Appendix C
Data and Results for the Updated Hydraulic Model

Updated Model Data

The 14 tables in this section of the appendix summarize updates to infrastructure and hydrologic data used in the current version of the hydraulic model.

TABLE C-1

Mike Urban Model Weir input Parameters

Weir Location	Mike Urban Weir ID	Crest Level[a] (ft)	Crest Width (ft)
Overflow Weir, from Sanitary to Microstrainer basin, at Wellington Avenue CSO Treatment Facility	Weir_1	-6.93	4
Overflow Weir, from Microstrainer basin 1 to Stormwater wet well, at Wellington Avenue CSO Treatment Facility [b]	Weir_WACSO_MS1	-8.5	15
Overflow Weir, from Microstrainer basin 2 to Stormwater wet well, at Wellington Avenue CSO Treatment Facility [b]	Weir_2	-13.75	10
Overflow from Thames Street Interceptor to America's Cup	ACRSWeir	5.47	2.25
Abandoned SSO Weir from Thames Street Interceptor	Weir_8W	2.54	8
Overflow Weir at Washington Street CSO Treatment Facility	Weir_7W	-0.85	130
Overflow from Marsh St. to Washington Street CSO Facility	Weir_6W	1.8	8
Weir located between twin 54" pipes near the intersection of America's Cup and Long Wharf Mall (south)	Weir_5W	1.95	13
Weir located between twin 54" pipes near the intersection of America's Cup and Long Wharf Mall (north)	Weir_4W	1.84	15
Weir located between twin 54" pipes near the intersection of Thames Street and Touro Street (south)	Weir_3W	2.2	13
Weir located between twin 54" pipes near the intersection of Thames Street and Touro Street (north)	Weir_2W	2.44	8
Weir located between twin 54" pipes near the intersection of Duke Street and Washington Square	Weir_1W	2.58	8
Overflow weir from Thames Street Interceptor to Wellington Avenue CSO Facility	Weir_WellingtonCSO	7.30	4.5

a) Elevation data. Vertical datum is mean sea level (MSL).
b) The Microstrainer is sub-divided into internal (1) and external (2) basins.

TABLE C-2

Mike Urban Model Orifice Input Parameters

Orifice/Gate Location	Orifice ID	Invert Level[a] (ft)	Height/Width/Diameter (ft)
Connecting Microstrainer and Back Wash wet wells, at WACSOTF	Orifice_MStoBW	-11.83	0.67
Connecting Stormwater and Back Wash wet wells, at WACSOTF	Orifice_MStoBW	-14.8	1.0
Narragansett gate modeled with Real-time Control (RTC)	Gate_1	41.5	1.5/1.5

a) Elevation data. Vertical datum is mean sea level (MSL).

TABLE C-3

Pumping Station Characteristics

Pump Station	Capacity (GPM)	Capacity (MGD)	Type	Construction, Upgrade Year	Additional Comments	Start/Stop Height above Invert (ft)	Wet well Invert Elevation[a] (ft)	Start/Stop Level (ft)	Max Wet Well Height (ft) (WW Height)
Alpond Drive	2x80	2x0.1152	Submersible, two Single phase/ Ejector Station	1980, 2001		4.02/0.52 5.02/2.02	8.0	13.0/9.5 14.0/11.0 (E)	8.98
Beach-Memorial Drive	2x200	2x0.288		1997, 1994		1.8/1.5 1.9/1.5	-3.45	-1.65/-1.95 -1.55/-1.95 (E)	8.43
Bliss Mine Road	3x2300	3x3.312	Dry Pit Submersible	1978, 2002	New control panel, SCADA, Variable frequency Drives	8.0/5.0[b] 9.0/5.8[b] 10.5/6.0[b]	-10.83	-2.83/-5.83 -1.83/-5.03 -0.33/-4.83	7.1
Carroll Avenue	50	0.072	Ejector Station	1980		7.1/12.1	17.0	13.0/18.0 (E)	5.9
Coddington Wharf	2x350	2x0.504		1978		4.0/2.5[b] 5.0/3.5[b]	-9.76	-5.76/-7.26 -4.76/-6.26	6.0
Dyer Street	2x900	2x1.296	Dry Pit Submersible	1958, 2002	New control panel, backup generator	5.0/3.0 6.0/4.0	-8.58	-3.58/-5.58 -2.58/-4.58	8.58
Goat Island	2x1200	1.728	Dry Pit Submersible	1966, 2002	New control panel, SCADA	3.5/2.5 3.8/2.9	-9.55	-6.05/-7.05 -5.75/-6.65	2.6
Hazard Road	2x40	2x0.0576	Submersible	1969, 2008		4.0/2.5[b] 4.5/3.0	23.0	27.0/25.5 27.5/26.0 (E)	6.1
Lee's Wharf	2x60	2x0.0864	Ejector Station, Submersible	1977, 2006		2.0/1.5[b] 2.2/1.5[b]	-2.0	0.0/-0.5 0.2/-0.5 (E)	9.0
Long Wharf	3x5600	3x8.064	Dry Pit Submersible	1956, 1974, 2007		7.5/3.5 8.5/6.5 9.0/6.5	-13.25	-5.75/-9.75 -4.75/-6.75 -4.25/-6.75	11.0
Maple Avenue	2x320, 320	2x0.4608, 0.4608	Submersible, bypass wet well	1941, 1999	New generator	5.5/2.0 6.0/2.0	37.0[c]	42.5/39.0 43.0/39.0	5.4
Murray Place	2x50 gallon	2x0.072	Ejector pump	1970	Control panel, ejector pump air compressors upgraded	6.0/2.0 8.0/4.0	-2.0	4.0/0.0 6.0/2.0 (E)	11.0

TABLE C-3
Pumping Station Characteristics

Pump Station	Capacity (GPM)	Capacity (MGD)	Type	Construction, Upgrade Year	Additional Comments	Start/Stop Height above Invert (ft)	Wet well Invert Elevation[a] (ft)	Start/Stop Level (ft)	Max Wet Well Height (ft) (WW Height)
Ruggles Avenue	2x40	2x0.0576	Submersible	1952, 1994		5.0/4.0[b] 6.0/4.5[b]	2.44	8.44/6.44 7.44/6.44	5.8
Wellington Avenue Sanitary	3x640	3x0.9216		1978, 2001	VFD, Improvements to Microstrainer	6.5/3.5[b] 7.8/6.0[b] 8.0/6.0[b]	-15.0	-8.5/-11.5 -7.2/-9.0 -7.0/-9.0	8.07
Wellington Stormwater Pumps[d]	3x6600, 1x6600	3x9.504, 1x9.504	3 Flygt submergible mixed, Model LL3356, Impeller Curve 810	2002		16.5/6.5 17.0/0.5 17.5/6.5	-23.0[e]	-6.5/-16.5 -6.0/-22.5 -5.5/-16.5	23.0
Wellington Avenue Backwash	2x250	2x0.360				6.5/3.5[c] 6.2/3.5[c]	-15.0[e]	-8.5/-11.5 -8.8/-11.5 (-2.0/-8.5)	15.0
Ranger Road	2x340	2x0.4896	Submergible	2003	10000 gallon overflow tank (1336.81 ft^3)	7.0/1.0[c] 7.5/1.5[c]	30.0	37.0/31.0 37.5/31.5	10.0
Washington Effluent Well	4x10400	4x14.98	Screw			3.0/1.5[b] 3.4/1.5[b] 3.7/1.5[b] 4.0/2.0[b]	-6.8	-3.8/-5.3 -3.4/-5.3 -3.1/-5.3 -2.8/-4.8	4.27
Washington Dewatering	2x800	2x1.152				9.65/1.15[c] 15.65/0.05[c]	-15.65	-6.0/-14.5 0.0/-15.6	14.8
Wave Avenue (Middletown)	1042 to 5035 3x2350[f] (modeled as 1x694.4 4x347.2)	1.5 to 7.25 3x3.84[f] (modeled as 1x1.0 4x0.5)				4.0/1.0[g] 5.5/2.0[g] 5.6/2.0[g] 5.7/2.0[g] 6.0/2.0[g]	7.00[g]	11.0/8.0 12.5/9.0 12.6/9.0 12.7/9.0 13.0/9.0	16.0
Coddington (Middletown)	730	1.05[h]				3.28/1.28[g] 5.28/2.28[g]	4.72	8.0/6.0 10.0/7.0	10.0

TABLE C-3
Pumping Station Characteristics

Pump Station	Capacity (GPM)	Capacity (MGD)	Type	Construction, Upgrade Year	Additional Comments	Start/Stop Height above Invert (ft)	Wet well Invert Elevation[a] (ft)	Start/Stop Level (ft)	Max Wet Well Height (ft) (WW Height)
Navy Coddington Cove	3x2420[f]	3x3.485[f]	Submergible, Centrifugal	1996, 1997		5.2/3.3[c] 6.2/4.2[c] 6.2/4.2[c]	7.0	12.2/10.3 13.2/11.2 13.2/11.2	10.0
Navy Training Station	3x2050[f]	3x2.952[f]	Submergible, Centrifugal	1996, 1997		6.1/3.0[c] 8.1/5.0[c] 8.1/5.0[c]	-1.0	5.1/2.0 7.1/4.0 7.1/4.0	11.0
Navy Coddington Point	2x1920[f]	2x2.765[f]	Submergible, Centrifugal	1996, 1997		3.6/2.3[c] 5.6/3.0[c]	-2.0	1.6/0.3 3.6/1.0	13.0
Navy Fort Adams	2x400[f]	2x0.576[i]	Submergible, Centrifugal	1996, 1997		4.2/1.8[c] 6.2/3.2[c]	1.0	5.2/2.8 7.2/4.2	8.0

Note: Most data obtained from *Engineering Evaluation – Pumping Stations and Force Mains* (United Water & Wright Pierce, 2010a).

a) Elevation data. Vertical datum is mean sea level (MSL).

b) Data obtained from the City of Newport's SCADA system.

c) Values are assumed based on metered data

d) From *Phase 2 CSO Control Plan Wellington Avenue CSO Facility* (AECOM, 2009).

e) United Water field crew measurements on 06-07-11.

f) Source, Jim Lauzon/United Water and Brian Simmons/ CIV NAVFAC MIDLANT, US Navy, Email: brian.simmons1@navy.mil

g) Assumed /Extrapolated values based on knowledge of other PSs of similar pumping capacity and ground surface elevation.

h) Estimated from yearly maximum flow measured at CH-23.

i) Decreased pump capacity to 0.2 MGD each in the model due to improve model stability.

TABLE C-4

Pumping Station Wet Well Characteristics

Pump Station	Bottom Elevation[a] (ft)	Max. WS Elev.[a] (ft)	Min. WS Elev.[a] (ft)	Grade Elev.[a] (ft)	Influent Sewer Diam. (ft)	Influent Sewer Inv. Elev.[a] (ft)	Effluent FM Diam. (ft)	Effluent FM Material	Effluent FM Inv. Elev.[a] (ft)	Diameter (ft), Bottom Diam. (ft), Length x Width x Height
Ruggles Avenue	2.44 (E)	5.44	4.44	18.25	(8/12)	9.60	(2/12)[b]	Polyethylene	2.7 (E)	8, 6, 2
Hazard Road	23.0[c]	26.1[c]	25.0[c]	28.37	(8/12)	25.0[c]	(6/12)	Cast iron	23.5[c]	8,6,2
Maple Avenue	36.98	45.98	39.68	53.31	(8/12)	38.8 (E)	(8/12)	Cast iron	44.49 (E)	8
Ranger Road	40.0 (E)	47.0(E)	41.0(E)	48.0(E)	(8/12)(E)	40.0(E)	(6/12)(E)	Cast iron(E)	41.5(E)	8
Lee's Wharf[d]	-2.0	5.00	-1.0	5.65	(8/12)	-1.0	(4/12)	Cast iron	0.0	6
Carroll Avenue[d]	17.0	24.47	17.5	24.47	(8/12)	19.0	(6/12)(E)	Cast iron	17.5	6
Alpond Drive[d]	8.0	15.0	9.5	16.2	(8/12)	11.0	(6/12)(E)	Cast iron	9.5	8
Murray Place	-2.0	9.0	-1.5	11.41	(8/12)	-1.0	(4/12)	PVC	-1.5	8
Beach Avenue	-3.45	4.0	-2.0	6.55	(6/12)	0.0	(6/12)	PVC	-2.5	8
Navy Coddington Cove[e]	7.0	17.0	9.5	17.0	(18/12)	9.67	(12/12)	PCI	14.0	18x10x10
Navy Training[e]	-1.0	10.0	2.0	10.0	(18/12)		(12/12)	CI	9.0	18x10x11
Navy Coddington Point[e]	-2.0	11.0	2.0	15.5	(18/12)	4.3	(12/12)	CI	11.0	15x10x13
Navy Fort Adams[e]	1.0	8.0	2.0	9.0	(12/12)	3.47	(8/12)	PVC	9.0	10x11x8

TABLE C-4
Pumping Station Wet Well Characteristics

Pump Station	Bottom Elevation[a] (ft)	Max. WS Elev.[a] (ft)	Min. WS Elev.[a] (ft)	Grade Elev.[a] (ft)	Influent Sewer Diam. (ft)	Influent Sewer Inv. Elev.[a] (ft)	Effluent FM Diam. (ft)	Effluent FM Material	Effluent FM Inv. Elev.[a] (ft)	Diameter (ft), Bottom Diam. (ft), Length x Width x Height
WACSO Sanitary[f]	-15.0	0.0	-12.0	9.0	(48/12)	-5.6	Weir_1, *L*=4, Crest = -6.93		-6.93	23x8
WACSO Backwash[f]	-15.0	0.0	-12.0	9.0	(48/12)	-7.2	(6/12)	PVC	-14.0	16x10
WACSO Microstrainer[f]	-15.0	0.0	-12.0	9.0	(48/12)	-7.2	Weir_2 *L*=15, Crest = -8.0		-8.0	40x30
WACSO Stormwater[f]	-23.0	0.0	-14.0	9.0	(48/12)	-9.2	(36/12)	PVC	-22.0	30x17
Coddington[f] (Middletown)	4.72	12.0	5.72	14.72	(10/12)	8.72	(10/12)	PVC	6.0	10.0
Wave Avenue[f] (Middletown)	7.00	14.0	8.0	17.11	(24/12)	7.9	(20/12)	PVC	7.5	10.0

Note: *L*: Weir crest length, (E) Estimated based on as-built drawings from the City of Newport.

a) Elevation data. Vertical datum is mean sea level (MSL).

b) Diameter increased in model to 3-inch in model to improve model stability.

c) As Builts not available, therefore values are assumed in correspondence to wet well dimensions and settings at Ruggles PS.

d) The pump station was modeled as a constant pump with a 6 ft diameter wet well. Start and stop levels were estimated.

e) Source: Jim Lauzon/UW and Brian Simmons/ CIV NAVFAC MIDLANT, US Navy, Email: brian.simmons1@navy.mil

f) Values assumed, except Grade Elevation which comes from GIS data.

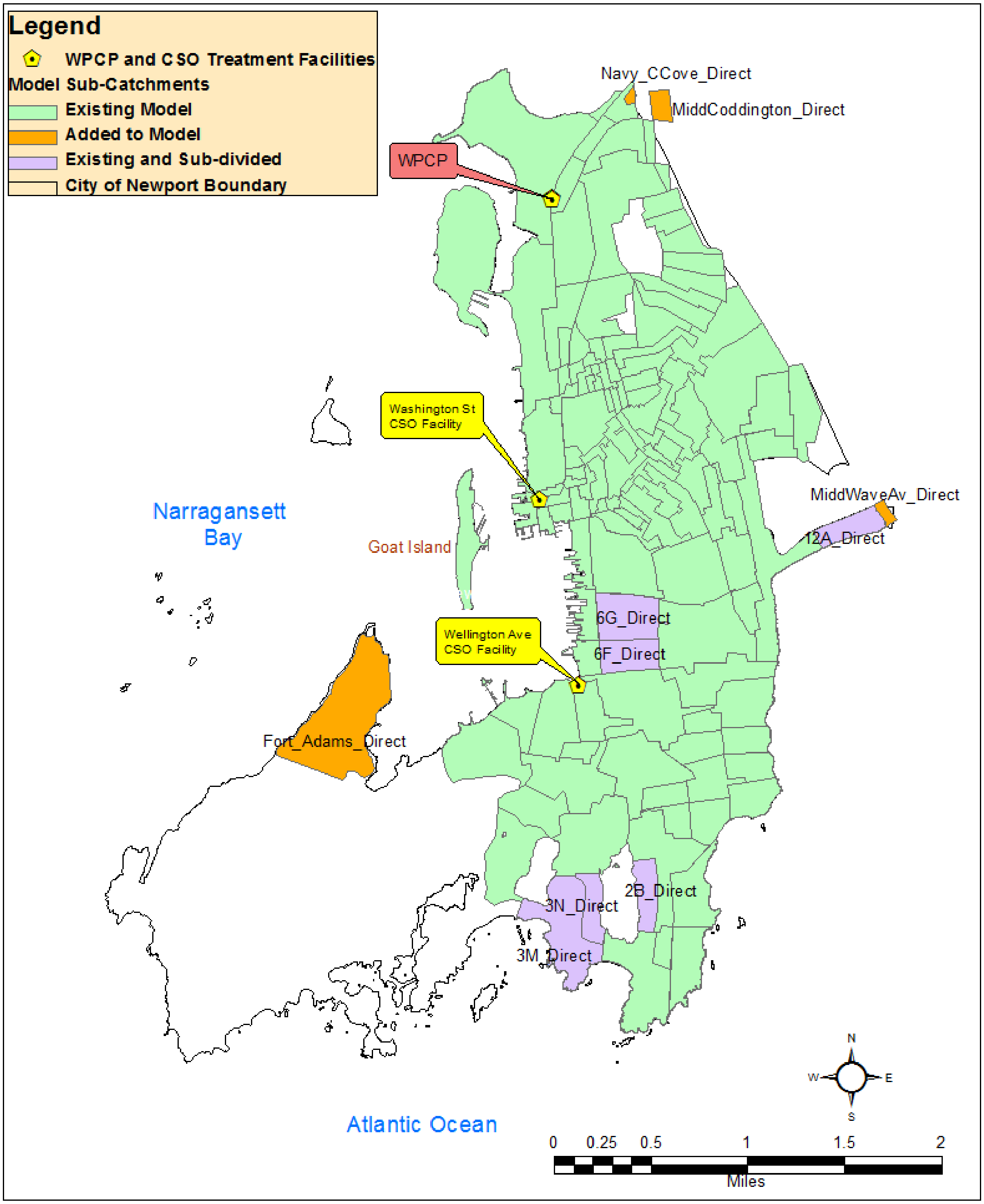


Figure C-1. Sub-catchments in the Hydraulic Model for Newport, RI

TABLE C-5

Geometry and Connection Setup in MU for Major Catchment 06-Updated Connections.

Catchment ID	Area (ac)	Connected to Node	Associated Meter	Associated Link
6A_Direct	67.16	SMH-079-44		
6B_Direct	17.51	SMH-092-20		
6C_Direct	90.17	SMH-118-111.1	CH-04	SP-071-1515
6D_Direct	14.27	SMH-099-82	CH-03	SP-087-1469
6E_Direct	14.34	SMH-072-31		
6F_Direct	30.84	J55		
6G_Direct	47.33	SMH-093-38		

TABLE C-6

Geometry and connection setup in MU for major Catchment-03

Catchment ID	Area (ac)	Connected to Node	Associated Meter	Associated Link
3A_Direct	69.93	SMH-129-124.2A		
3B_Direct	76.60	SMH-152-38		
3C_Direct	29.08	SMH-142-3		
3D_Direct	16.52	SMH-141-73		
3E_Direct	27.00	SMH-141-69		
3F_Direct	23.69	DMH-142-244	CH-01	SP-118-1462
3G_Direct	49.59	SMH-120-29		
3H_Direct	13.18	SMH-120-36		
3I_Direct	24.80	SMH-131-14		
3J_Direct	21.10	SMH-120-33		
3K_Direct	21.46	SMH-131-7		
3L_Direct	16.83	SMH-141-77		
3M_Direct	78.55	SMH-174-5		
3N_Direct	22.72	SMH-175-12		

TABLE C-7

Geometry and Connection Setup in MU for Major Catchment-02

Sub-Catchment	Area (ac)	Connected to Node	Associated Meter	Associated Link
2A_Direct	39.13	SMH-185-37	CH-26	SP-153-3
2B_Direct	25.35	SMH-153-53		
2C_Direct	42.50	SMH-185-35		
2D_Direct	11.31	SMH-185-32		
2E_Direct	69.69	SMH-185-31		
2F_Direct	64.83	SMH-175-13		

TABLE C-8

Geometry and connection setup in MU for Fort Adams Catchments-Updated connections.

Catchment ID	Area (ac)	Connected to Node	Associated Meter	Associated Link
Fort Adams	132.95	SMH-124-1	CH-12	SP-118-1425

TABLE C-9

Geometry and connection setup in MU for major Catchment-12

Sub-Catchment	Area (ac)	Connected to Node	Associated Meter	Associated Link
12A_Direct	24.80	SMH-084-24	CH-34	SP-061-332
12B_Direct	35.76	J294		
12C_Direct	96.46	SMH-060-19		
12D_Direct	39.10	SMH-060-20		
12E_Direct	20.03	SMH-061-10		
12F_Direct	24.52	SMH-060-6		
12G_Direct	82.23	SMH-060-29		

TABLE C-10

Geometry and connection setup in MU for Catchment-Navy_Coddington_Cove

Sub-Catchment	Area (ac)	Connected to Node	Associated Meter	Associated Link
Navy_CCove_Direct	100.0[a]	Dummy_NavyCove		

a) Area is assumed.

TABLE C-11
Geometry and connection setup in MU for Catchment-Coddington_Middletown

Sub-Catchment	Area (ac)	Connected to Node	Associated Meter	Associated Link
MiddCoddington_Direct	100.0 [a]	SMH-Dummy-CodMid1	CH-23	SP-009-119

a) Area is assumed.

TABLE C-12
Geometry and connection setup in MU for Catchment-WaveAvenue_Middletown

Sub-Catchment	Area (ac)	Connected to Node	Associated Meter	Associated Link
MiddWaveAv_Direct	125.0 [a]	SMH-Dummy-WaveAv1	CH-03	SP-087-1469

a) Area is assumed.

TABLE C-13
Updated calibration parameters for FRC

MU-Catchment	Reduction factor	Imperviousness (%)	Initial Loss (in)	Time of Concentration (Min)	Time-Area Curve
2B_Direct	0.79	1.0	0.024	7	TACurve1
2F_Direct	0.79	1.0	0.024	7	TACurve1
3B_Direct	0.50	0.5	0.024	7	TACurve2
3M_Direct	0.50	0.5	0.024	7	TACurve1
3N_Direct	0.50	0.5	0.024	7	TACurve1
6A_Direct	0.90	5.0	0.024	7	TACurve1
4A_Direct	0.9	4.25	0.024	7	TACurve1
4B_Direct	0.9	4.25	0.024	7	TACurve1
4C_Direct	0.9	4.25	0.024	7	TACurve1
4D_Direct	0.9	4.25	0.024	7	TACurve1
4E_Direct	0.9	4.25	0.024	7	TACurve1
6B_Direct	0.9	5.0	0.024	7	TACurve1
6C_Direct	0.9	13.0	0.024	7	TACurve1
6D_Direct	0.9	3.0	0.024	7	TACurve1
6E_Direct	0.9	5.0	0.024	7	TACurve1
6F_Direct	0.9	5.0	0.024	7	TACurve1
6G_Direct	0.9	5.0	0.024	7	TACurve1
7A_Direct	0.9	0.1	0.024	7	TACurve1
7B_Direct	0.9	3.5	0.024	7	TACurve1

TABLE C-13

Updated calibration parameters for FRC

MU-Catchment	Reduction factor	Imperviousness (%)	Initial Loss (in)	Time of Concentration (Min)	Time-Area Curve
7C_Direct	0.9	0.15	0.024	7	TACurve1
8B_Direct	0.9	10.0	0.024	7	TACurve1
8C_Direct	0.9	2.0	0.024	7	TACurve1
9A_Direct	0.9	4	0.024	7	TACurve1
10_19_Direct	0.9	5.0	0.024	7	TACurve1
10_20_Direct	0.9	10	0.024	7	TACurve1
10_21_Direct	0.9	10	0.024	7	TACurve1
10_22_Direct	0.9	20	0.024	7	TACurve1
10_23_Direct	0.9	40	0.024	7	TACurve1
10_24_Direct	0.9	20	0.024	7	TACurve1
10_25_Direct	0.9	20	0.024	7	TACurve1
11A_Direct	0.9	5.0	0.024	7	TACurve1
11B_Direct	0.9	5.0	0.024	7	TACurve1
12G_Direct	0.9	2.5	0.024	7	TACurve1
Fort Adams_Direct	0.9	1.5	0.024	7	TACurve1
Navy_CCove_Direct	0.9	0.5	0.024	7	TACurve1
MiddCoddington_Direct	0.9	1.0	0.024	7	TACurve1
MiddWaveAv_Direct	0.9	3.0	0.024	7	TACurve1

TABLE C-14
Calibration Parameters for SRC

Catchment Area	Percentage of Total Area Contributing Flow to RDII (%)	Additional flow[1] (MGD)	*Umax*	*Lmax*	*CQof*	*CK*	*CKif*	*CKbf*
1A_Direct	15		0.5	6	0.3	3	10	2000
1B, 1C_Direct	14		0.5	6	0.3	3	10	2000
2All_Direct	4.5		0.4	5	0.4	3	10	2000
3All_Direct	5.0		0.4	4	0.5	3	10	2000
4All_Direct	20		0.4	1	0.4	2.5	10	2000
6C_Direct	30		0.5	2.5	0.2	10	10	2000
6D_Direct	30		0.5	2.5	0.2	3	2	2000
6F_Direct	40	0.02	0.5	3	0.2	10	10	2000
6G_Direct	45	0.02	0.5	3	0.2	10	10	2000
7A_Direct	1.2		0.4	4	0.5	2.5	10	2000
7B_Direct	15		0.4	4	0.5	2.5	10	2000
7C_Direct	1.2	0.01	0.4	4	0.5	2.5	10	2000
8B_Direct	0.5		0.4	2	0.7	2.5	100	2000
9_Direct	8.0		0.4	4	0.5	3	10	2000
11All_Direct	3		0.3	4	0.3	3	15	2000
10_##_Direct, Upstream of CH-20_Direct	20		0.5	3	0.2	3	10	2000
10_23_Direct	90		0.5	6	0.3	3	1	2000
10_24_, 10_25_ Direct	70		0.5	6	0.3	3	1	2000
10_22_Direct	70		0.5	6	0.3	3	1	2000
10_21_Direct	25		0.5	6	0.3	3	1	2000
10_20_Direct	25		0.4	6	0.2	3	100	2000
10_##_Direct, Upstream of CH-31	20		0.1	1	0.2	3	10	2000

TABLE C-14
Calibration Parameters for SRC

Catchment Area	Percentage of Total Area Contributing Flow to RDII (%)	Additional flow[1] (MGD)	*Umax*	*Lmax*	*CQof*	*CK*	*CKif*	*CKbf*
12All_Direct except 12B	6		0.5	15	0.2	2.5	10	2000
12B_Direct	3	0.07	0.5	15	0.2	2.5	10	2000
Fort_Adams_Direct	0.5	0.03	0.4	2	0.7	2.5	100	2000
Navy_CCove_Direct	0.2	0.01	0.4	2	0.7	2.5	100	2000
MiddCoddington_Direct_Direct	0.7	0.04	0.4	2	0.7	2.5	100	2000
MiddWaveAv_Direct	20		0.3	3	0.2	20	250	500

[1] From base flow observed in the metered flow data.

