
Error in storm volumes:	16.21	20	
Error in summer storm volumes:	51.78	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.747	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.570		
Monthly NSE	0.871		

KNIFE RIVER AT NAPPA ROAD (HYDSTRA 02021001)

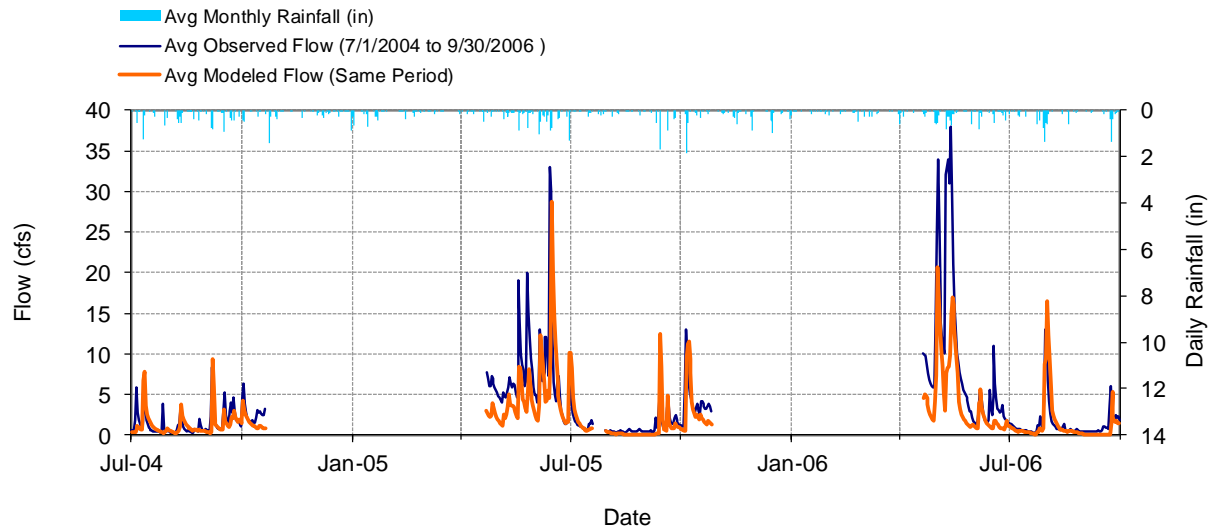


Figure 137. Mean daily flow at Knife River at Nappa Road

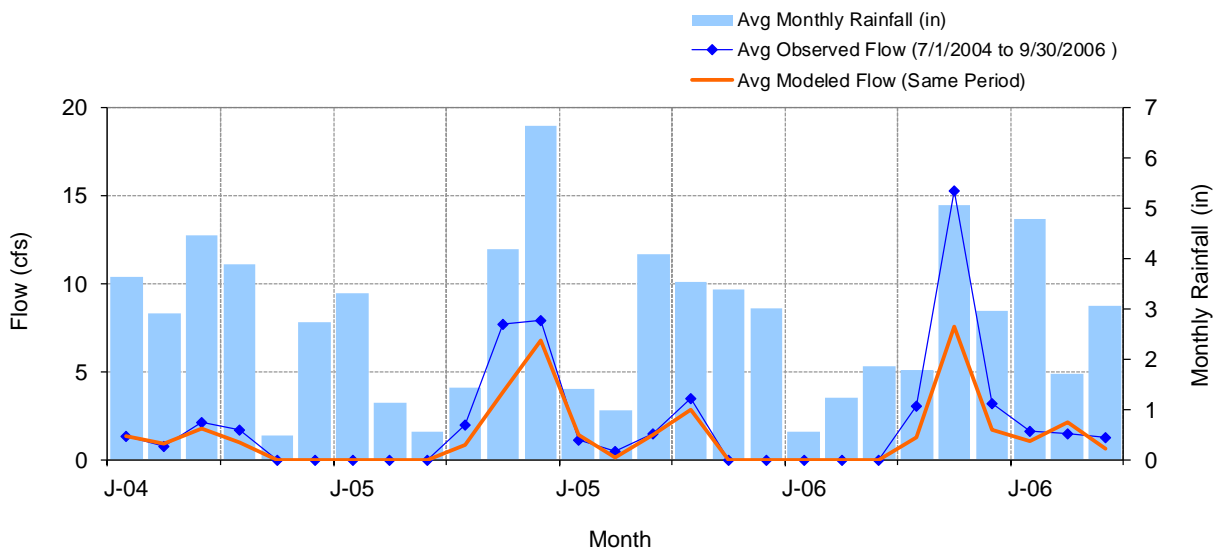


Figure 138. Mean monthly flow at Knife River at Nappa Road

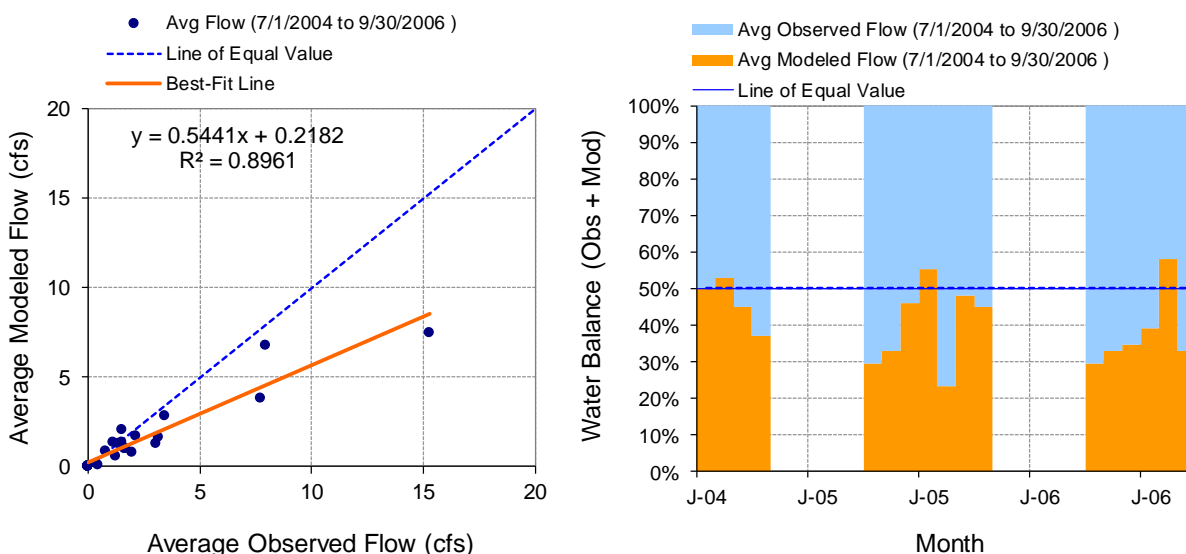


Figure 139. Monthly flow regression and temporal variation at Knife River at Nappa Road

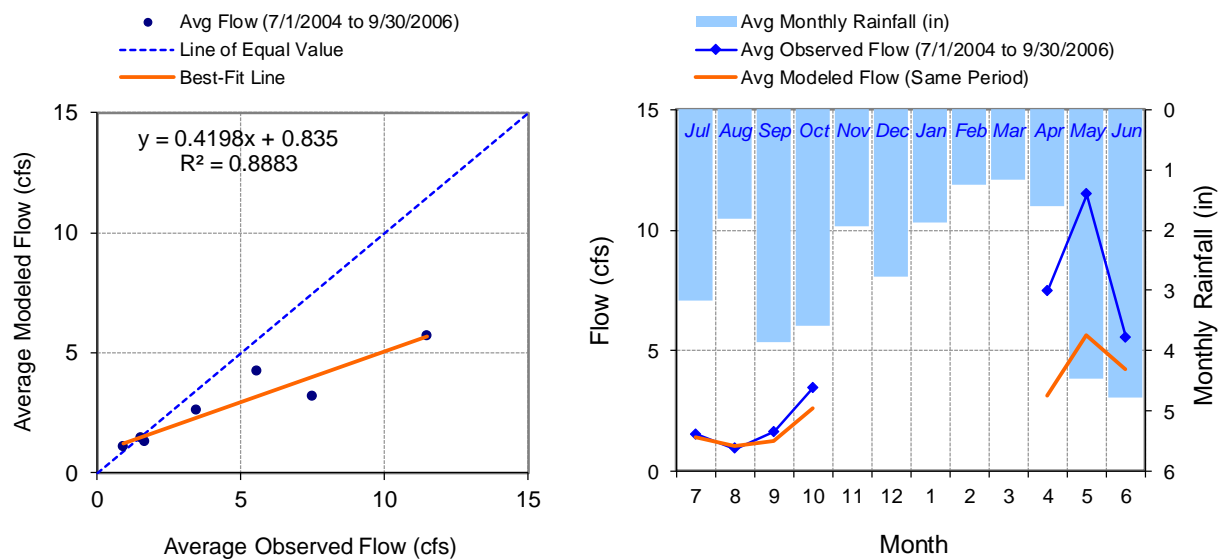


Figure 140. Seasonal regression and temporal aggregate at Knife River at Nappa Road

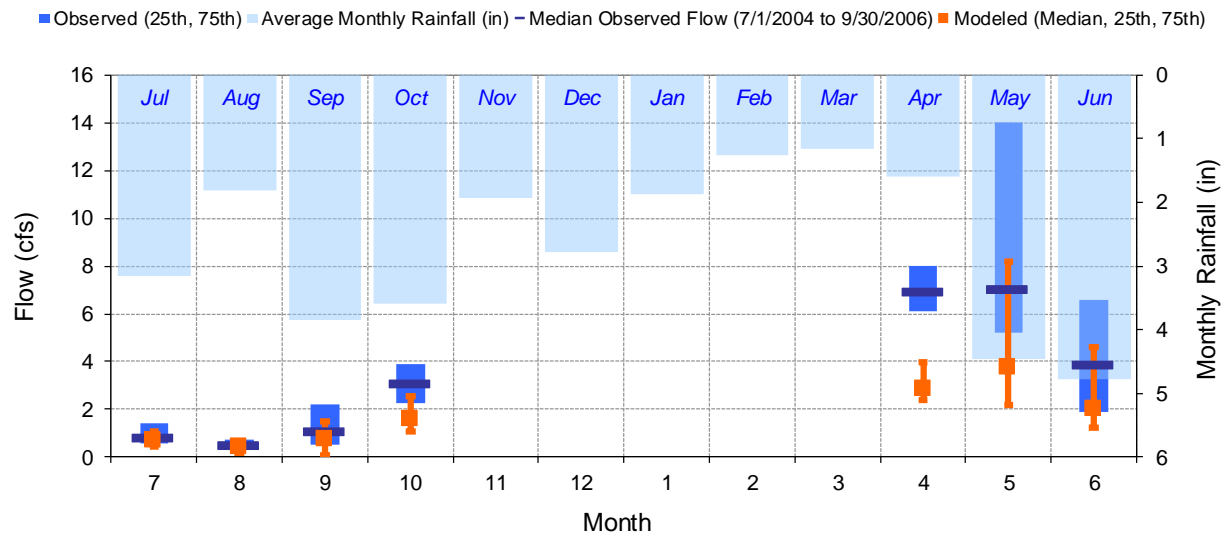


Figure 141. Seasonal medians and ranges at Knife River at Nappa Road

Table 9. Seasonal summary at Knife River at Nappa Road

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jul	1.52	0.81	0.56	1.40	1.41	0.68	0.44	1.05
Aug	0.91	0.52	0.41	0.74	1.03	0.44	0.16	0.68
Sep	1.63	1.10	0.54	2.20	1.25	0.75	0.08	1.50
Oct	3.47	3.10	2.25	3.90	2.58	1.62	1.08	2.54
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	7.48	6.90	6.10	8.00	3.15	2.84	2.39	3.96
May	11.48	7.05	5.23	14.00	5.66	3.75	2.17	8.18
Jun	5.55	3.85	1.90	6.60	4.22	2.02	1.22	4.61

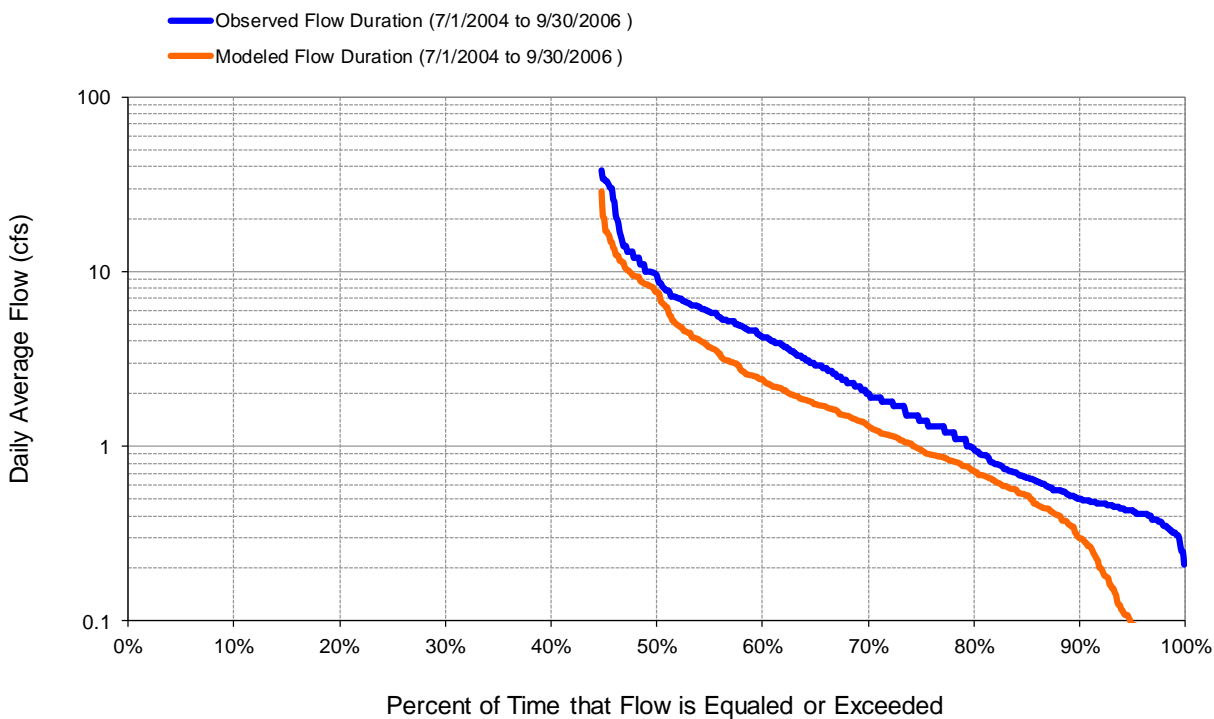


Figure 142. Flow exceedance at Knife River at Nappa Road

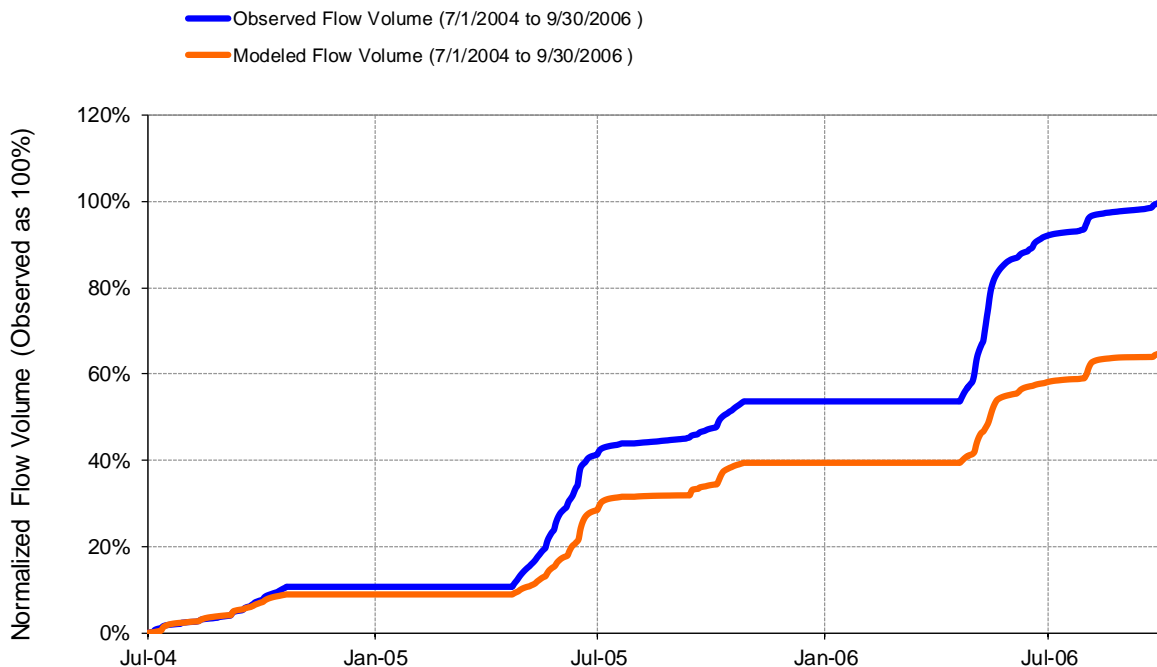


Figure 143. Flow accumulation at Knife River at Nappa Road

Table 10. Summary statistics at Knife River at Nappa Road

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 120 2.25-Year Analysis Period: 7/1/2004 - 9/30/2006 Flow volumes are (inches/year) for upstream drainage area		Knife River near Two Harbors, Nappa Rd Manually Entered Data Drainage Area (sq-mi): 2.71	
Total Simulated In-stream Flow:	6.78	Total Observed In-stream Flow:	10.44
Total of simulated highest 10% flows:	3.20	Total of Observed highest 10% flows:	4.76
Total of Simulated lowest 50% flows:	0.68	Total of Observed Lowest 50% flows:	1.07
Simulated Summer Flow Volume (months 7-9):	1.99	Observed Summer Flow Volume (7-9):	2.18
Simulated Fall Flow Volume (months 10-12):	0.72	Observed Fall Flow Volume (10-12):	0.97
Simulated Winter Flow Volume (months 1-3):	0.00	Observed Winter Flow Volume (1-3):	0.00
Simulated Spring Flow Volume (months 4-6):	4.07	Observed Spring Flow Volume (4-6):	7.28
Total Simulated Storm Volume:	1.99	Total Observed Storm Volume:	2.69
Simulated Summer Storm Volume (7-9):	0.71	Observed Summer Storm Volume (7-9):	0.69
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-35.08	10	
Error in 50% lowest flows:	-36.85	10	
Error in 10% highest flows:	-32.86	15	
Seasonal volume error - Summer:	-9.00	30	
Seasonal volume error - Fall:	-25.56	30	
Seasonal volume error - Winter:	0.00	30	
Seasonal volume error - Spring:	-44.17	30	
Error in storm volumes:	-26.21	20	
Error in summer storm volumes:	2.67	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.524	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.452		
Monthly NSE	0.662		

KNIFE RIVER AT AIRPORT ROAD (HYDSTRA 02009001)

