COMPARISON OF ESTIMATED AND OBSERVED STORMWATER RUNOFF FOR FIFTEEN WATERSHEDS IN WEST-CENTRAL FLORIDA, USING FIVE COMMON DESIGN TECHNIQUES

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science for a changing world

calculate subsurface storage and flow.

Typical observed and simulated hydrographs for the South, Forked and Rock Creek watersheds are shown on figure 31. These watersheds are natural watersheds which are characterized by low slopes, large wetland areas and high water tables. Observed hydrographs in the 3 watersheds are similar in shape, characterized by flat peaks and long recession limbs. Simulated hydrographs do not match the observed hydrographs in either size or shape. Surface detention, subsurface storage and flow, and discharge from the surficial aquifer system to the stream influence the shape of the observed hydrographs in these watersheds.

The Army Corps of Engineers HEC-1 Model

The HEC-1 model calculates a peak discharge, runoff volume, and time to peak, and outputs a simulated flood hydrograph. Peak discharges were overestimated for 55 storms and underestimated 11 storms (table 7 and fig. 32). Runoff volumes were overestimated for 44 storms and underestimated for 22 storms but overestimates of peak discharge did not occur for many of the same storms as overestimates of runoff volumes.

The average errors between estimated and observed peak discharge rates and runoff volumes are smaller for the six urban watersheds than for the six natural watersheds. The average errors for peak discharges and runoff volumes for the urban watersheds of Arctic Street, Kirby Street, St. Louis Street, Gandy Boulevard, Allen Creek and Clower Creek were about 88 and 25 percent greater than observed peak discharge and runoff volumes. The average errors for the six natural watersheds were about 201 and 74 percent greater than observed peak discharges and runoff volumes. The average errors for the three watersheds with mixed characteristics were 98 percent greater than observed peak discharges and 43 percent greater than observed runoff volumes. The smallest estimation error for peak discharges was 2.5 percent greater than the observed peak discharge and was calculated for a storm occurring in the Grace Creek watershed. The largest error was 1,017 percent greater than the observed peak discharge and was calculated for a storm occurring in the CFI-3 watershed. The smallest and largest runoff volume errors were calculated for storms in the Gandy Boulevard and CFI-3 Creek watersheds. The error for runoff volume was 0.41 percent less than the observed runoff volume for a storm occurring in the Gandy Boulevard watershed and 1,020 percent greater than the observed runoff volume for a storm occurring in the CFI-3 Creek watershed (table 7).