Seasonal Groundwater and Tidal Effects in Sanitary Sewer Flows

The effects of seasonal groundwater and tides are documented in this technical memorandum.

Newport CSO LTCP Implementation (Project #10-039) - Seasonal Groundwater and Tidal Effects in Sanitary Sewer Flows in Newport, RI

PREPARED FOR: City of Newport, RI

PREPARED BY: CH2M HILL

DATE: July 2011

This section summarizes the main findings on the characterization of measured groundwater (GW) fluctuations and pipe flow discharges during the flow monitoring period between April 2010 and April 2011 in the City of Newport, RI.

Purpose

The purpose of the analysis was to identify the locations in the collection system where pipe flow is most affected by GW infiltration and tidal oscillations and use this data to make improvements to the hydrologic and hydraulic (H&H) model to better reproduce metered flows and improve CSO facility and WPCP effluent discharge and volume estimates.

Methodology

Several sources of data were used to perform the analysis on seasonal groundwater and tidal effects, including:

- Flow monitoring data at 35 meters
- Rainfall data at three rain gauges
- GW level data at 31 locations
- Tidal water levels recorded at the NOAA Station (ID: 8452660) located in Newport Harbor.

The data is from the monitoring period between April 2010 and April 2011. All data was recorded at 15-min intervals, except tide data which is recorded at 1-hour intervals.

The first part of the analysis was a temporal and spatial characterization of the recorded tides, GW levels, and pipe flows across the collection system (CS). GW can infiltrate the collection system through cracks, non-sealed pipe junctions, and other defects. Seasonal variability in GW conditions, induced by rainfall and snowmelt, tidal oscillations, or GW extraction and recharge, plays a significant role in determining base sanitary flow (BSF) characteristics during dry weather flow (DWF) periods and wet weather flow (WWF) event periods. The analysis was focused on the locations of major GW variation as related to pipe flow infiltration.

The second part of the analysis consisted in determining the influence of tides on BSF, focusing on meters near the coastline where the tidal effects are most prominent. In areas near the coastline, groundwater table variation is driven by tidal fluctuations as sea waters percolate the underground and infiltrate the collection system. Influences on the BSF patterns are characterized by peaks associated with tidal oscillations.

The final part of the analysis involved comparing the flow data to existing dry weather diurnal patterns and rainfall-derived inflow and infiltration (RDII) parameters from the 2010 H&H model to determine if updates to the model need to be made to reflect potential GW influences.

Results

In total, 18 GW gauges displayed data with reasonably good quality. The remaining gauges displayed either erroneous data or incomplete records, thus were discarded for subsequent analysis. Six GW gauges showed significant GW table fluctuations over the monitoring period: CH-09, CH-17, CH-21, CH-31, CH-33 and CH-34. The groundwater data for the entire period for each of the six meters are shown in Figures 1 through 6. A summary of the variations in groundwater level for the six meters are shown below in Table 1. The rainfall gauges were assigned based on spatial proximity. Rainfall data from all three rain gauges (RG1, RG2, and RG3) are plotted in Figure 7. The GW data for the remaining gauges are plotted in Figure 8.

TABLE 1

Summary GW Gauges Exhibiting Significant Changes in Level

GW Level[a] \ GW Gauge	09	17	21	31	33[b]	34
Max (ft)	8.3	6.9	5.8	7.1	5.6	5.9
Min (ft)	6.4	5.2	2.6	3.1	3.1	2.8
Variation (ft)	1.9	1.7	3.3	4.0	2.5	3.1

a) Relative to manhole invert

b) Data available for the period 04/28/2010 to 10/05/2010

Figure 9 shows the location of the six GW gauges as well as the locations of the flow meters and rain gauges. The extent of groundwater and tidal impact is also displayed.

The next step consisted in characterizing tidal GW intrusion on the recorded pipe flows. The data review looked at effects of rainfall and tidal influences over short and long-term periods. Short-term fluctuations in GW are primarily influenced by semi-diurnal tidal cycles of about 12.4 hours and semi-monthly spring and neap tide cycles of about 29 hours, where the tide amplitude varies between approximately 0.9 ft and 3 ft. Long-term fluctuations in GW are typically driven by rainfall volume and soil conditions. The effects of rainfall and tides on GW levels and metered flows were visually inspected at a smaller scale to determine semi-diurnal and semi-monthly effects. Figures 10 through 15 show data for the six GW gauges for a 10-day period from August 10 to August 20, 2010.

Table 2 summarizes the local impact (weak, mild, strong) of rainfall and tides on GW levels and metered flows. Short-term scale fluctuations in GW are primarily influenced by semi-diurnal and semi-monthly tidal cycles at CH-17, CH-21, and CH-31. GW table elevations at CH-34 are primarily rainfall-driven since they are not located near the Harbor. Flow data was strongly influenced by rain for meters CH-09, CH-21 and CH-34 and by tides for CH-17.

Long-term fluctuations are summarized in Table 3. Review of long-term data shows seasonal responses that are a result of GW table shifts beyond the immediate influence of rainfall and semi-diurnal or semi-monthly tidal oscillations. In general, there was not a strong correlation between the seasonal fluctuations seen in the groundwater levels and the seasonal fluctuations seen in the flow meter data. A stronger correlation was seen with rainfall data as compared to GW influences.

Overall, flows at CH-17 CH-21, and CH-31 displayed a mild to strong temporal correlation with GW in the short-term analyses. Flow data at CH-34 showed a mild correlation with GW over a long-term time scale. Rainfall was strongly correlated with flow fluctuations at CH-09, CH-21 and CH-34 in the short-term, while CH-09, CH-31 and CH-34 showed mild to strong correlations with rainfall in the long-term. Flow data at CH-33 appeared to have no impact from either GW table fluctuations or rainfall in either the short or long-term. An analysis of flow data trends showed that over long-term time scales there was an increased groundwater level during the spring thaw, which slowly declined during the summer months. Meter CH-09 showed contrasting trends over a long-term scale compared to other meters. Discussions with the City's operator indicated that operational adjustments were implemented during the metering period which affected the flow to the meter.

The final part of the analysis reviewed 2010 H&H model inputs for DWF diurnal patterns and RDII parameters and compared them to the flow data for the 18 GW locations. Figures 16 through 19 show the modeled and measured flow series along with tidal elevation for the locations that most significantly impact CSO and WPCP effluent discharge and volume estimates. Table 4 summarizes the maximum difference between observed and modeled peak flows in addition to the differences in daily average volume for four DWF periods. Meters CH-09 and CH-22 had the most significant differences; the difference for meter CH-22 was largely due to tidal influences, while the differences at CH-09 were caused by operational changes.

TABLE 2

Short-term Impacts of Rainfall and Tides on GW Levels and Metered Flows

Location	GW influenced by:		Flow influenced by:	
	Rain	**Tides**	**Rain**	**Tides**
CH-09	Weak	Weak	Strong	Mild
CH-17	Mild	Strong	Mild	Strong
CH-21	Strong	Strong	Strong	Mild
CH-31	Weak	Strong	Mild	Mild
CH-33	Strong	Weak	Weak	Weak
CH-34	Strong	Weak	Strong	Weak

TABLE 3

Long-term Seasonal Trends in GW Levels and Metered Flows

Location	GW Seasonality	Flow Seasonality
CH-09	Weak	Mild
CH-17	Mild	Weak
CH-21	Strong	Weak
CH-31	Weak	Mild
CH-33	Strong	Weak
CH-34	Strong	Mild

TABLE 4

Differences Between Modeled and Measured Flows during DWF Periods Associated with Tidal Fluctuations during 2-day Periods

Meter	07/28-29/ 2010		06/11-12/2010		08/14-15/2010		11/15-16/2010	
	Peak flow Diff. (MGD)	**Volume Diff. [a] (MG)**	**Peak flow Diff. (MGD)**	**Volume Diff. [a] (MG)**	**Peak flow Diff. (MGD)**	**Volume Diff. [a] (MG)**	**Peak flow Diff. (MGD)**	**Volume Diff. [a] (MG)**
CH-02	0.23	0.089	0.25	0.016	0.39	0.085	NA	NA
CH-08	0.12	0.038	0.31	0.053	0.42	0.070	0.01	0.029
CH-18	0.02	0.007	0.10	0.009	0.26	0.045	0.05	0.014
CH-22	0.30	0.032	1.20	0.169	0.46	0.065	NA	NA
CH-09	1.15	0.069	0.24	1.450	5.61	1.850	-0.04[b]	-0.174[b]

a) These are daily averaged volumes.
b) A negative sign indicates that the model overestimates flows during this period.

Based on the analysis and volume differences shown in Table C-8 for DWFs, tidal effects for meter CH-22 were incorporated in the 2010 H&H model. Figure 20 shows the monthly representative diurnal patterns for CH-22. Improvements in model prediction at CH-22 directly affect the model estimates of inflows to the Long Wharf Pump Station (LWPS) and consequently the flows pumped to the water pollution control plant (WPCP) and effluent discharges as the Washington Street CSO Facility (WSCSO). Figures 21 and 22 show how the tidal effects visible in the flow meter data were translated and reproduced in the model for the July 13, 2010 storm event.

Additional adjustments to the RDII model parameters were made during the recalibration period for CH-22 as well as other meters that showed GW influence. The changes in the RDII parameters help to account for semi-monthly and long-term scale variations in GW table and pipe infiltration to better reproduce inflows to WSCSO and improve CSO discharge estimates.

Conclusion

The impact of GW infiltration and tidal influences were seen in the flow data of 18 meters, but was most significant for six meters: CH-09, CH-17, CH-21, CH-31, CH-33 and CH-34. Of these six meters, the flow data at CH-21, CH-17 and CH-31 had a mild to strong correlation to GW data. Flow data at CH-34 showed a mild correlation with GW over a long-term time scale. Flow data at CH-09, CH-21, CH-31, and CH-34 were most affected by rainfall, although operational adjustments more significantly affected flow data for CH-09. Flow data at CH-33 was not affected by GW or rainfall influences.

Review of flow and 2010 H&H model input data for the 18 meters impacted by GW infiltration and tidal influences indicated that meter CH-22 showed the most significant difference in volume during DWF periods. The diurnal pattern for CH-22 was adjusted to improve the effluent discharges and volumes at the two CSO facilities and the WPCP. Semi-monthly and long-term GW impacts at the 18 meters were accounted for by adjustments to RDII parameters in the model during recalibration.

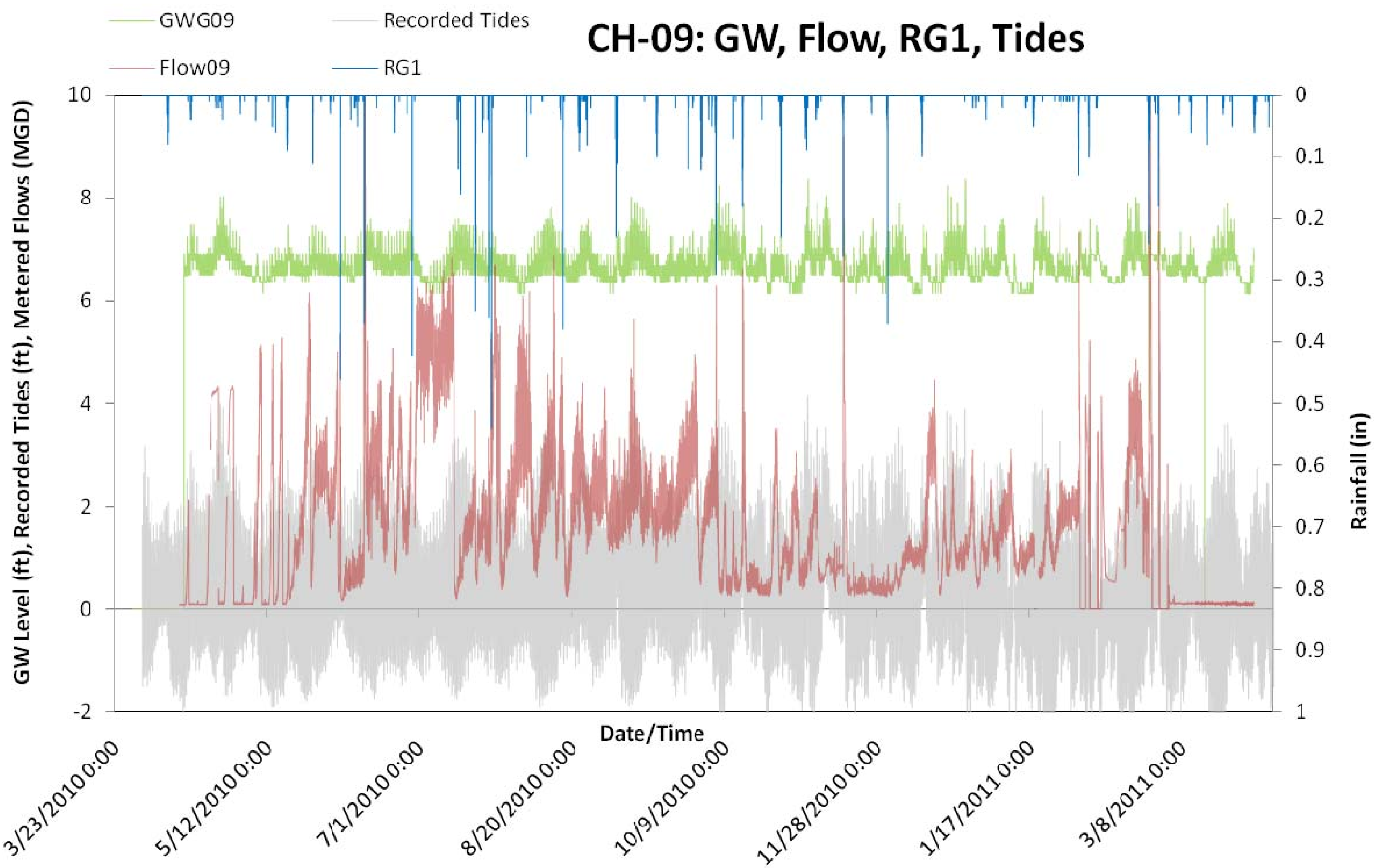


Figure 1. CH-09 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 1-year Period

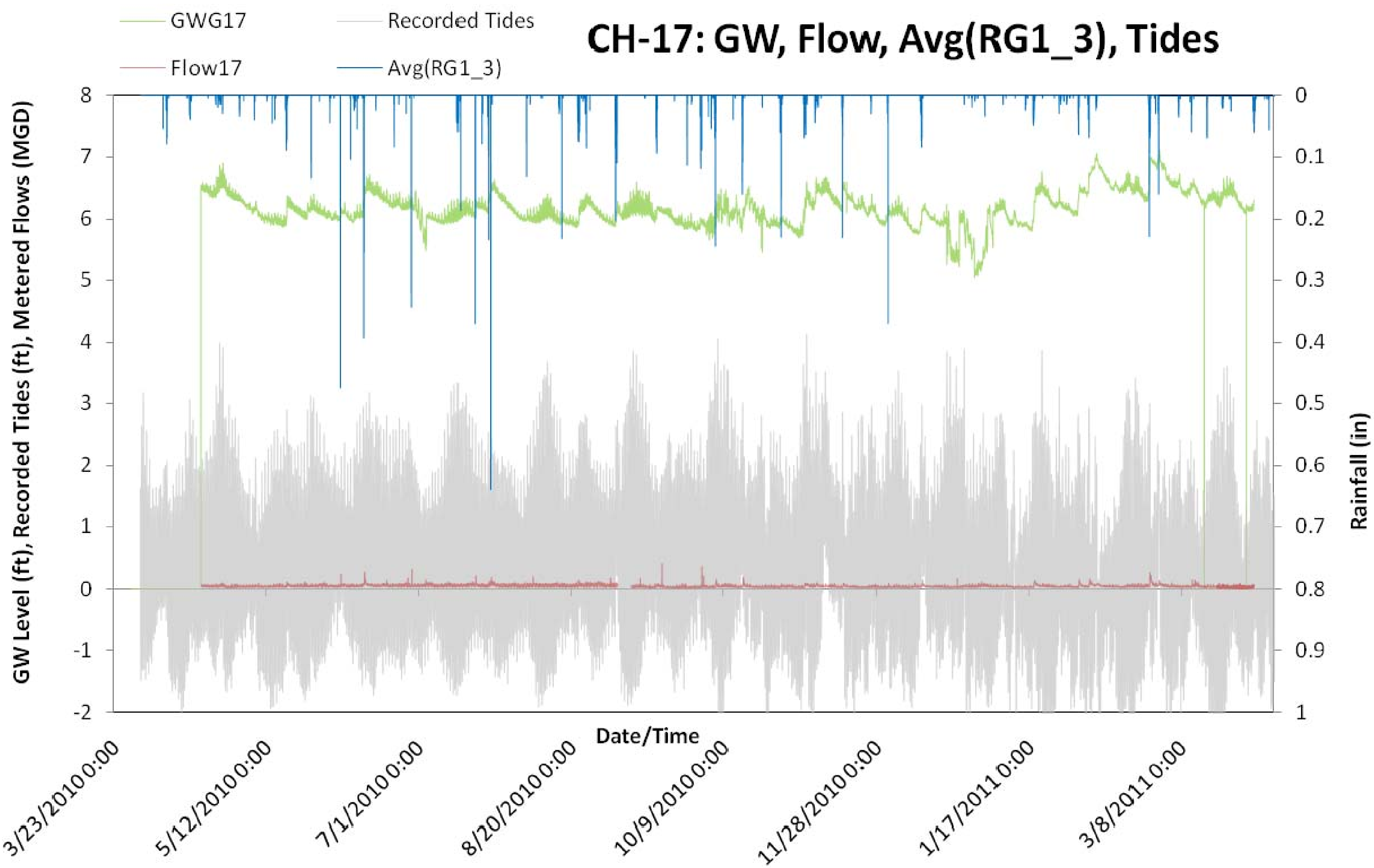


Figure 2. CH-17 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 1-year Period

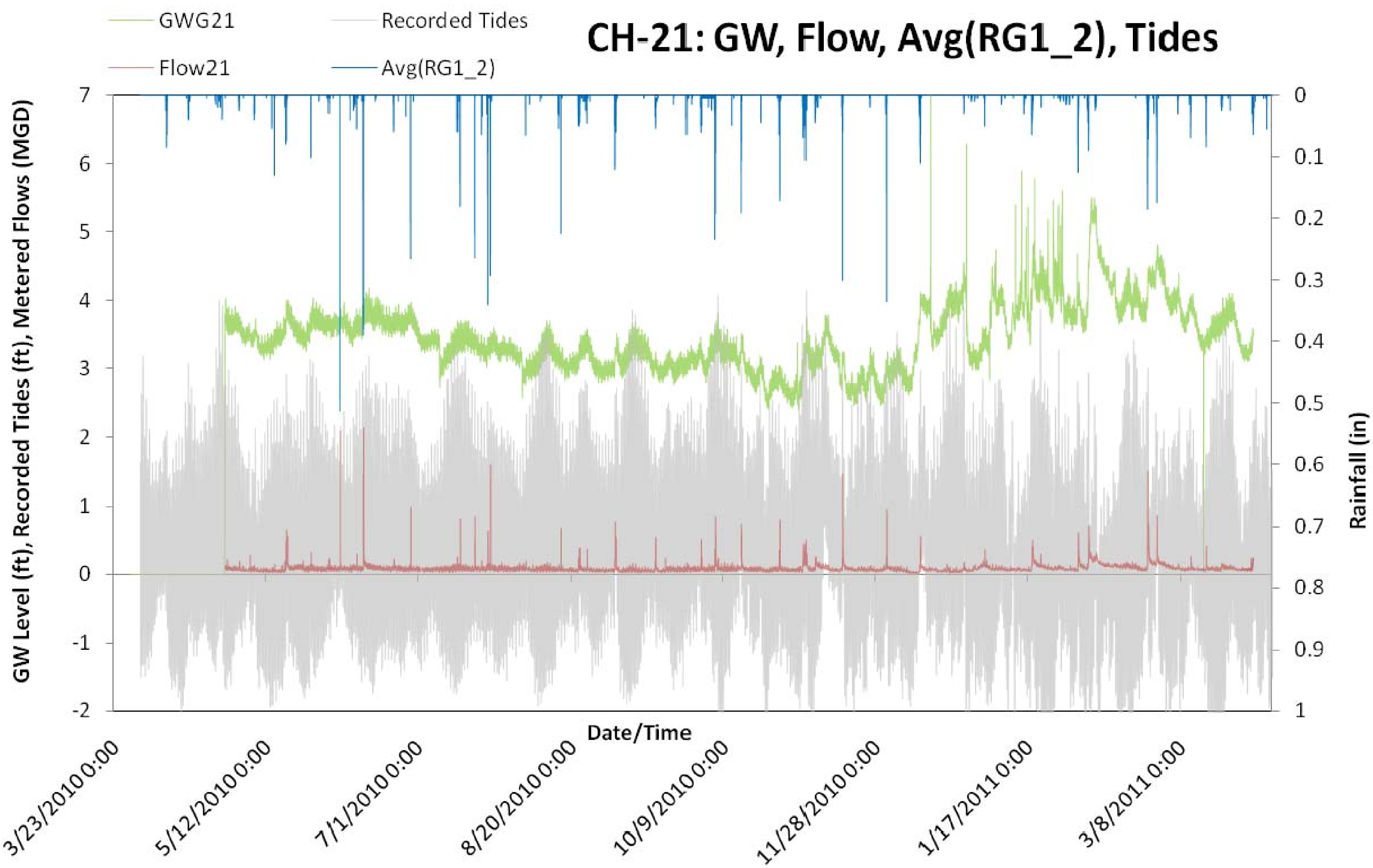


Figure 3. CH-21 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 1-year Period

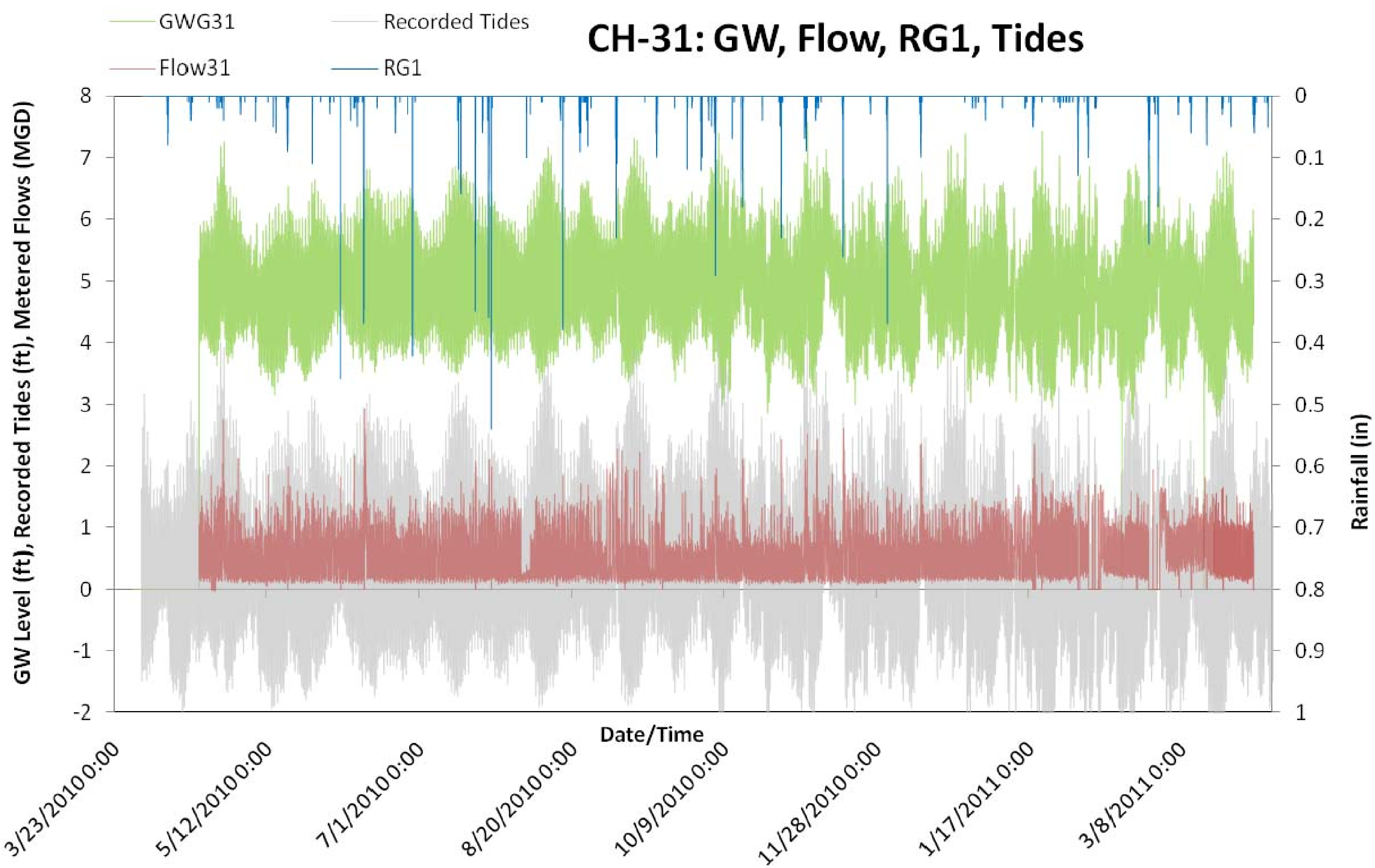


Figure 4. CH-31 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 1-year Period

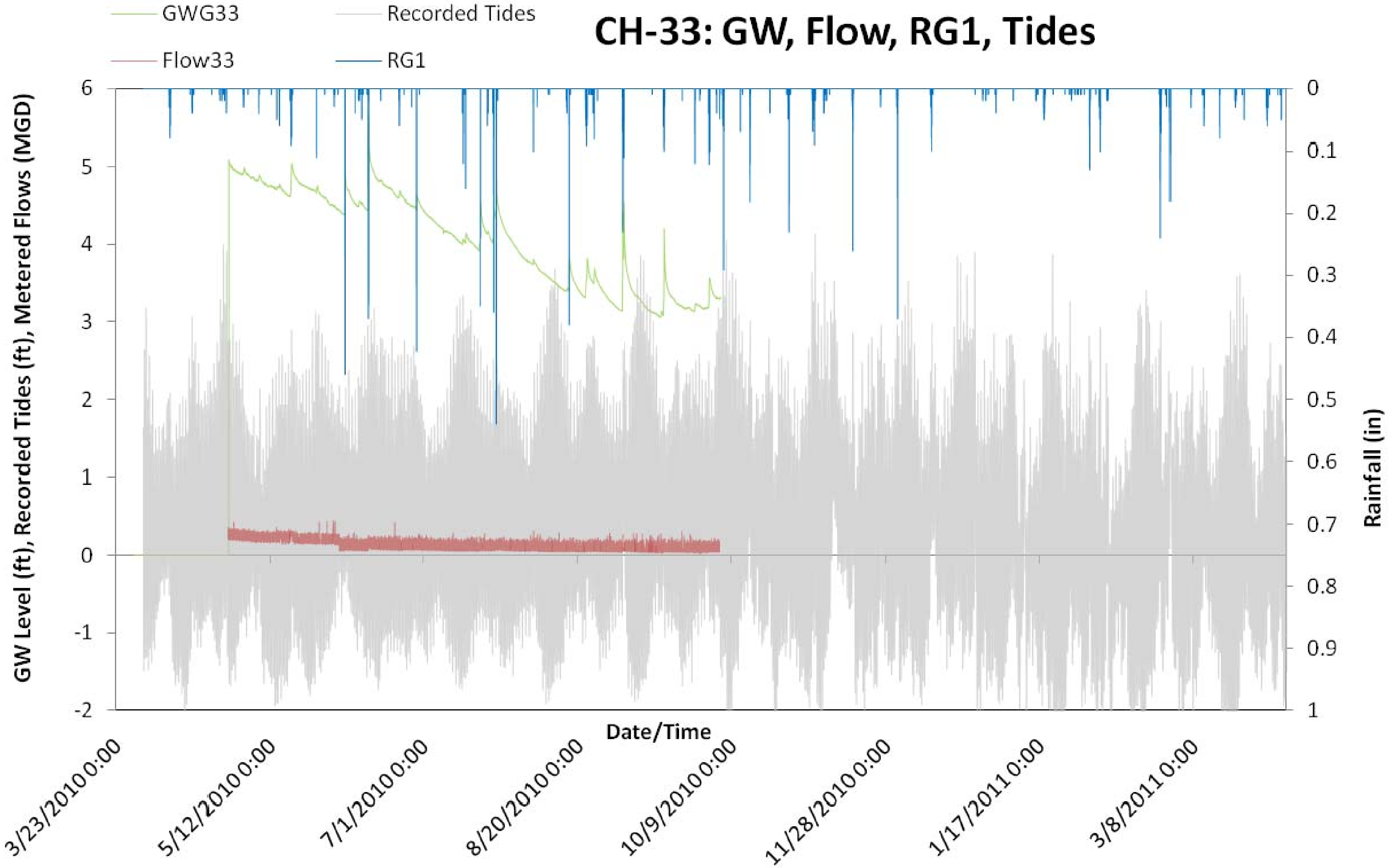


Figure 5. CH-33 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 1-year Period