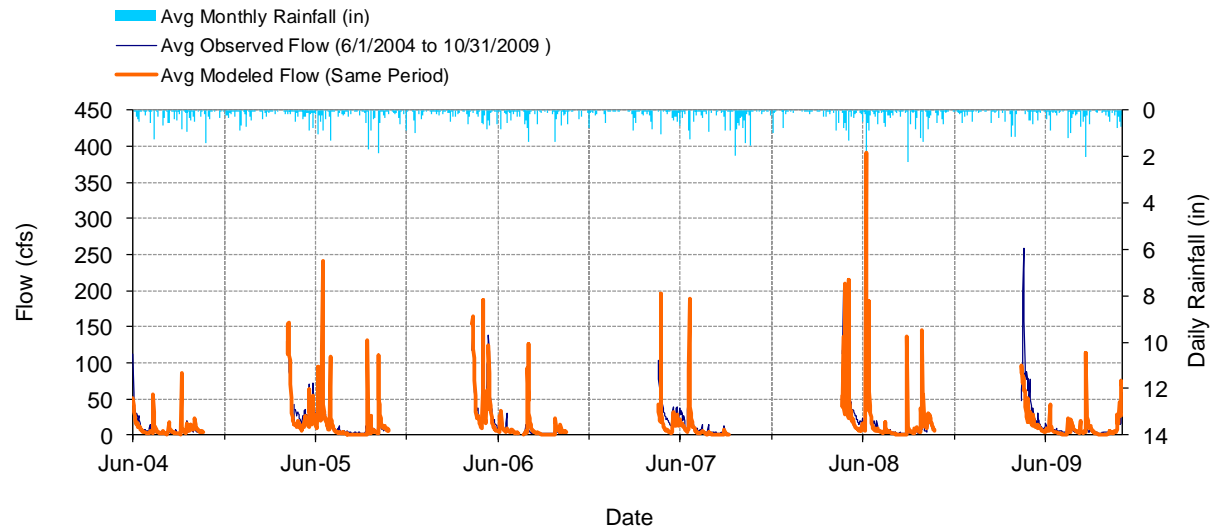


Figure 144. Mean daily flow at Knife River at Airport Road

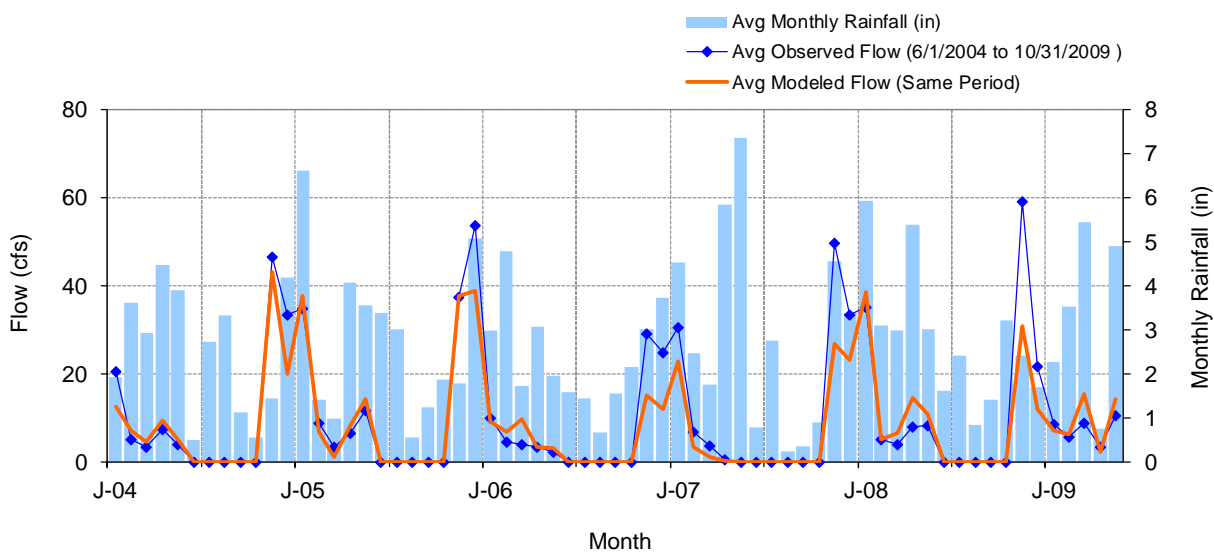


Figure 145. Mean monthly flow at Knife River at Airport Road

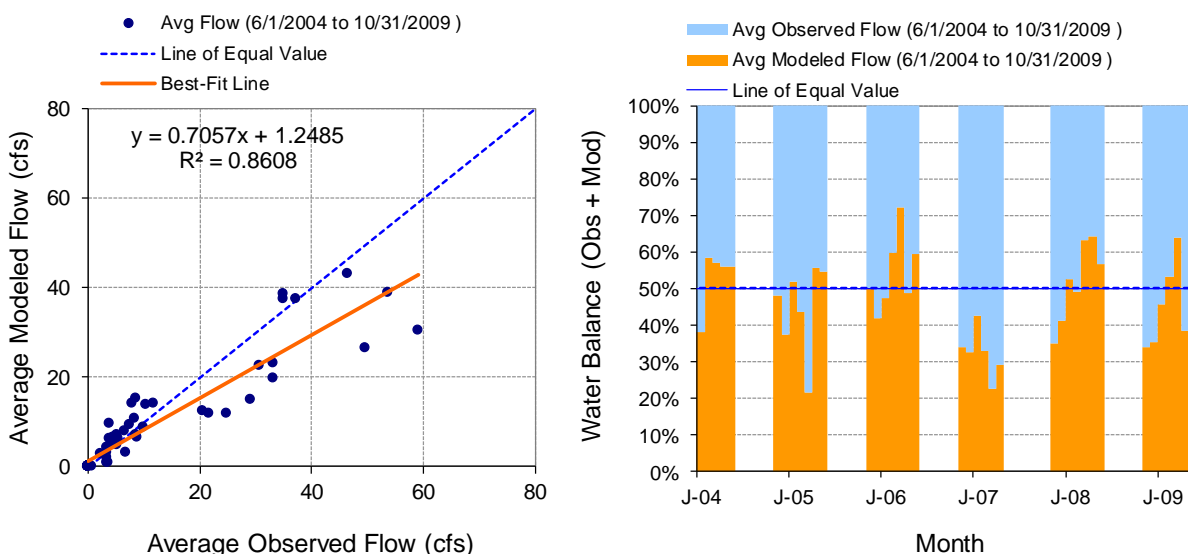


Figure 146. Monthly flow regression and temporal variation at Knife River at Airport Road

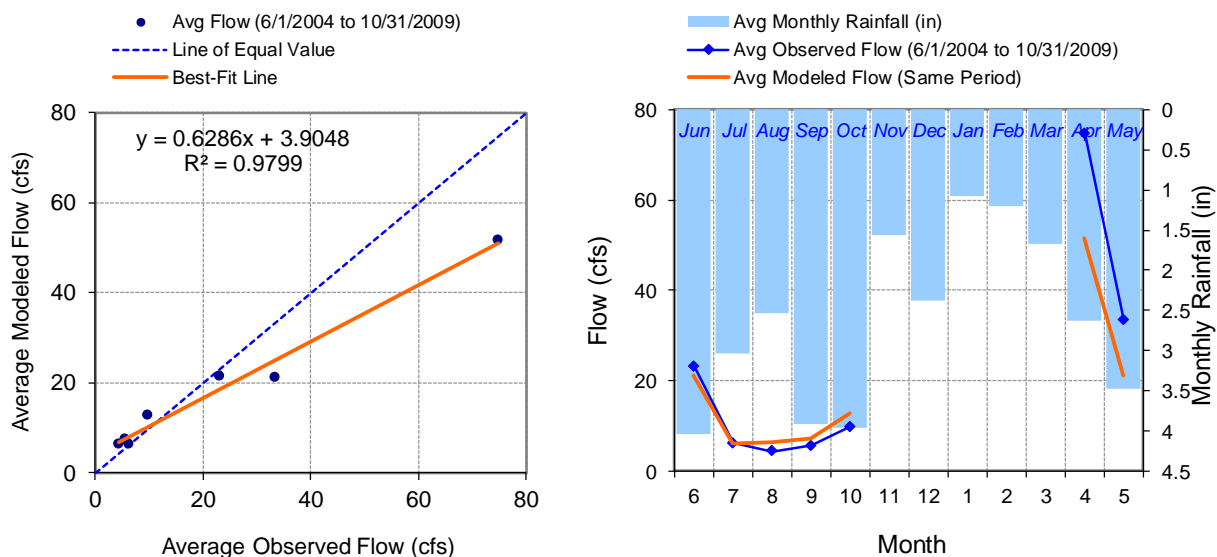


Figure 147. Seasonal regression and temporal aggregate at Knife River at Airport Road

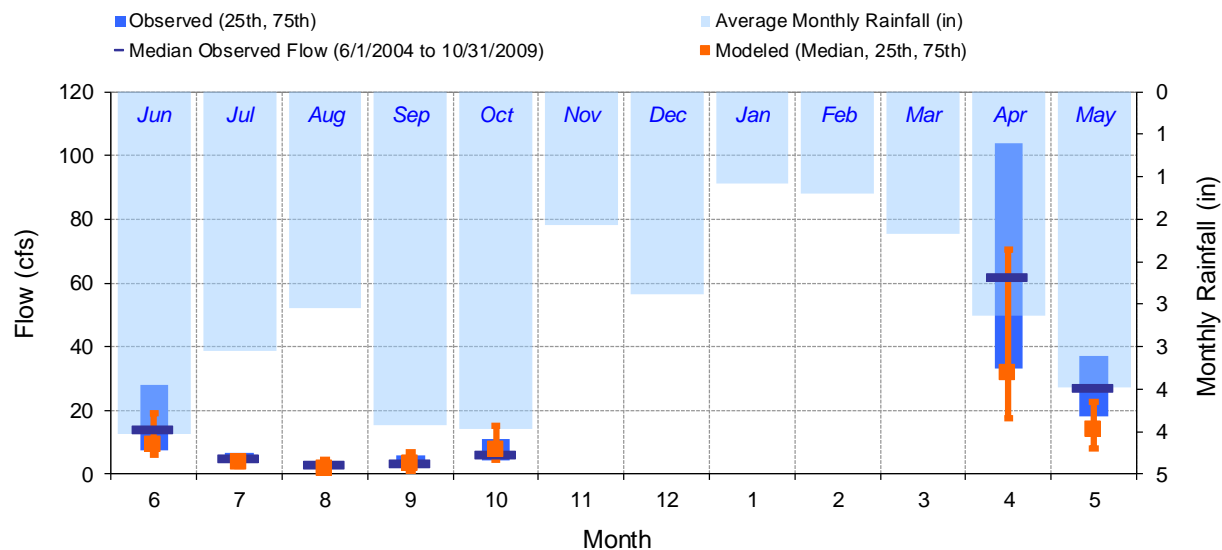


Figure 148. Seasonal medians and ranges at Knife River at Airport Road

Table 11. Seasonal summary at Knife River at Airport Road

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jun	23.20	14.00	7.50	28.00	21.24	9.12	5.90	19.19
Jul	6.17	5.10	3.90	6.78	6.07	3.66	2.57	5.45
Aug	4.38	3.10	2.50	4.00	6.29	1.74	0.79	4.37
Sep	5.57	3.50	2.80	5.83	7.18	3.29	0.78	7.00
Oct	9.78	6.00	4.45	11.00	12.67	7.79	4.48	15.19
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	74.73	62.00	33.00	104.00	51.51	31.92	17.70	70.58
May	33.29	27.00	18.00	37.00	21.14	13.93	7.96	22.59

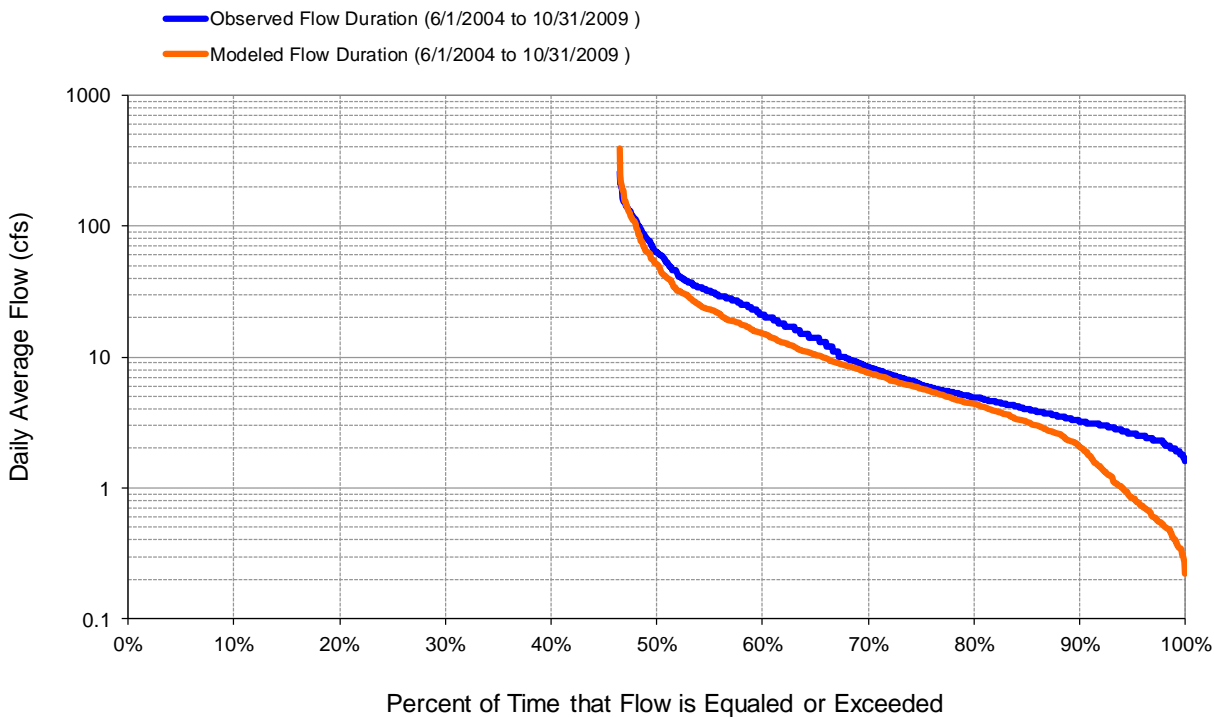


Figure 149. Flow exceedance at Knife River at Airport Road

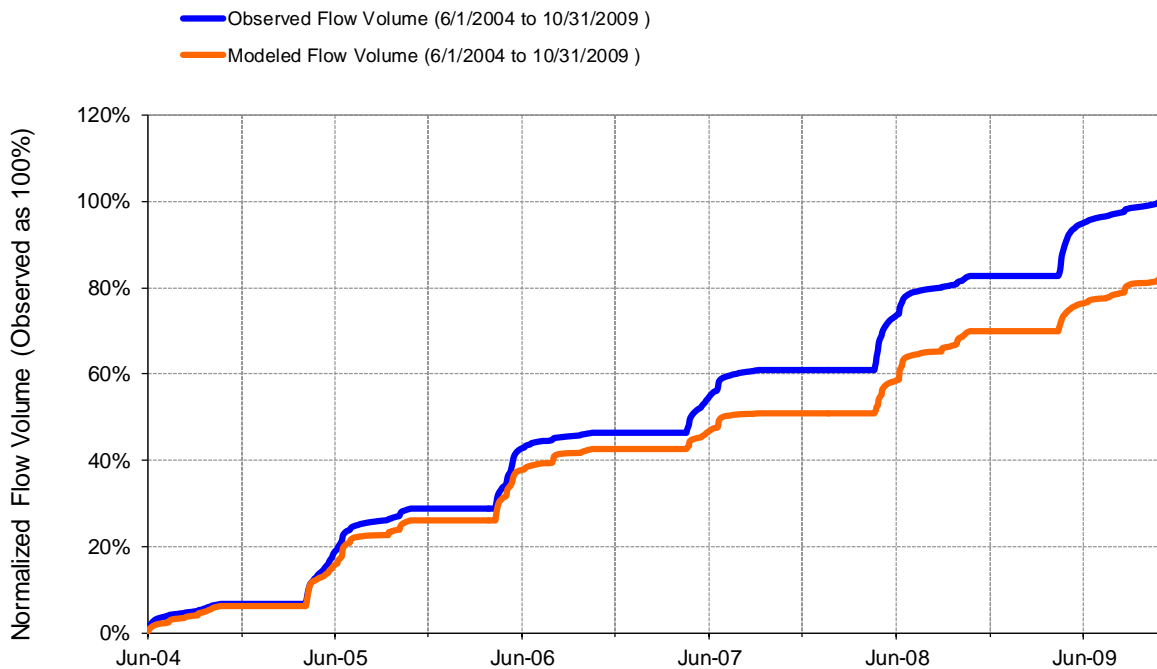


Figure 150. Flow accumulation at Knife River at Airport Road

Table 12. Summary statistics at Knife River at Airport Road

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 130 5.42-Year Analysis Period: 6/1/2004 - 10/31/2009 Flow volumes are (inches/year) for upstream drainage area		Knife River near Two Harbors, Airport Rd Manually Entered Data Drainage Area (sq-mi): 14.5	
Total Simulated In-stream Flow:	7.82	Total Observed In-stream Flow:	9.42
Total of simulated highest 10% flows:	4.21	Total of Observed highest 10% flows:	4.60
Total of Simulated lowest 50% flows:	0.73	Total of Observed Lowest 50% flows:	0.99
Simulated Summer Flow Volume (months 7-9):	1.60	Observed Summer Flow Volume (7-9):	1.32
Simulated Fall Flow Volume (months 10-12):	0.69	Observed Fall Flow Volume (10-12):	0.53
Simulated Winter Flow Volume (months 1-3):	0.00	Observed Winter Flow Volume (1-3):	0.00
Simulated Spring Flow Volume (months 4-6):	5.53	Observed Spring Flow Volume (4-6):	7.57
Total Simulated Storm Volume:	2.68	Total Observed Storm Volume:	2.17
Simulated Summer Storm Volume (7-9):	0.69	Observed Summer Storm Volume (7-9):	0.34
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-17.00	10	
Error in 50% lowest flows:	-26.45	10	
Error in 10% highest flows:	-8.39	15	
Seasonal volume error - Summer:	21.14	30	
Seasonal volume error - Fall:	29.57	30	
Seasonal volume error - Winter:	0.00	30	
Seasonal volume error - Spring:	-26.92	30	
Error in storm volumes:	23.28	20	
Error in summer storm volumes:	99.76	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.579	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.518		
Monthly NSE	0.749		

KNIFE RIVER NEAR TWO HARBORS (HYDSTRA 02026001/USGS 04015330)

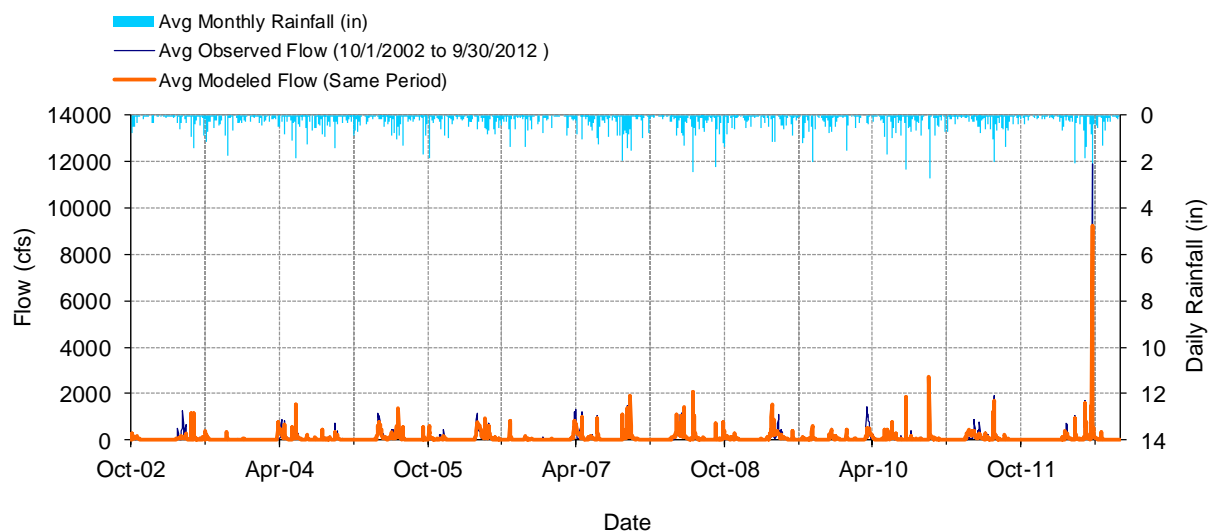


Figure 151. Mean daily flow at Knife River near Two Harbors

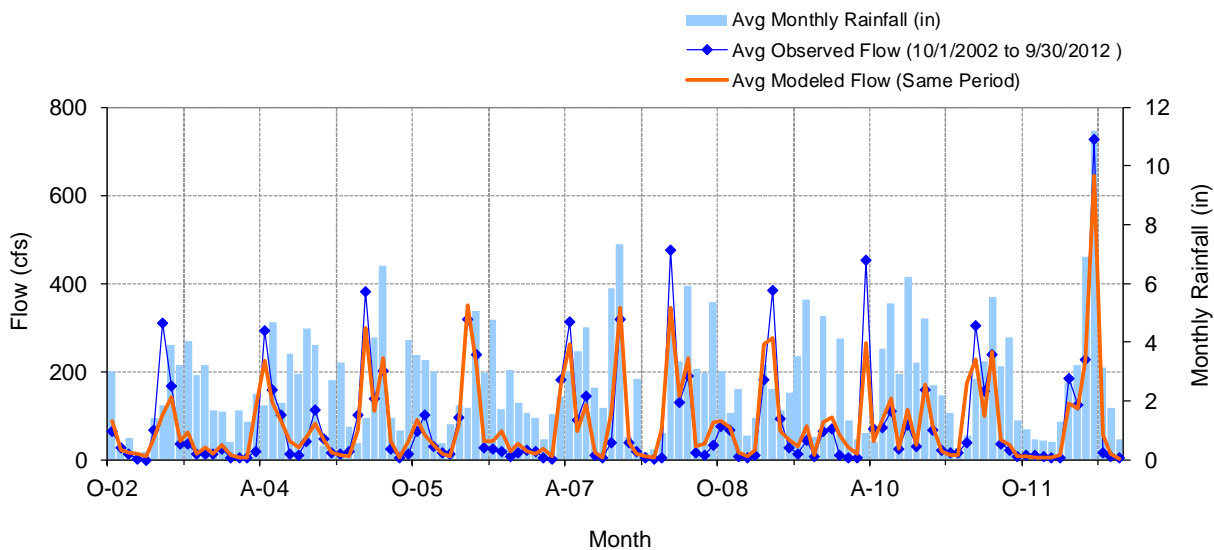


Figure 152. Mean monthly flow at Knife River near Two Harbors

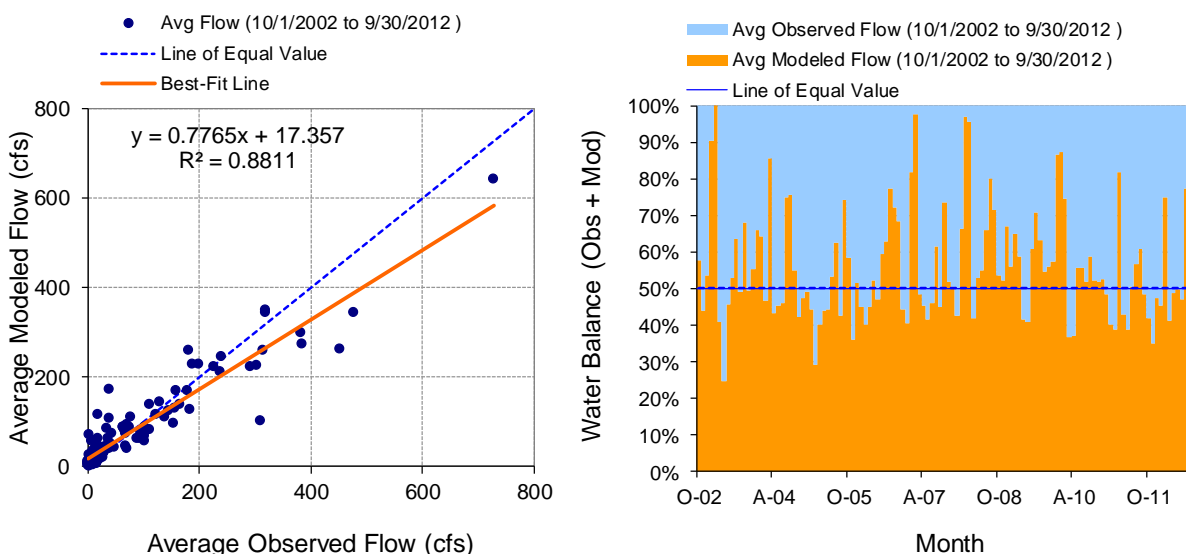


Figure 153. Monthly flow regression and temporal variation at Knife River near Two Harbors