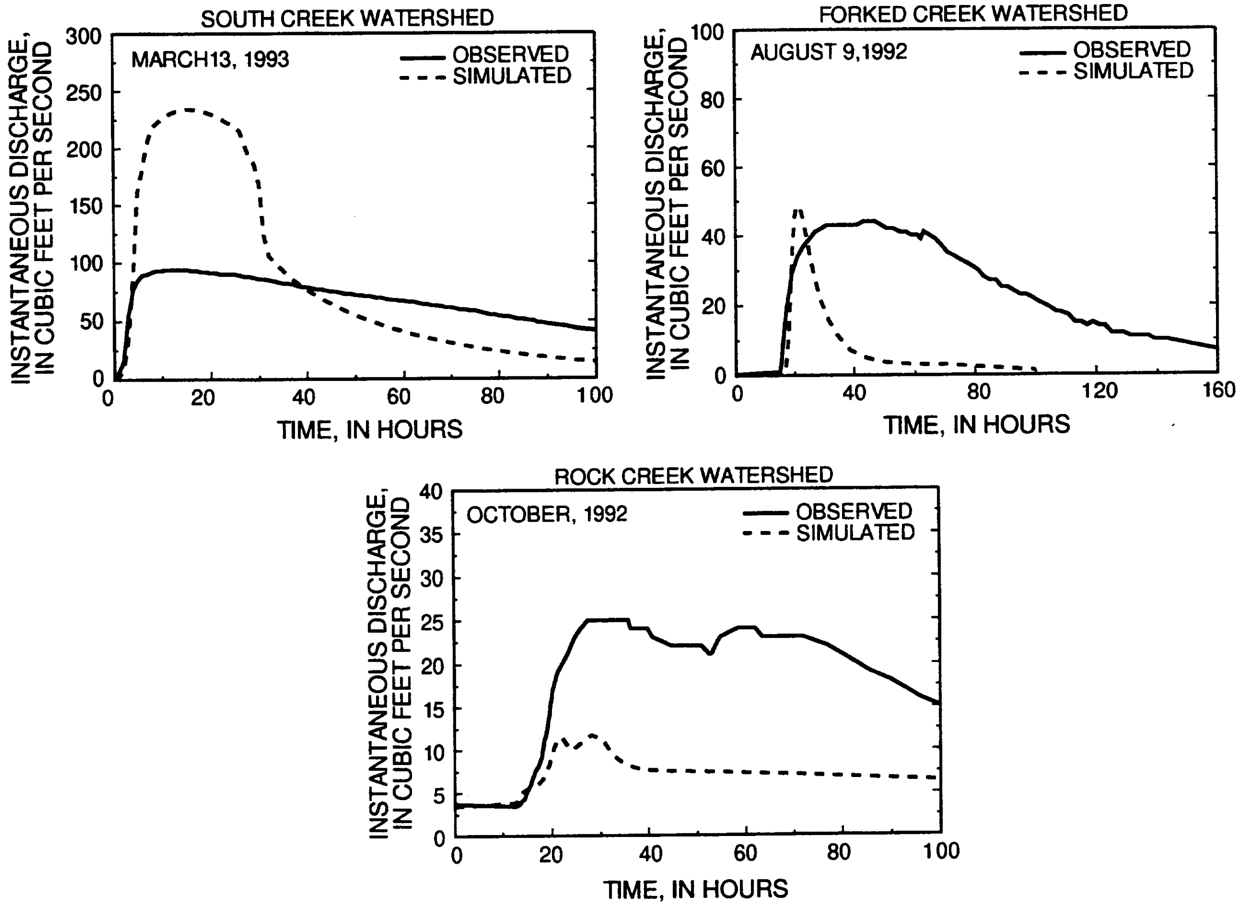

Figure 31. Typical observed hydrographs for storms occurring in the South, Forked, and Rock Creek watersheds and corresponding hydrographs simulated using the NRCS TR-20 model.

Table 7. Comparison of peak discharges and runoff volumes estimated using the U.S. Army Corps of Engineers HEC-1 model and observed peak discharges and runoff volumes

[cfs, cubic feet per second; in, inches; E, early; L, late; -, negative values represent underestimations; U, urban; N, natural; M, mixed]