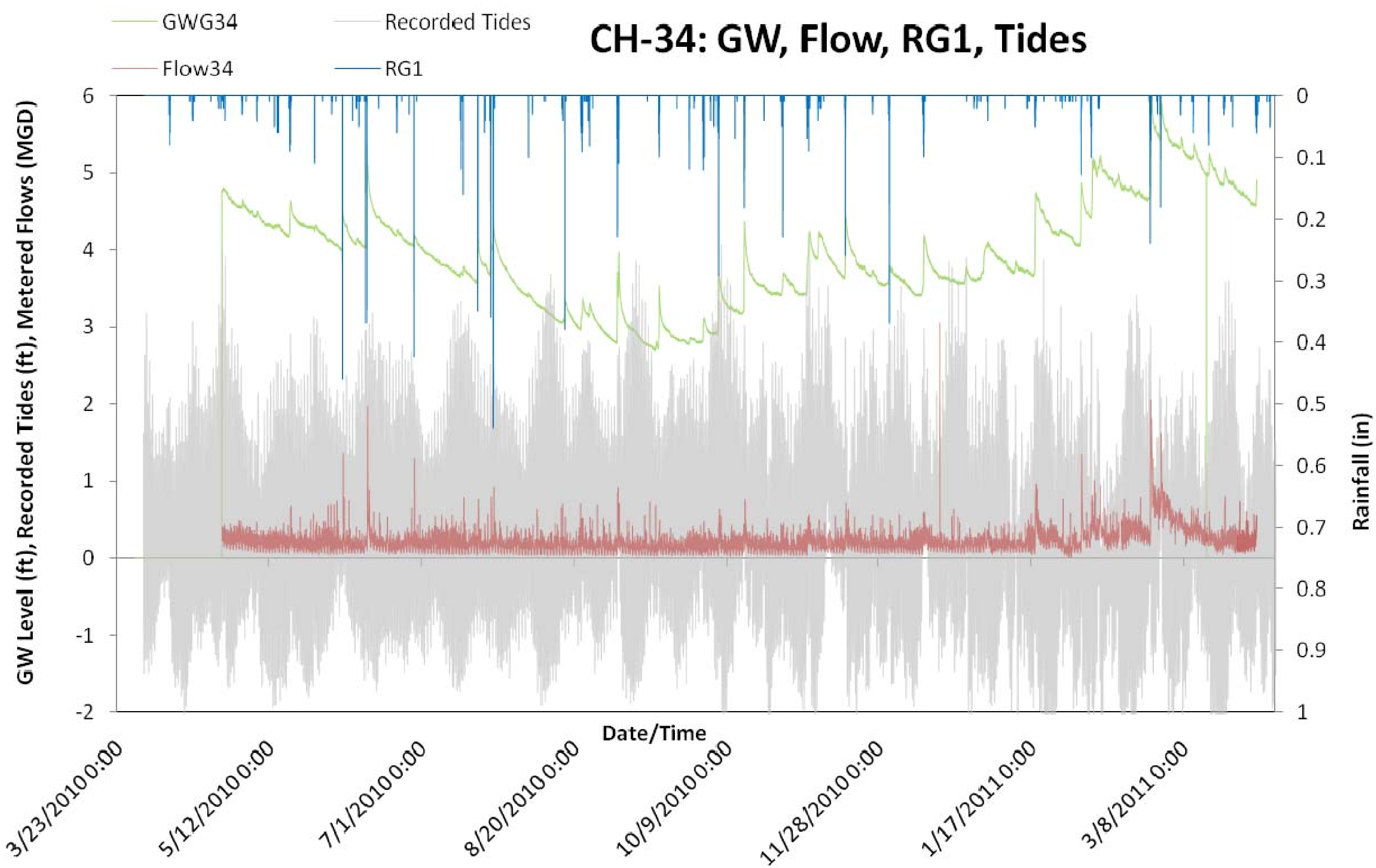


Figure 6. CH-34 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 1-year Period

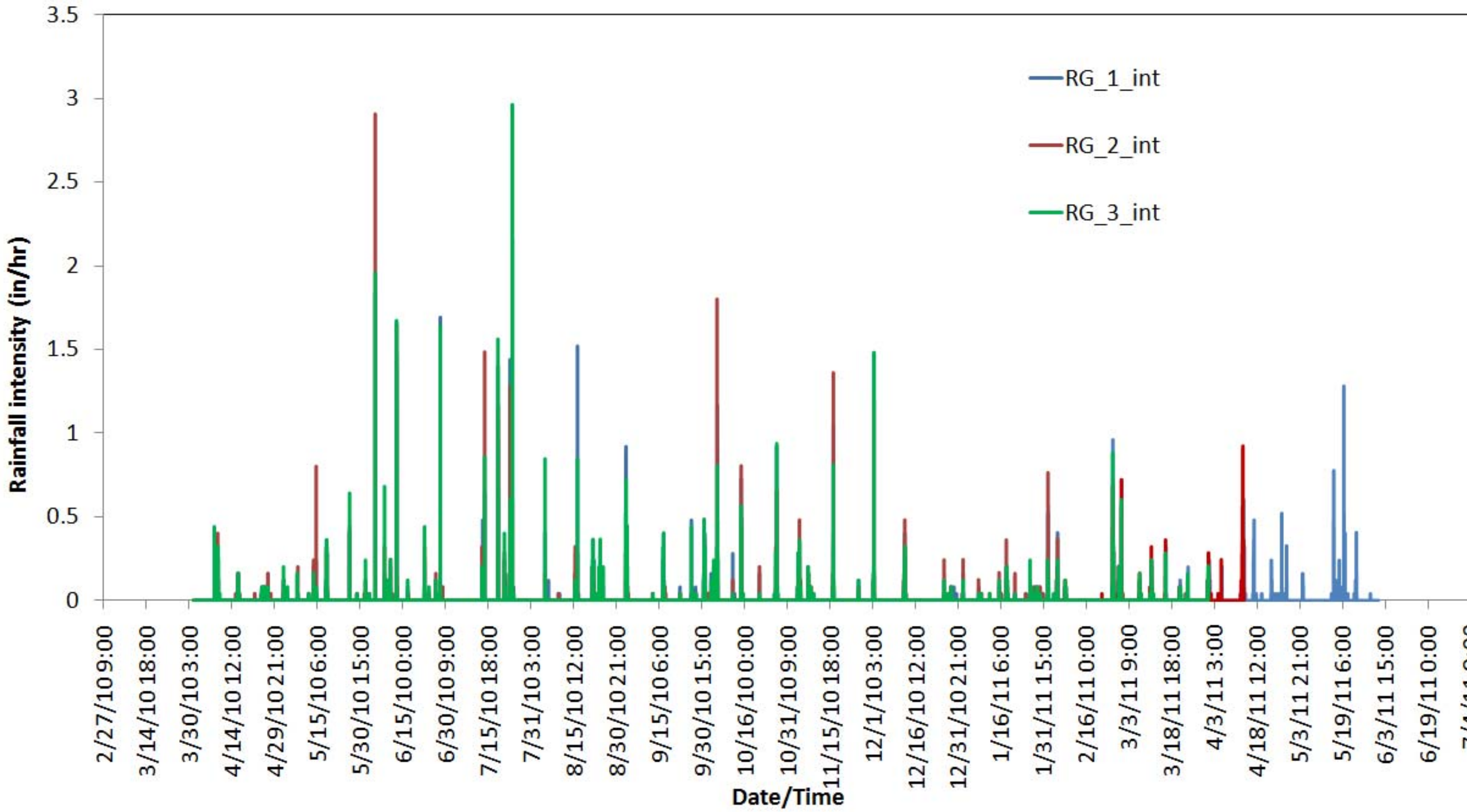


Figure 7. Rainfall Data for the Period 04/2010 to 05/2011

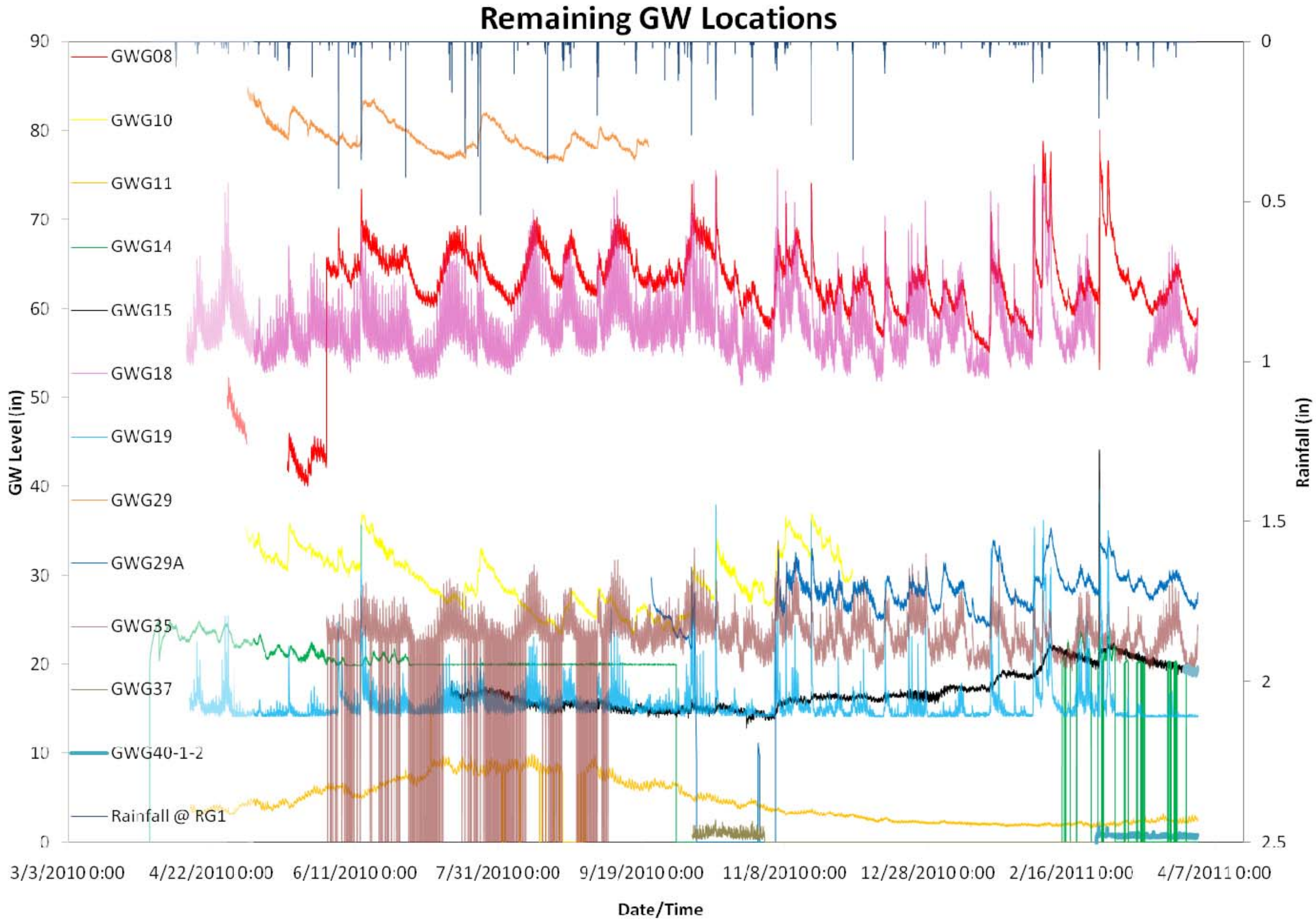


Figure 8. Remaining Data Considered for GW Analysis

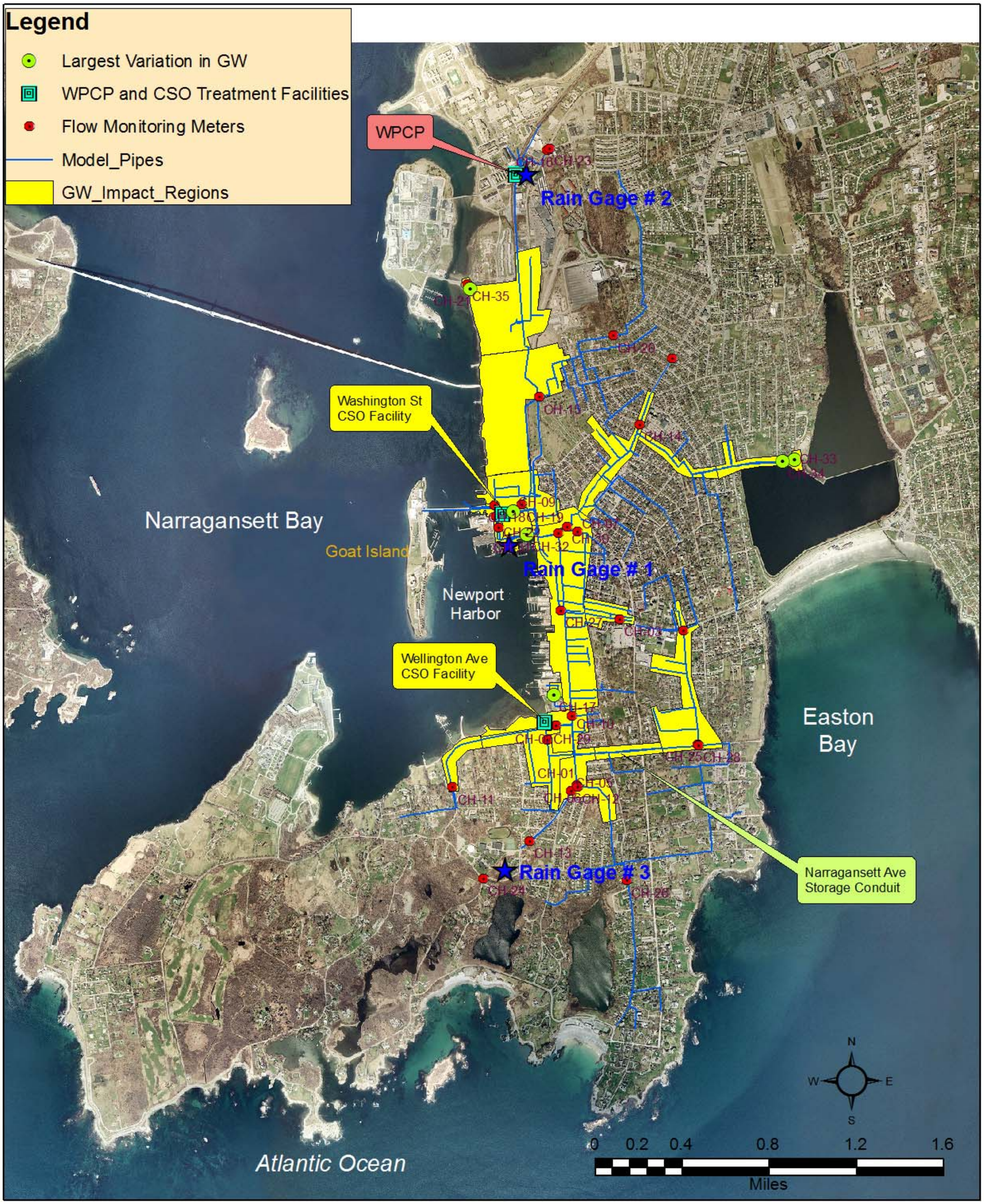


Figure 9. Groundwater and Tidal Influence and Impact Regions

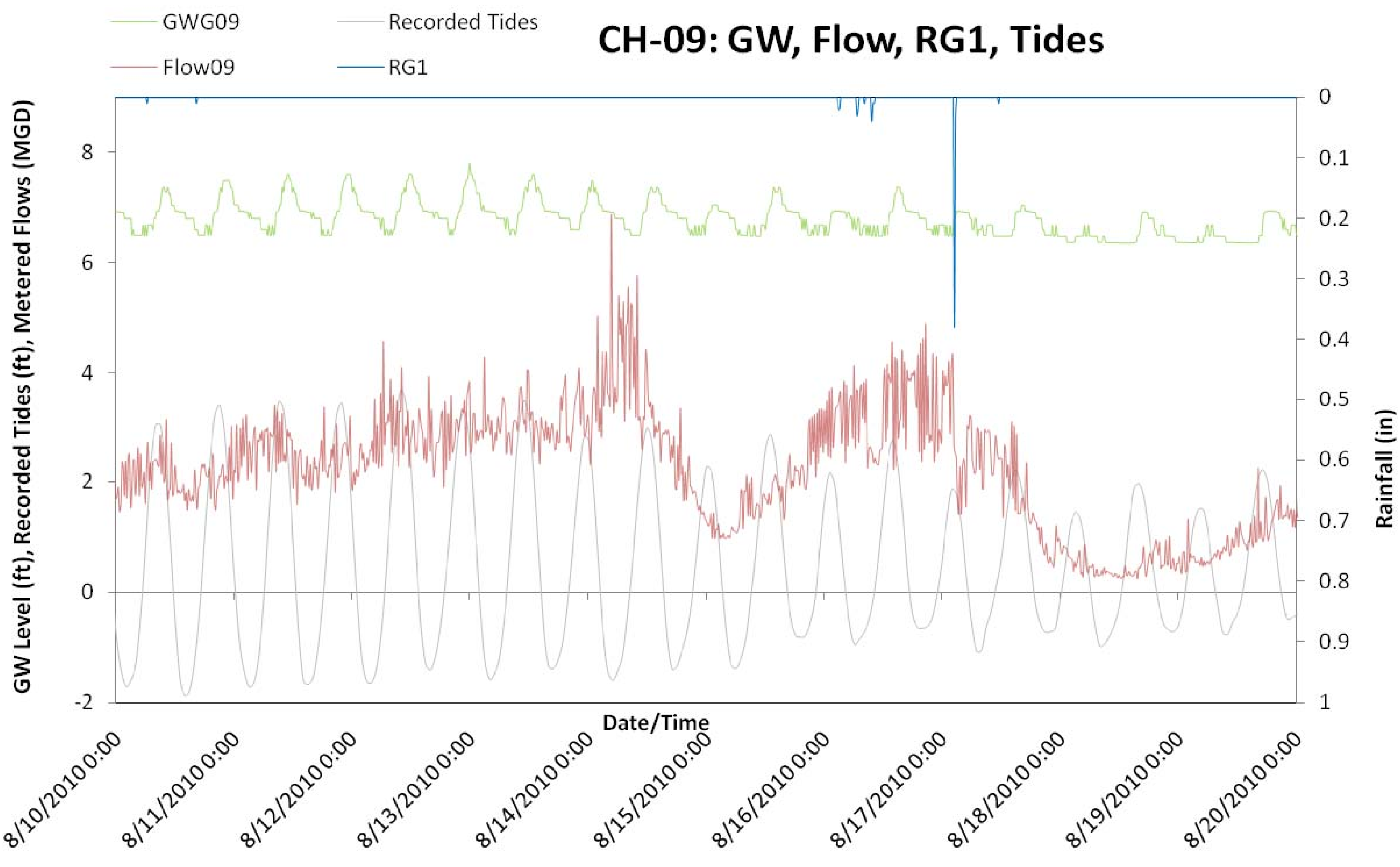


Figure 10. CH-09 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 10-day Period

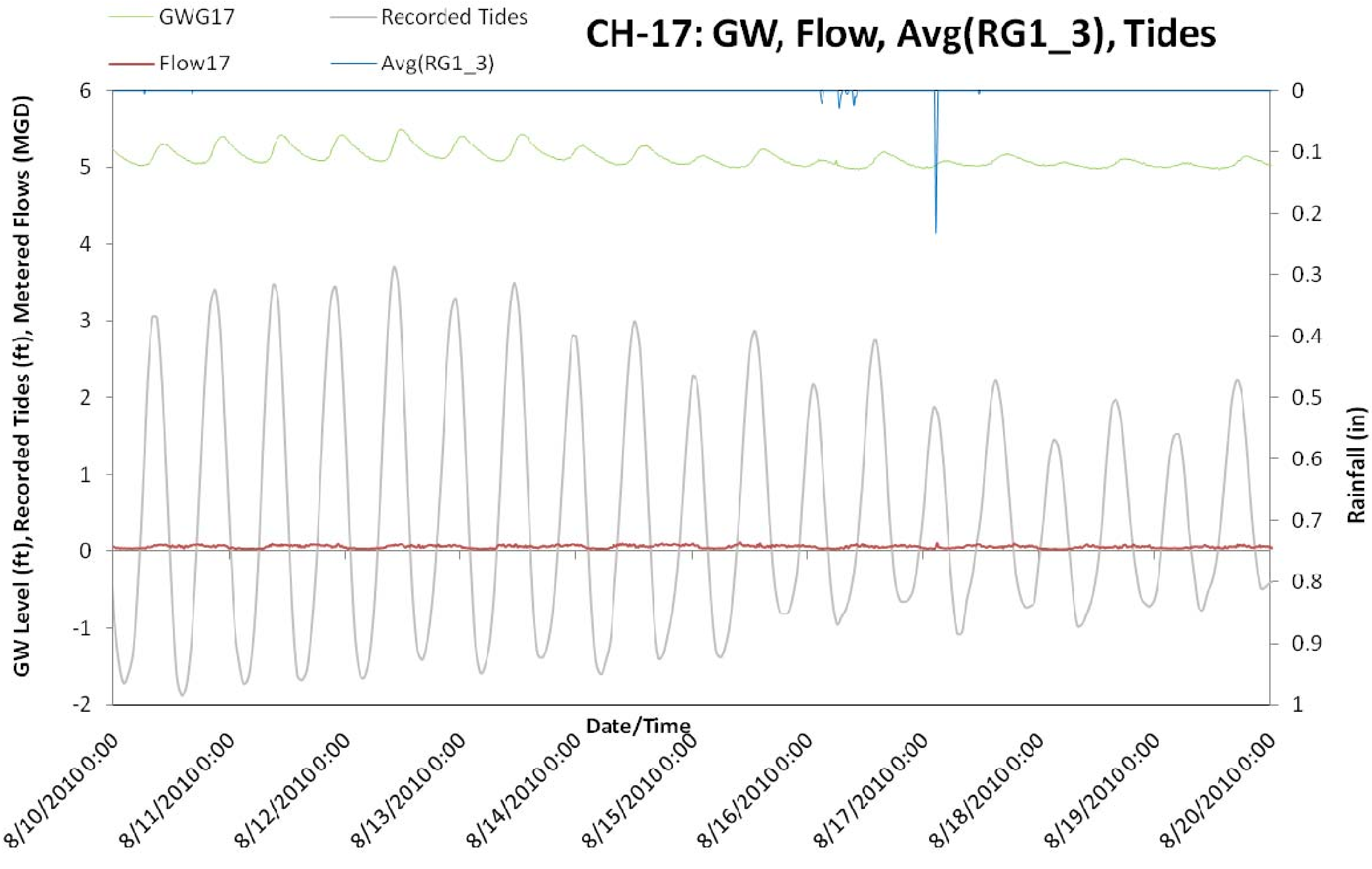


Figure 11. CH-17 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 10-day Period

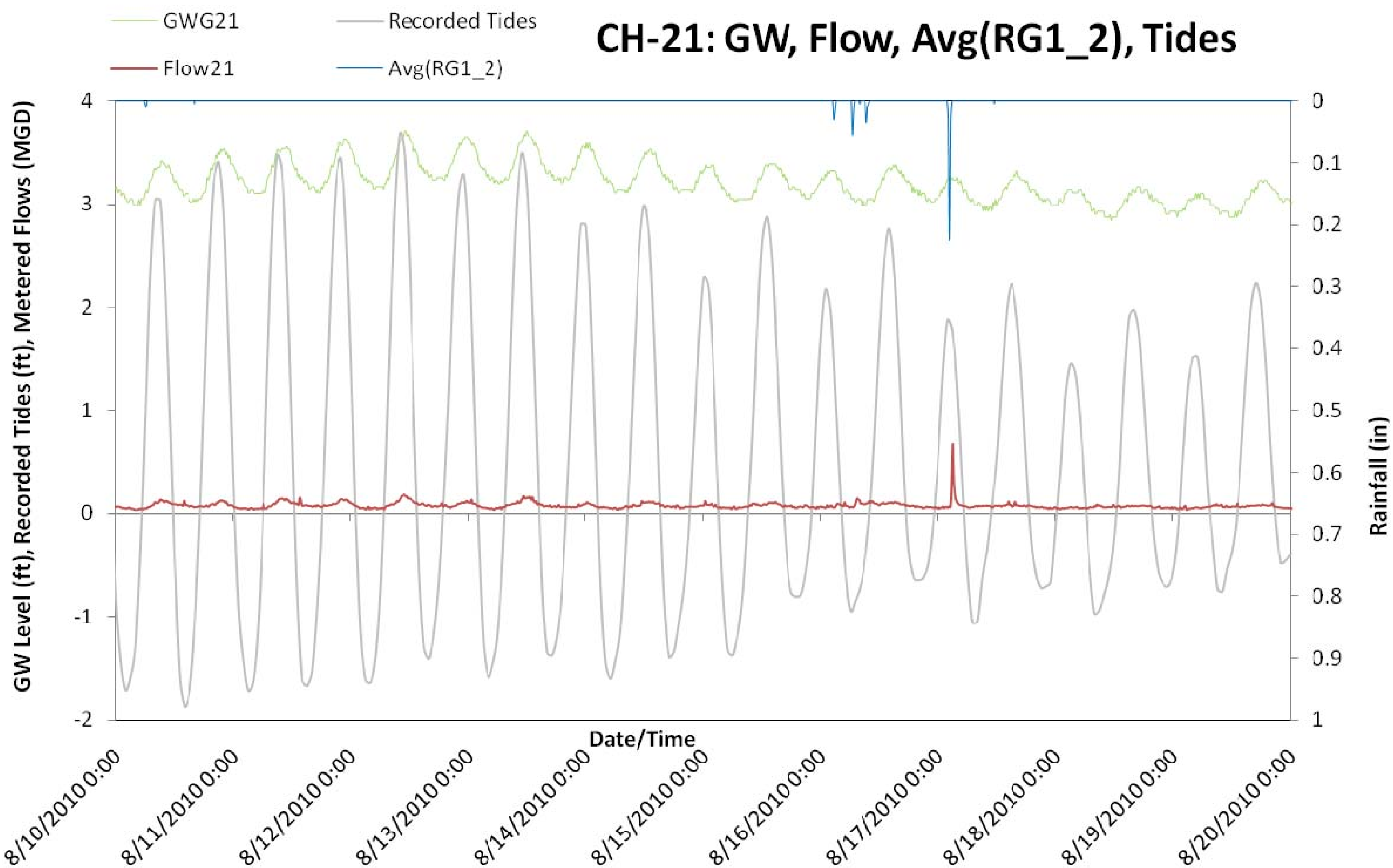


Figure 12. CH-21 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 10-day Period