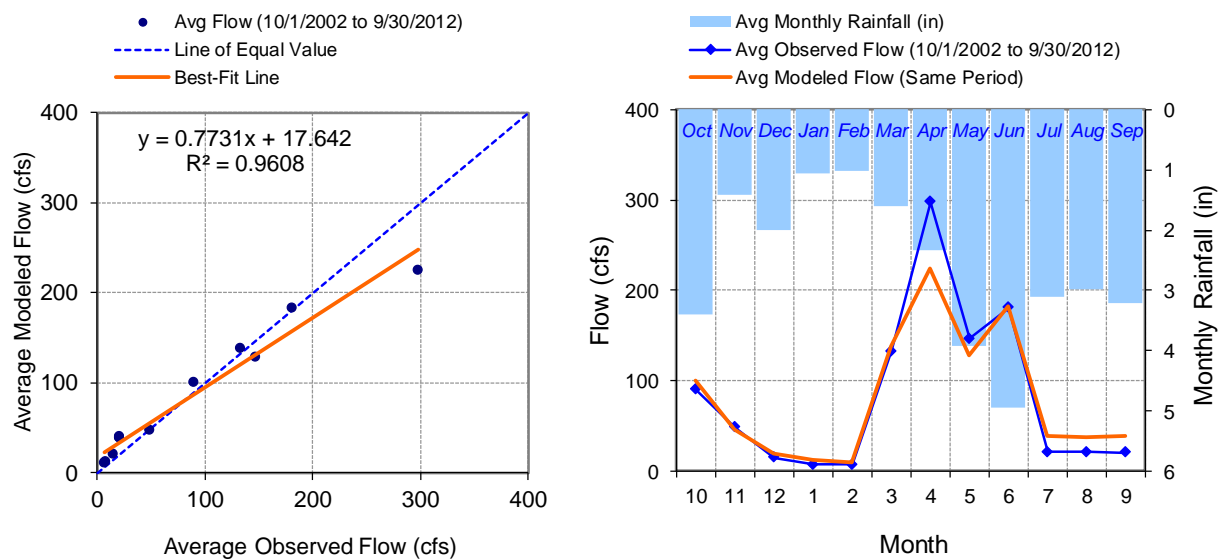


Figure 154. Seasonal regression and temporal aggregate at Knife River near Two Harbors

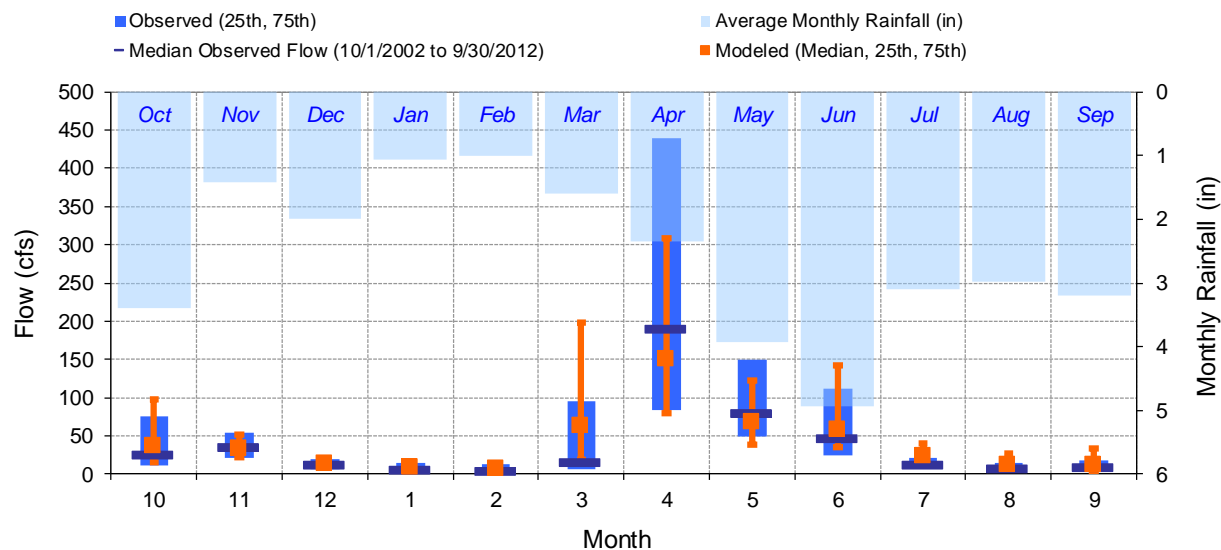


Figure 155. Seasonal medians and ranges at Knife River near Two Harbors

Table 13. Seasonal summary at Knife River near Two Harbors

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	89.75	25.00	12.00	75.00	99.96	37.21	14.73	98.61
Nov	48.11	35.00	22.00	55.00	46.19	33.96	21.58	51.59
Dec	14.70	13.00	6.50	19.00	19.78	13.61	10.09	19.12
Jan	7.32	5.20	3.10	14.00	12.01	9.04	6.20	13.43
Feb	7.07	3.90	0.19	13.00	9.38	7.39	5.70	10.56
Mar	132.51	15.50	6.50	95.25	137.63	63.99	18.58	198.51
Apr	297.71	190.00	84.00	439.25	223.87	151.11	80.04	307.76
May	146.75	79.00	49.00	150.00	128.08	68.56	38.68	122.13
Jun	180.91	47.00	25.00	112.00	182.45	59.03	35.65	141.47
Jul	21.15	13.00	8.93	21.00	39.01	23.55	13.74	39.77
Aug	20.97	7.20	5.40	15.00	37.91	12.83	5.05	27.14
Sep	20.04	8.20	5.30	18.00	38.48	12.17	2.73	33.54

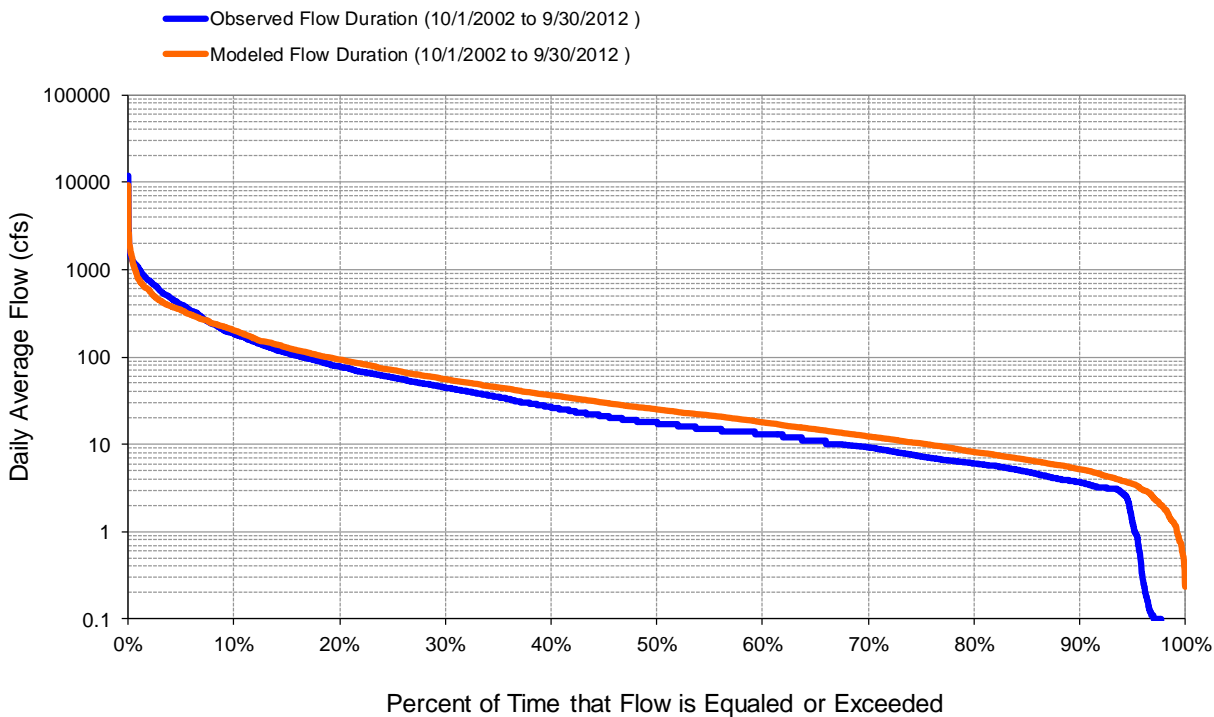


Figure 156. Flow exceedance at Knife River near Two Harbors

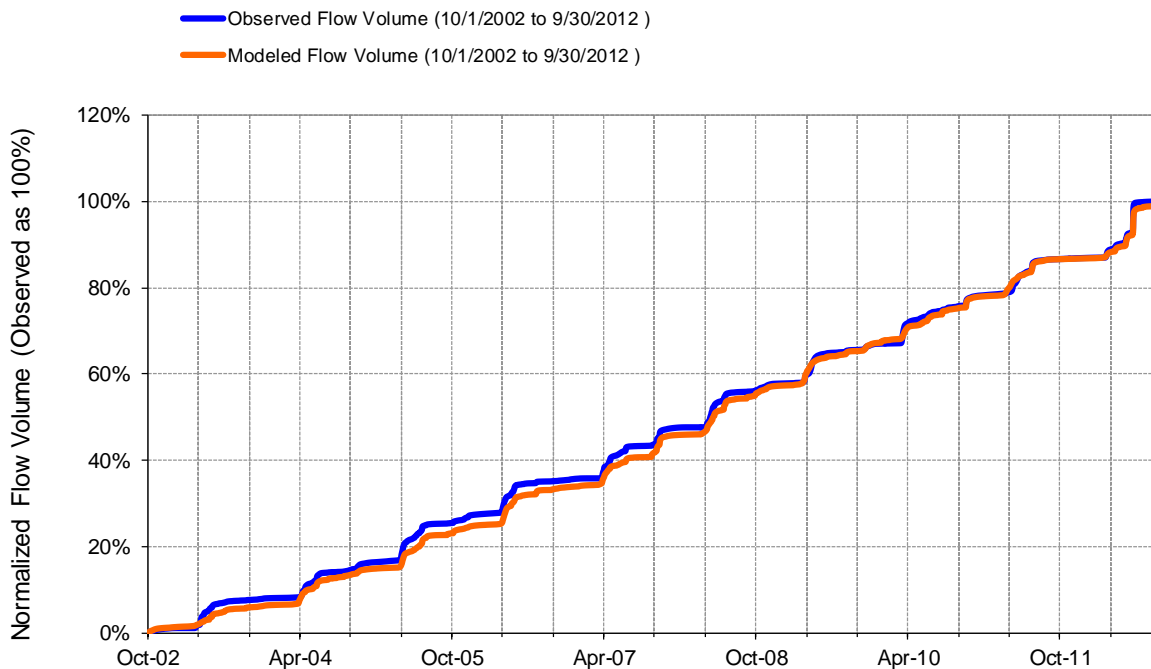


Figure 157. Flow accumulation at Knife River near Two Harbors

Table 14. Summary statistics at Knife River near Two Harbors

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 40 10-Year Analysis Period: 10/1/2002 - 9/30/2012 Flow volumes are (inches/year) for upstream drainage area Run 6a		Knife River near Two Harbors, MN61 Manually Entered Data Drainage Area (sq-mi): 83.6	
Total Simulated In-stream Flow:	13.21	Total Observed In-stream Flow:	13.36
Total of simulated highest 10% flows:	7.72	Total of Observed highest 10% flows:	8.92
Total of Simulated lowest 50% flows:	0.92	Total of Observed Lowest 50% flows:	0.65
Simulated Summer Flow Volume (months 7-9):	1.57	Observed Summer Flow Volume (7-9):	0.85
Simulated Fall Flow Volume (months 10-12):	2.27	Observed Fall Flow Volume (10-12):	2.08
Simulated Winter Flow Volume (months 1-3):	2.18	Observed Winter Flow Volume (1-3):	2.02
Simulated Spring Flow Volume (months 4-6):	7.19	Observed Spring Flow Volume (4-6):	8.41
Total Simulated Storm Volume:	5.75	Total Observed Storm Volume:	6.47
Simulated Summer Storm Volume (7-9):	0.83	Observed Summer Storm Volume (7-9):	0.41
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-1.10	10	
Error in 50% lowest flows:	40.79	10	
Error in 10% highest flows:	-13.45	15	
Seasonal volume error - Summer:	85.56	30	
Seasonal volume error - Fall:	8.89	30	
Seasonal volume error - Winter:	8.15	30	
Seasonal volume error - Spring:	-14.53	30	
Error in storm volumes:	-11.03	20	
Error in summer storm volumes:	104.80	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.787	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.577		
Monthly NSE	0.868		

GOOSEBERRY RIVER NEAR CASTLE DANGER (HYDSTRA 02012004)

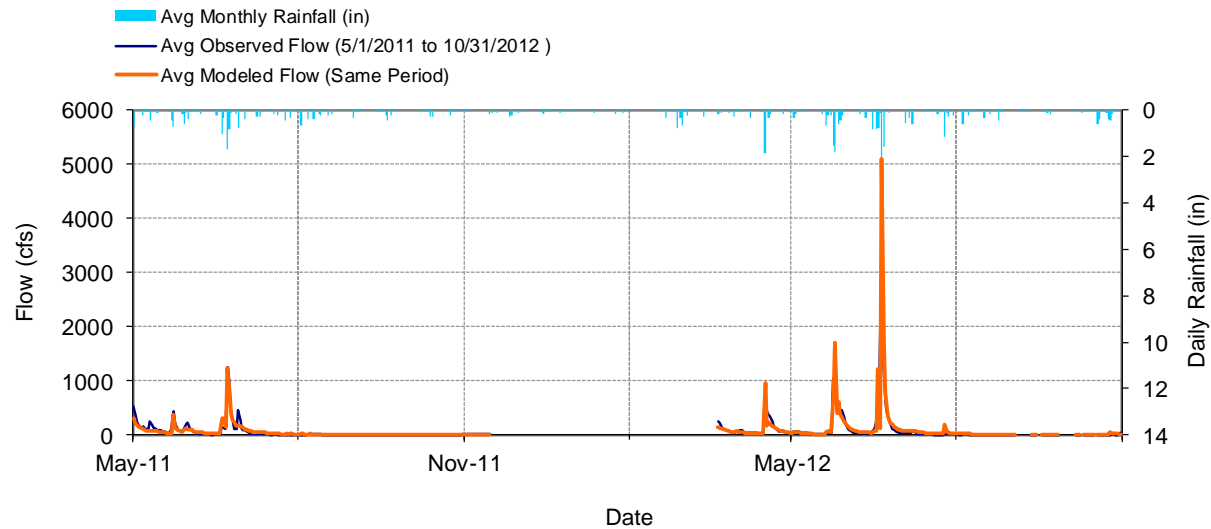


Figure 158. Mean daily flow at Gooseberry River near Castle Danger

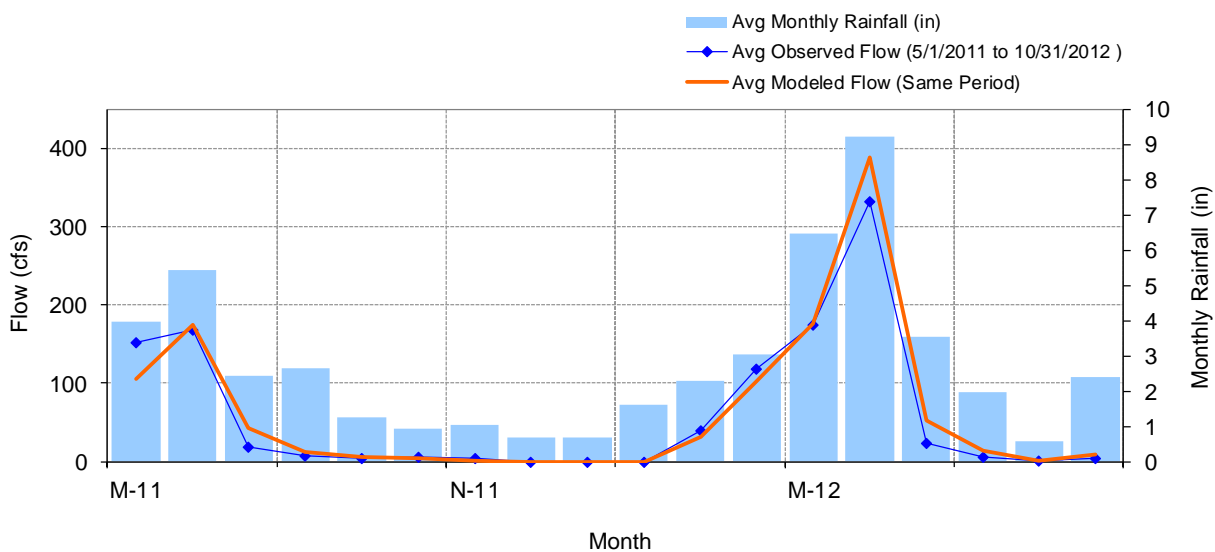


Figure 159. Mean monthly flow at Gooseberry River near Castle Danger

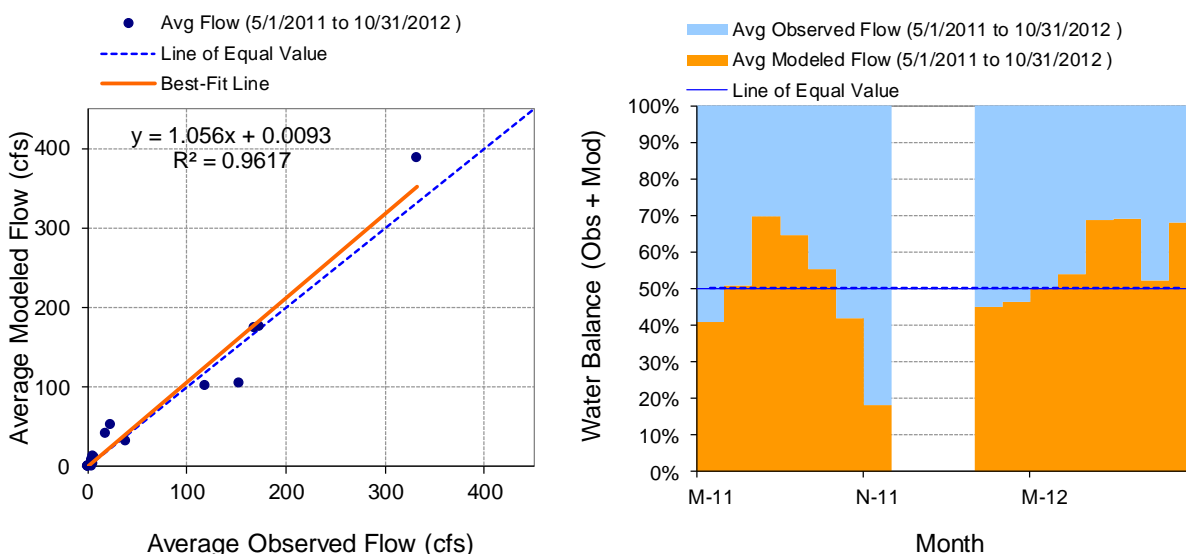


Figure 160. Monthly flow regression and temporal variation at Gooseberry River near Castle Danger

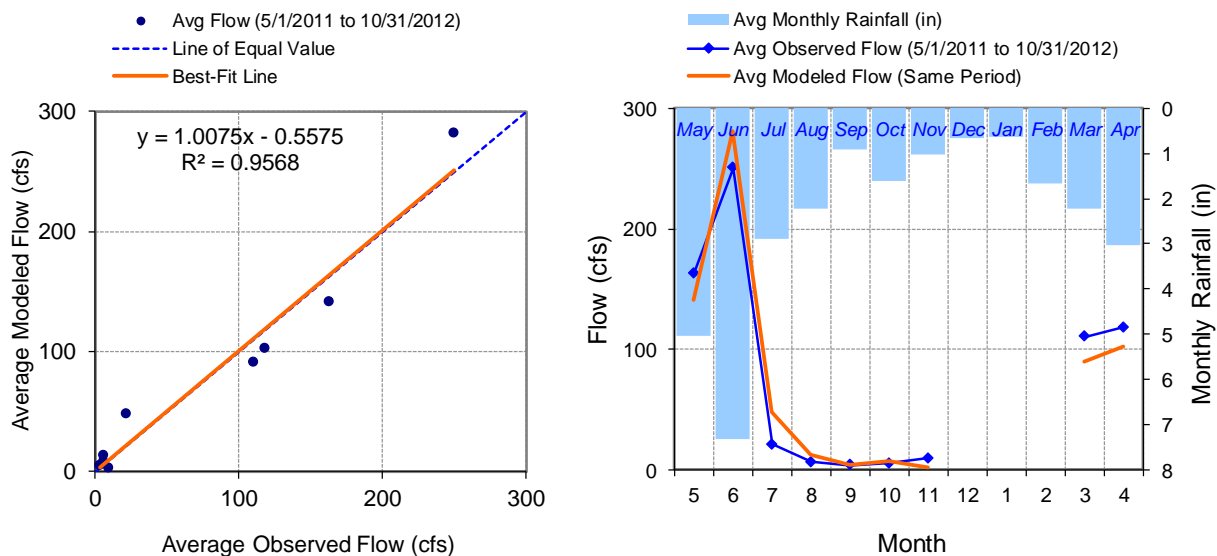


Figure 161. Seasonal regression and temporal aggregate at Gooseberry River near Castle Danger