Watershed name	Watershed classification	Peak discharge (cfs)				Runoff volume (in)				Date of storm
		Estimated	Observed	Error cfs	Error Percent	Estimated	Observed	Error Inches	Error Percent	
Arctic Street storm drain	U	154	120	34	28.3	1.06	0.76	0.30	39.5	08/03/76
		301	133	168	126	1.40	.97	.43	44.3	08/04/76
		147	137	10	7.30	.61	.58	.03	5.17	09/26/77
		339	142	197	139	1.86	1.30	.56	43.1	05/20/78
Kirby Street drainage ditch	U	77	57	20	35.1	.40	.30	.10	33.3	07/19/75
		218	95	123	129	1.19	.77	.42	54.5	08/30/75
		61	96	-35	-36.5	.27	.76	-.49	-64.5	08/15/78
St. Louis Street drainage ditch	U	303	357	-54	-15.1	2.10	.92	1.18	128	05/15/76
		167	226	-59	-26.1	1.00	.40	.60	150	06/18/76
		184	326	-142	-43.6	1.16	.45	.71	158	06/29/77
Gandy Boulevard drainage ditch	U	523	223	300	135	.67	.50	.17	34.0	06/18/75
		474	301	173	57.5	1.06	1.19	-.13	-10.9	07/11/75
		267	207	60	29.0	.39	.71	-.32	-45.1	08/07/75
		1407	692	715	103	2.45	2.46	-.01	-0.41	05/15/76
		737	410	327	79.8	.95	.87	.08	9.20	05/17/76
Allen Creek	U	764	341	423	124	.39	.69	-.30	-43.5	07/28/76
		897	379	518	137	.52	.60	.08	-13.3	07/01/77E
		1433	819	614	75.0	.99	1.64	-.65	-39.6	07/01/77L
		677	335	342	102	.41	.51	-.10	-19.6	07/03/77
		267	89	178	200	.23	.18	.05	27.8	12/02/77
		1280	286	994	348	.78	.71	.07	9.86	02/18/78
IMC Creek	N	2	11	-9	-81.8	.05	.66	-.61	-92.4	11/23/88
		52	5	47	940	.71	.17	.54	318	07/12/89
		16	4	12	300	.49	.36	.13	36.1	02/23/90
		24	9	15	167	.34	.47	-.13	-27.7	07/21/90
Grace Creek	N	101	59	42	71.2	.80	1.00	.20	20.0	08/07/88
		41	40	1	2.50	.28	.72	-.44	-61.1	08/23/88
		48	16	32	200	.34	.23	.11	47.8	07/12/90
		71	25	46	184	.92	.54	.38	70.4	07/14/90
CFI-3 Creek	N	10	19	-9	-47.4	.28	.44	-.16	-36.4	07/05/89
		34	7	27	386	.87	.29	.58	200	02/23/90
		67	6	61	1017	1.12	.10	1.02	1020	06/02/90
Walker Creek	M	2463	971	1492	154	12.80	6.89	5.91	85.8	June 92
		553	438	115	26.3	1.01	.91	.10	11.0	07/23/92

Table 7. Comparison of peak discharges and runoff volumes estimated using the U.S. Army Corps of Engineers HEC-1 model and observed peak discharges and runoff volumes

[cfs, cubic feet per second; in, inches; E, early; L, late; -, negative values represent underestimations; U, urban; N, natural; M, mixed] (Continued)

Watershed name	Watershed classification	Peak discharge (cfs) Estimated	Peak discharge (cfs) Observed	Peak discharge Error cfs	Peak discharge Error Percent	Runoff volume (in) Estimated	Runoff volume (in) Observed	Runoff volume Error Inches	Runoff volume Error Percent	Date of storm
		250	398	-148	-37.2	.49	.96	-.47	-49.0	08/07/92
		446	334	112	33.5	.89	.77	.12	15.6	09/04/92
		600	278	322	116	1.17	.41	.76	185	09/05/92
		336	199	137	68.8	.74	.56	.18	32.1	09/25/92
Walker Creek (cont.)		408	292	116	39.7	.75	.74	.01	1.35	09/26/92
		285	235	50	21.3	.72	.76	-.04	-5.26	01/15/93
		508	319	189	59.2	1.38	.94	.44	46.8	04/01/93
		459	237	222	93.7	.98	.46	.52	113	07/01/93
Clower Creek	U	136	77	59	76.6	1.63	1.45	.18	12.4	02/05/92
		309	205	104	50.7	17.19	17.08	.11	.64	June 92
		108	66	42	63.6	1.14	1.07	.07	6.54	09/02/92
		224	110	114	103	2.55	2.31	.24	10.4	09/13/92
		104	42	62	148	1.33	.67	.66	98.5	09/14/92
		155	60	95	158	1.96	1.37	.59	43.1	03/13/92
		268	116	152	131	3.90	2.90	1.00	34.5	04/01/92
Catfish Creek	M	200	70	130	186	.46	.21	.25	119	01/14/93
		197	76	121	159	.54	.25	.29	116	01/15/93
		354	140	214	153	.86	.49	.37	75.5	03/13/93
		837	300	537	179	2.34	1.41	.93	66.0	04/01/93
South Creek	N	1710	442	1268	287	12.75	4.30	8.45	197	June 92
		138	143	-5	-3.50	.04	.13	-.09	-69.2	09/06/92
		142	96	46	47.9	.23	.39	-.16	-41.0	09/13/92
		245	94	151	161	.93	.69	.24	34.8	03/13/32
		244	168	76	45.2	.84	1.27	-.43	-33.9	04/01/93
Forked Creek	N	1365	287	1078	376	13.19	8.54	4.65	54.4	June 92
		56	45	11	24.4	.26	.82	-.56	-68.3	08/09/92
Gottfied Creek	M	485	119	366	308	12.30	6. 70	5.60	83.6	June 92
		19	21	-2	-9.52	.08	.32	-.24	-75.0	08/11/92
		40	18	22	122	.42	.50	-.08	-16.0	October 92
Rock Creek	N	300	109	191	175	10.62	5.64	4.98	88.3	June 92
		22	24	-2	-8.33	.14	.24	-.10	-41.7	09/25/92
		18	25	-7	-28.0	.33	.78	-.45	-57.7	October 92