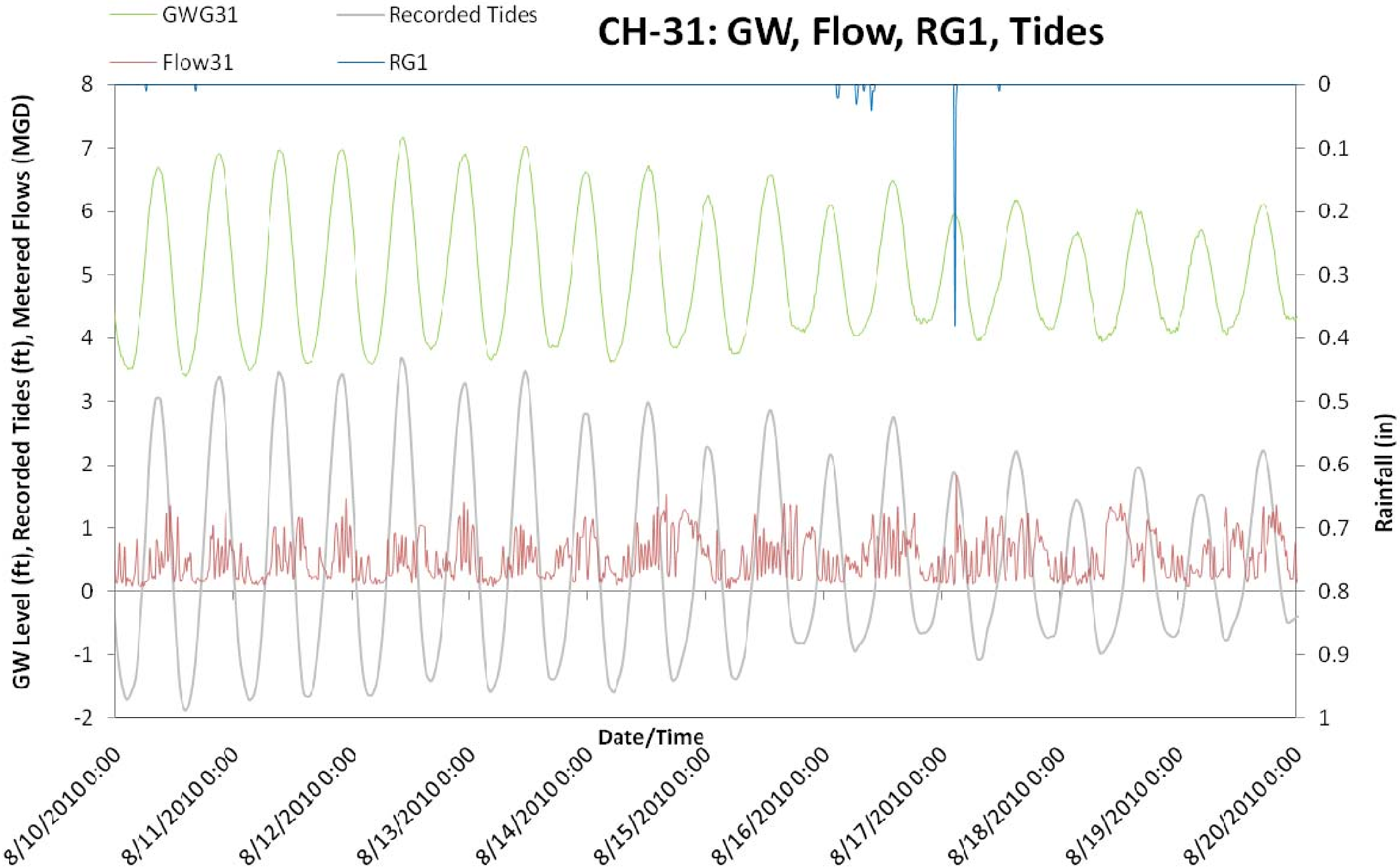


Figure 13. CH-31 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 10-day Period

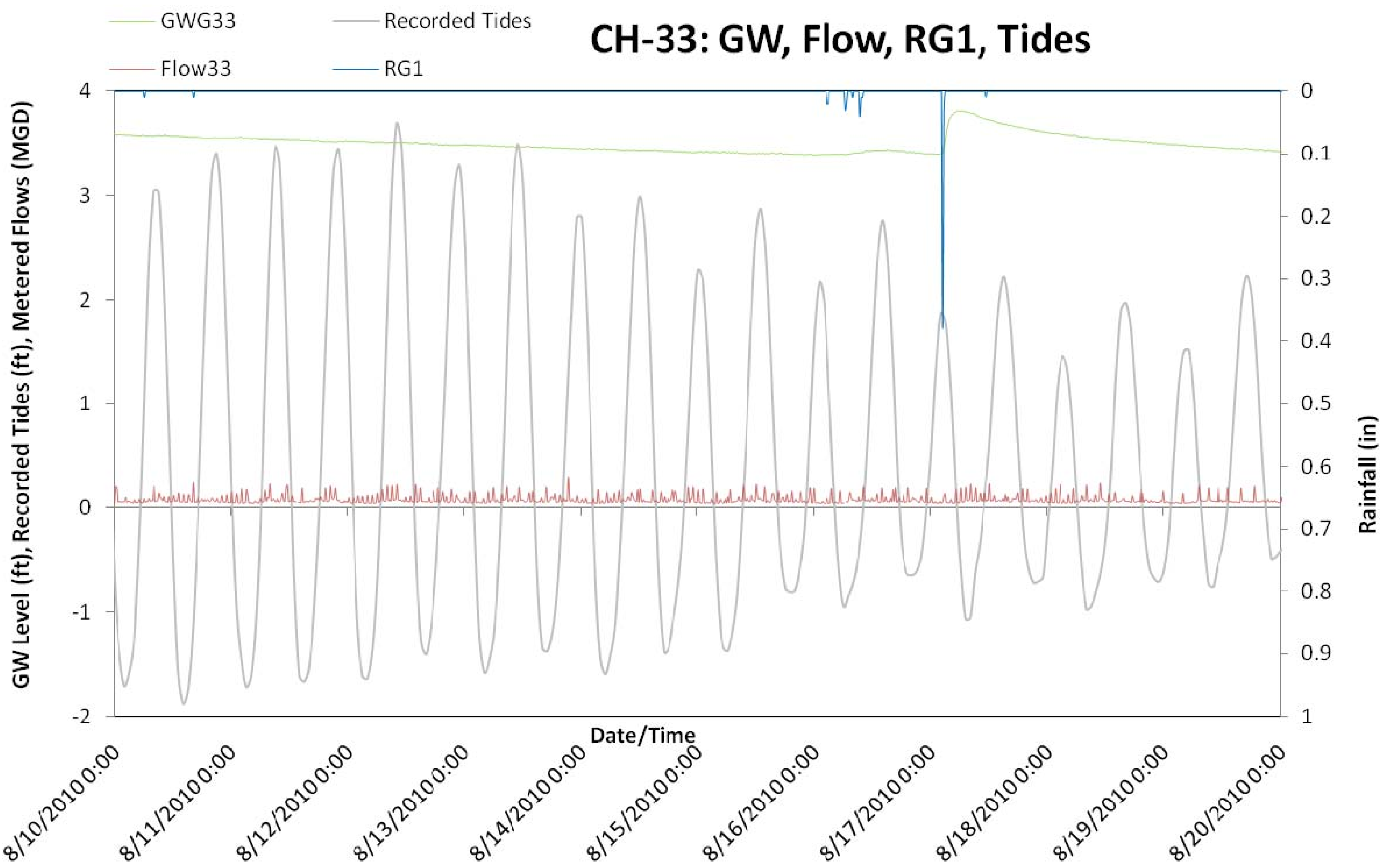


Figure 14. CH-33 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 10-day Period

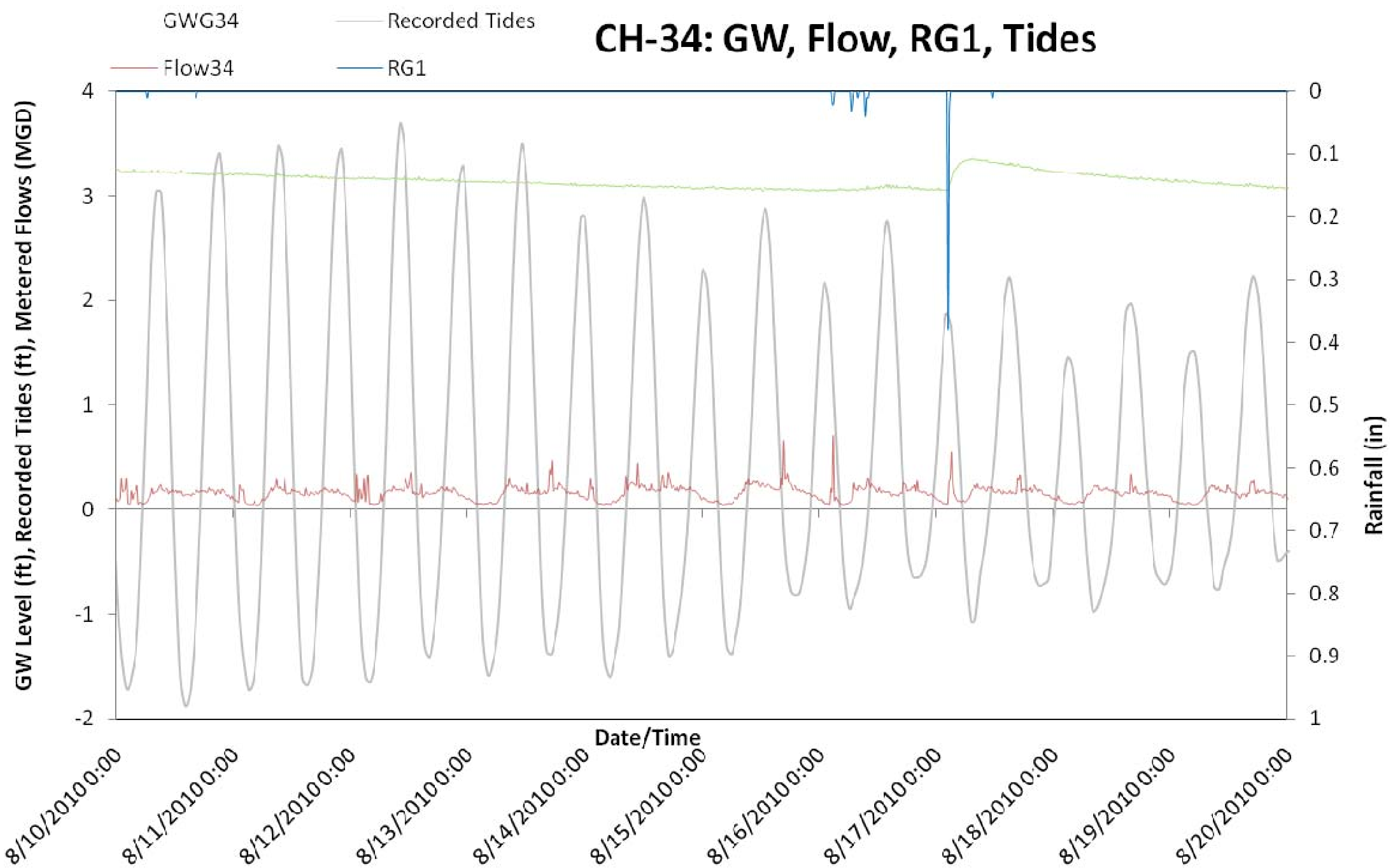


Figure 15. CH-34 GW and Flow Fluctuations with Corresponding Regional Rainfall and Recorded Tidal Data, 10-day Period

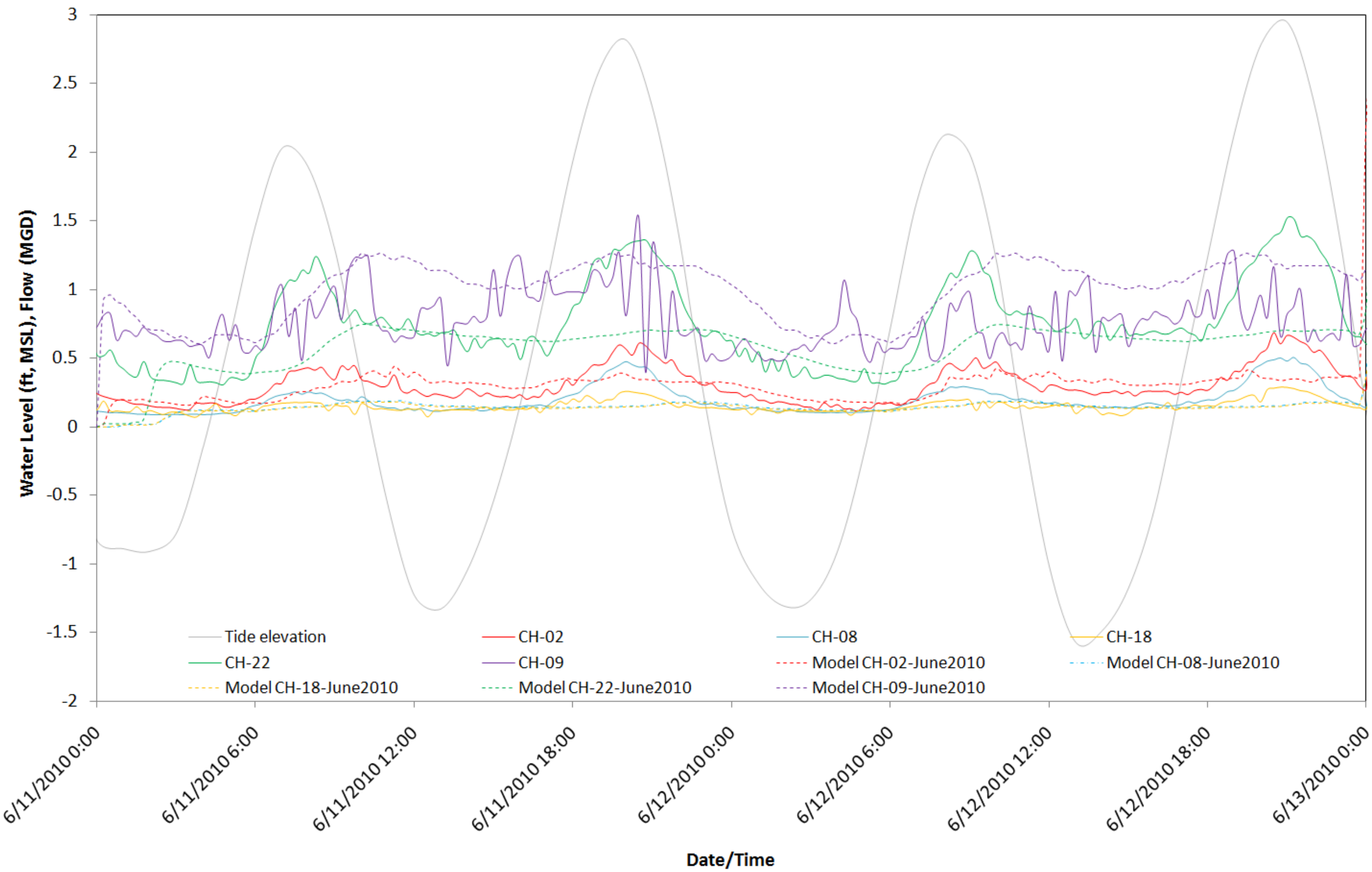


Figure 16. Measured and Modeled Flow Discharges at Locations CH-02, CH-08, CH-09, CH-18, and CH-22, and Their Dependence on Tidal Fluctuations During the Period 06/11-12/2010

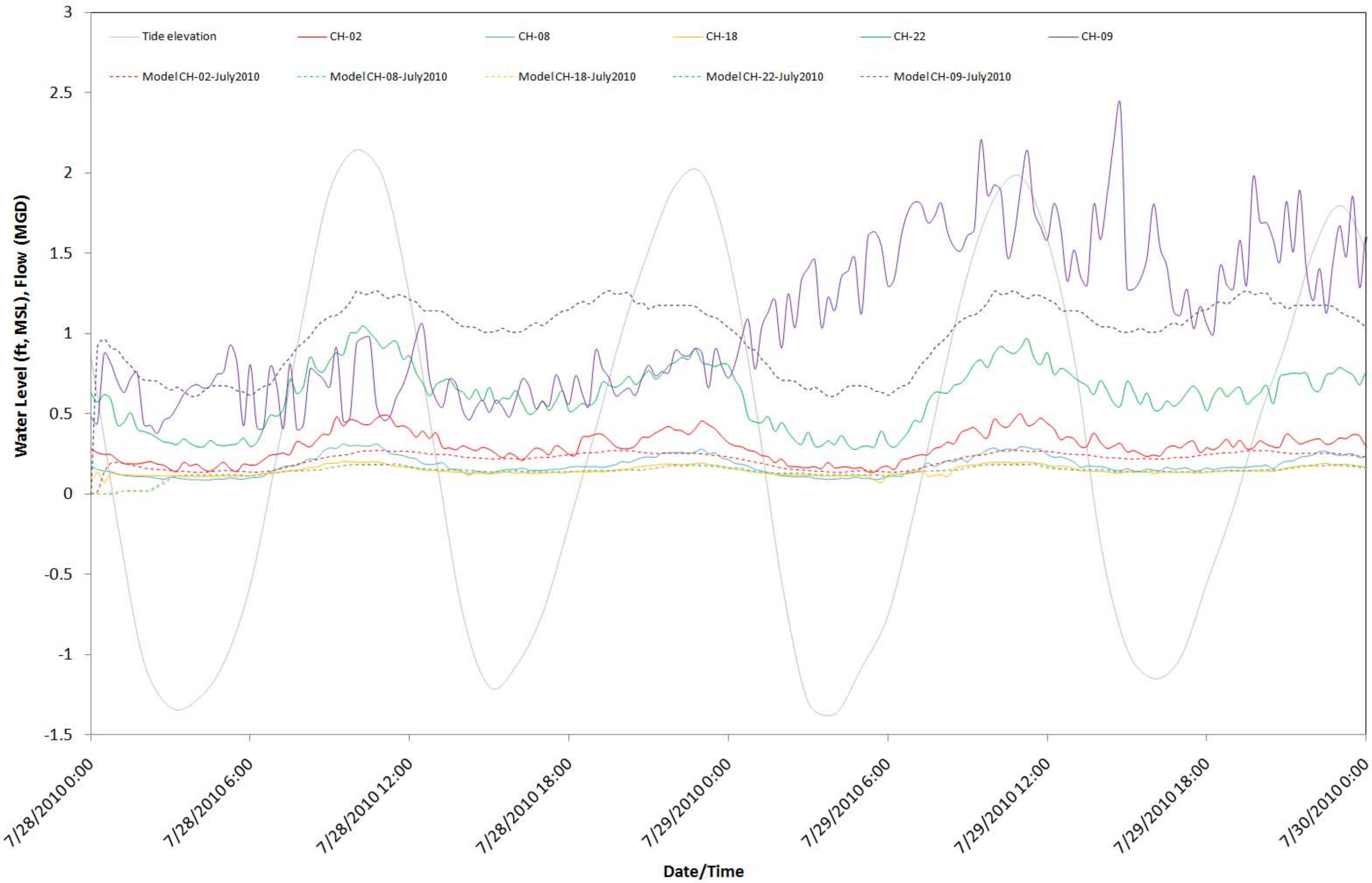


Figure 17. Measured and Modeled Flow Discharges at Locations CH-02, CH-08, CH-09, CH-18, and CH-22, and Their Dependence on Tidal Fluctuations During the Period 07/28-29/2010

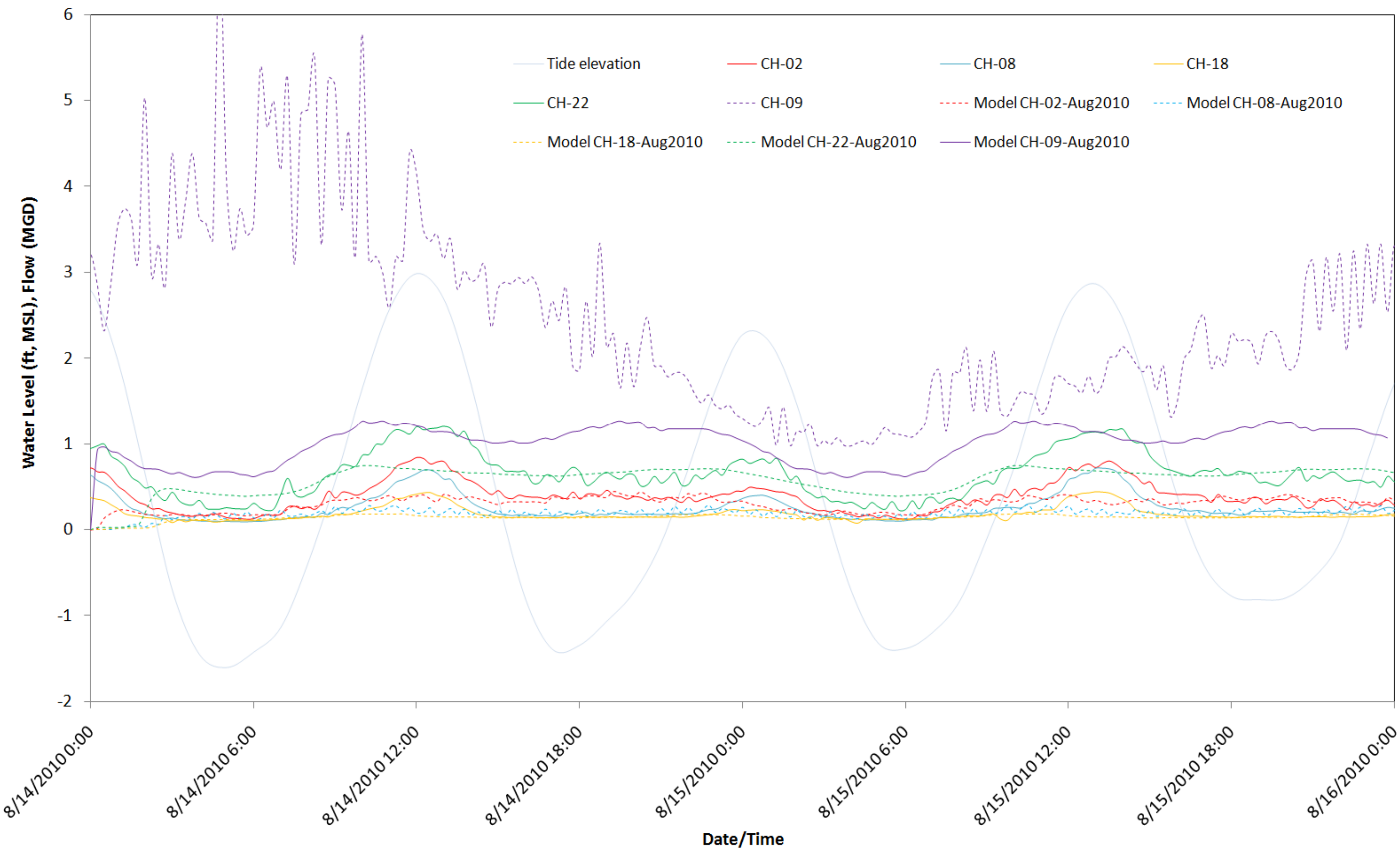


Figure 18. Measured and Modeled Flow Discharges at Locations CH-02, CH-08, CH-09, CH-18, and CH-22, and Their Dependence on Tidal Fluctuations During the Period 08/14-15/2010

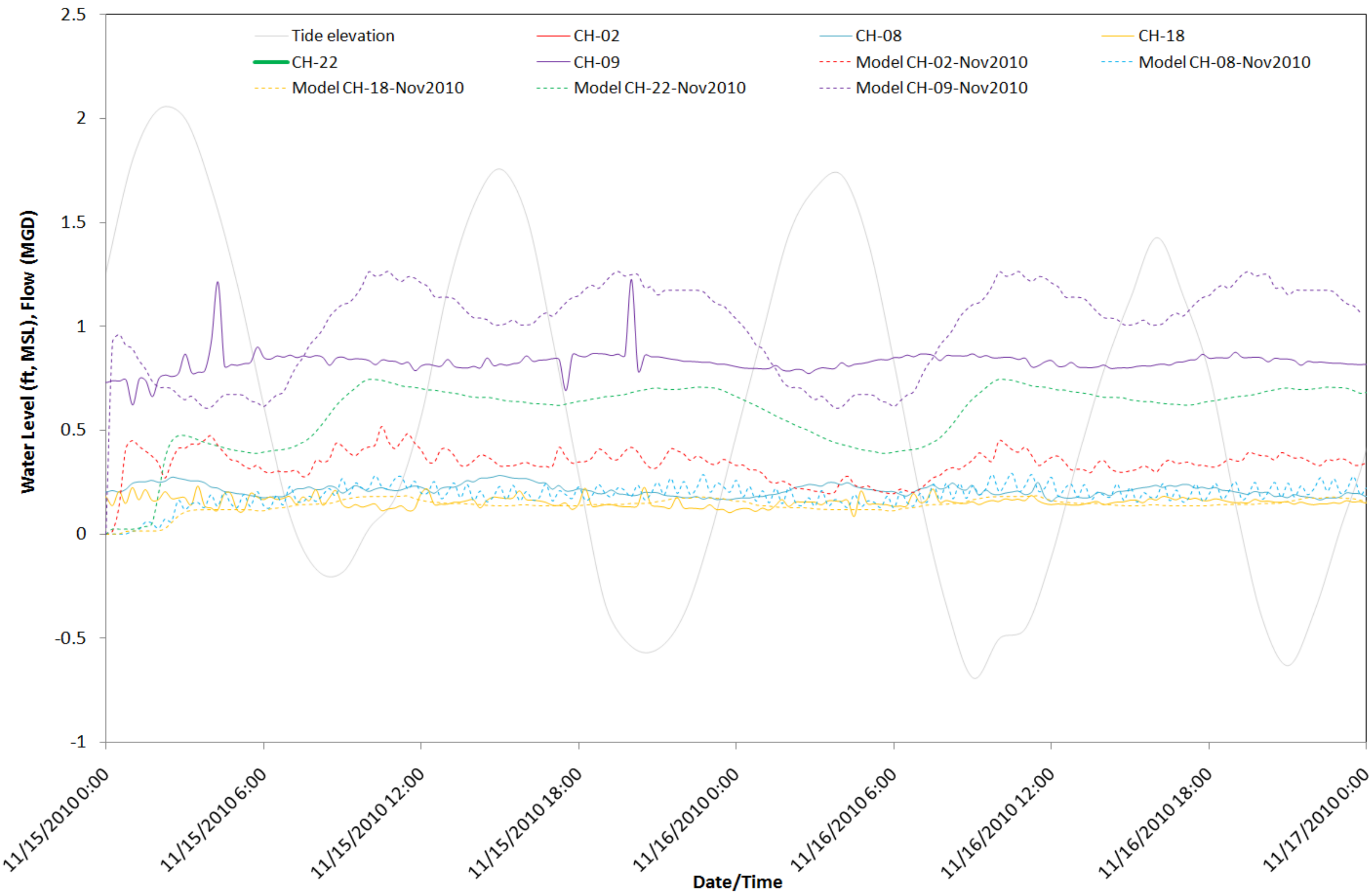


Figure 19. Measured and Modeled Flow Discharges at Locations CH-02, CH-08, CH-09, CH-18, and CH-22, and Their Dependence on Tidal Fluctuations During the Period 11/15-16/2010