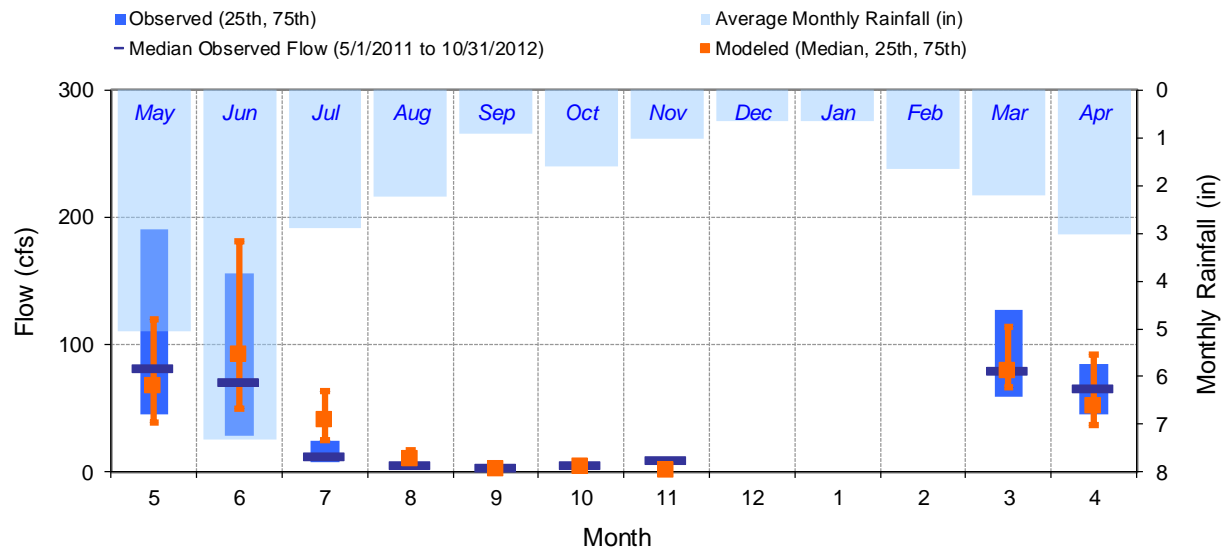


Figure 162. Seasonal medians and ranges at Gooseberry River near Castle Danger

Table 15. Seasonal summary at Gooseberry River near Castle Danger

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
May	163.06	81.50	45.25	190.25	140.53	67.65	38.74	119.98
Jun	250.32	70.50	28.50	155.75	281.12	92.69	50.08	180.92
Jul	21.17	12.00	7.40	24.75	47.61	41.21	24.84	63.26
Aug	6.21	5.70	4.43	7.38	12.54	10.72	7.20	17.50
Sep	3.51	3.20	2.60	4.75	4.26	2.87	1.90	5.99
Oct	5.55	4.90	3.55	6.55	7.17	4.49	1.96	7.46
Nov	9.41	9.30	9.10	9.75	2.10	1.89	1.61	2.48
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	110.18	79.00	59.00	127.00	90.03	79.25	66.83	114.08
Apr	118.27	66.00	45.75	84.50	102.46	51.34	36.91	92.11

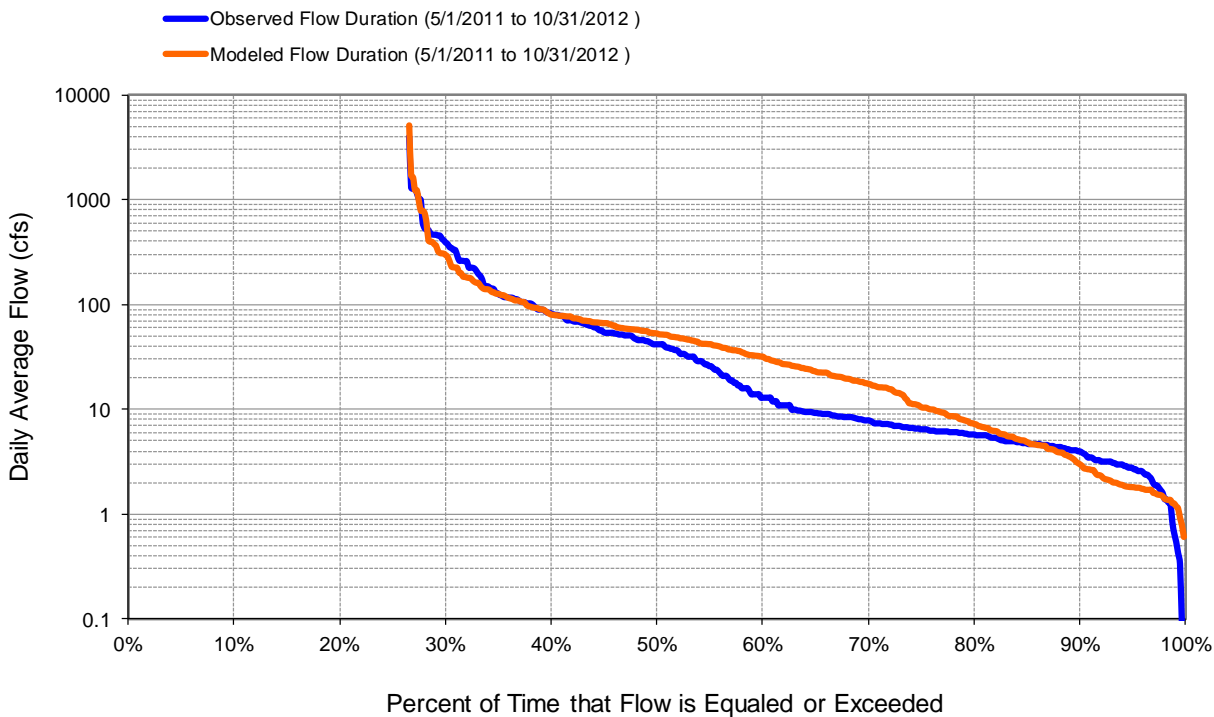


Figure 163. Flow exceedance at Gooseberry River near Castle Danger

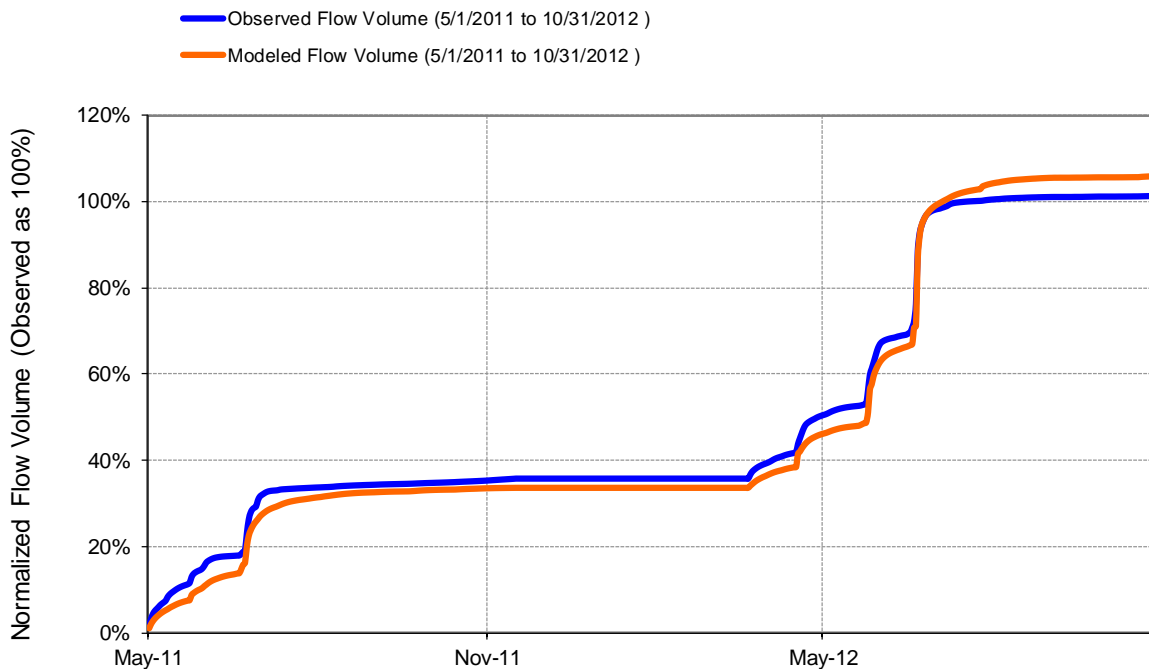
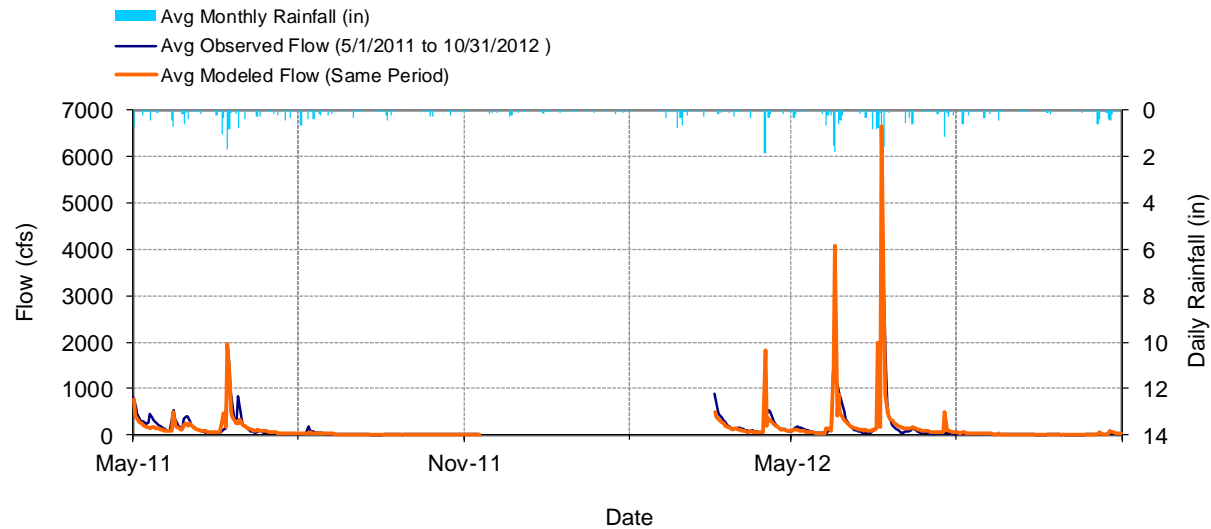
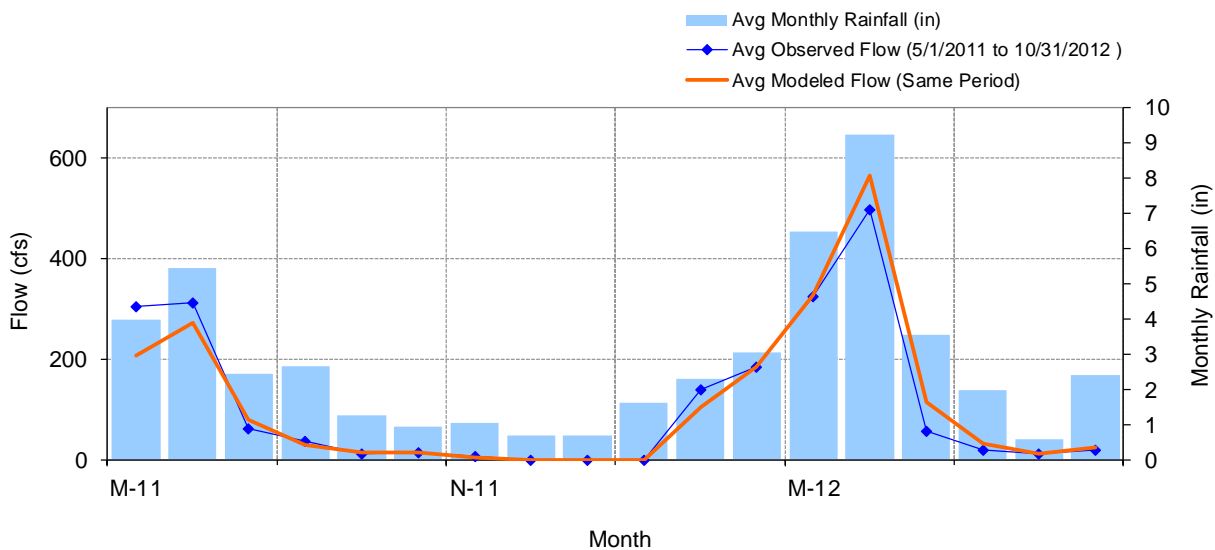


Figure 164. Flow accumulation at Gooseberry River near Castle Danger

Table 16. Summary statistics at Gooseberry River near Castle Danger

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 50 1.51-Year Analysis Period: 5/1/2011 - 10/31/2012 Flow volumes are (inches/year) for upstream drainage area		Gooseberry River nr Castle Danger, 0.34 mi us of MN61 Manually Entered Data Drainage Area (sq-mi): 74.8	
Total Simulated In-stream Flow:	11.23	Total Observed In-stream Flow:	10.63
Total of simulated highest 10% flows:	7.34	Total of Observed highest 10% flows:	7.44
Total of Simulated lowest 50% flows:	0.60	Total of Observed Lowest 50% flows:	0.36
Simulated Summer Flow Volume (months 7-9):	1.30	Observed Summer Flow Volume (7-9):	0.62
Simulated Fall Flow Volume (months 10-12):	0.14	Observed Fall Flow Volume (10-12):	0.15
Simulated Winter Flow Volume (months 1-3):	0.33	Observed Winter Flow Volume (1-3):	0.40
Simulated Spring Flow Volume (months 4-6):	9.46	Observed Spring Flow Volume (4-6):	9.47
Total Simulated Storm Volume:	6.24	Total Observed Storm Volume:	6.18
Simulated Summer Storm Volume (7-9):	0.26	Observed Summer Storm Volume (7-9):	0.19
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	5.59	10	
Error in 50% lowest flows:	65.79	10	
Error in 10% highest flows:	-1.37	15	
Seasonal volume error - Summer:	110.98	30	
Seasonal volume error - Fall:	-4.59	30	
Seasonal volume error - Winter:	-18.29	30	
Seasonal volume error - Spring:	-0.08	30	
Error in storm volumes:	1.06	20	
Error in summer storm volumes:	37.25	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.830	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.669		
Monthly NSE	0.949		

BEAVER RIVER NEAR BEAVER BAY (HYDSTRA 02006003)**Figure 165. Mean daily flow at Beaver River near Beaver Bay****Figure 166. Mean monthly flow at Beaver River near Beaver Bay**

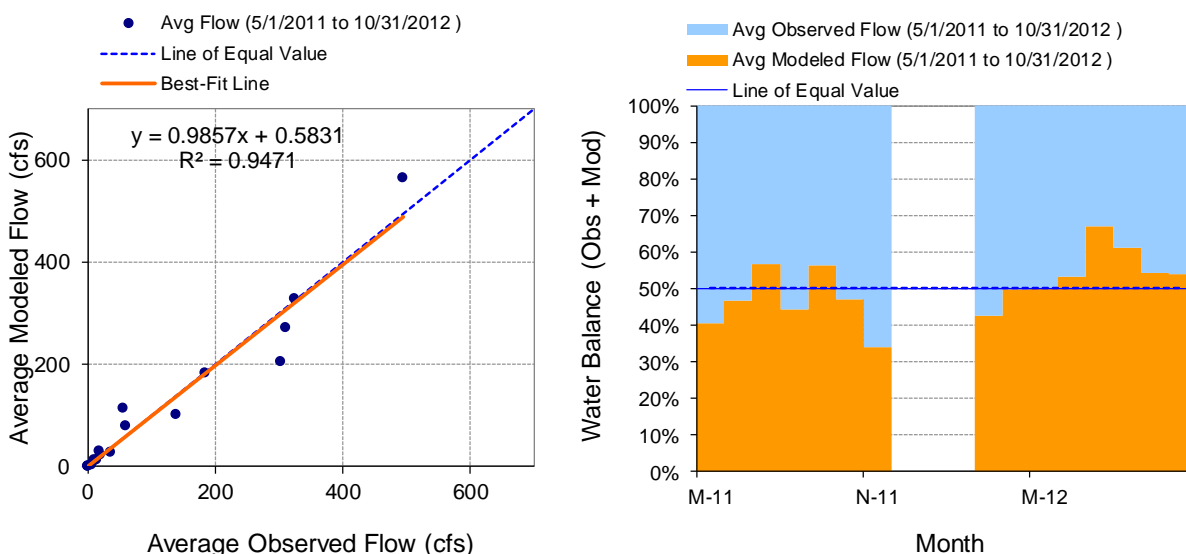


Figure 167. Monthly flow regression and temporal variation at Beaver River near Beaver Bay

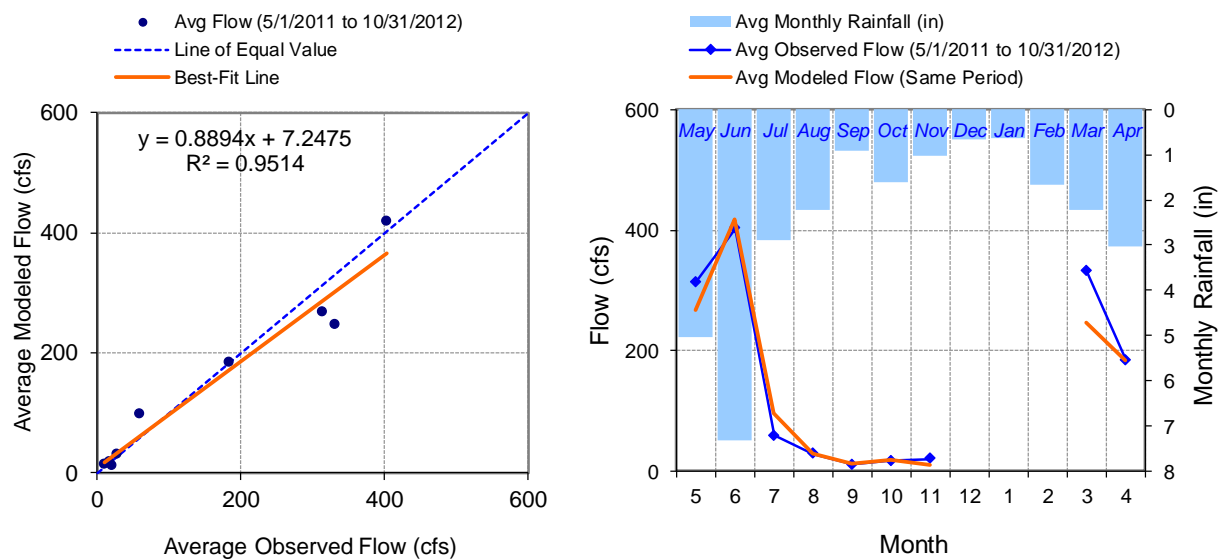


Figure 168. Seasonal regression and temporal aggregate at Beaver River near Beaver Bay