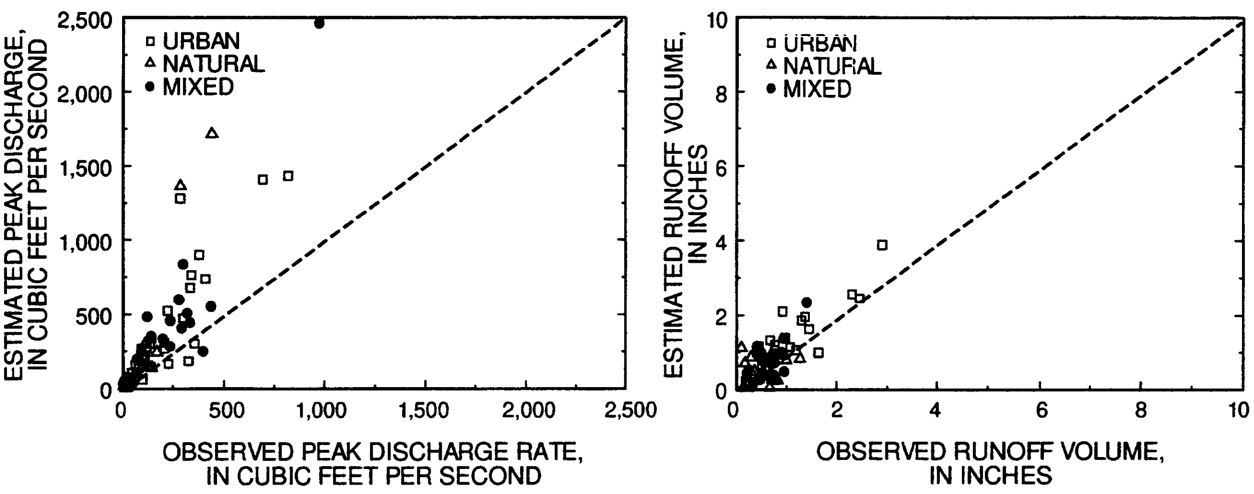

Figure 32. Comparison of the observed and estimated peak discharge rates and runoff volumes calculated using the U.S. Army Corps of Engineers HEC-1 model.

Errors between estimated and observed peak discharges and runoff volumes were compared to the average watershed curve number rather than to individual watershed characteristics because the NRCS curve number method was used to calculate runoff in this model. Comparisons indicate decreasing error in peak discharges and runoff volumes as the curve number increases (fig. 33).

Typical observed and simulated hydrographs for storms occurring in the Gandy Boulevard, and Clower Creek watersheds are shown on figure 34. Both watersheds are urban and drain through storm sewers. The model overestimated peak discharges for all storms in these watersheds. The initial rising limb of the simulated hydrographs matches the observed hydrographs in these watersheds, but the peak was overpredicted and the recession limbs are shorter than the recession limbs of the observed hydrographs. Predicted peak discharges occur about an hour after the observed peak discharges.