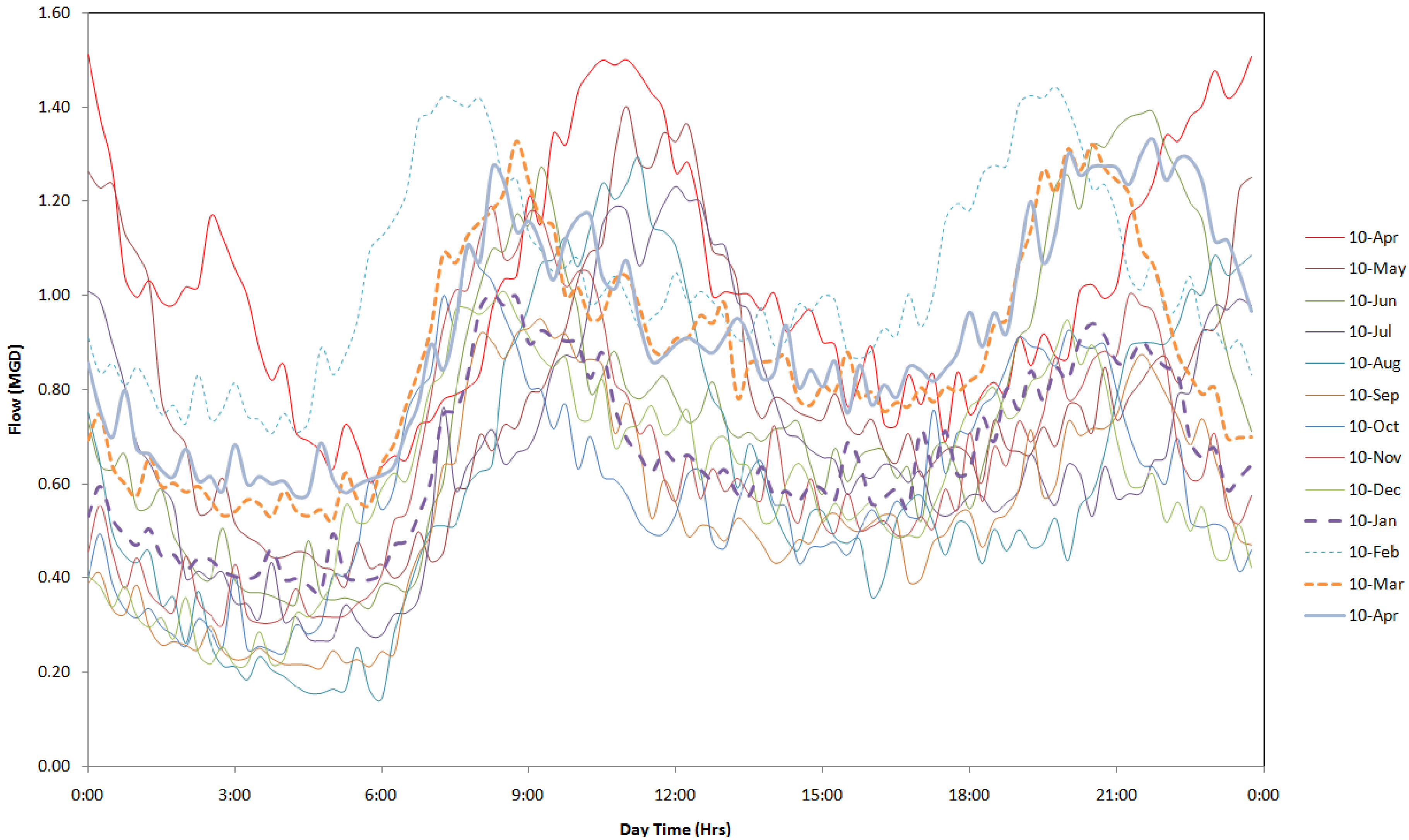


Figure 20. Monthly diurnal patterns for CH-22 Representing the Period 04/2010 to 04/2011.

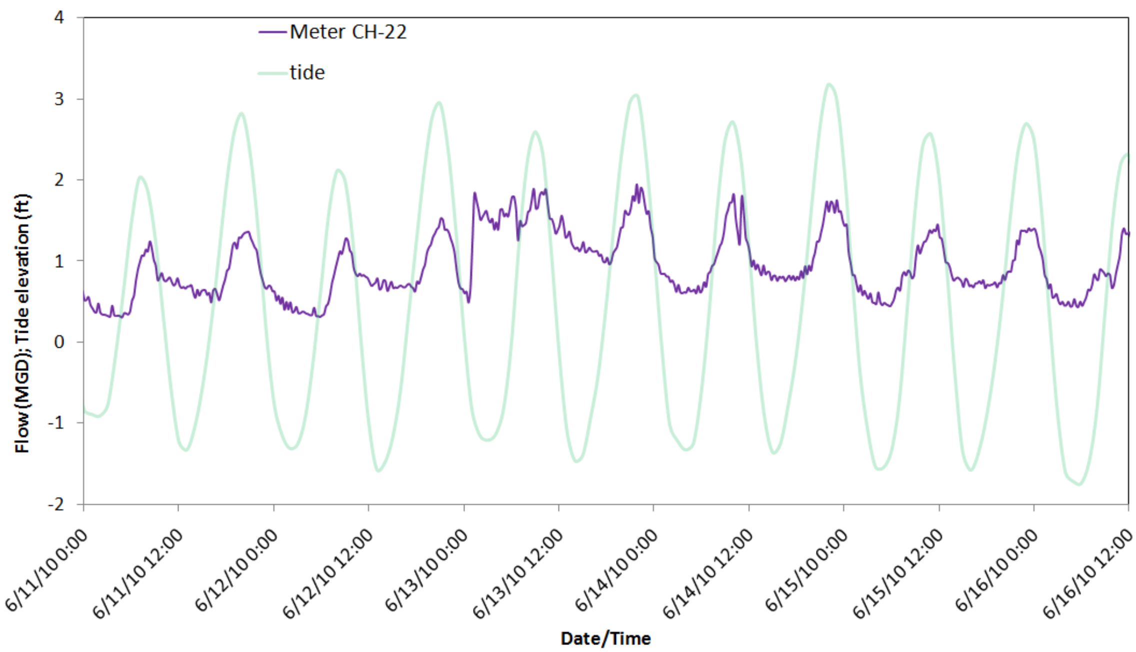


Figure 21. Tidal Data and Measured Flow Discharge at CH-22 During the Period 06/11-16/2010

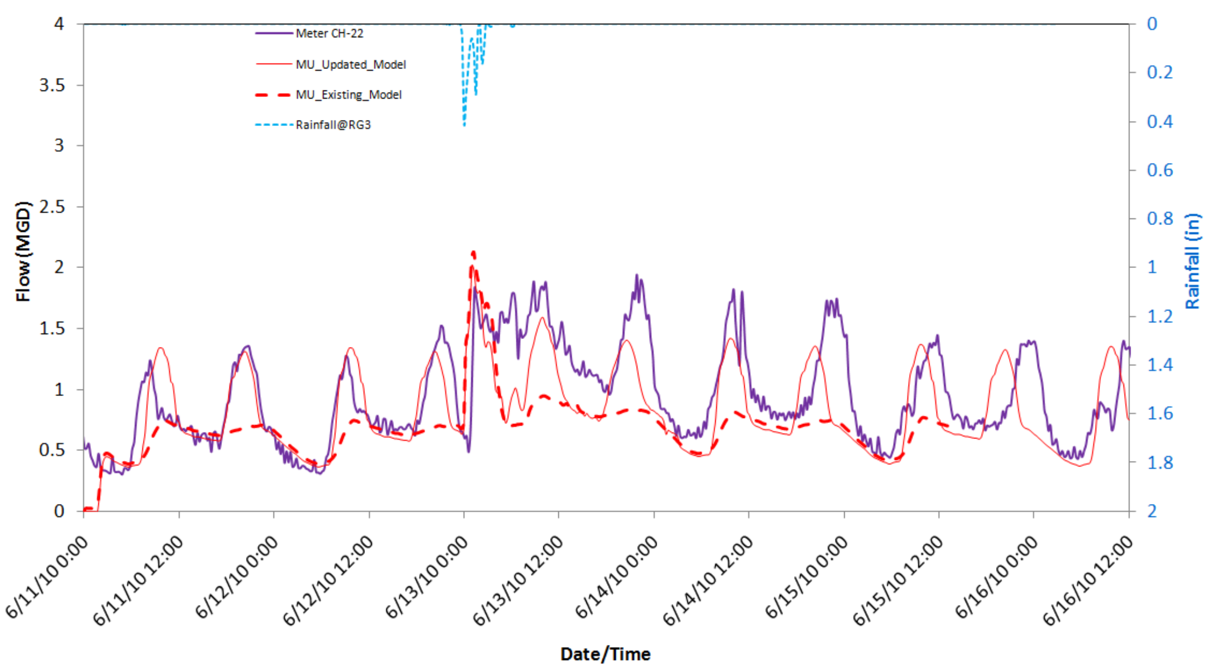


Figure 22. Measured and Predicted Flows at the Location of CH-22 During the Period 06/11-16/2010

Model Calibration and Validation

The 30 charts in this section of the appendix compare results from the updated model with measured flows for storms that occurred on April 13, 2011, August 15, 2011 and October 19, 2011.

Storm Event 04/11-16/2011

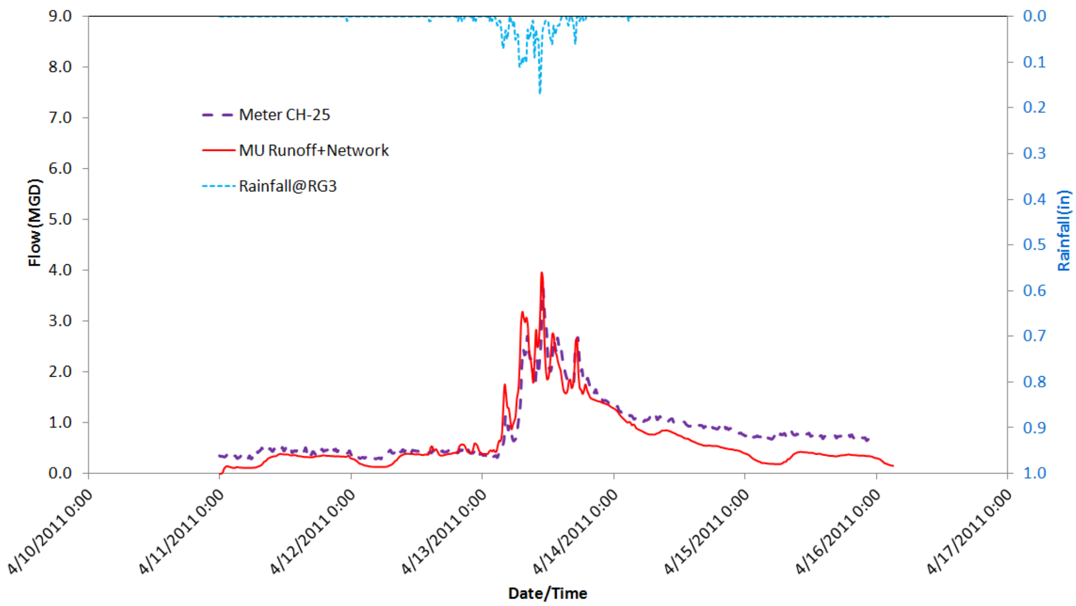


Figure C-2. Comparison between measured and modeled flow hydrographs at meter CH-25 in Catchment-01 during the period 04/11-16/2011.

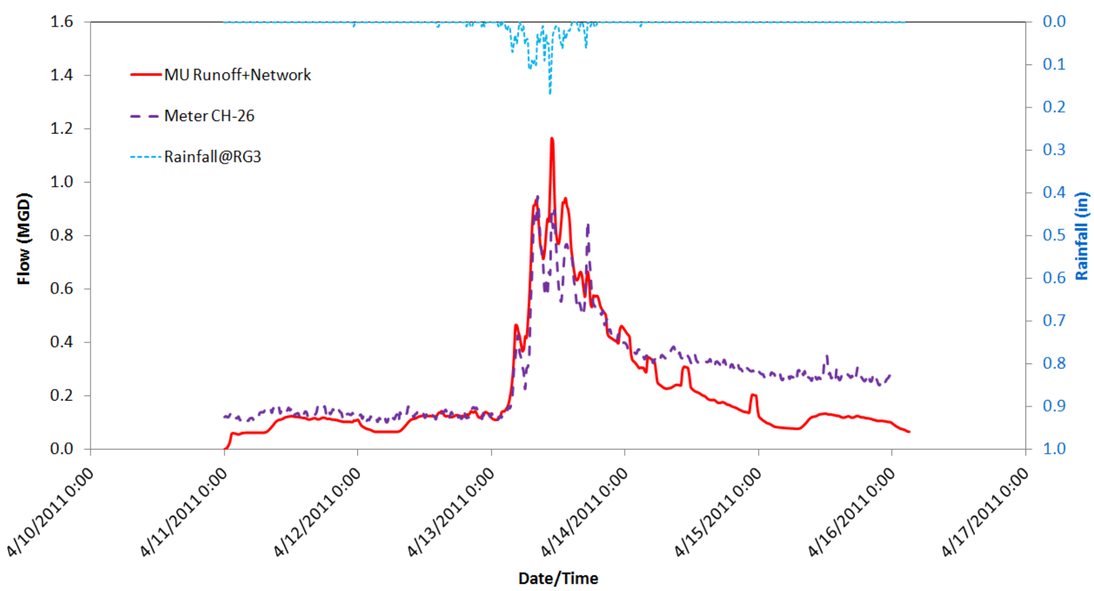
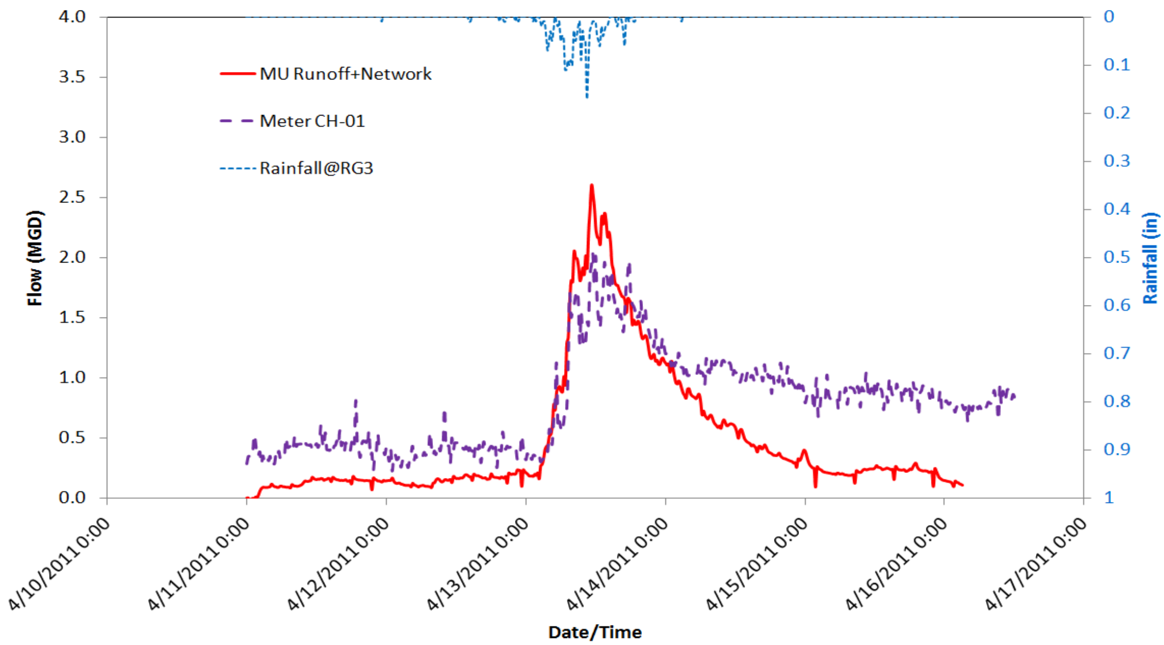


Figure C-3. Comparison between measured and modeled flow hydrographs at meter CH-26 in Catchment-02 during the period 04/11-16/2011.



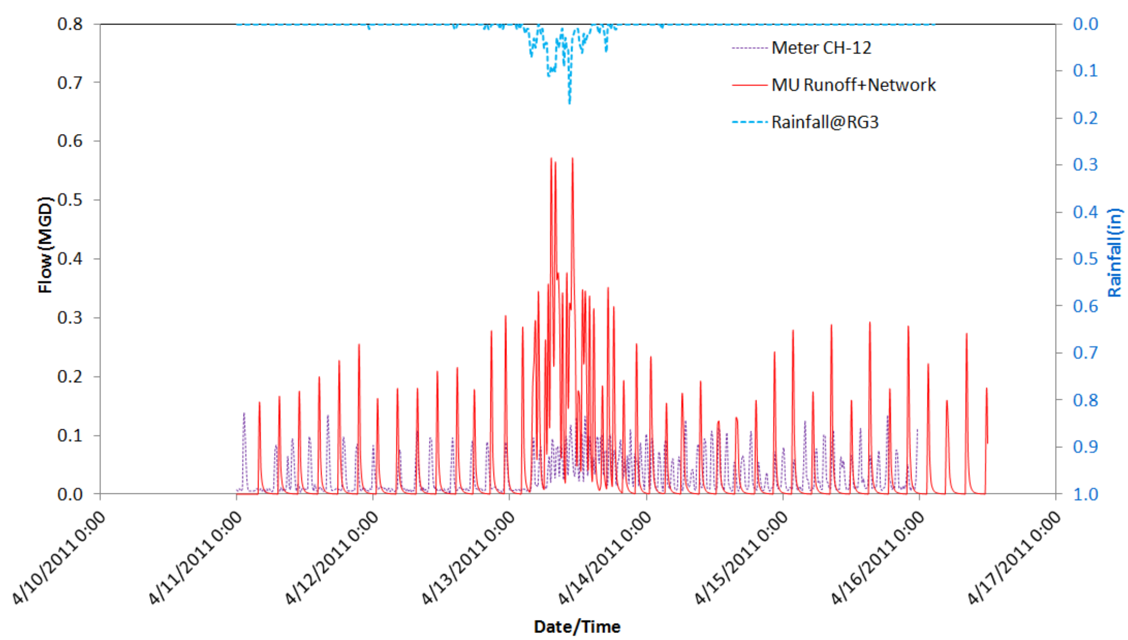
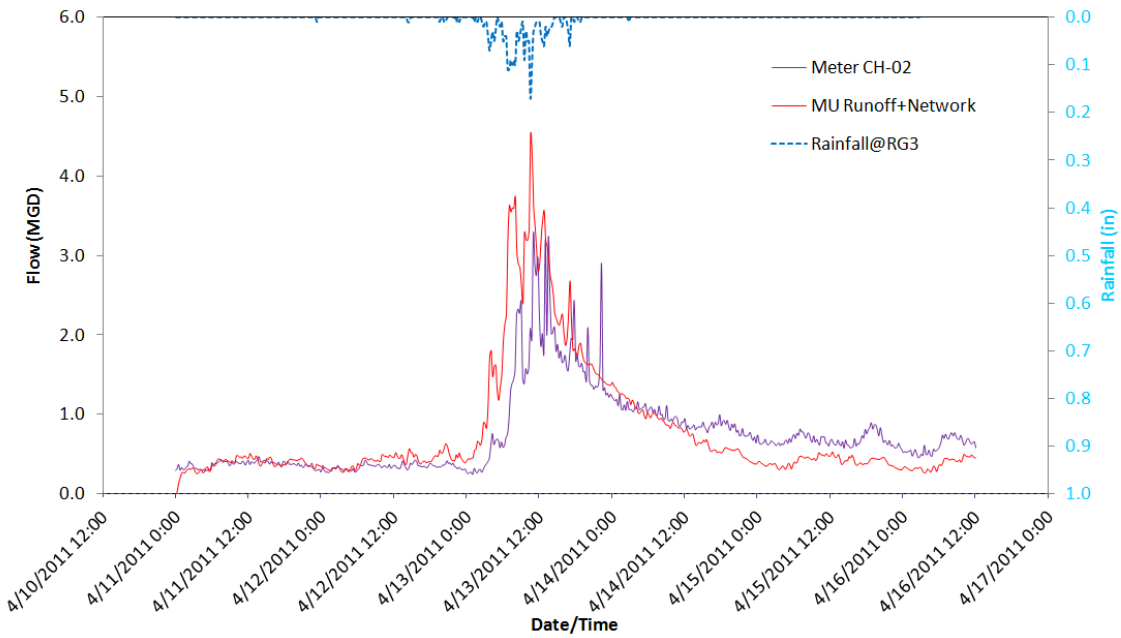


Figure C-4. Comparison between measured and modeled flow hydrographs at meters CH-01, and CH-12 in Catchment-03 during the period 04/11-16/2011.



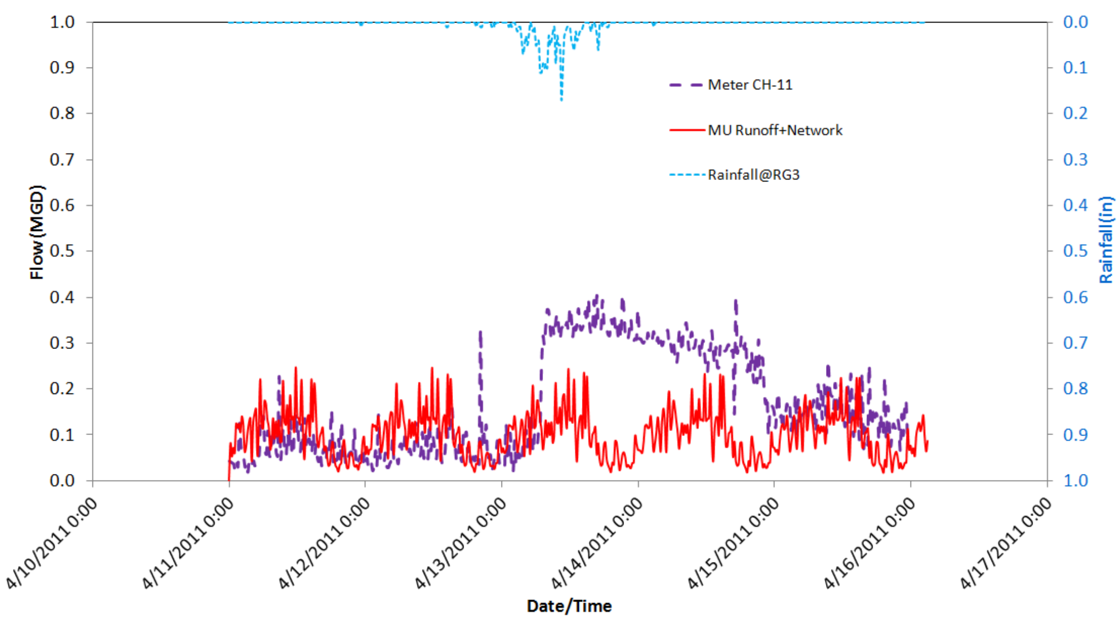
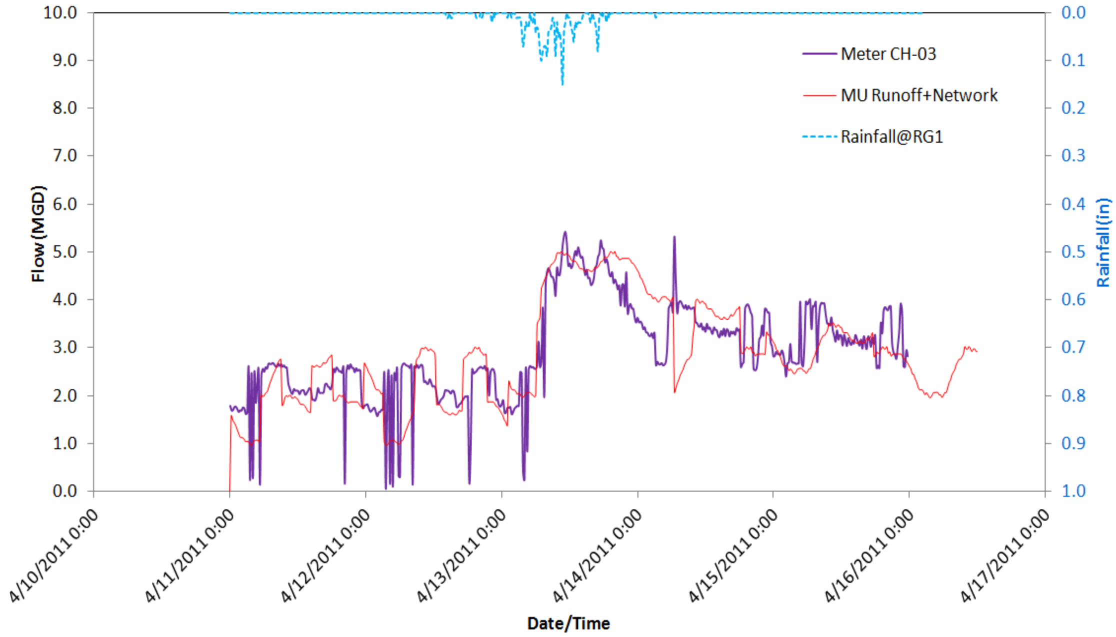


Figure C-5. Comparison between measured and modeled flow hydrographs at meters CH-02, and CH-11 in Catchment-04 during the period 04/11-16/2011.



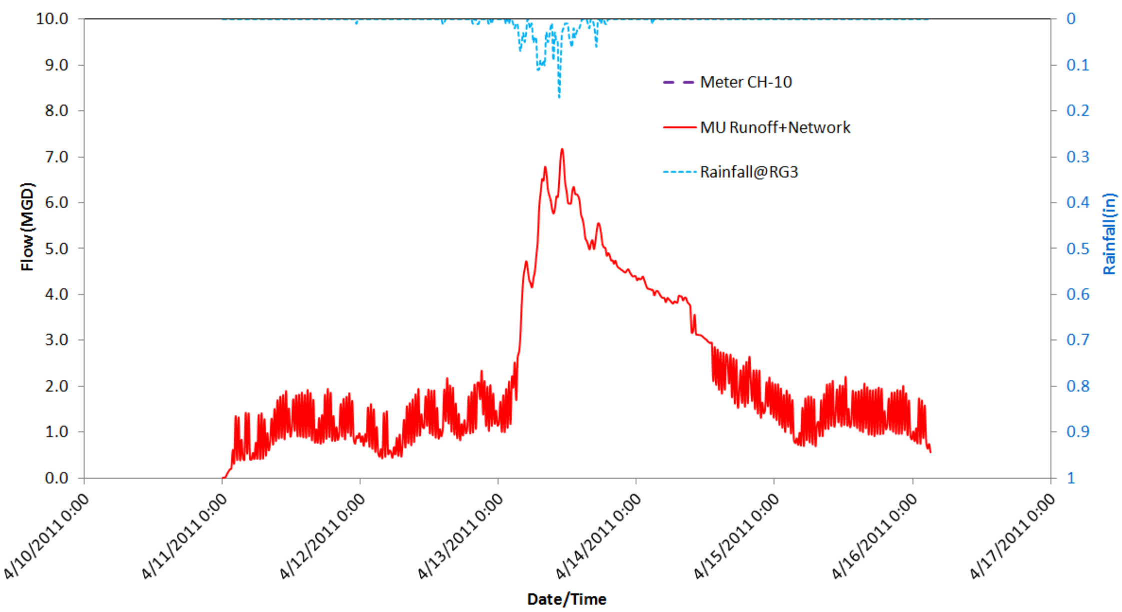


Figure C-6. Comparison between measured and modeled flow hydrographs at meters CH-03 and CH-10 in Catchment-06 during the period 04/11-16/2011.