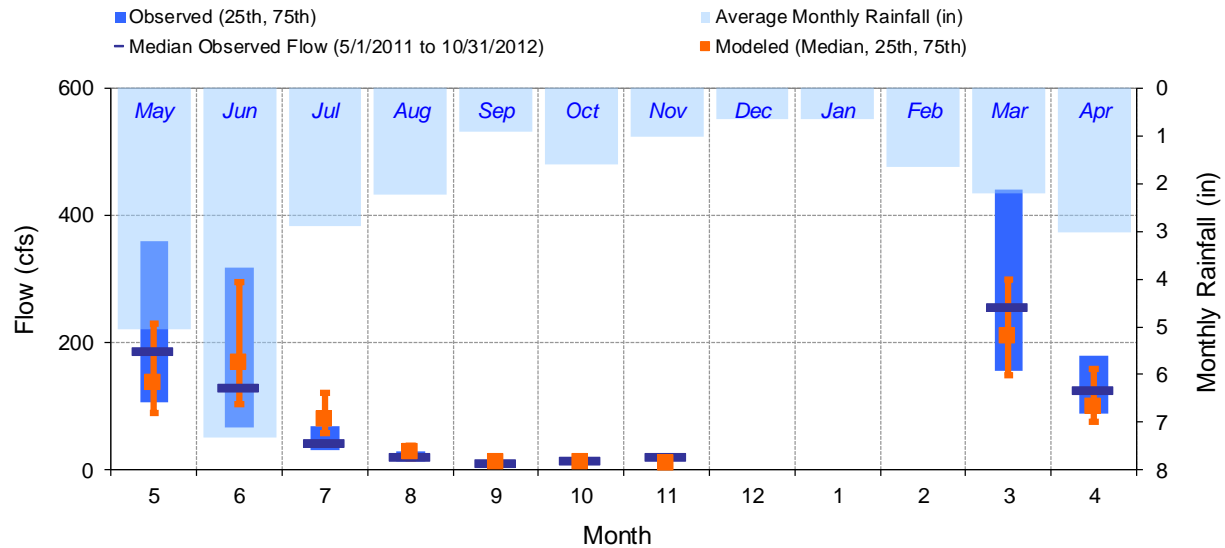
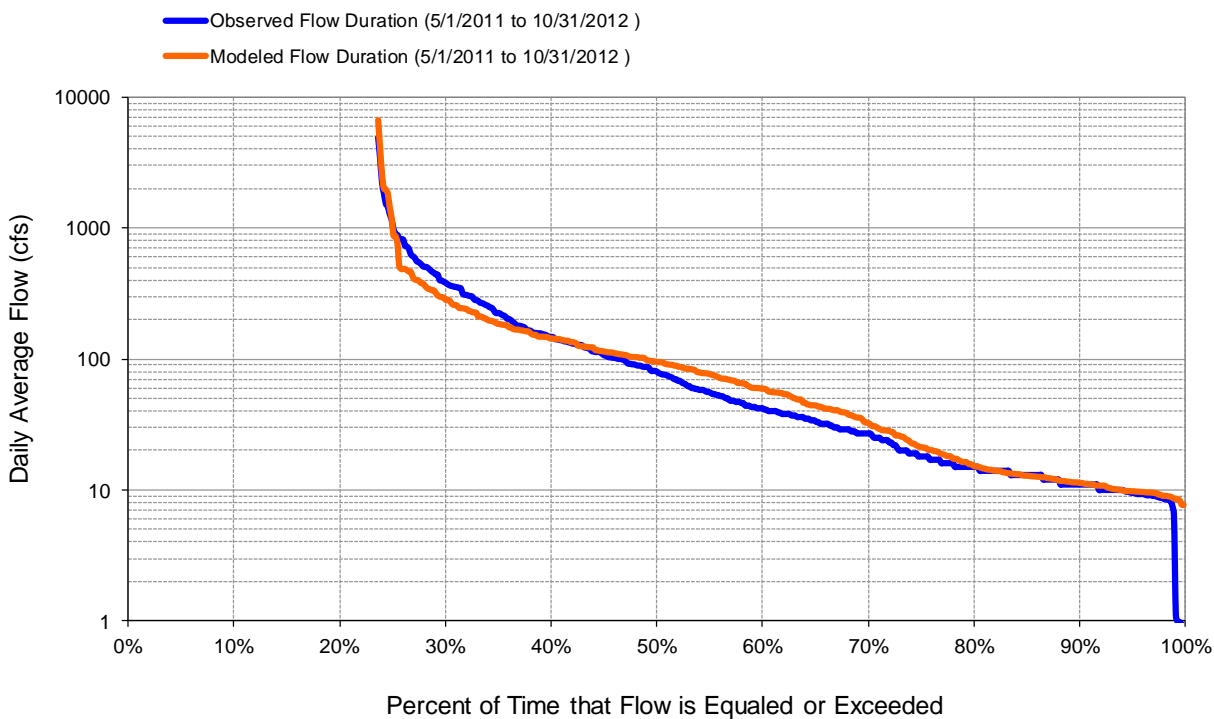
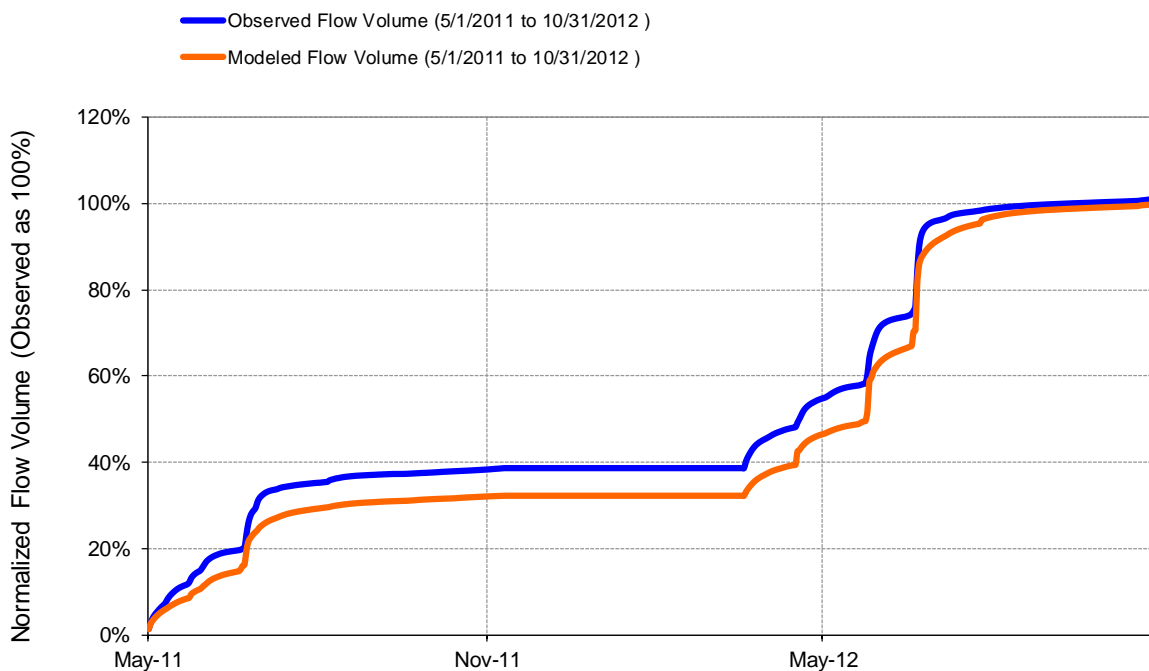


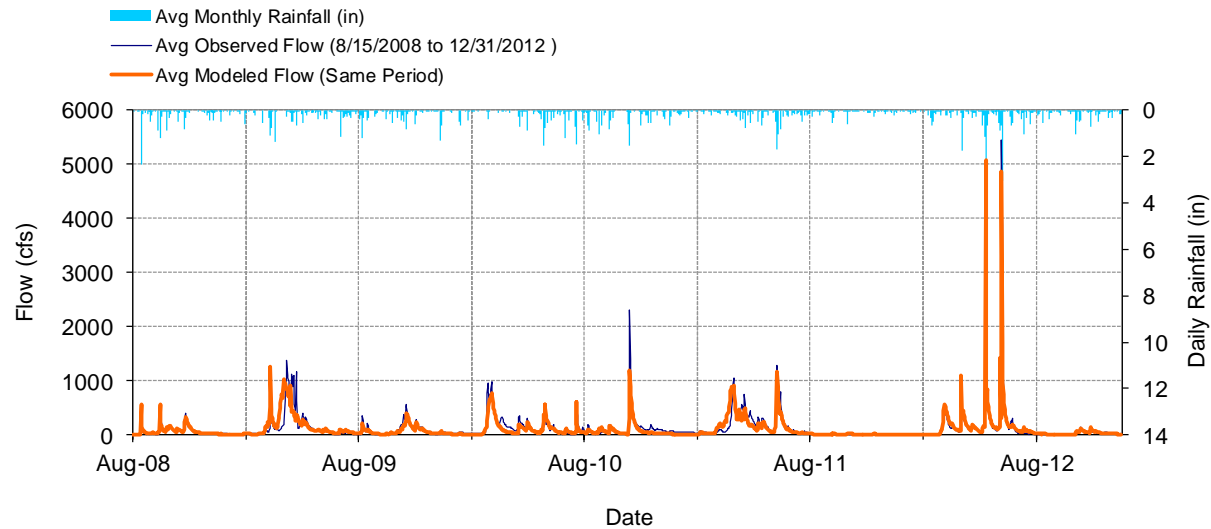
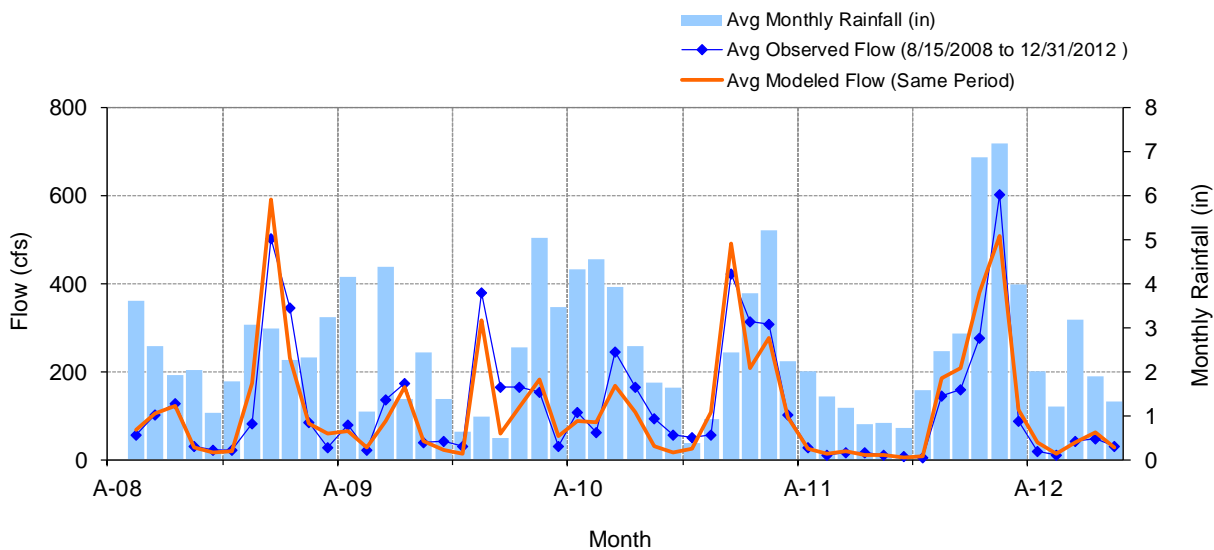
Figure 169. Seasonal medians and ranges at Beaver River near Beaver Bay

Table 17. Seasonal summary at Beaver River near Beaver Bay

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
May	313.85	186.00	107.00	360.25	266.28	137.84	89.20	230.09
Jun	402.87	129.50	66.50	318.00	418.15	167.76	103.09	295.13
Jul	58.42	42.50	32.25	68.75	96.57	80.69	57.29	120.92
Aug	28.00	20.00	14.00	30.00	29.91	27.62	19.34	37.96
Sep	10.16	11.00	9.35	11.25	12.60	11.90	10.78	13.95
Oct	17.17	14.00	11.00	17.00	18.06	12.42	9.82	19.00
Nov	20.33	20.00	18.00	23.00	10.43	10.15	9.69	11.04
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	332.00	255.00	156.00	440.00	245.88	210.74	148.61	299.12
Apr	184.47	125.00	89.25	179.50	183.40	98.77	75.51	158.07

**Figure 170. Flow exceedance at Beaver River near Beaver Bay****Figure 171. Flow accumulation at Beaver River near Beaver Bay****Table 18. Summary statistics at Beaver River near Beaver Bay**

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 60 1.51-Year Analysis Period: 5/1/2011 - 10/31/2012 Flow volumes are (inches/year) for upstream drainage area		Beaver River nr Beaver Bay, 1.2mi us of MN61 Manually Entered Data Drainage Area (sq-mi): 121.6	
Total Simulated In-stream Flow:	12.21	Total Observed In-stream Flow:	12.33
Total of simulated highest 10% flows:	7.25	Total of Observed highest 10% flows:	7.52
Total of Simulated lowest 50% flows:	0.91	Total of Observed Lowest 50% flows:	0.76
Simulated Summer Flow Volume (months 7-9):	1.75	Observed Summer Flow Volume (7-9):	1.21
Simulated Fall Flow Volume (months 10-12):	0.25	Observed Fall Flow Volume (10-12):	0.25
Simulated Winter Flow Volume (months 1-3):	0.65	Observed Winter Flow Volume (1-3):	0.88
Simulated Spring Flow Volume (months 4-6):	9.57	Observed Spring Flow Volume (4-6):	9.99
Total Simulated Storm Volume:	6.16	Total Observed Storm Volume:	6.07
Simulated Summer Storm Volume (7-9):	0.31	Observed Summer Storm Volume (7-9):	0.32
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-0.97	10	
Error in 50% lowest flows:	20.05	10	
Error in 10% highest flows:	-3.57	15	
Seasonal volume error - Summer:	44.08	30	
Seasonal volume error - Fall:	-2.71	30	
Seasonal volume error - Winter:	-25.94	30	Clear
Seasonal volume error - Spring:	-4.20	30	
Error in storm volumes:	1.47	20	
Error in summer storm volumes:	-1.37	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.735	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.645		
Monthly NSE	0.941		

BAPTISM RIVER NEAR BEAVER BAY (HYDSTRA 01092001)**Figure 172. Mean daily flow at Baptism River near Beaver Bay****Figure 173. Mean monthly flow at Baptism River near Beaver Bay**

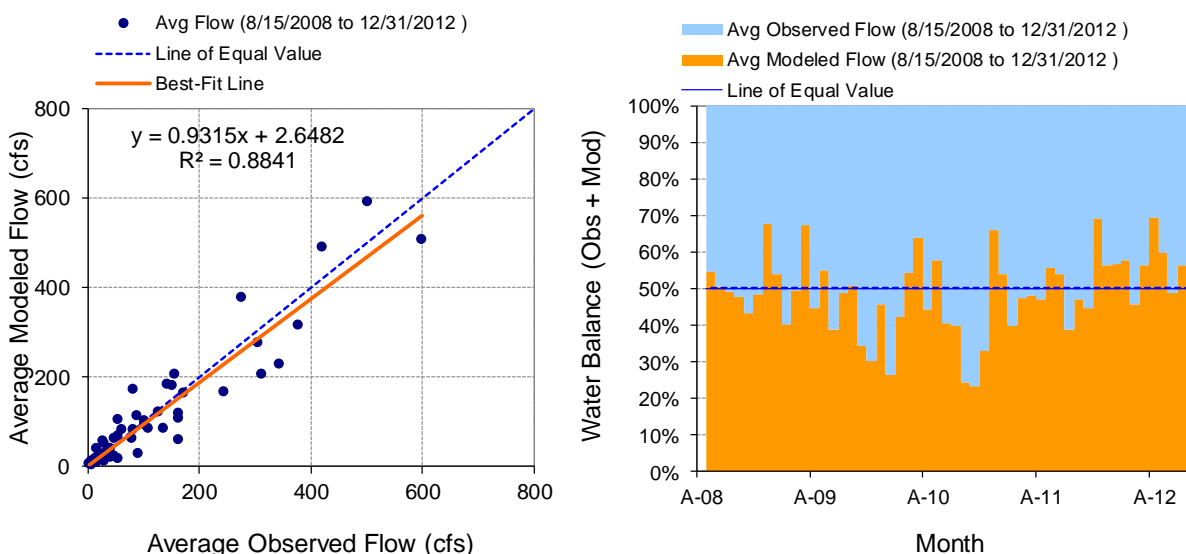


Figure 174. Monthly flow regression and temporal variation at Baptism River near Beaver Bay

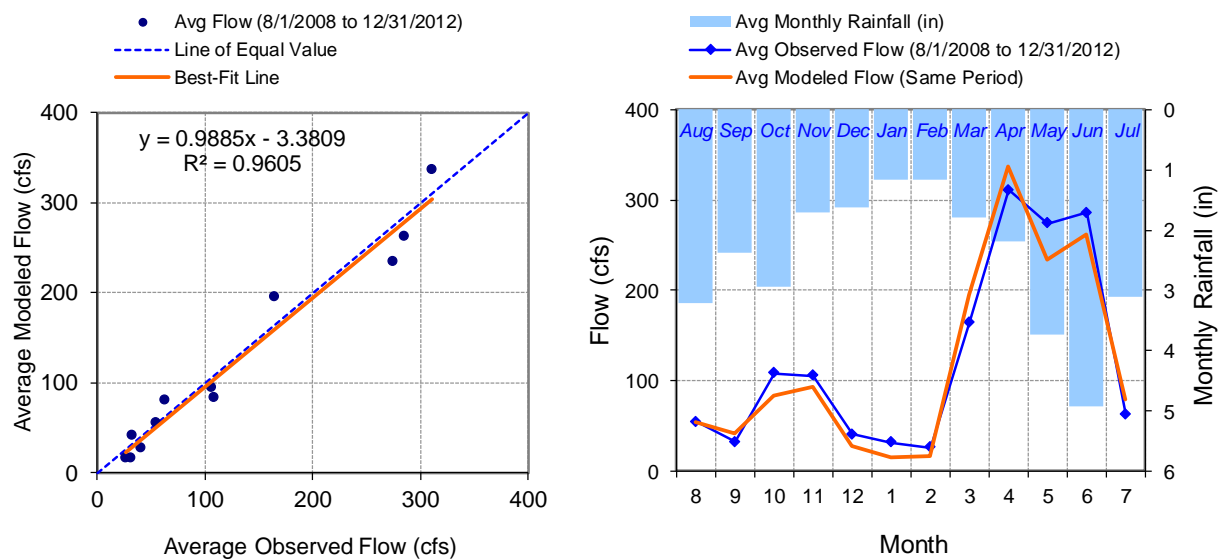


Figure 175. Seasonal regression and temporal aggregate at Baptism River near Beaver Bay

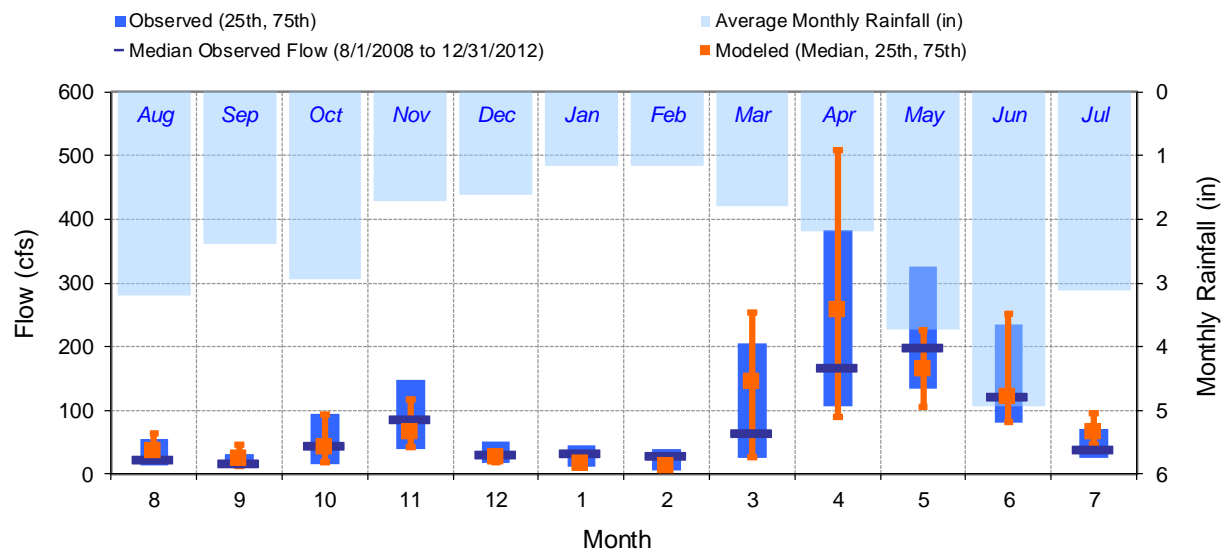


Figure 176. Seasonal medians and ranges at Baptism River near Beaver Bay

Table 19. Seasonal summary at Baptism River near Beaver Bay

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Aug	54.70	23.00	13.00	55.00	54.80	36.84	22.35	64.21
Sep	32.09	16.00	10.25	30.75	41.20	24.76	13.30	46.23
Oct	107.87	45.00	16.50	95.50	82.95	42.78	18.61	94.49
Nov	105.55	85.00	39.00	148.50	93.38	65.47	42.95	117.42
Dec	40.75	31.00	18.58	51.50	27.14	26.27	19.44	34.23
Jan	31.28	33.00	11.75	46.10	15.07	16.33	11.49	18.57
Feb	25.99	27.73	6.60	39.27	16.06	12.76	11.27	17.61
Mar	164.42	63.97	25.75	205.75	194.74	144.89	25.69	252.88
Apr	311.19	167.00	105.75	383.25	336.87	258.52	89.43	509.08
May	274.31	197.50	133.50	325.25	234.31	164.48	104.55	226.67
Jun	285.70	121.00	81.00	234.00	261.91	121.35	82.46	251.14
Jul	62.25	37.50	24.75	71.75	79.81	65.94	46.55	95.10