Simulated storm hydrographs for the remaining 4 urban watersheds did not match observed hydrographs (fig. 35). Observed hydrographs for the Arctic Street and Kirby Street watersheds respond quickly and peaked rapidly. Whereas the simulated hydrographs rose slower, overpredicted the peak, and peaked about 2 to 3 hours after the observed peak. The model consistently underestimated peak discharges and overestimated runoff volumes in the St. Louis Street watershed. The observed hydrographs had steep rising and falling limbs and short duration times indicating little or no surface- or ground-water storage occurs in this watershed; whereas the simulated hydrographs did not rise or fall as steeply and the duration time was about 3 times as long. Simulated peak discharges occurred about 2 hours after the observed peak. In the Allen Creek watershed, the model consistently overestimated peak discharges and predicted the peak to occur between 1 to 2 hours before the observed peaks.

Observed and simulated hydrographs for 3 different storm types that occurred in the Walker Creek watershed are shown in figure 36. The Walker Creek watershed has a mixture of natural and urban areas. The storms included a high intensity 4-day storm resulting from a local low pressure system (June, 1992), winter frontal storms (Jan 15, 1993), and high intensity, short duration summer thunderstorms (Sept 4, 1992).

The model overestimated the peak discharge and runoff volume for the 4-day storm by about 154 percent and 86 percent, respectively (table 7). Simulated peaks occurred about 3 hours after the observed peaks; however, the general shape of the simulated hydrograph matches the observed hydrograph, except the peaks are overpredicted. Runoff volume was overestimated by about 86 percent.

The estimated and observed peak discharge and runoff volume for the January 15, 1993 storm, a winter frontal storm, differed by 21.3 and 5.3 percent (table 7), respectively. The observed hydrograph

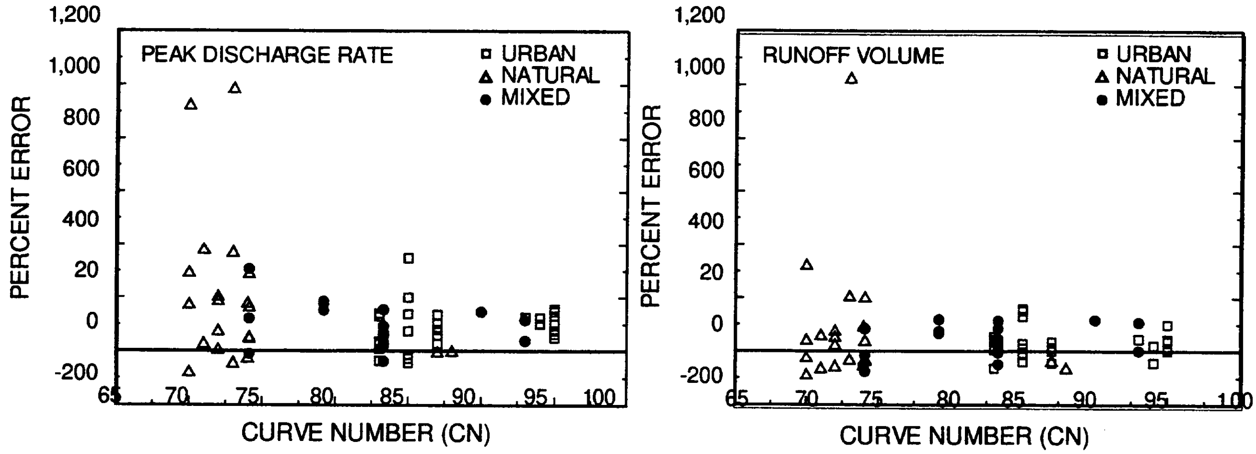

Figure 33. Comparison of the percent error between observed and estimated peak discharge rates and runoff volumes with the average curve number using the U.S. Army Corps of Engineers HEC-1 model.