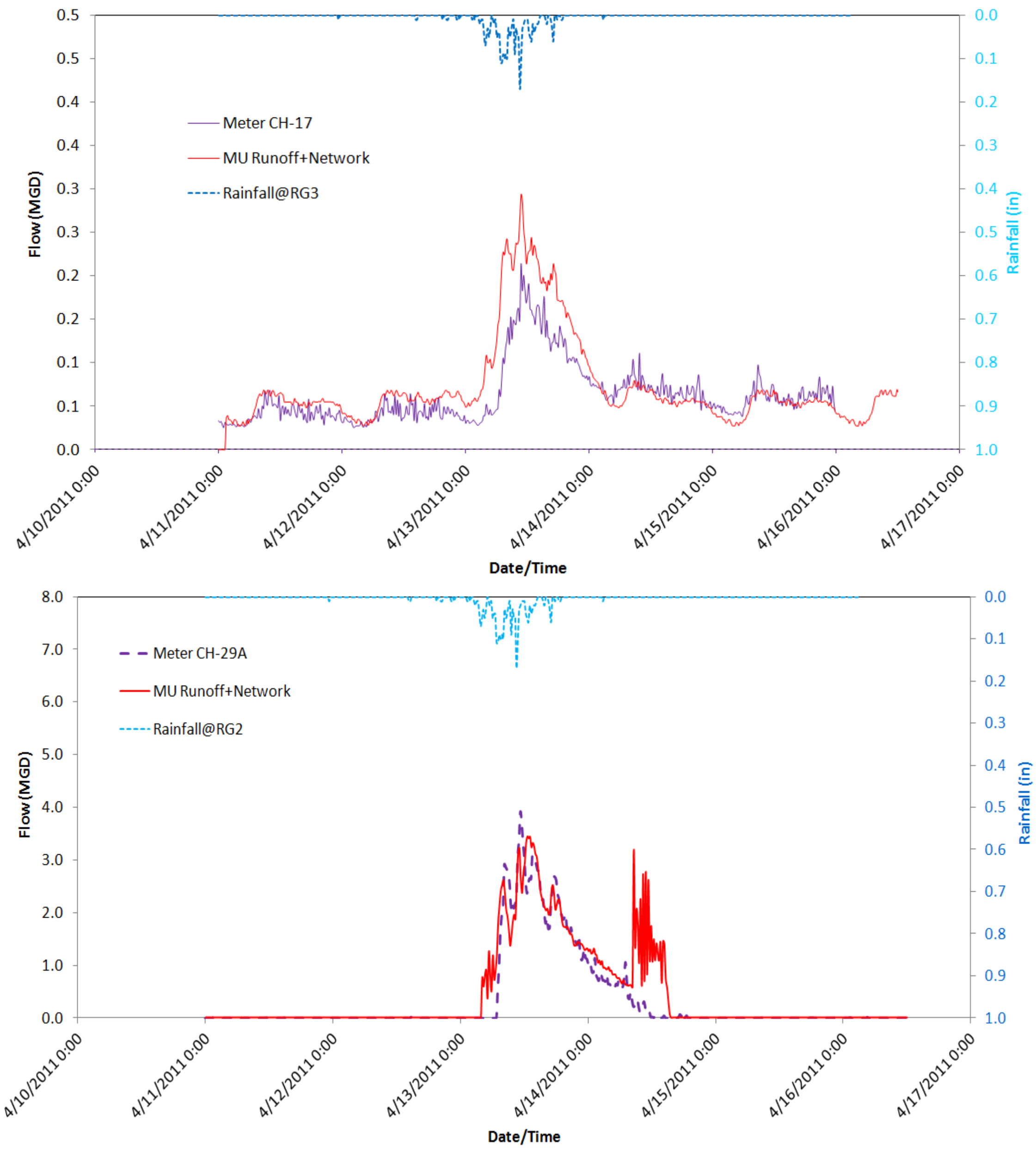


Figure C-7. Comparison between measured and modeled flow hydrographs at meters CH-17 and CH-29A in Catchment-06 during the period 04/11-16/2011.

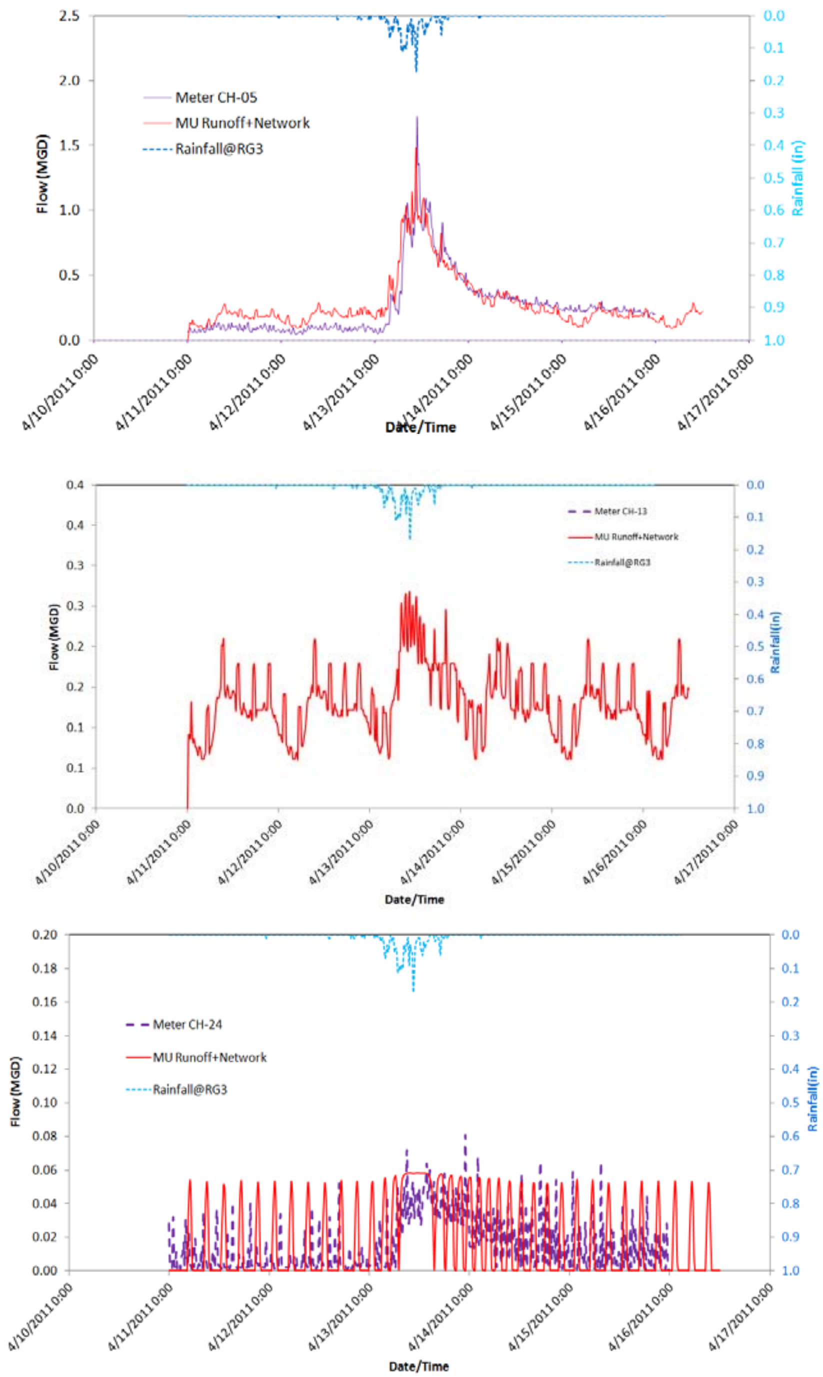
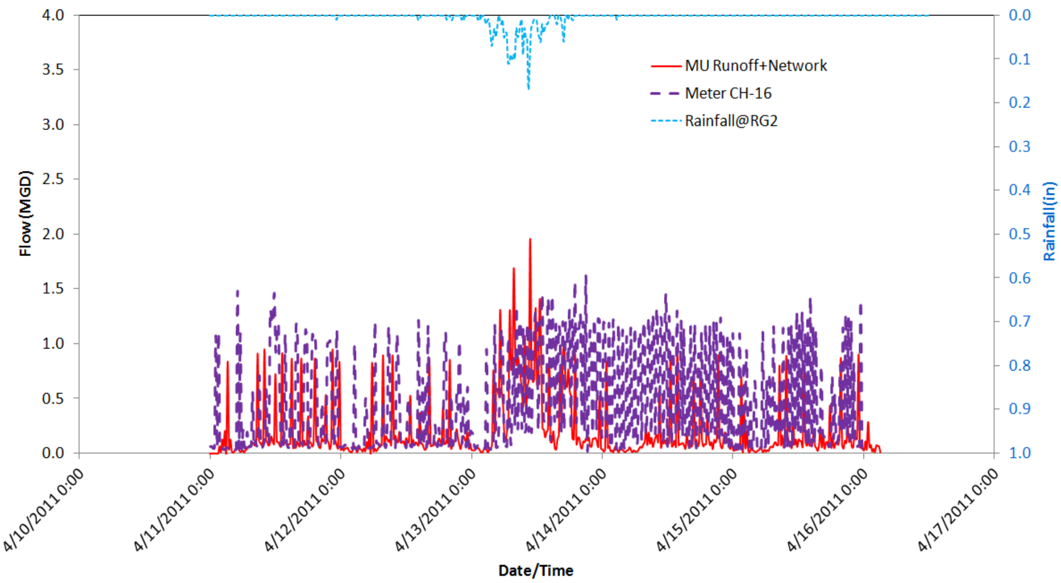


Figure C-8. Comparison between measured and modeled flow hydrographs at meters CH-05, CH-13, and CH-24 in Catchment-07 during the period 04/11-16/2011.



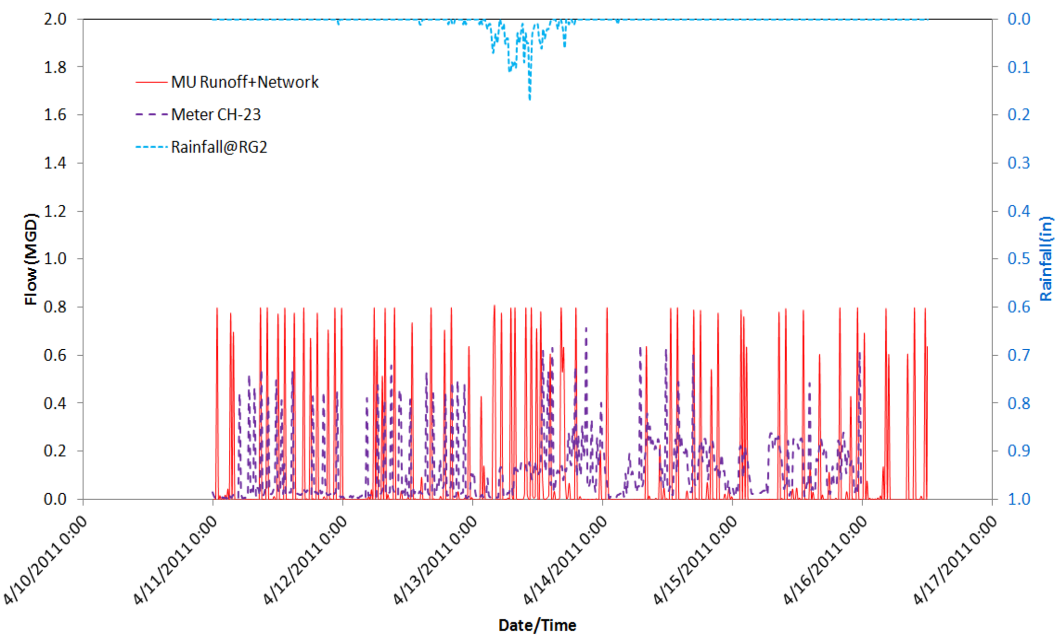
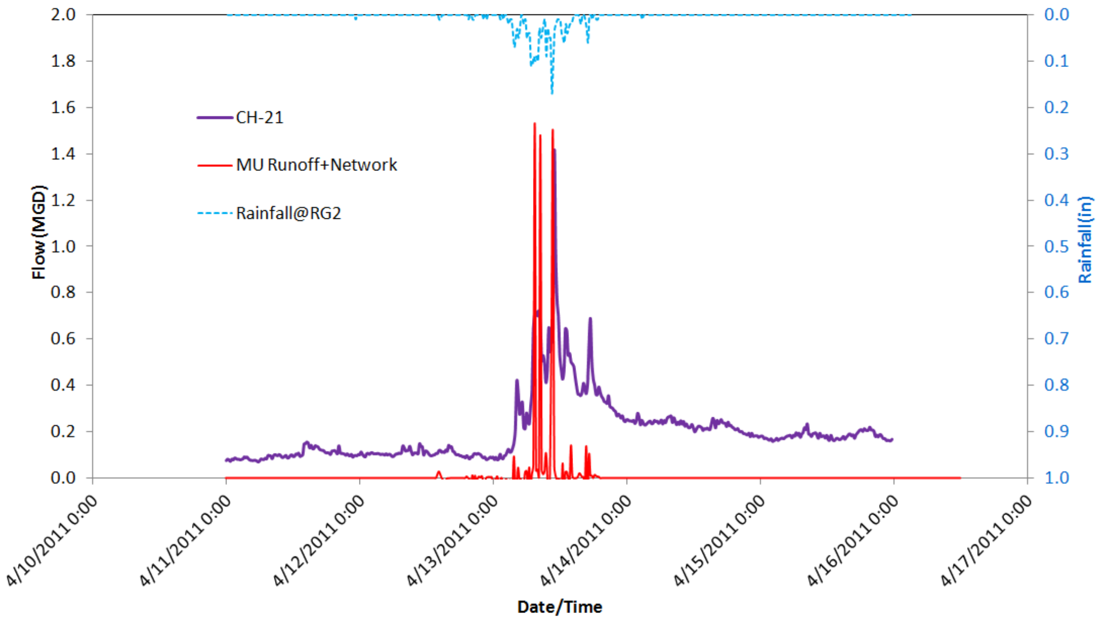


Figure C-9. Comparison between measured and modeled flow hydrographs at meters CH-16, and CH-23 in Catchment-08 during the period 04/11-16/2011.



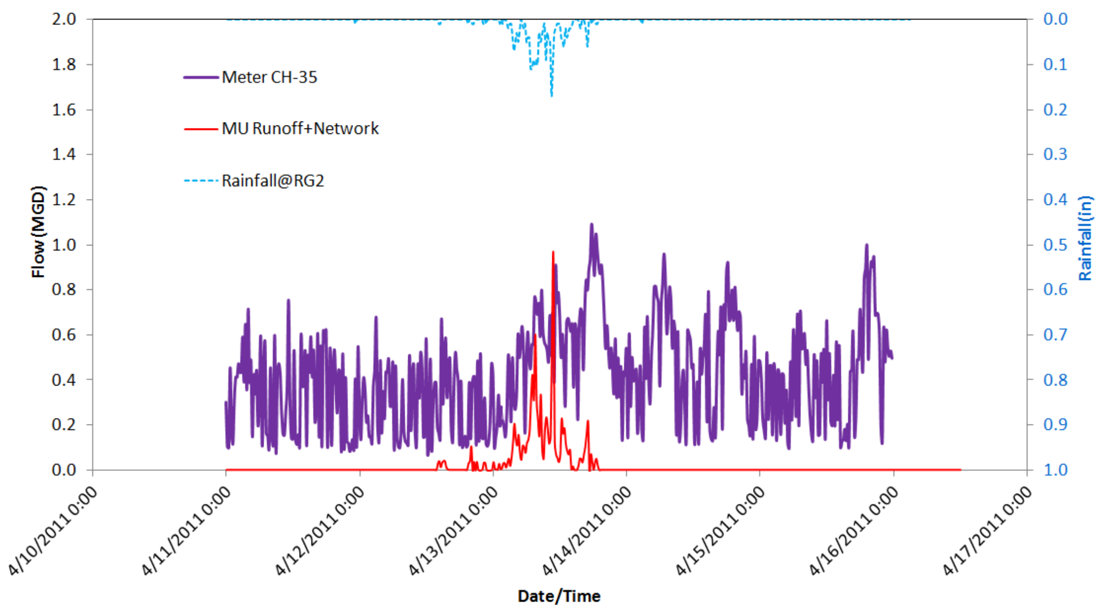


Figure C-10. Comparison between measured and modeled flow hydrographs at meters CH-21 and CH-35 in Catchment-08 during the period 04/11-16/2011.

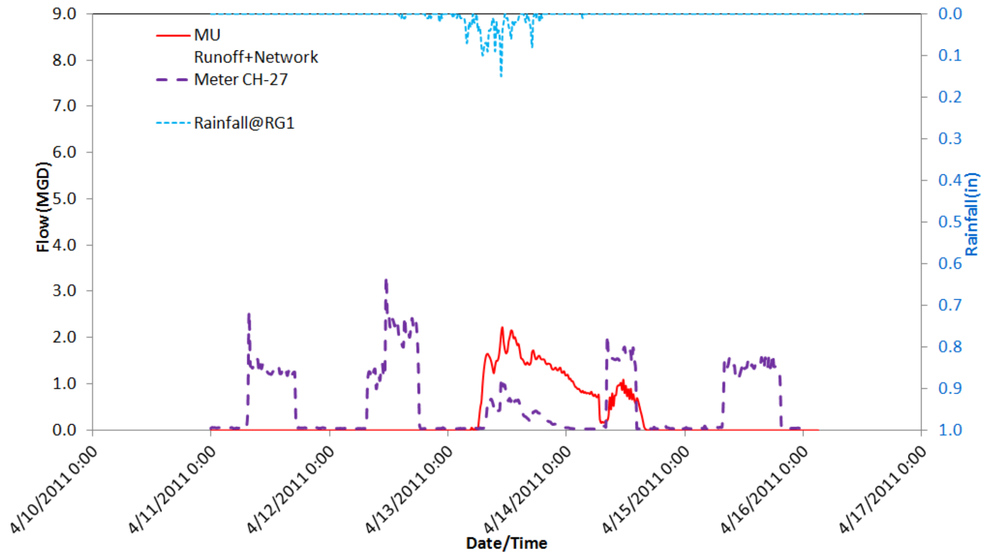


Figure C-11. Comparison between measured and modeled flow hydrographs at meter CH-27 in Catchment-09 during the period 04/11-16/2011.

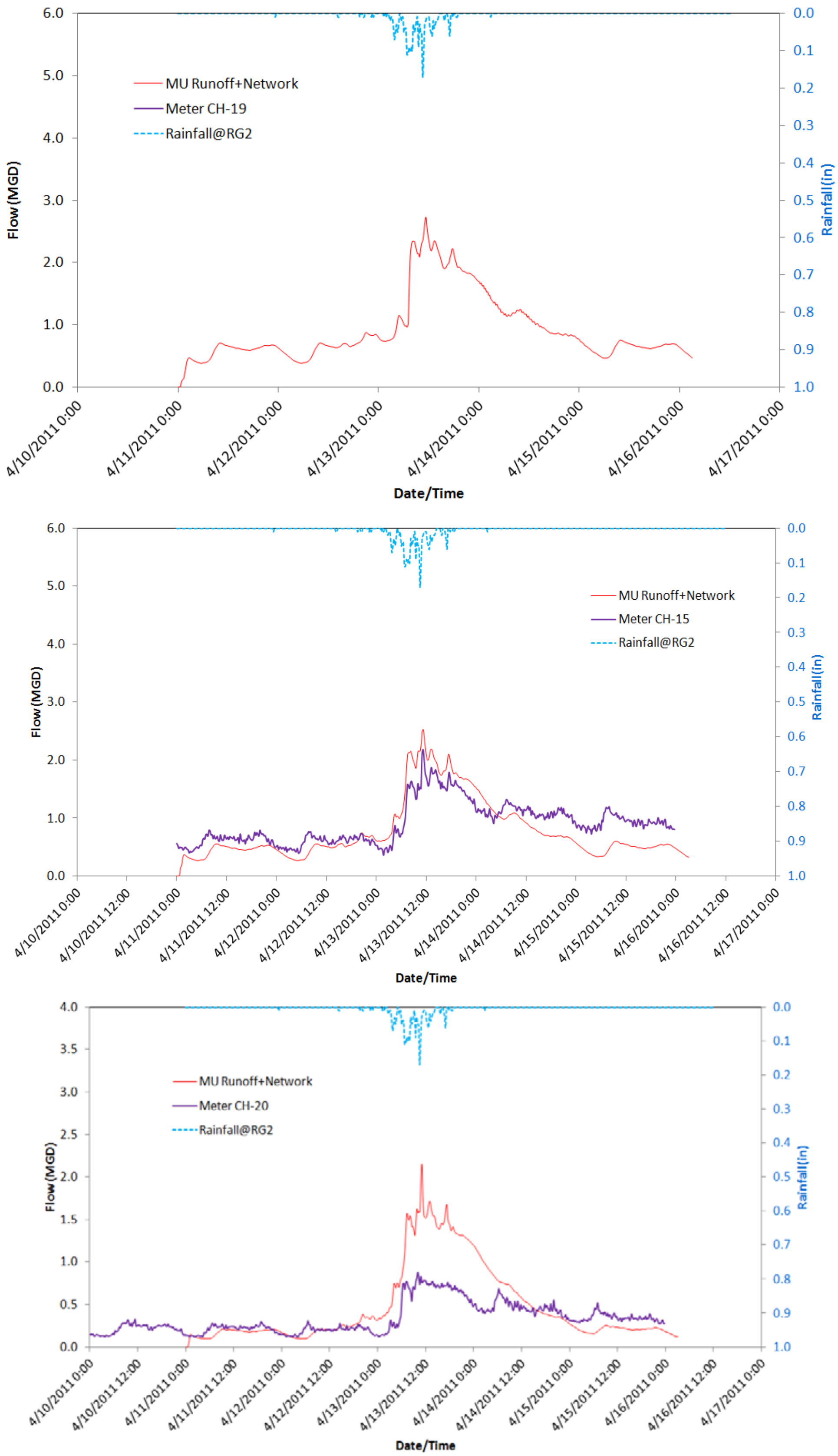
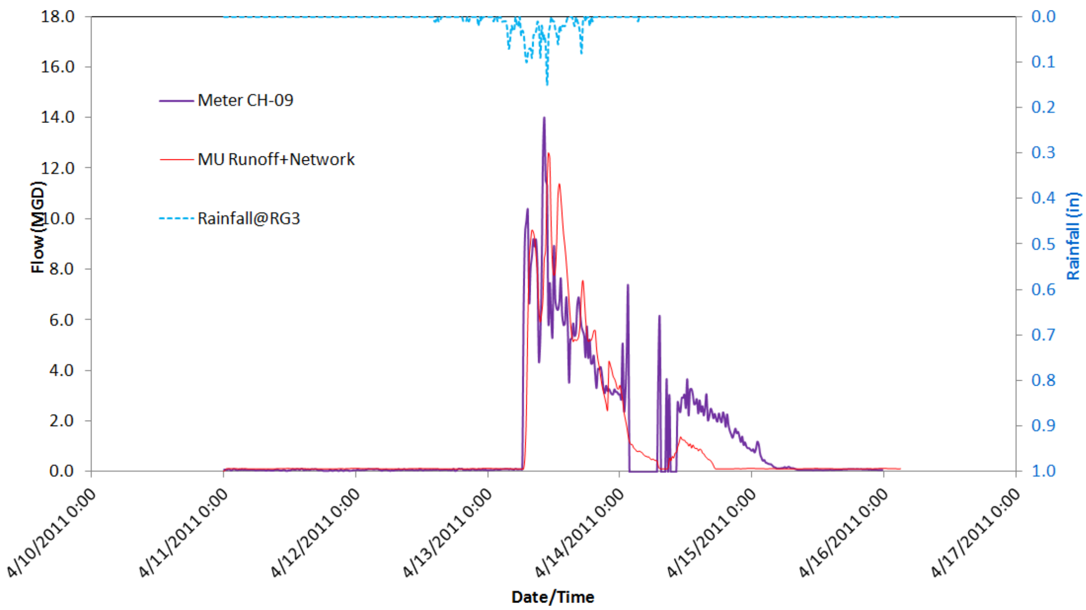


Figure C-12. Comparison between measured and modeled flow hydrographs at meters CH-19, CH-15, and CH-20 in Catchment-10 during the period 04/11-16/2011.