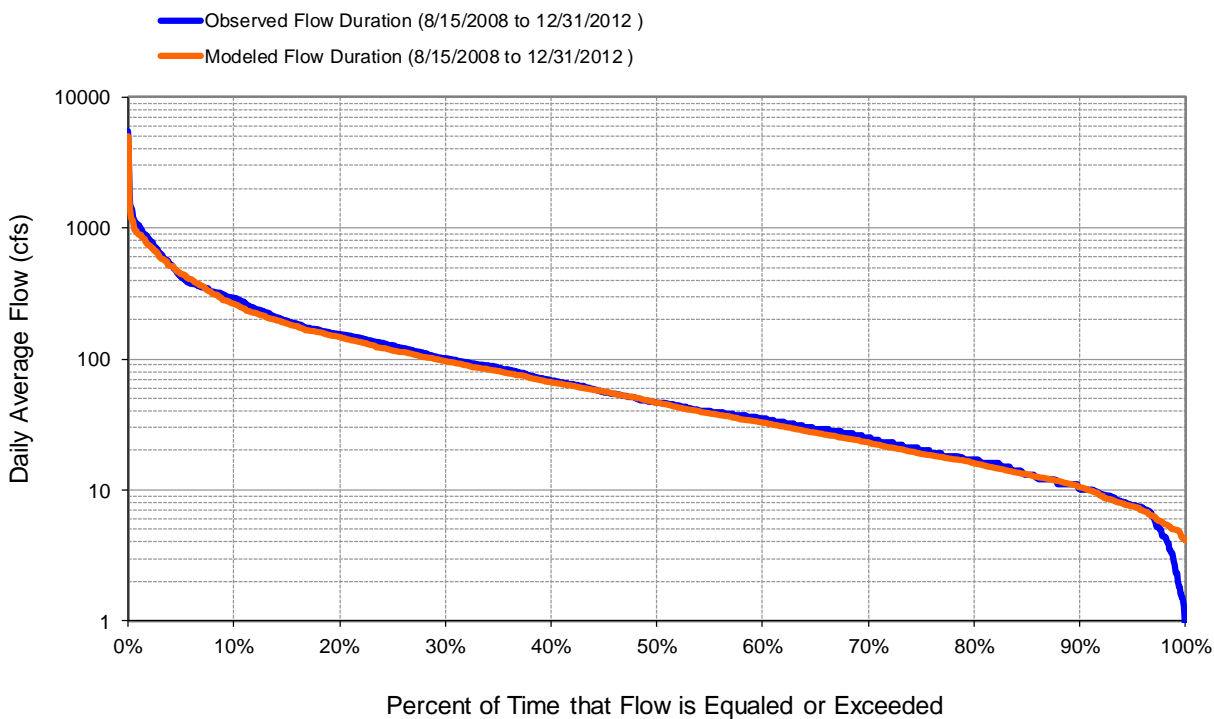


Figure 177. Flow exceedance at Baptism River near Beaver Bay

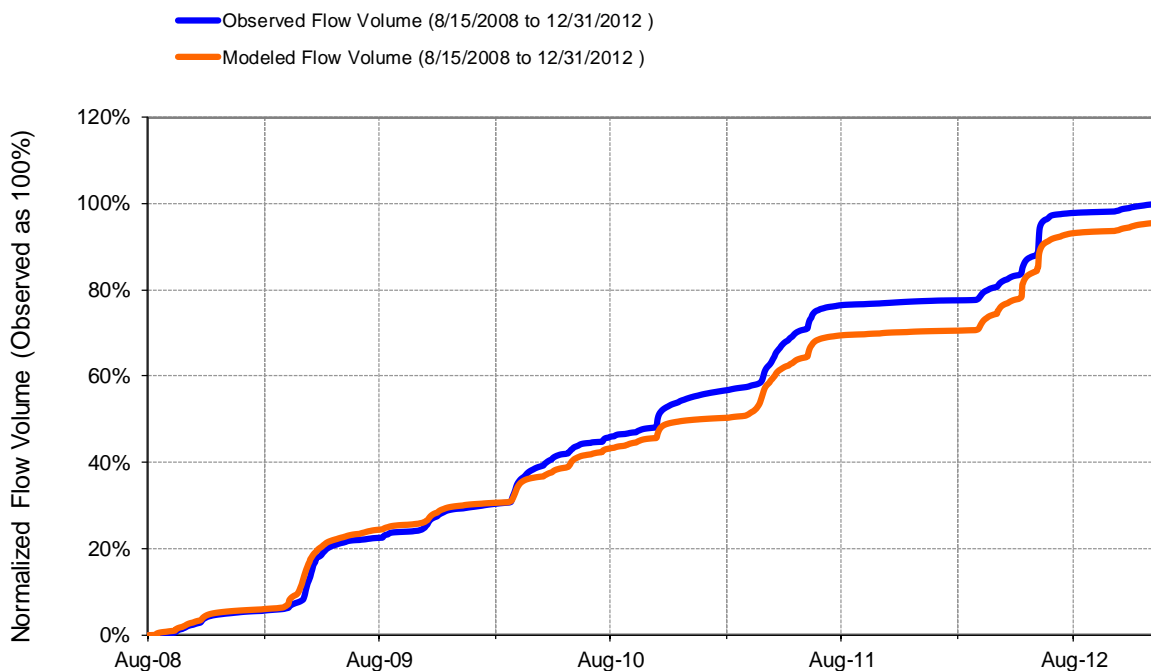
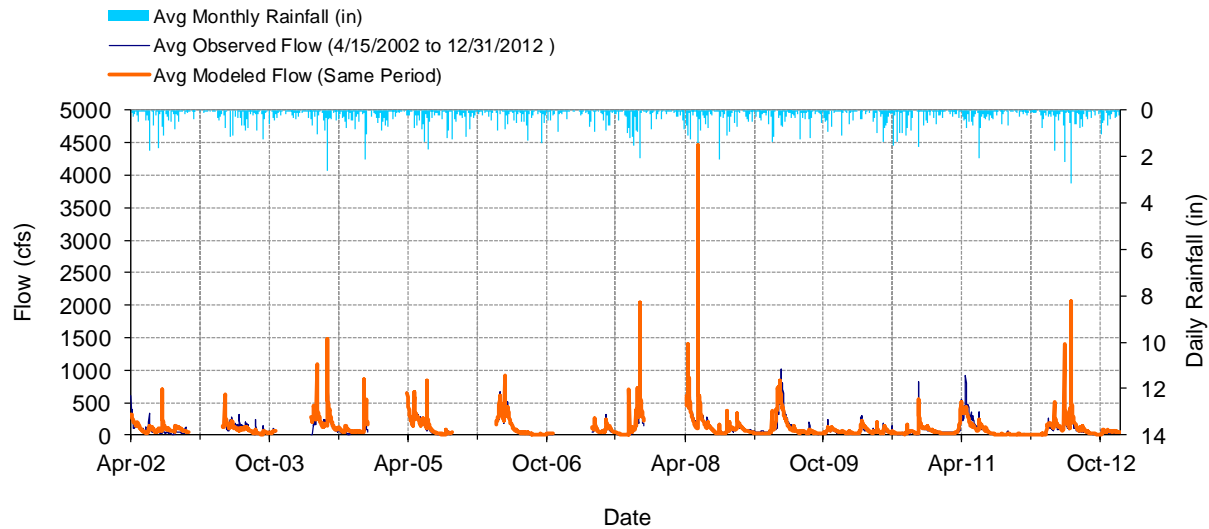
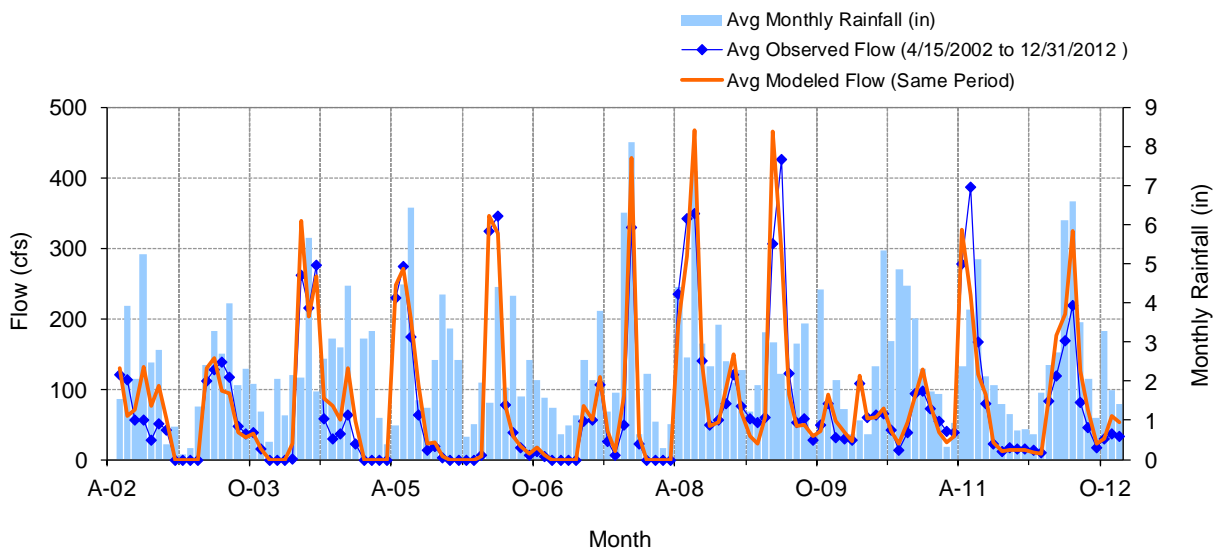


Figure 178. Flow accumulation at Baptism River near Beaver Bay

Table 20. Summary statistics at Baptism River near Beaver Bay

HSPF Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM DSN 70 4.38-Year Analysis Period: 8/1/2008 - 12/31/2012 Flow volumes are (inches/year) for upstream drainage area Run 6h		Baptism River near Beaver Bay Manually Entered Data Drainage Area (sq-mi): 140		
Total Simulated In-stream Flow:	11.13	Total Observed In-stream Flow:	11.64	
Total of simulated highest 10% flows:	5.75	Total of Observed highest 10% flows:	6.00	
Total of Simulated lowest 50% flows:	1.04	Total of Observed Lowest 50% flows:	1.08	
Simulated Summer Flow Volume (months 7-9):	1.44	Observed Summer Flow Volume (7-9):	1.23	
Simulated Fall Flow Volume (months 10-12):	1.88	Observed Fall Flow Volume (10-12):	2.36	
Simulated Winter Flow Volume (months 1-3):	1.69	Observed Winter Flow Volume (1-3):	1.65	
Simulated Spring Flow Volume (months 4-6):	6.12	Observed Spring Flow Volume (4-6):	6.41	
Total Simulated Storm Volume:	3.54	Total Observed Storm Volume:	3.96	
Simulated Summer Storm Volume (7-9):	0.41	Observed Summer Storm Volume (7-9):	0.49	
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	<i>Run (n-1)</i>	<i>Run (n-2)</i>
Error in total volume:	-4.35	10	-6.22	
Error in 50% lowest flows:	-3.76	10	-3.76	
Error in 10% highest flows:	-4.16	15	-7.84	
Seasonal volume error - Summer:	17.58	30	17.58	
Seasonal volume error - Fall:	-20.06	30	-20.06	
Seasonal volume error - Winter:	2.31	30	2.31	
Seasonal volume error - Spring:	-4.48	30	-7.92	
Error in storm volumes:	-10.43	20	-16.21	
Error in summer storm volumes:	-15.44	50	-15.44	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.647	Model accuracy increases	0.765	
Baseline adjusted coefficient (Garrick), E':	0.599		0.613	
Monthly NSE	0.881		0.890	

Note: Run (n-1) shows the model performance when some large observed peaks that are labeled as poor or unreliable are removed.

POPLAR RIVER NEAR LUTSEN (HYDSTRA 01063003)**Figure 179. Mean daily flow at Poplar River near Lutsen****Figure 180. Mean monthly flow at Poplar River near Lutsen**

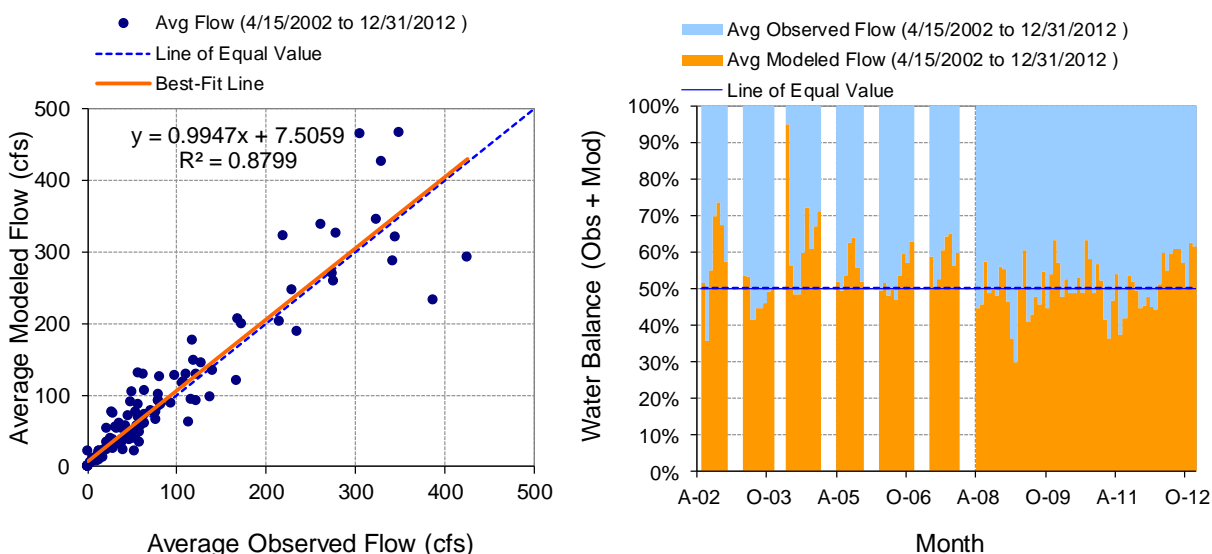


Figure 181. Monthly flow regression and temporal variation at Poplar River near Lutsen

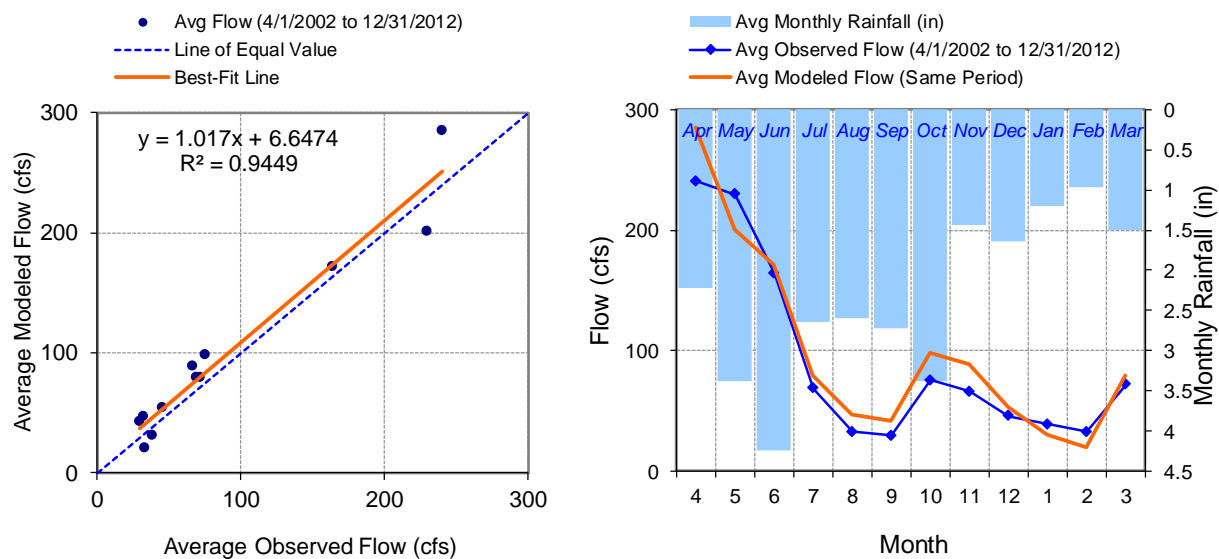


Figure 182. Seasonal regression and temporal aggregate at Poplar River near Lutsen

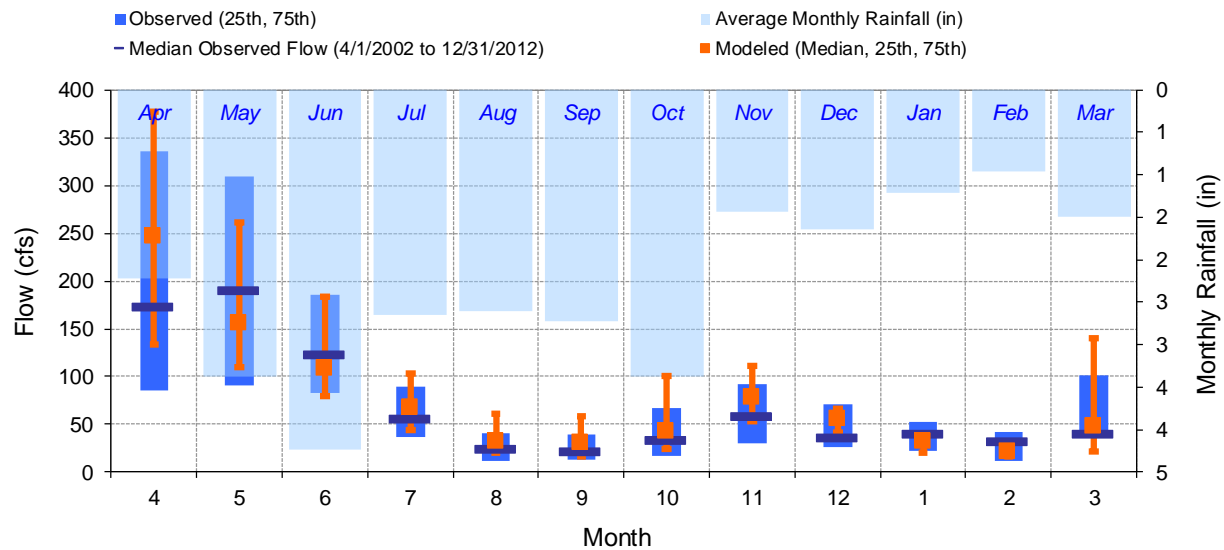


Figure 183. Seasonal medians and ranges at Poplar River near Lutsen

Table 21. Seasonal summary at Poplar River near Lutsen

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Apr	240.46	172.64	85.00	335.82	284.82	246.30	134.14	377.38
May	229.60	190.24	91.41	310.00	200.49	156.33	110.42	261.01
Jun	164.13	122.65	83.00	185.54	171.62	108.88	79.98	183.80
Jul	68.61	56.00	36.92	89.53	79.19	68.23	44.42	103.44
Aug	32.32	24.00	12.00	40.15	46.43	32.43	19.65	60.51
Sep	29.61	21.00	13.00	39.71	41.83	31.13	15.95	58.28
Oct	75.58	34.00	16.50	67.02	97.80	42.26	24.04	100.14
Nov	66.15	58.78	30.18	91.84	88.72	78.71	52.68	111.52
Dec	45.72	36.00	26.71	71.29	53.44	56.47	41.89	66.69
Jan	38.57	40.50	22.64	52.16	30.18	32.12	19.94	39.96
Feb	32.70	32.00	12.00	41.96	19.86	21.24	16.68	25.12
Mar	71.76	40.00	38.36	101.00	79.27	47.89	22.16	139.90