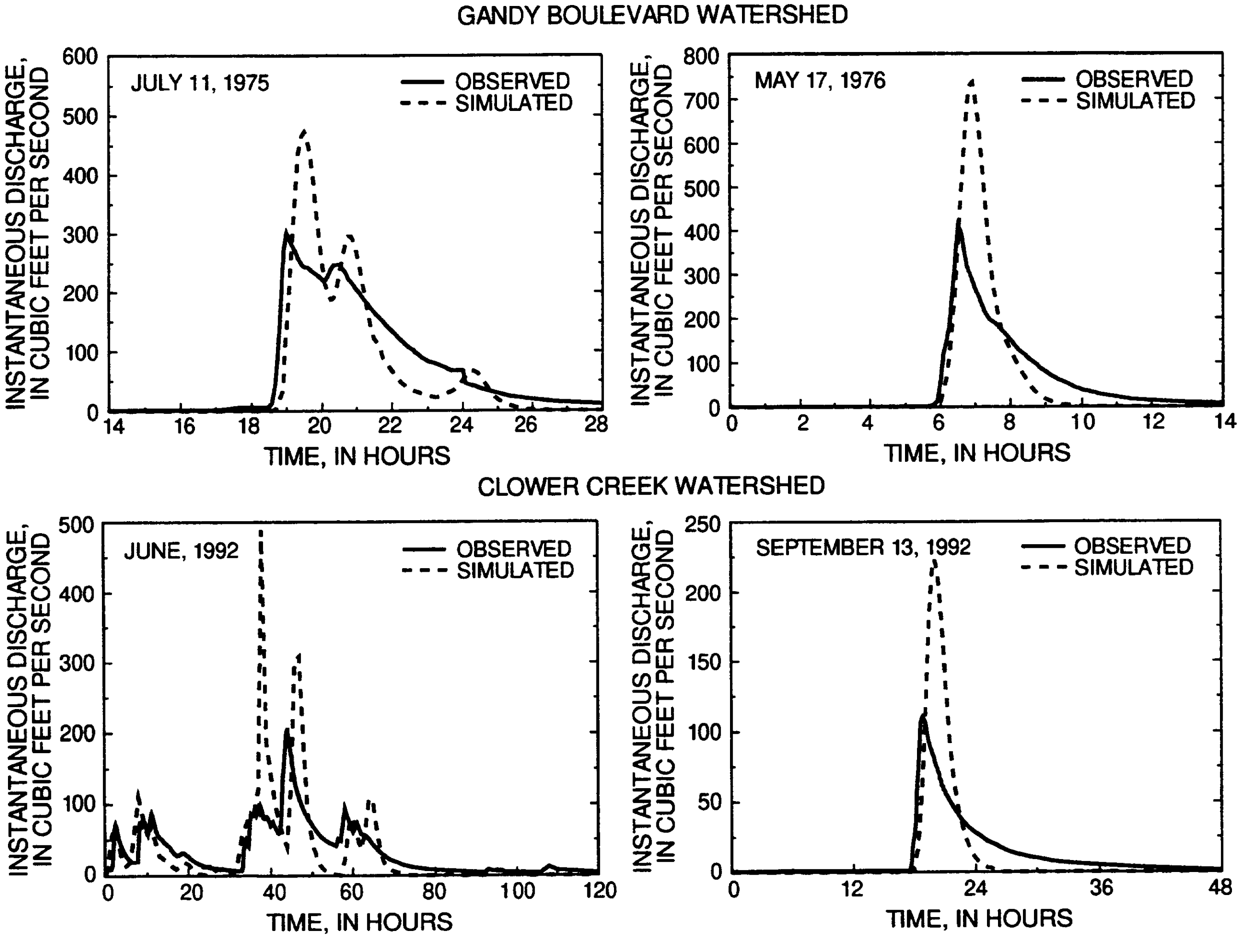

Figure 34. Typical observed hydrographs for storms occurring in the Gandy Boulevard and Clower Creek watersheds and corresponding hydrographs simulated using the U.S. Army Corps of Engineers HEC-1 model.