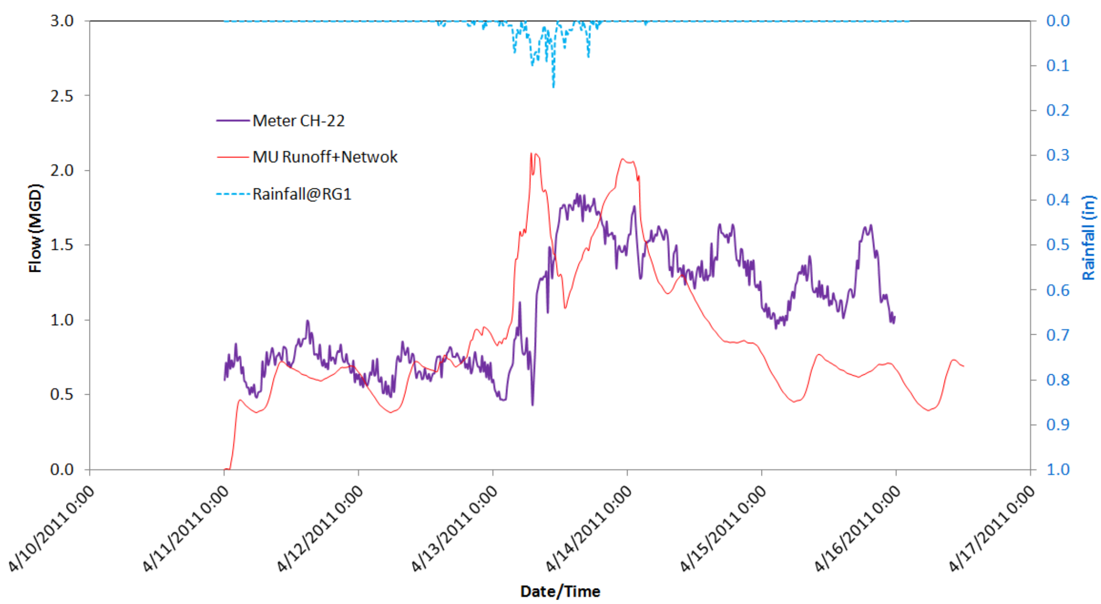
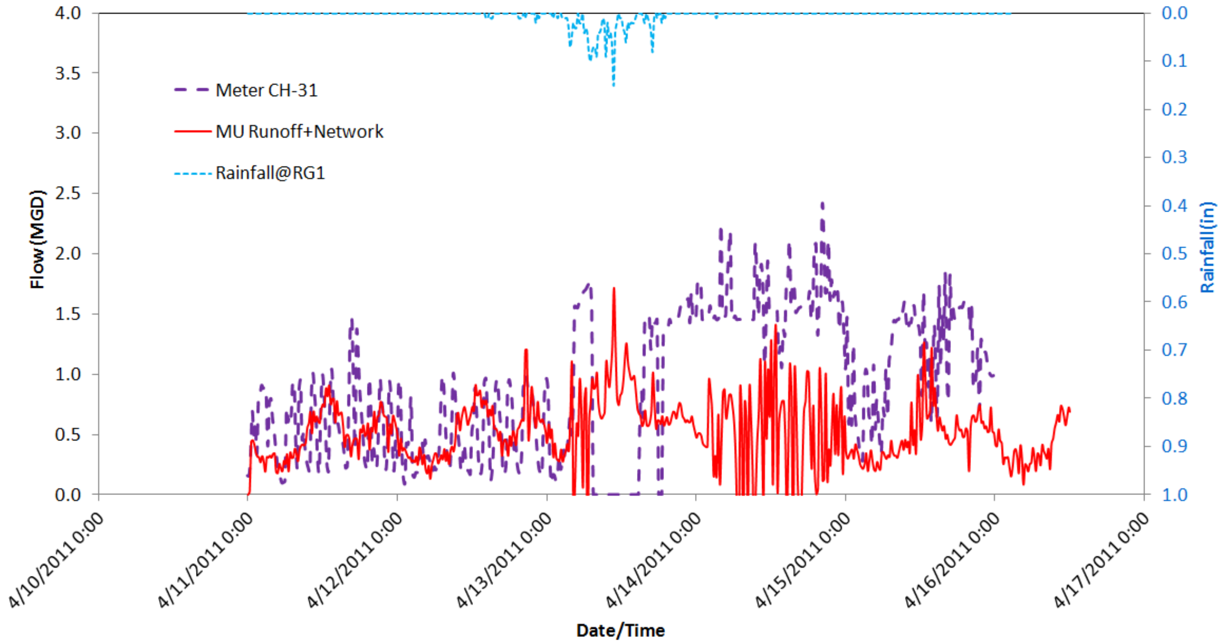


Figure C-13. Comparison between measured and modeled flow hydrographs at meters CH-09 and CH-22 in Catchment-10 during the period 04/11-16/2011.



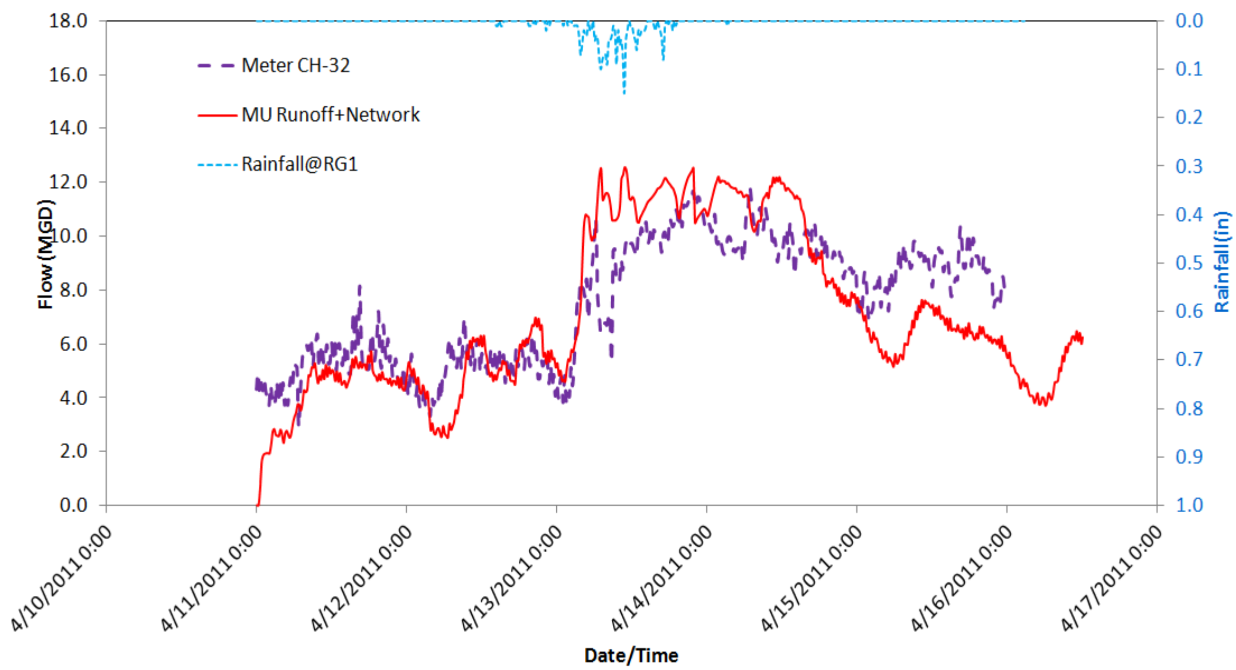


Figure C-14. Comparison between measured and modeled flow hydrographs at meters CH-31 and CH-32 in Catchment-10 during the period 04/11-16/2011.

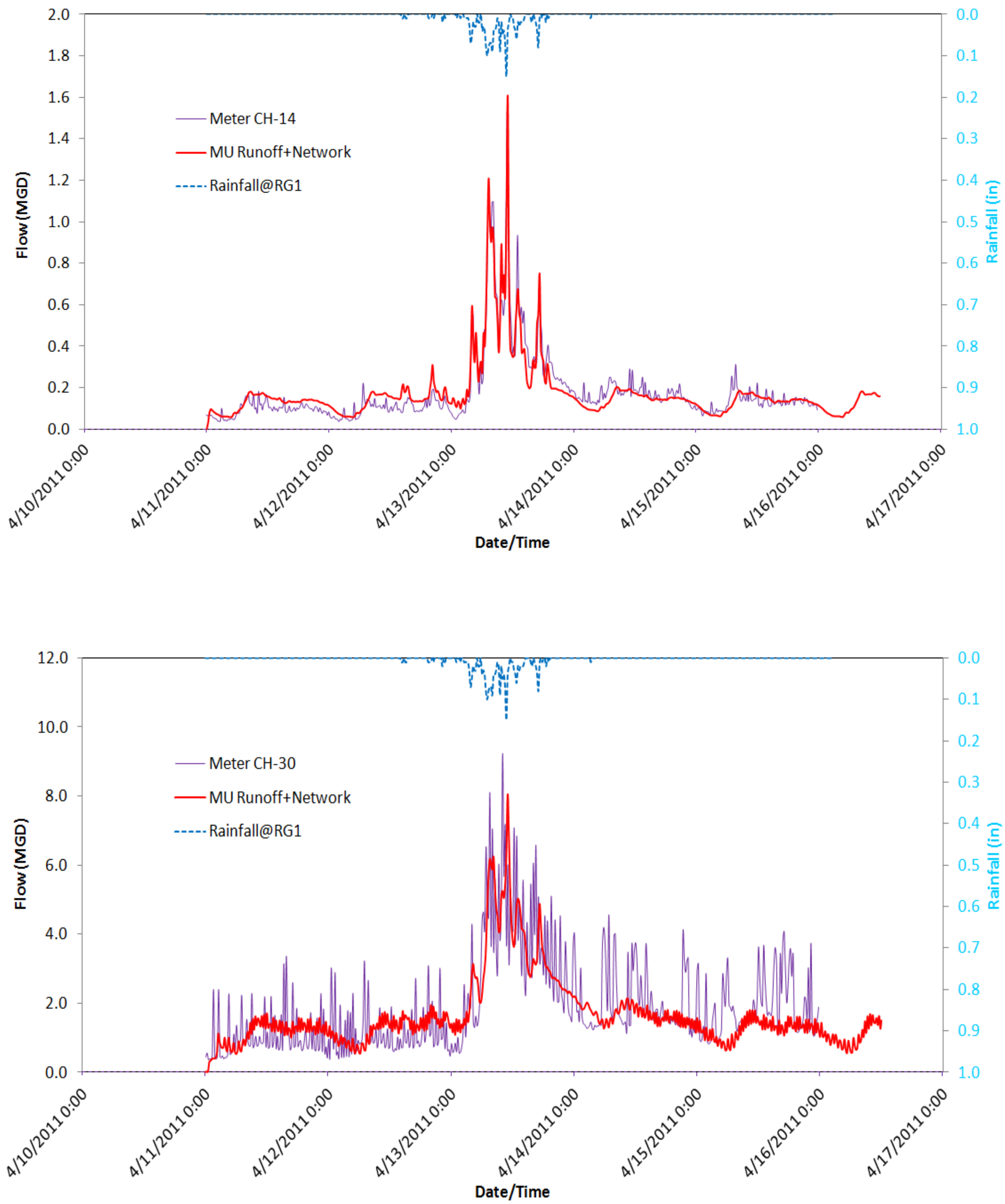


Figure C-15. Comparison between measured and modeled flow hydrographs at meters CH-14 and CH-30 in Catchment-11 during the period 04/11-16/2011.

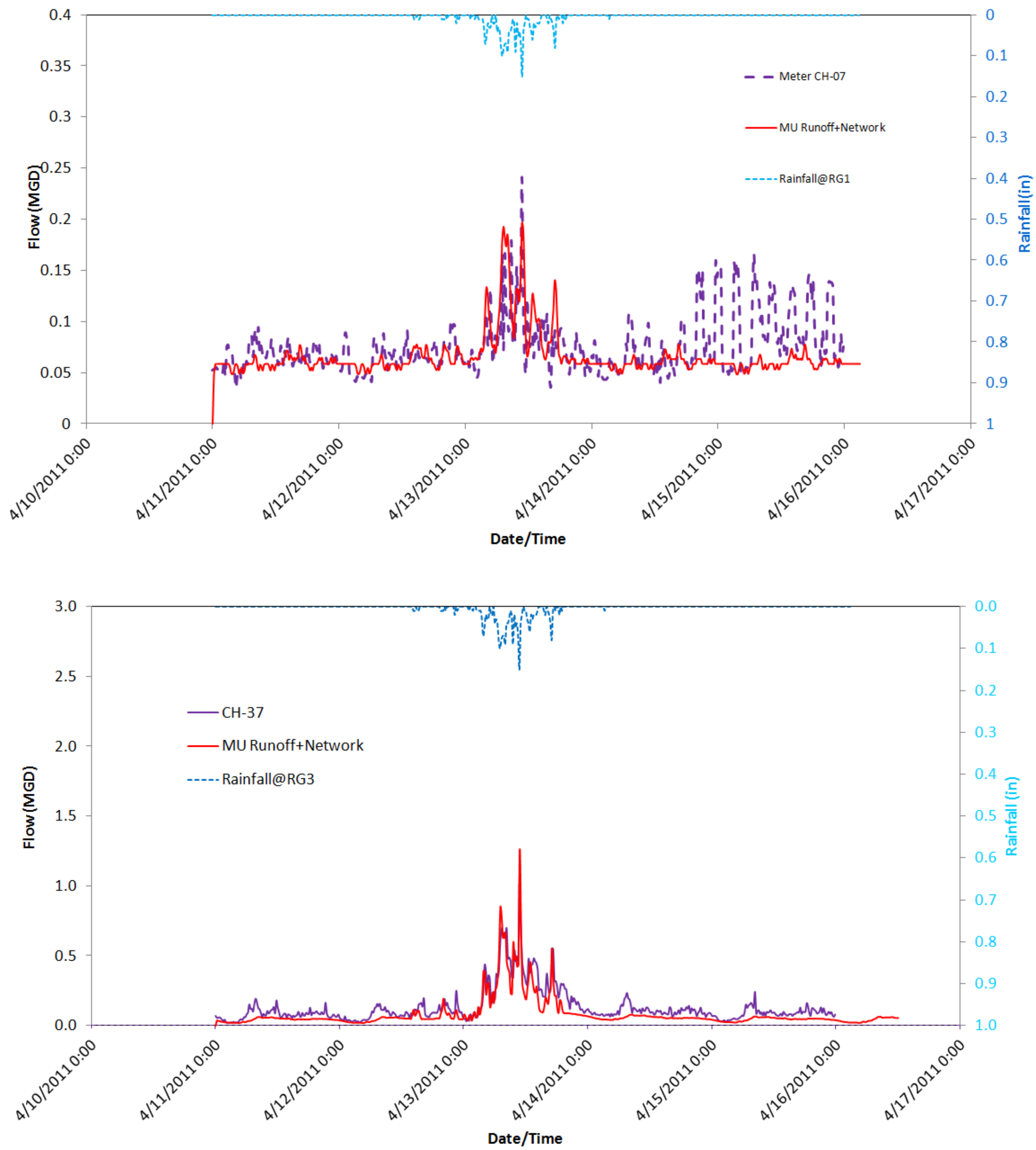
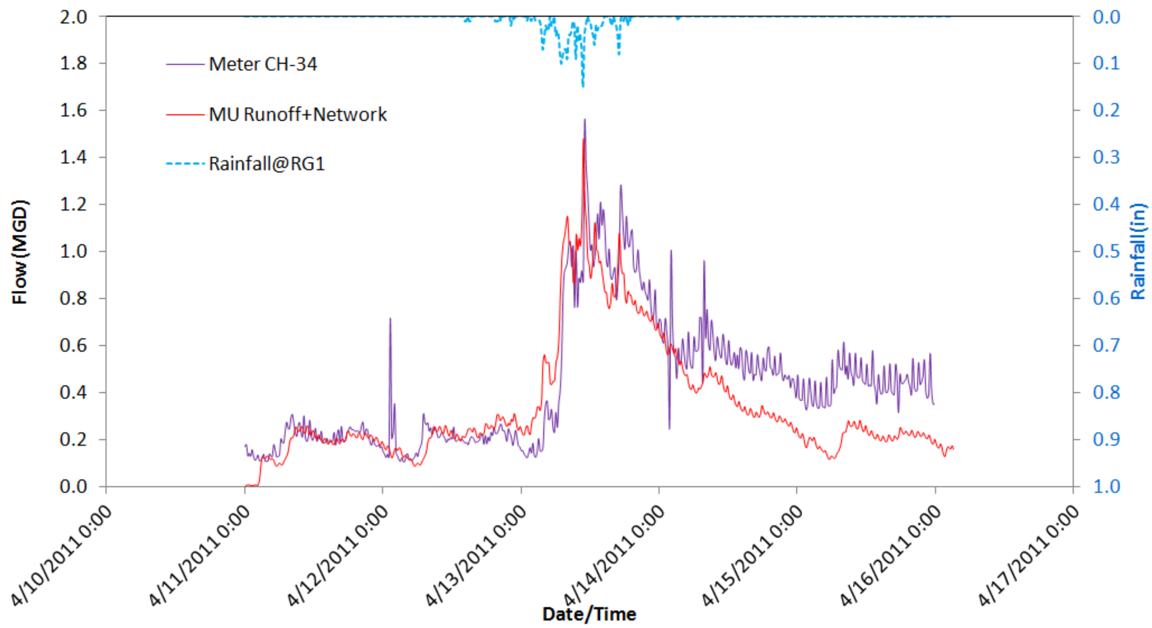


Figure C-16. Comparison between measured and modeled flow hydrographs at meters CH-07, and CH-37 in Catchment-11 during the period 04/11-16/2011.



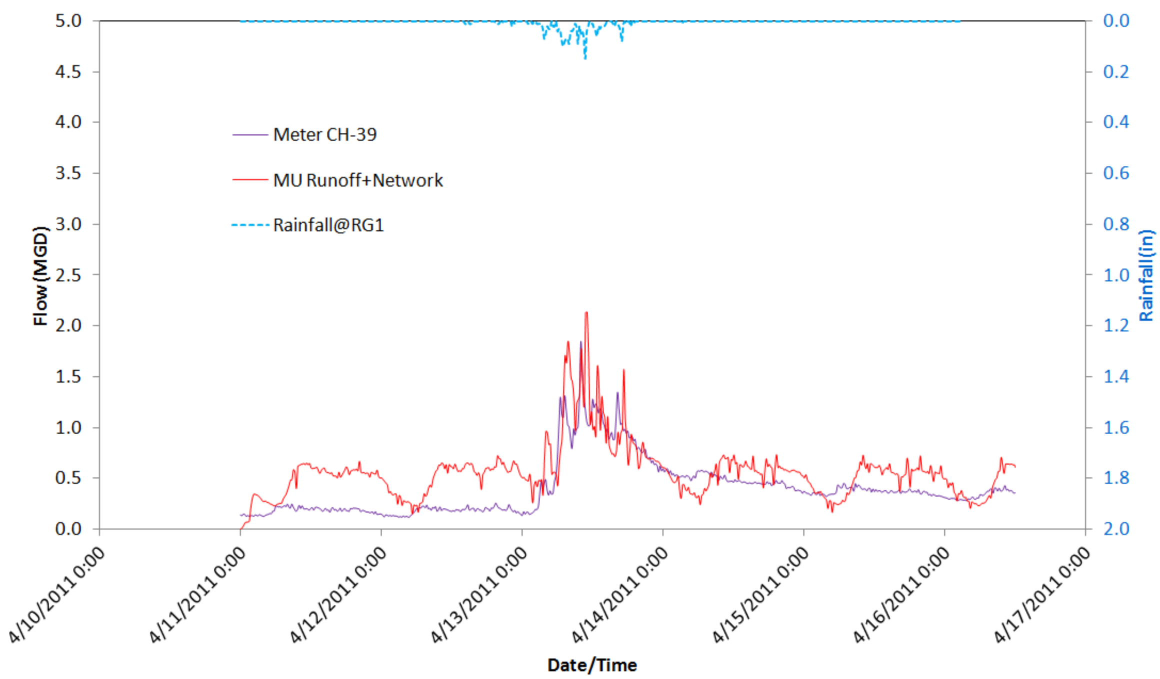
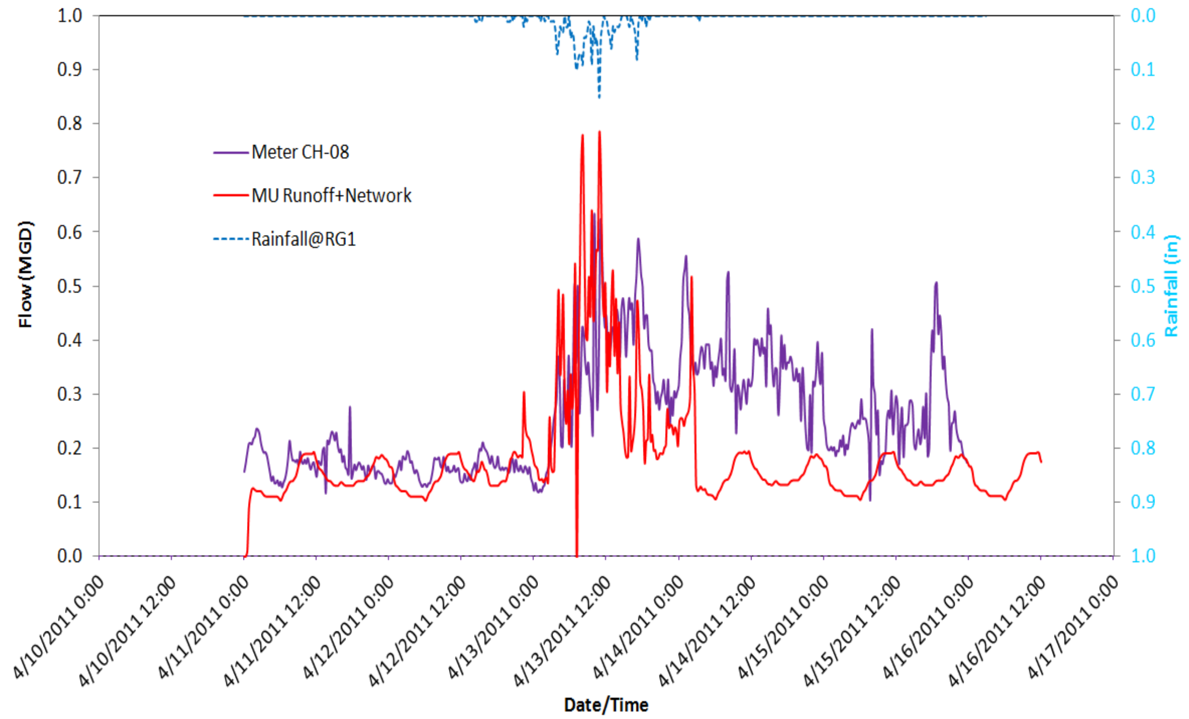


Figure C-17. Comparison between measured and modeled flow hydrographs at meters CH-34, and CH-39 in Catchment-12 during the period 04/11-16/2011.



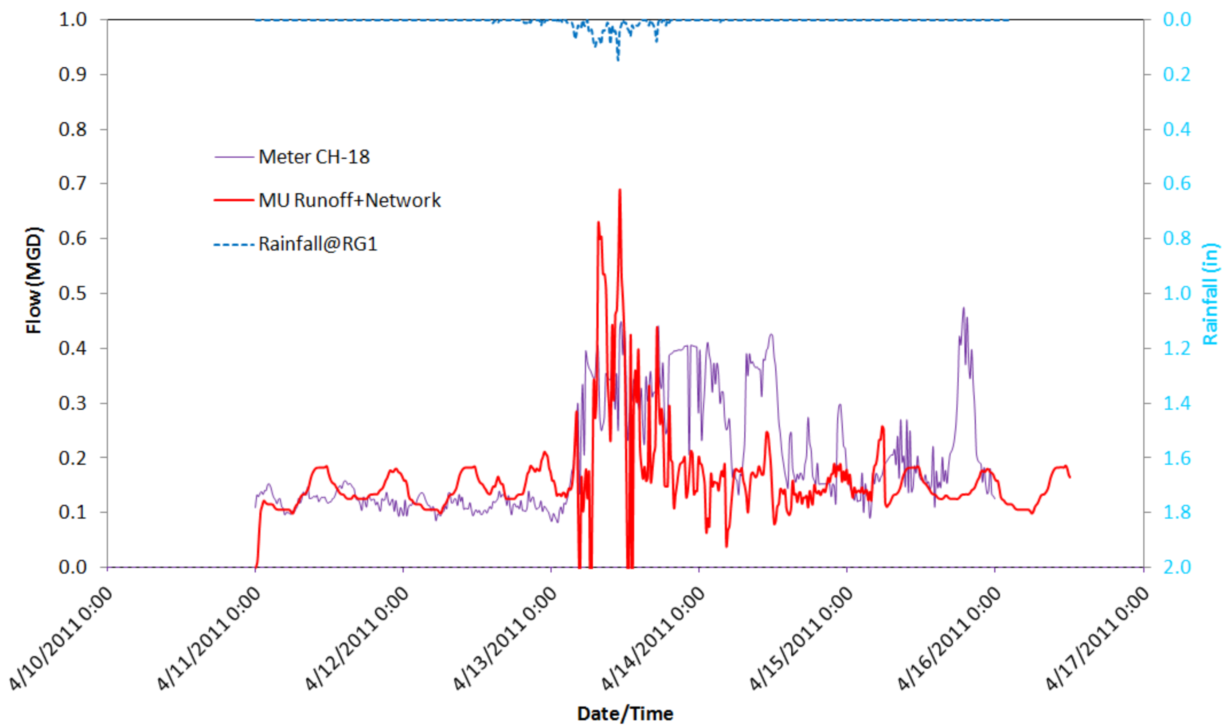


Figure C-18. Comparison between measured and modeled flow hydrographs at meters CH-08, and CH-18 in Catchment-13 during the period 04/11-16/2011.

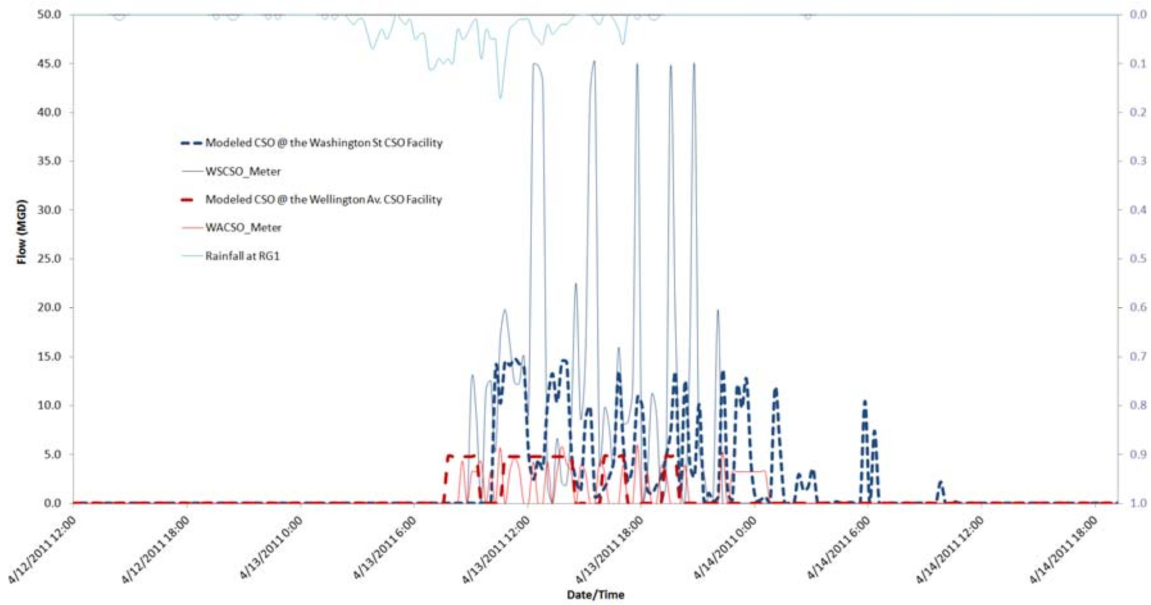


Figure C-19. Comparison between CSO SCADA Data and Modeled CSO Flow hydrographs at the two CSO Facilities during the Period 04/11-16/2011.