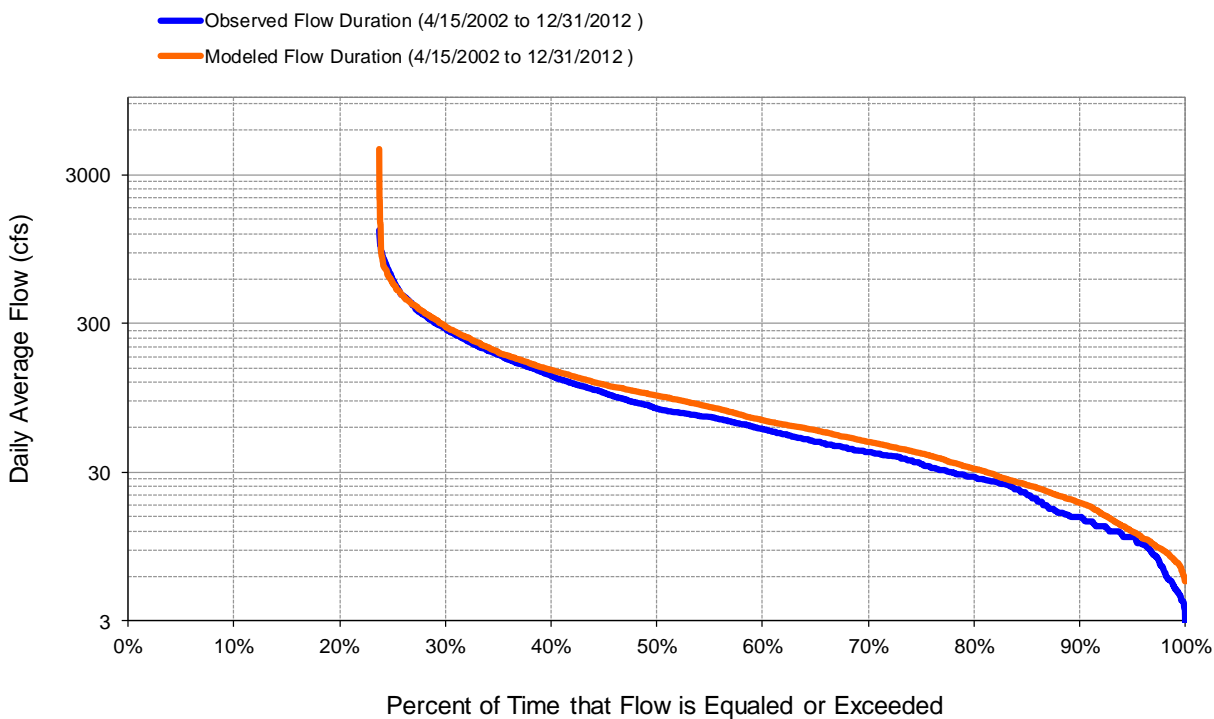


Figure 184. Flow exceedance at Poplar River near Lutsen

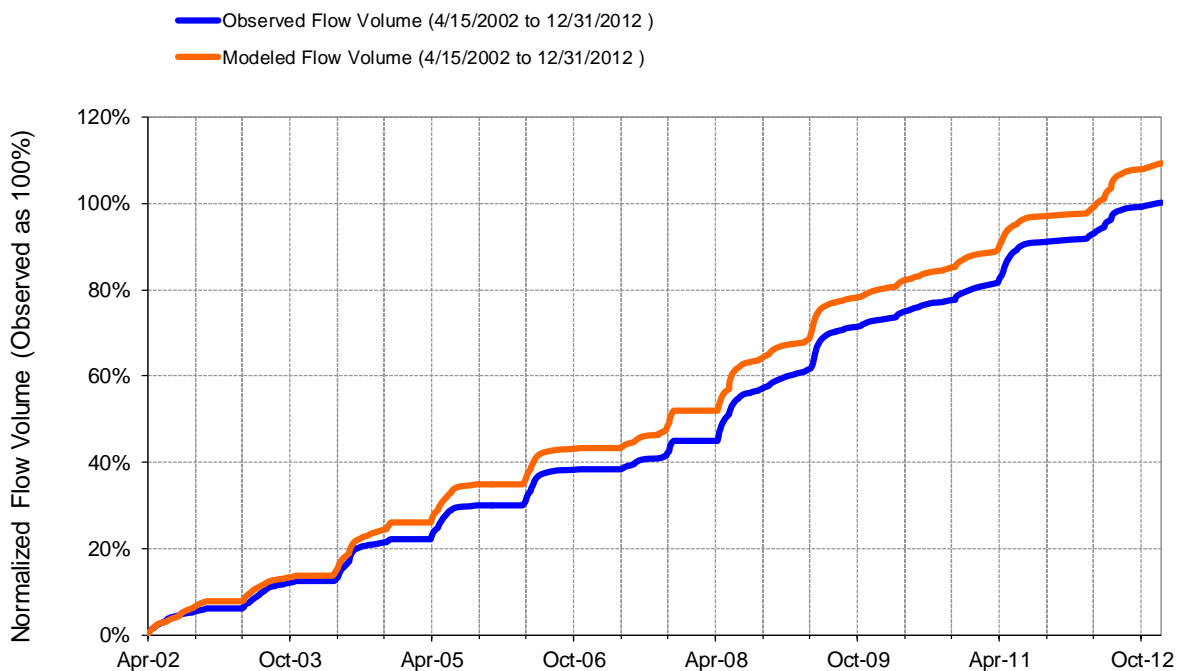
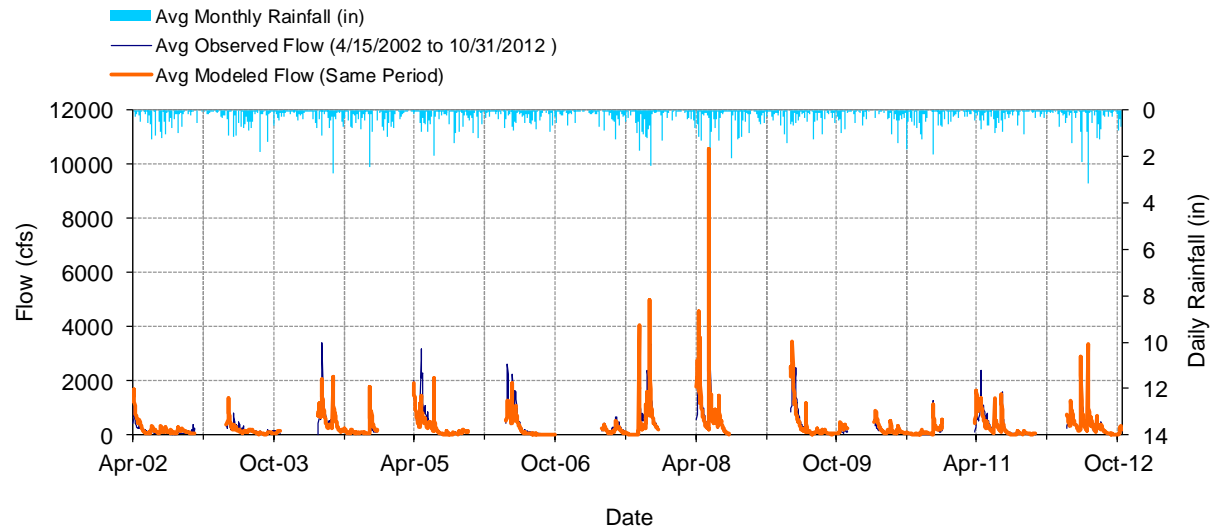
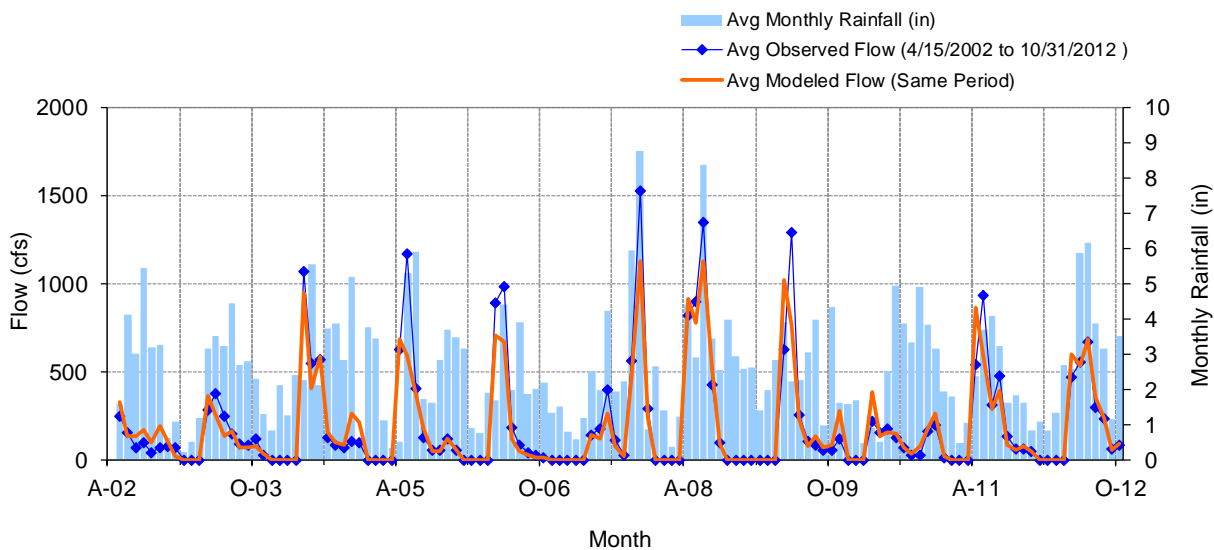


Figure 185. Flow accumulation at Poplar River near Lutsen

Table 22. Summary statistics at Poplar River near Lutsen

HSPF Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM DSN 80 10.72-Year Analysis Period: 4/1/2002 - 12/31/2012 Flow volumes are (inches/year) for upstream drainage area		Poplar River near Lutsen, 0.2 mi us of MN61 Manually Entered Data Drainage Area (sq-mi): 114		
Total Simulated In-stream Flow:	10.03	Total Observed In-stream Flow:	9.18	
Total of simulated highest 10% flows:	4.08	Total of Observed highest 10% flows:	3.91	
Total of Simulated lowest 50% flows:	1.46	Total of Observed Lowest 50% flows:	1.24	
Simulated Summer Flow Volume (months 7-9):	1.72	Observed Summer Flow Volume (7-9):	1.35	
Simulated Fall Flow Volume (months 10-12):	1.75	Observed Fall Flow Volume (10-12):	1.36	
Simulated Winter Flow Volume (months 1-3):	0.49	Observed Winter Flow Volume (1-3):	0.54	
Simulated Spring Flow Volume (months 4-6):	6.07	Observed Spring Flow Volume (4-6):	5.94	
Total Simulated Storm Volume:	1.93	Total Observed Storm Volume:	1.99	
Simulated Summer Storm Volume (7-9):	0.29	Observed Summer Storm Volume (7-9):	0.31	
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	<i>Run (n-1)</i>	<i>Run (n-2)</i>
Error in total volume:	9.25	10	8.11	
Error in 50% lowest flows:	17.97	10	17.97	
Error in 10% highest flows:	4.39	15	1.68	
Seasonal volume error - Summer:	28.19	30	28.19	
Seasonal volume error - Fall:	28.85	30	28.85	
Seasonal volume error - Winter:	-8.67	30	-8.67	
Seasonal volume error - Spring:	2.11	30	0.32	
Error in storm volumes:	-3.07	20	-8.63	
Error in summer storm volumes:	-5.11	50	-5.11	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.499	Model accuracy increases	0.720	
Baseline adjusted coefficient (Garrick), E':	0.598		0.609	
Monthly NSE	0.837		0.848	

Note: Run (n-1) shows the model performance when some large observed peaks that are labeled as poor or unreliable are removed.

BRULE RIVER NEAR HOVLAND (HYDSTRA 01022001)**Figure 186. Mean daily flow at Brule River near Hovland****Figure 187. Mean monthly flow at Brule River near Hovland**

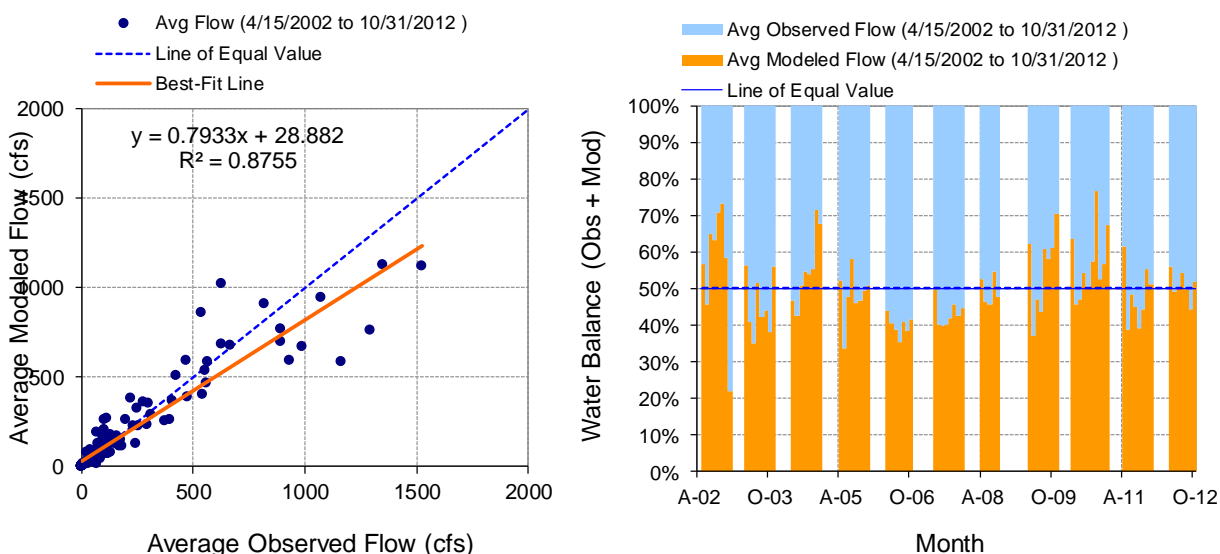


Figure 188. Monthly flow regression and temporal variation at Brule River near Hovland

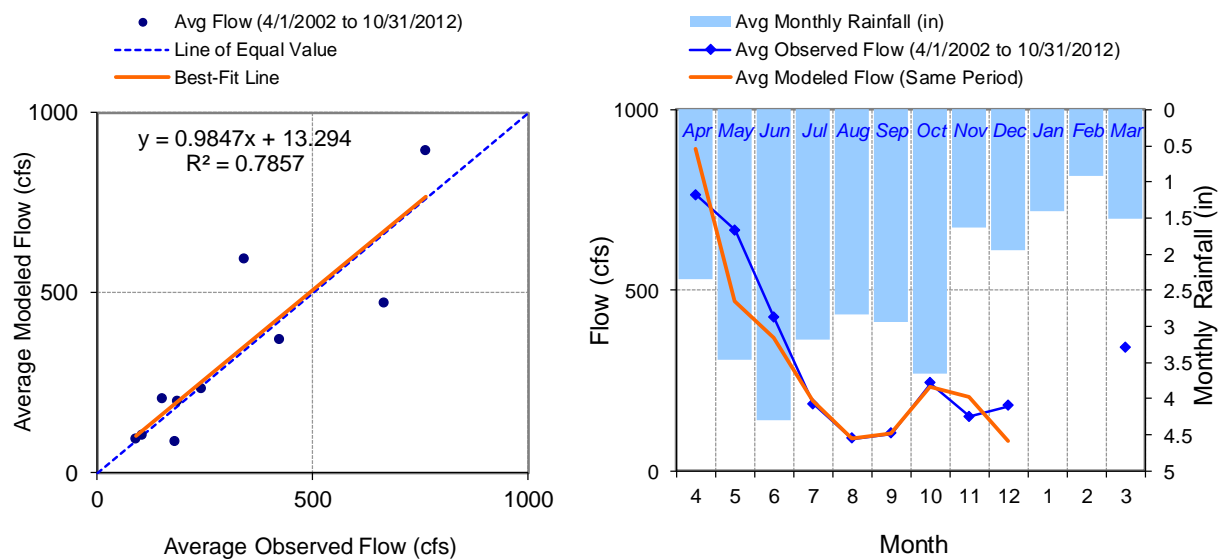


Figure 189. Seasonal regression and temporal aggregate at Brule River near Hovland

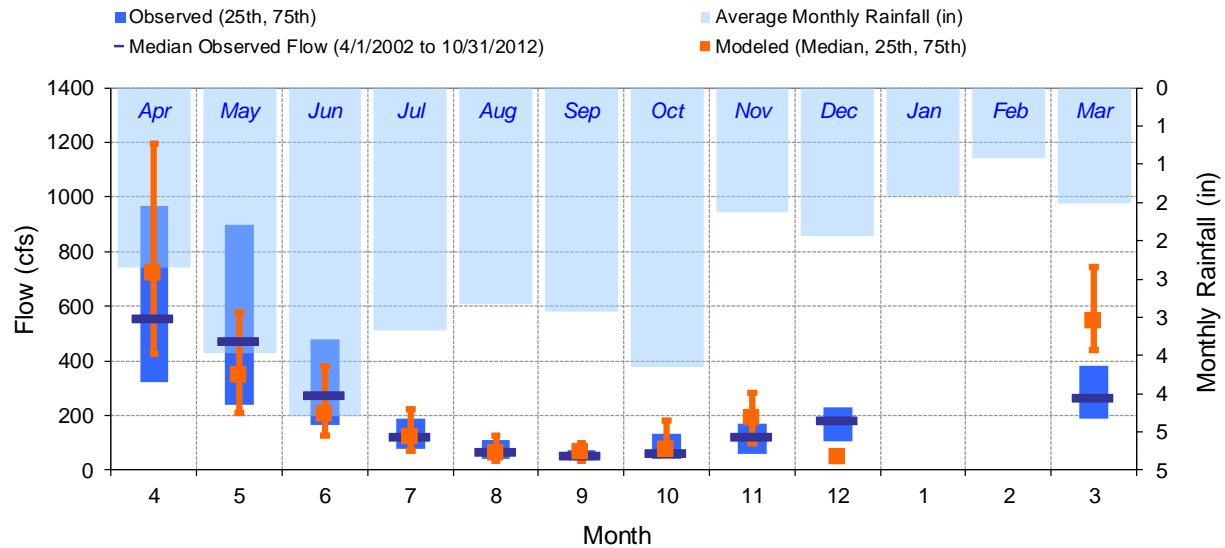
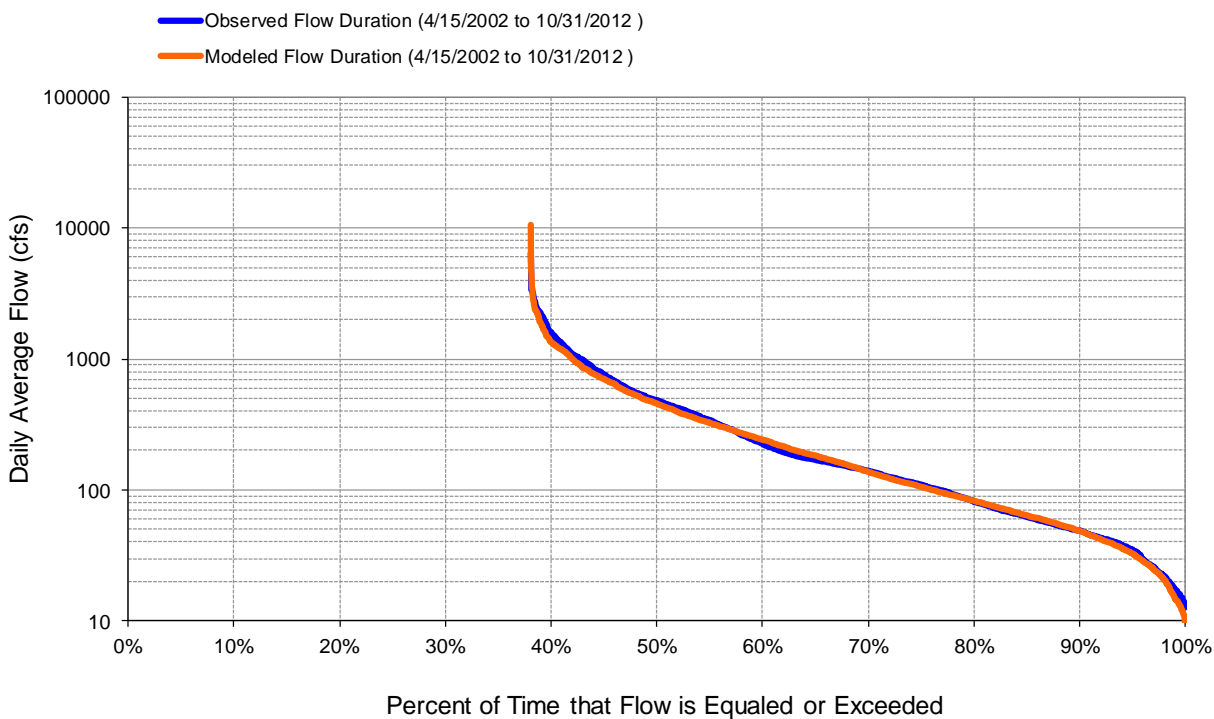
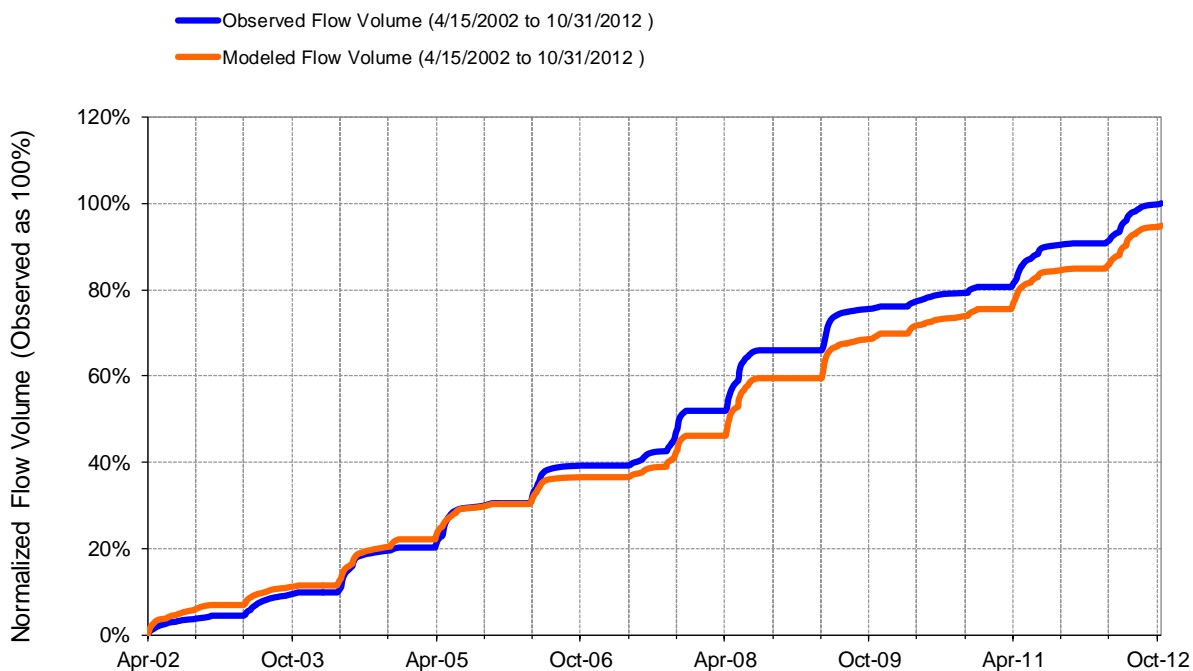


Figure 190. Seasonal medians and ranges at Brule River near Hovland

Table 23. Seasonal summary at Brule River near Hovland

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Apr	763.84	553.59	324.45	969.50	891.77	719.28	428.06	1196.93
May	666.44	471.75	239.34	900.00	469.85	348.86	209.65	577.55
Jun	422.87	272.42	167.00	479.97	369.34	205.06	125.76	381.14
Jul	185.21	119.93	79.00	188.00	194.92	121.28	71.99	224.23
Aug	88.33	68.29	39.33	112.11	91.18	61.54	32.51	125.64
Sep	103.25	52.00	37.50	71.17	102.90	64.46	34.22	96.47
Oct	242.36	63.73	42.00	134.52	231.26	77.58	52.46	183.85
Nov	150.83	120.93	60.14	171.84	203.47	191.32	100.26	280.87
Dec	180.38	182.11	106.76	230.46	82.94	50.20	45.45	55.68
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	340.05	262.50	190.75	380.00	590.78	544.47	438.57	746.23

**Figure 191. Flow exceedance at Brule River near Hovland****Figure 192. Flow accumulation at Brule River near Hovland****Table 24. Summary statistics at Brule River near Hovland**

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 90 10.55-Year Analysis Period: 4/1/2002 - 10/31/2012 Flow volumes are (inches/year) for upstream drainage area		Brule River near Hovland, MN61 Manually Entered Data Drainage Area (sq-mi): 264	
Total Simulated In-stream Flow:	9.81	Total Observed In-stream Flow:	10.35
Total of simulated highest 10% flows:	4.40	Total of Observed highest 10% flows:	4.82
Total of Simulated lowest 50% flows:	1.12	Total of Observed Lowest 50% flows:	1.13
Simulated Summer Flow Volume (months 7-9):	1.71	Observed Summer Flow Volume (7-9):	1.65
Simulated Fall Flow Volume (months 10-12):	1.41	Observed Fall Flow Volume (10-12):	1.35
Simulated Winter Flow Volume (months 1-3):	0.16	Observed Winter Flow Volume (1-3):	0.09
Simulated Spring Flow Volume (months 4-6):	6.53	Observed Spring Flow Volume (4-6):	7.26
Total Simulated Storm Volume:	2.93	Total Observed Storm Volume:	3.17
Simulated Summer Storm Volume (7-9):	0.53	Observed Summer Storm Volume (7-9):	0.44
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-5.28	10	
Error in 50% lowest flows:	-1.28	10	
Error in 10% highest flows:	-8.81	15	
Seasonal volume error - Summer:	3.36	30	
Seasonal volume error - Fall:	4.84	30	
Seasonal volume error - Winter:	73.73	30	Clear
Seasonal volume error - Spring:	-10.11	30	
Error in storm volumes:	-7.52	20	
Error in summer storm volumes:	19.98	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.520	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.572		
Monthly NSE	0.827		

Appendix C. Detailed Flow Validation Results

KNIFE RIVER NEAR TWO HARBORS (HYDSTRA 02026001//USGS 04015330)

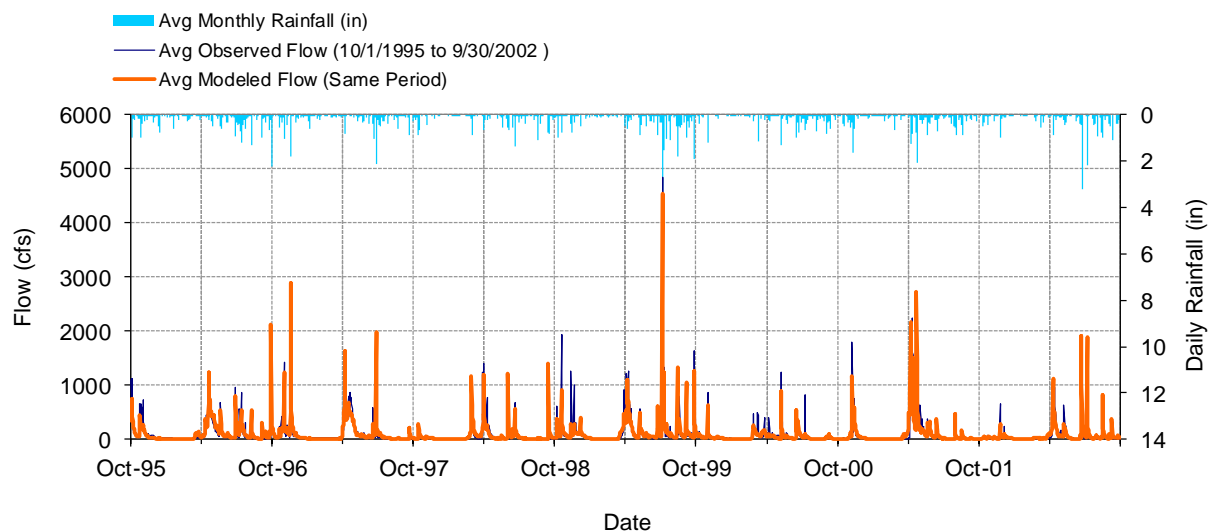


Figure 193. Mean daily flow at Knife River near Two Harbors

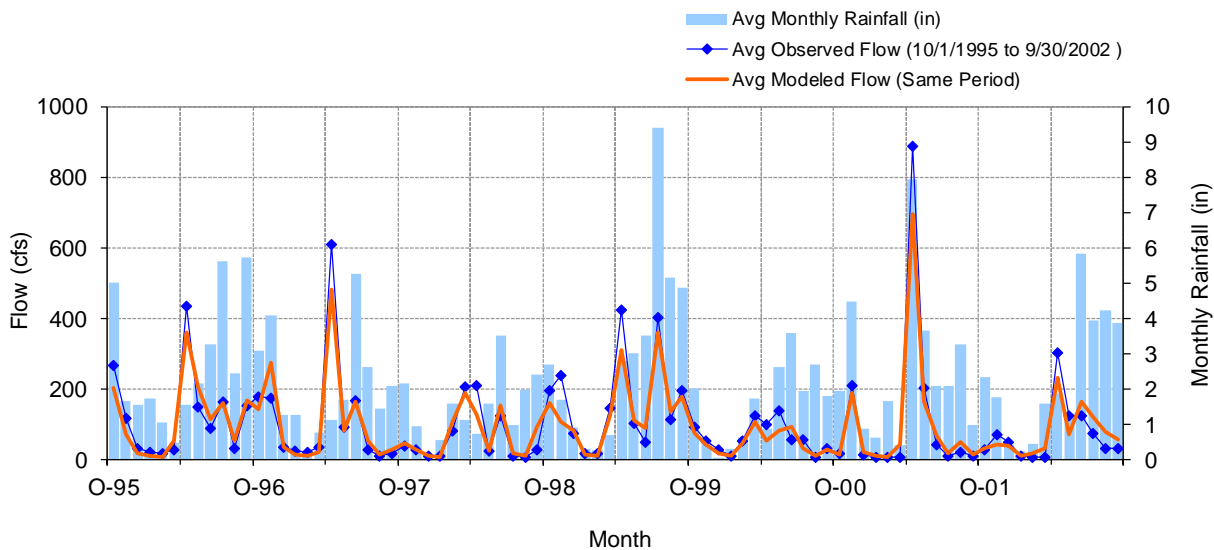


Figure 194. Mean monthly flow at Knife River near Two Harbors

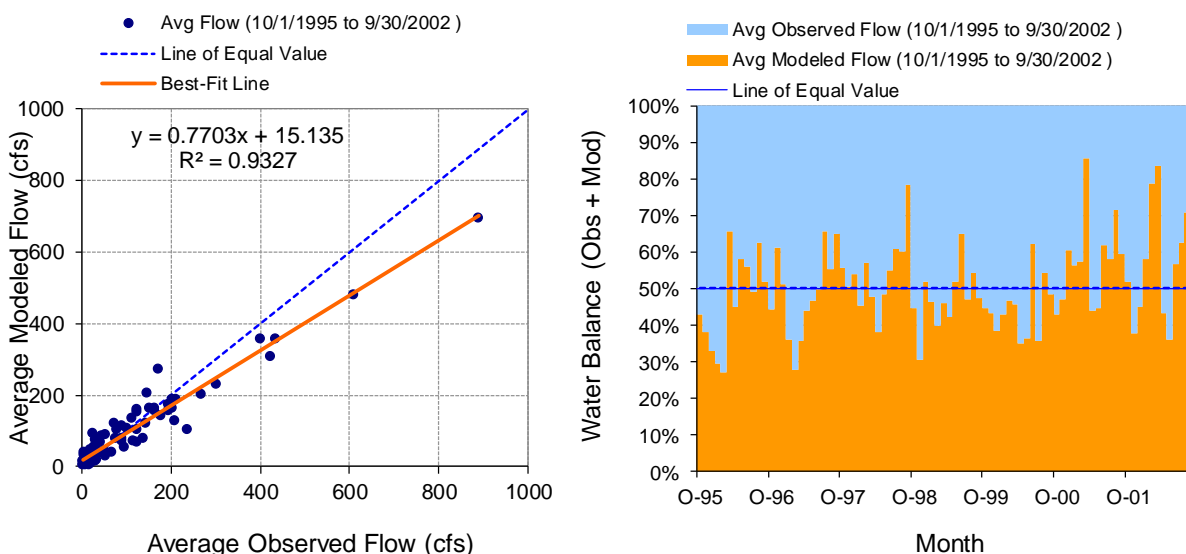


Figure 195. Monthly flow regression and temporal variation at Knife River near Two Harbors

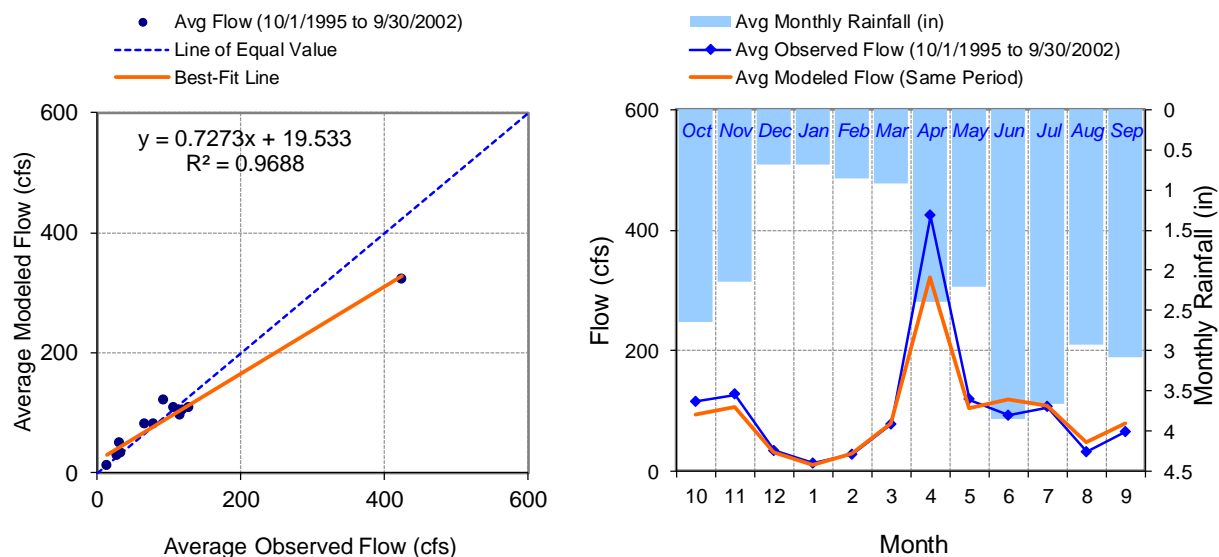


Figure 196. Seasonal regression and temporal aggregate at Knife River near Two Harbors

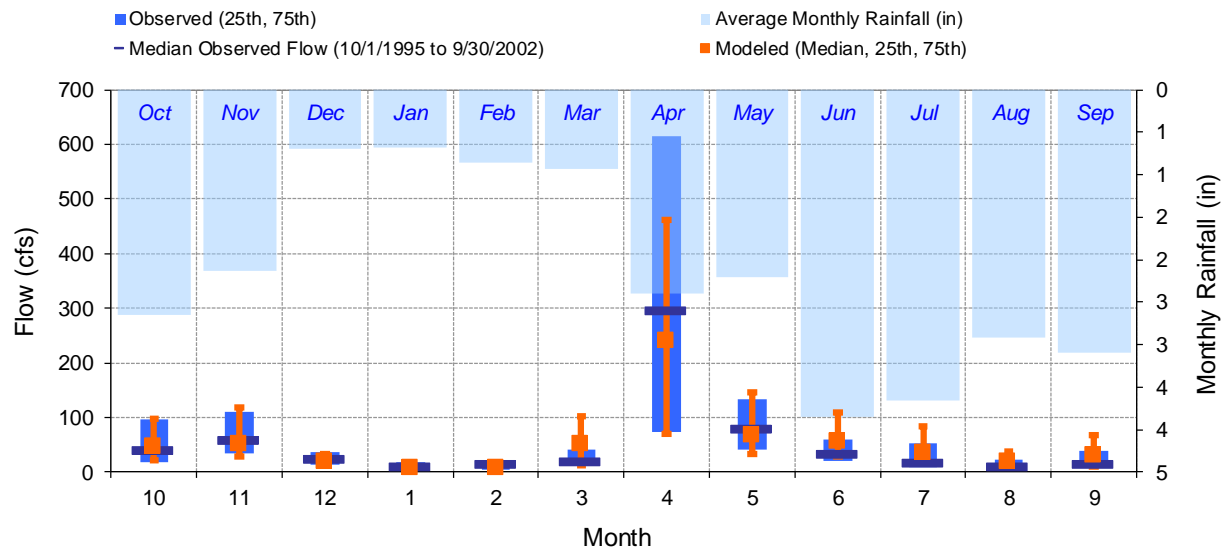


Figure 197. Seasonal medians and ranges at Knife River near Two Harbors

Table 25. Seasonal summary at Knife River near Two Harbors

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	115.60	41.00	18.00	97.00	94.25	46.10	21.18	97.70
Nov	126.61	58.00	34.00	111.50	106.79	51.44	28.02	117.42
Dec	33.49	25.00	14.00	36.00	30.88	19.66	12.10	33.92
Jan	13.09	10.00	7.40	19.00	9.72	8.77	7.30	11.82
Feb	27.47	14.00	4.83	17.00	27.97	7.74	5.64	11.52
Mar	77.82	20.00	11.00	42.00	79.35	51.45	12.95	102.89
Apr	423.60	296.00	74.25	614.75	321.64	240.32	69.25	462.18
May	118.22	79.00	41.00	134.00	104.00	66.96	34.29	146.01
Jun	92.14	33.50	21.00	60.75	119.09	57.33	29.27	108.43
Jul	105.90	18.00	10.00	52.00	107.36	36.46	18.15	83.82
Aug	31.07	11.00	7.10	22.00	48.60	19.69	9.13	37.76
Sep	65.14	15.00	8.63	38.00	79.44	30.53	10.99	66.87

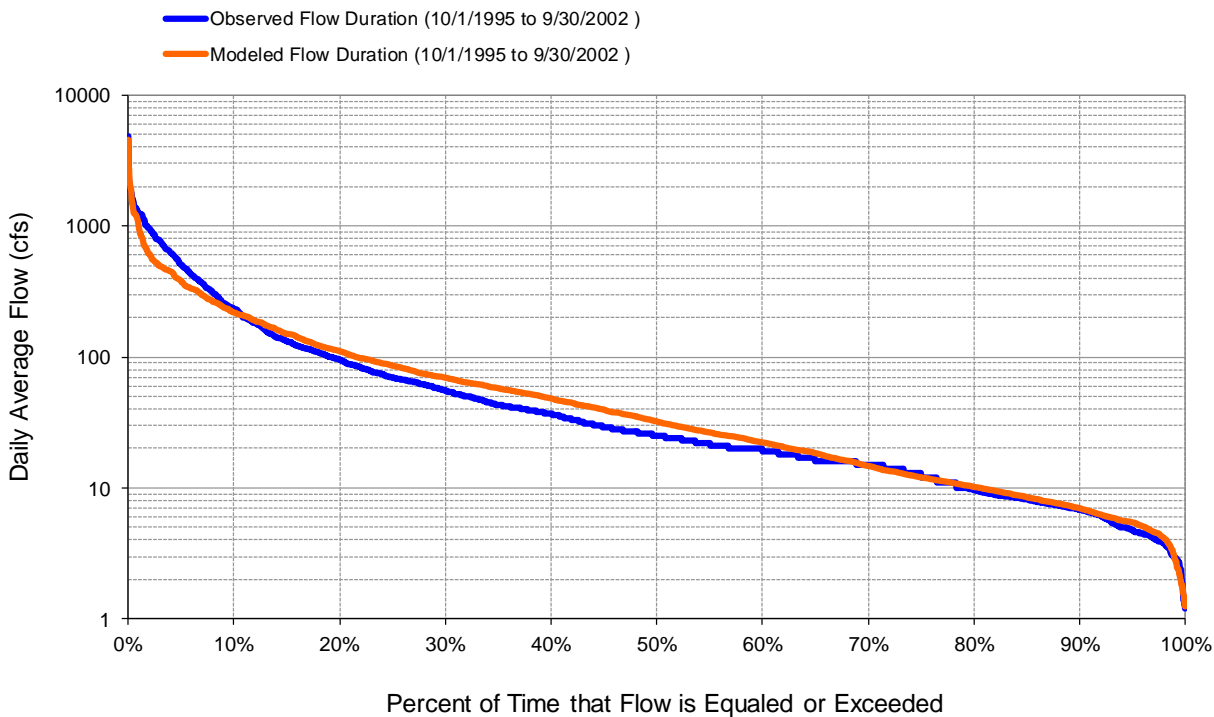


Figure 198. Flow exceedance at Knife River near Two Harbors

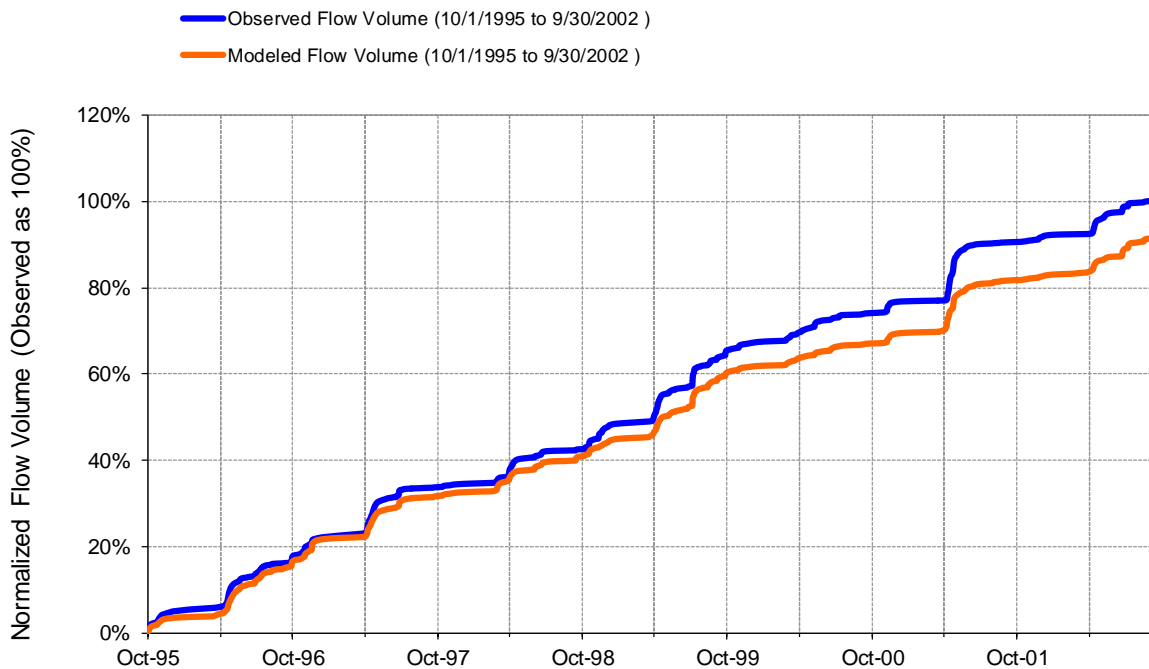


Figure 199. Flow accumulation at Knife River near Two Harbors

Table 26. Summary statistics at Knife River near Two Harbors

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 40 7-Year Analysis Period: 10/1/1995 - 9/30/2002 Flow volumes are (inches/year) for upstream drainage area Run 6a		Knife River near Two Harbors, MN61 Manually Entered Data Drainage Area (sq-mi): 83.6	
Total Simulated In-stream Flow:	15.26	Total Observed In-stream Flow:	16.62
Total of simulated highest 10% flows:	8.59	Total of Observed highest 10% flows:	10.90
Total of Simulated lowest 50% flows:	1.15	Total of Observed Lowest 50% flows:	1.04
Simulated Summer Flow Volume (months 7-9):	3.21	Observed Summer Flow Volume (7-9):	2.76
Simulated Fall Flow Volume (months 10-12):	3.15	Observed Fall Flow Volume (10-12):	3.75
Simulated Winter Flow Volume (months 1-3):	1.58	Observed Winter Flow Volume (1-3):	1.60
Simulated Spring Flow Volume (months 4-6):	7.32	Observed Spring Flow Volume (4-6):	8.51
Total Simulated Storm Volume:	6.57	Total Observed Storm Volume:	8.34
Simulated Summer Storm Volume (7-9):	1.83	Observed Summer Storm Volume (7-9):	1.91
<i>Errors (Simulated-Observed)</i>	<i>Error Statistics</i>	<i>Recommended Criteria</i>	
Error in total volume:	-8.17	10	
Error in 50% lowest flows:	10.73	10	
Error in 10% highest flows:	-21.20	15	
Seasonal volume error - Summer:	16.42	30	
Seasonal volume error - Fall:	-15.88	30	
Seasonal volume error - Winter:	-1.20	30	
Seasonal volume error - Spring:	-14.06	30	
Error in storm volumes:	-21.17	20	
Error in summer storm volumes:	-4.54	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.747	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.615		
Monthly NSE	0.782		