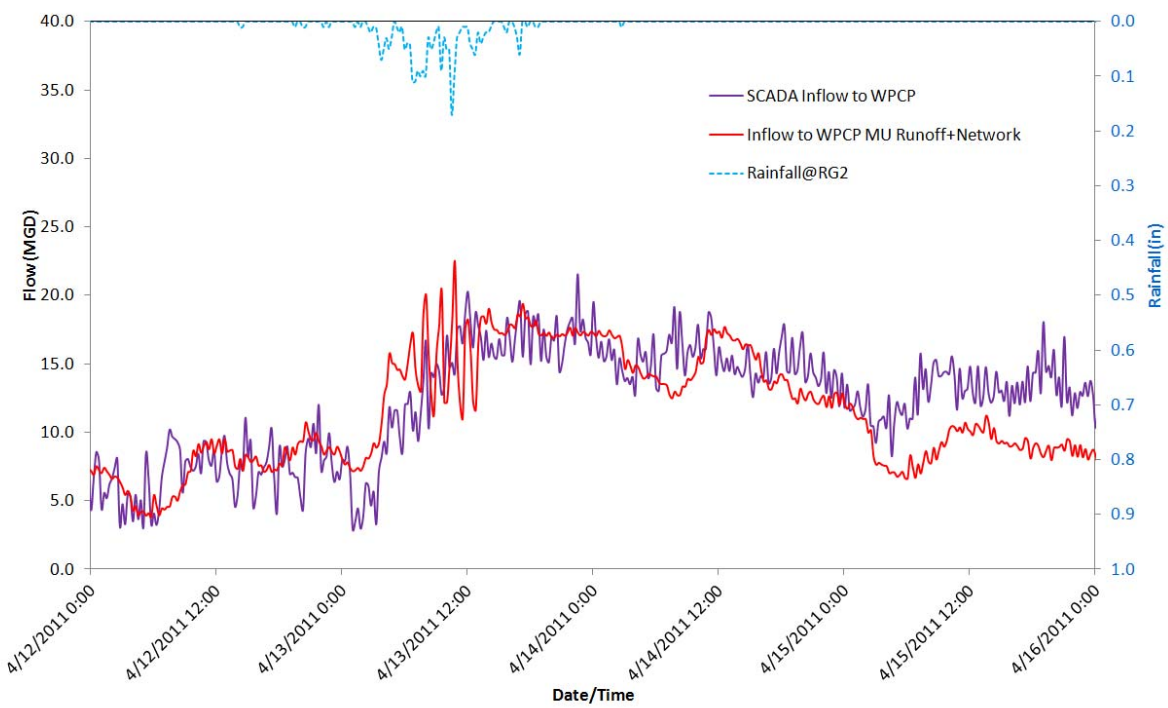


Figure C-20. Comparison between SCADA Data and Modeled Inflow Hydrographs at WPCP during the Period 04/11-16/2011.

Storm Event 08/13-18/2011

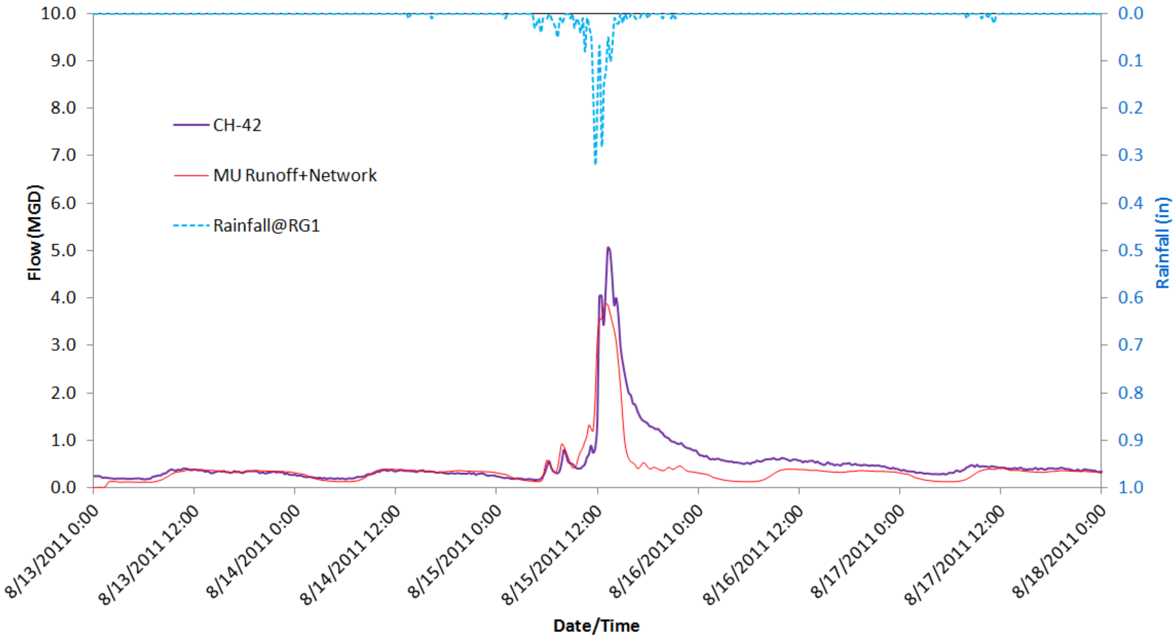


Figure C-21. Comparison between measured and modeled flow hydrographs at meter CH-42 in Catchment-6 during the period 08/13-18/2011.

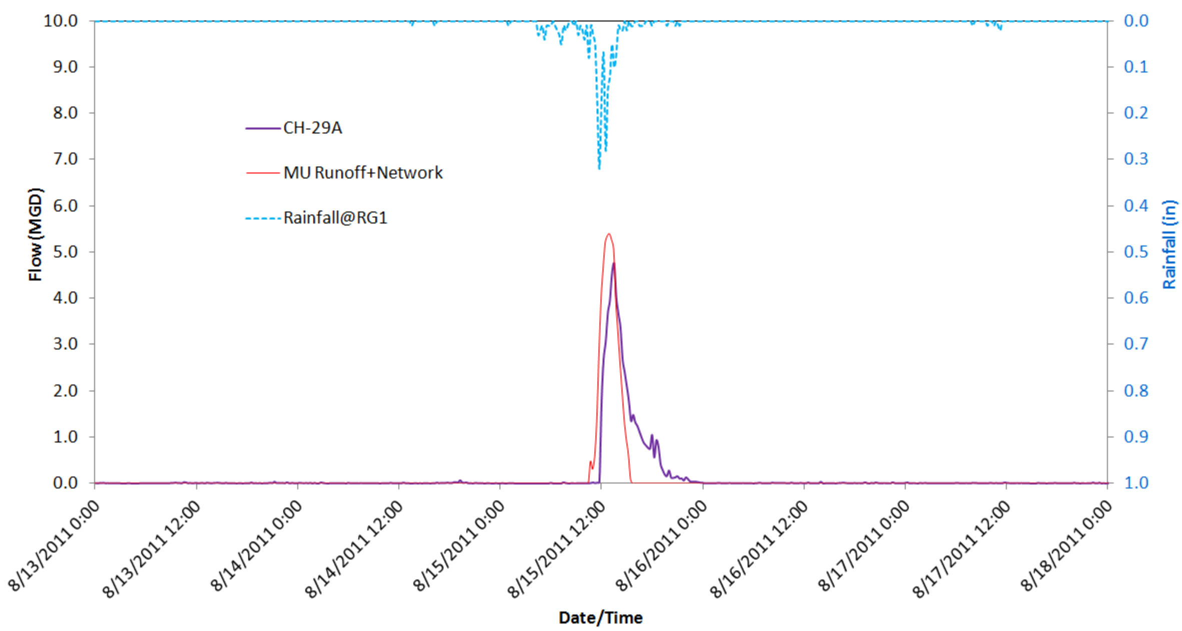


Figure C-22. Comparison between measured and modeled flow hydrographs at meter CH-29A in Catchment-04 during the period 08/13-18/2011.

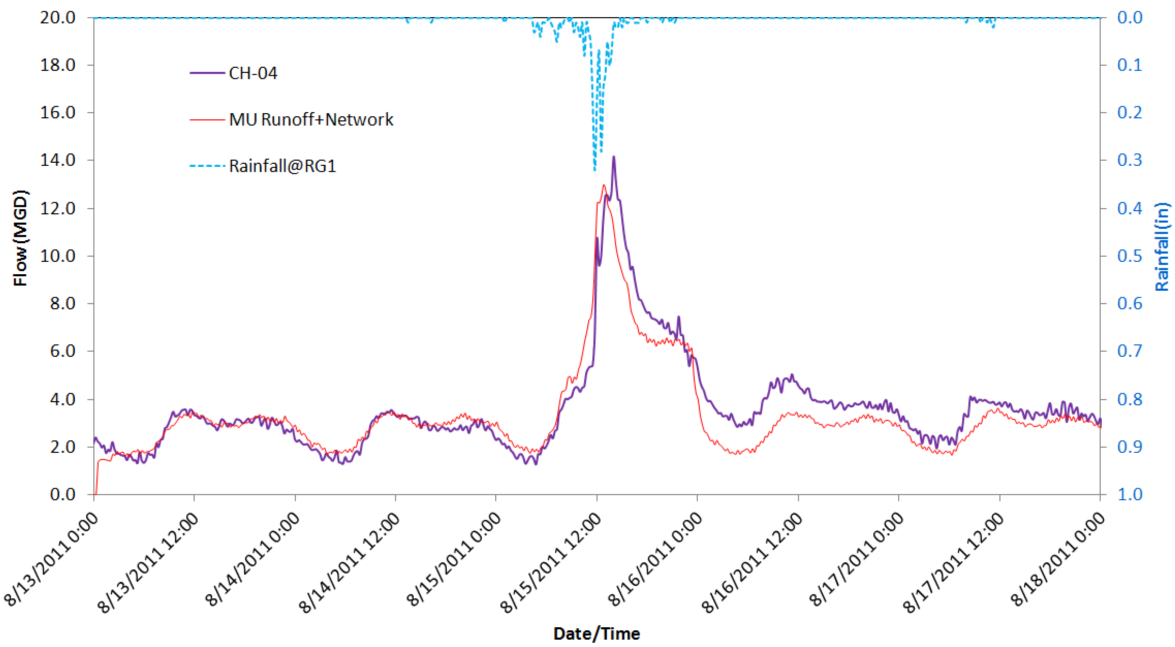


Figure C-23. Comparison between measured and modeled flow hydrographs at meter CH-04 in Catchment-06 during the period 08/13-18/2011.

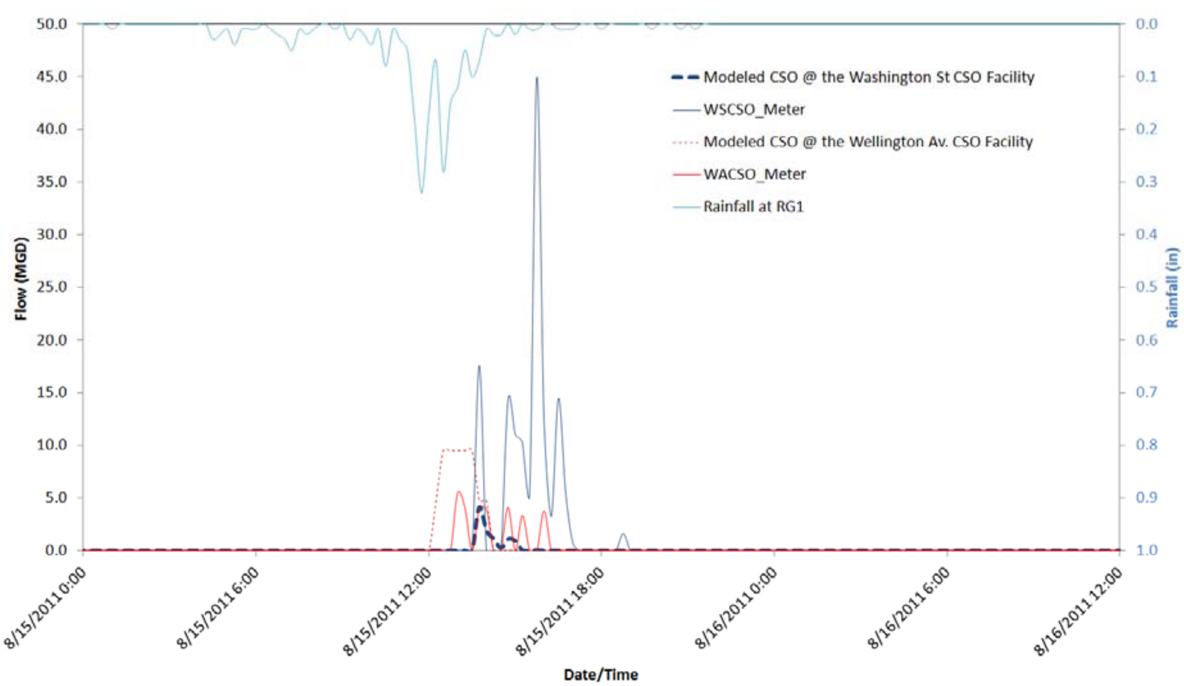


Figure C-24. Comparison between CSO SCADA Data and Modeled CSO Flow hydrographs at the two CSO Facilities during the Period 08/13-18/2011.

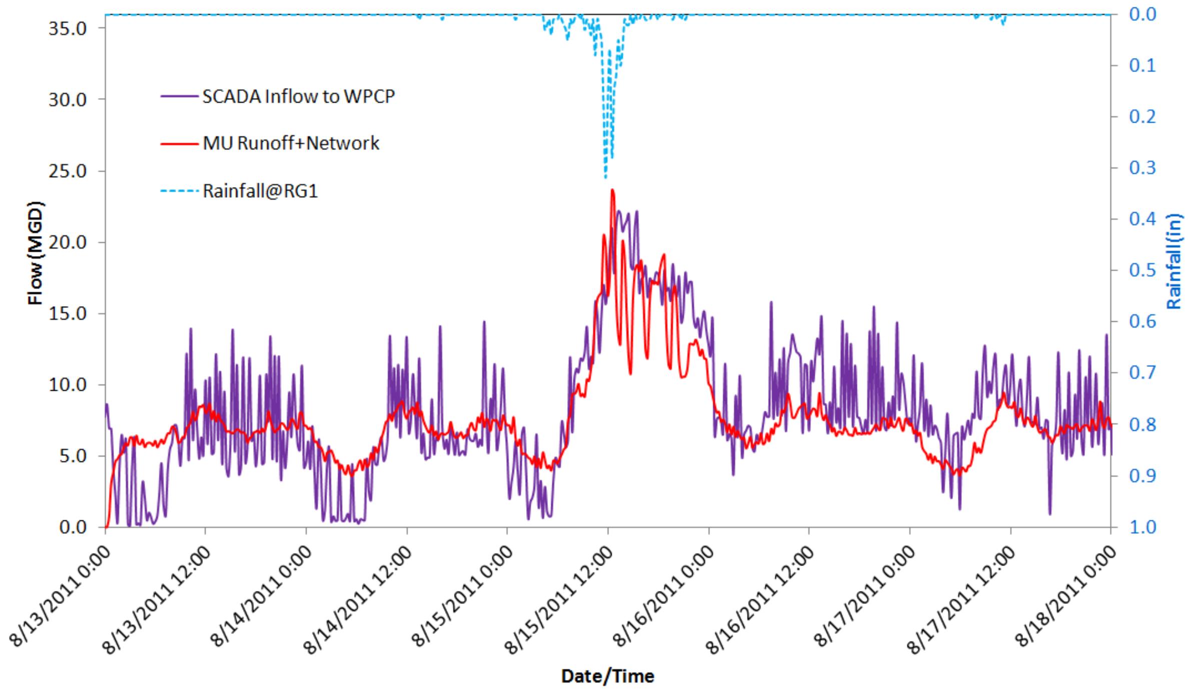


Figure C-25. Comparison between SCADA Data and Modeled Inflow Hydrographs at WPCP during the Period 08/13-18/2011.

Storm Event 10/18-23/2011

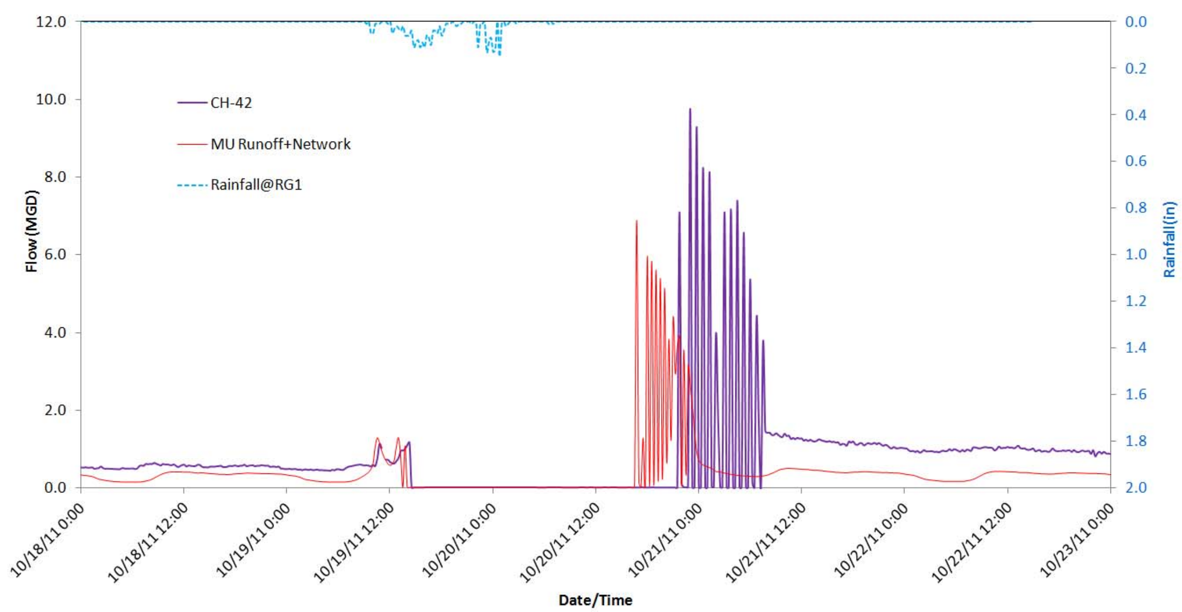


Figure C-26. Comparison between measured and modeled flow hydrographs at meter CH-42 in Catchment-6 during the period 10/18-23/2011.

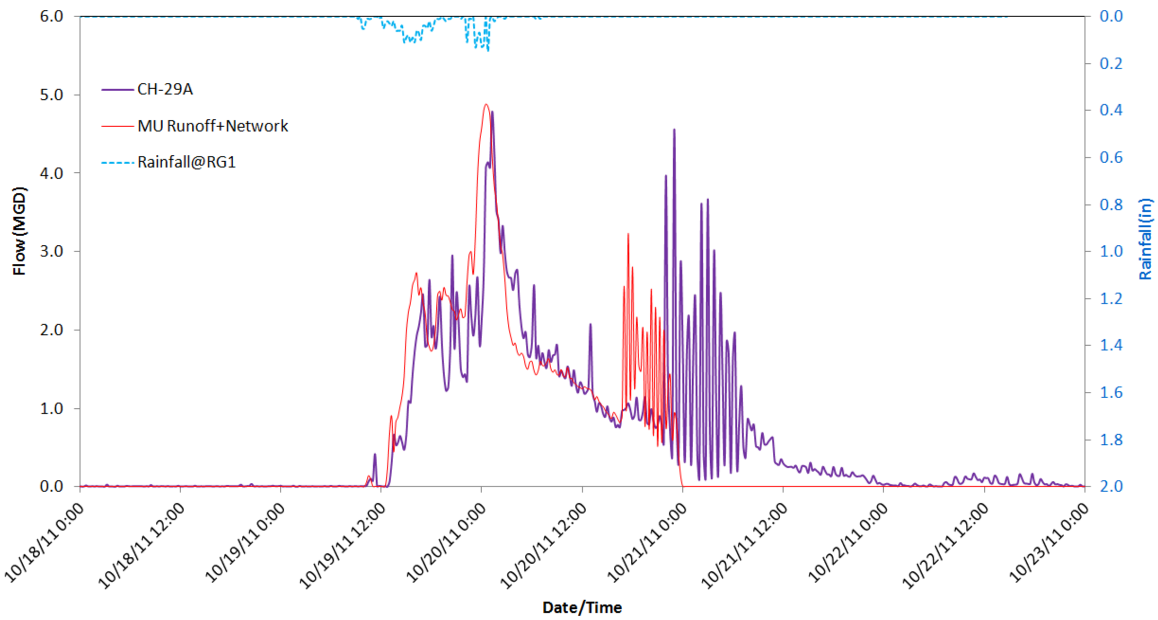


Figure C-27. Comparison between measured and modeled flow hydrographs at meter CH-29A in Catchment-04 during the period 10/18-23/2011.

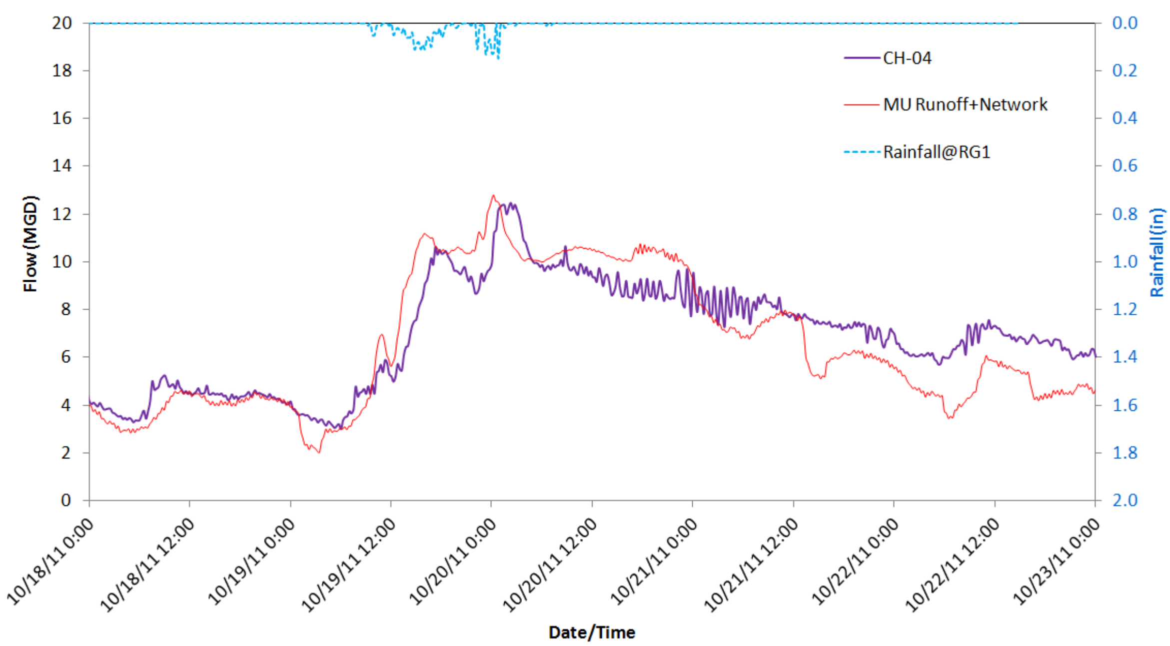


Figure C-28. Comparison between measured and modeled flow hydrographs at meter CH-04 in Catchment-06 during the period 10/18-23/2011.

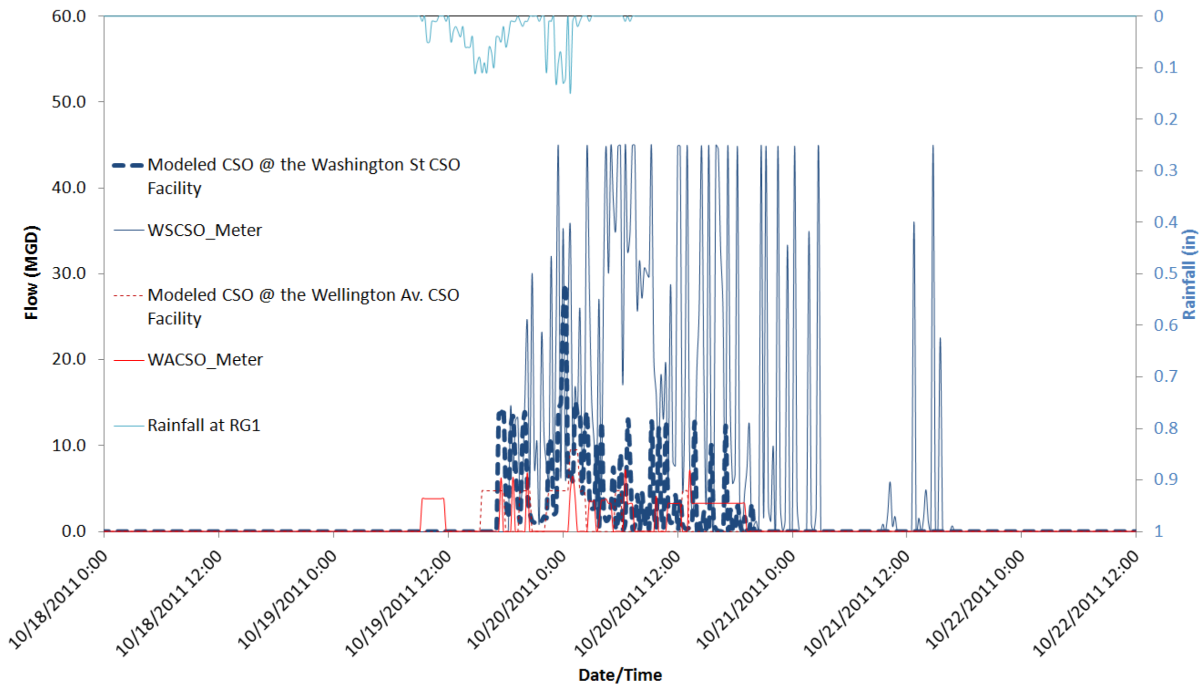


Figure C-29. Comparison between CSO SCADA Data and Modeled CSO Flow hydrographs at the two CSO Facilities during the Period 10/18-23/2011.

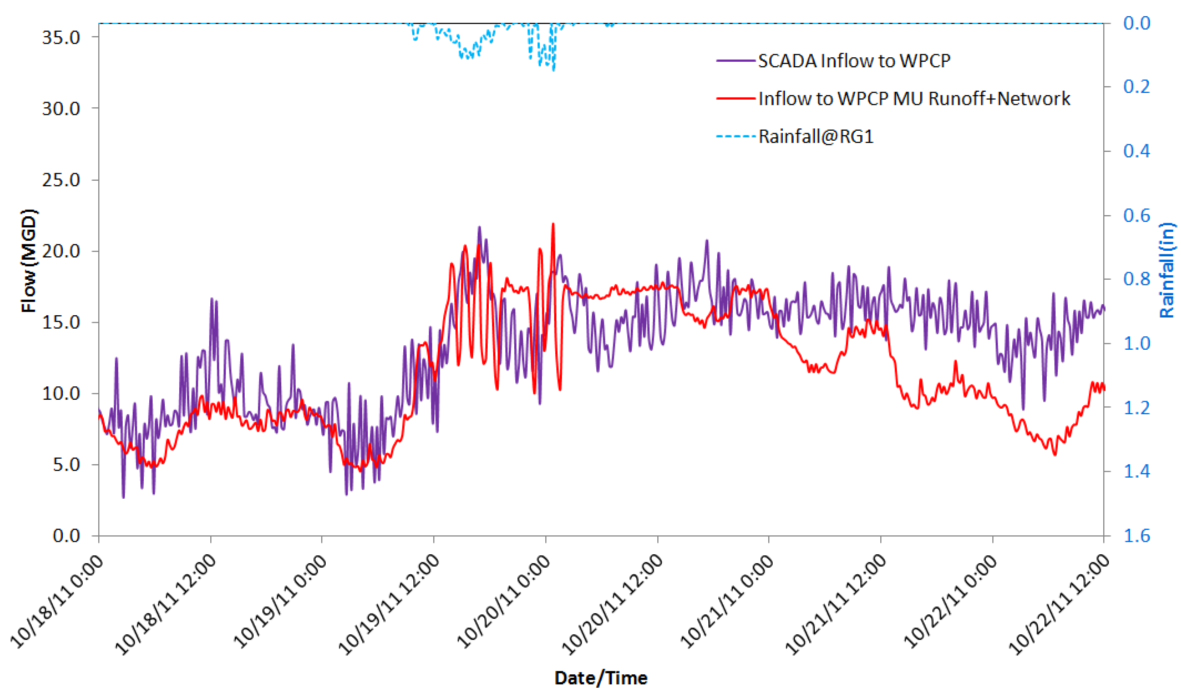


Figure C-30. Comparison between SCADA Data and Modeled Inflow Hydrographs at WPCP during the Period 10/18-23/2011.