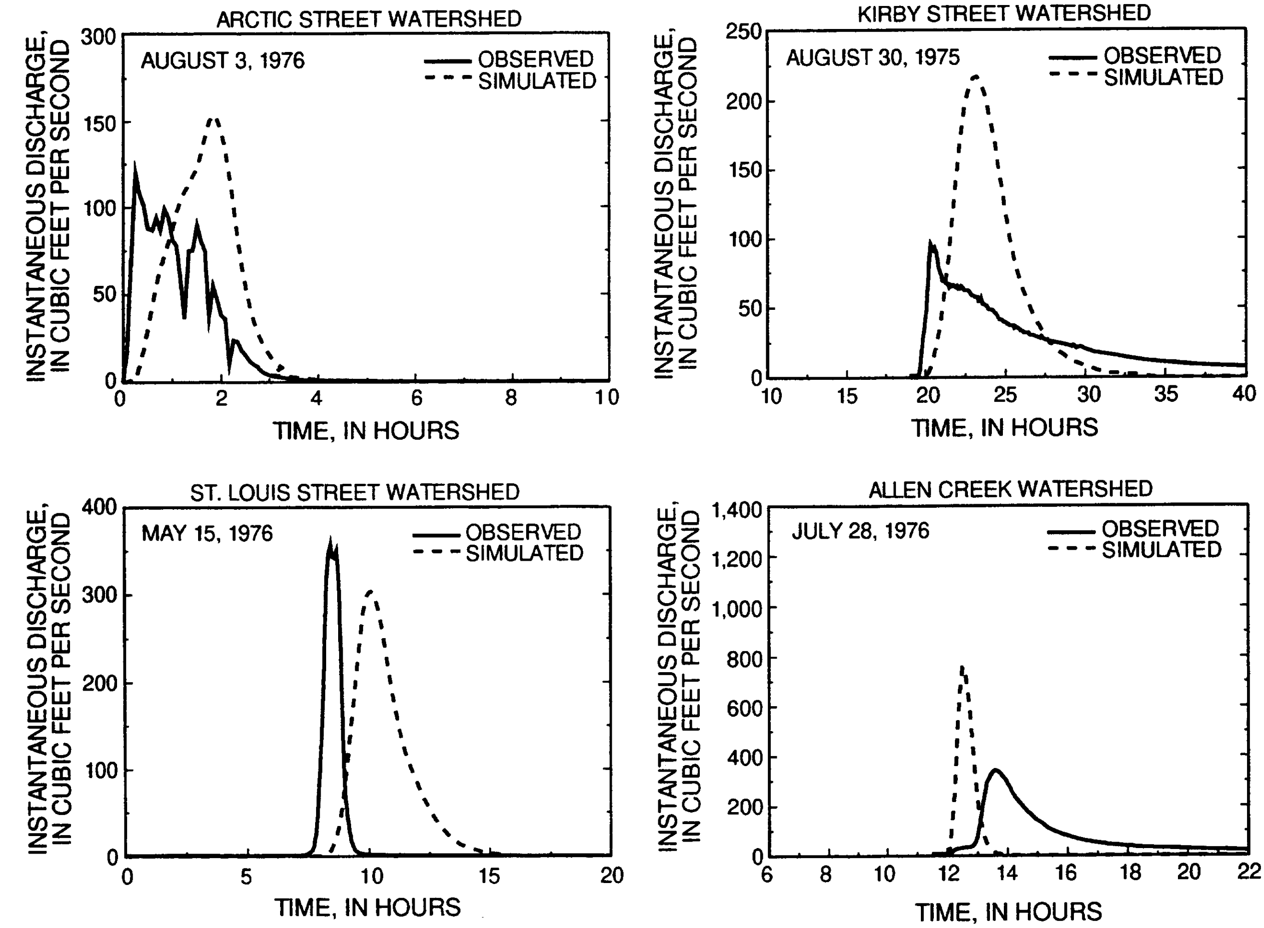

Figure 35. Typical observed hydrographs for storms occurring in the Arctic Street, Kirby Street, St. Louis Street, and Allen Creek watersheds and corresponding hydrographs simulated using the U.S. Army Corps of Engineers HEC-1 model.

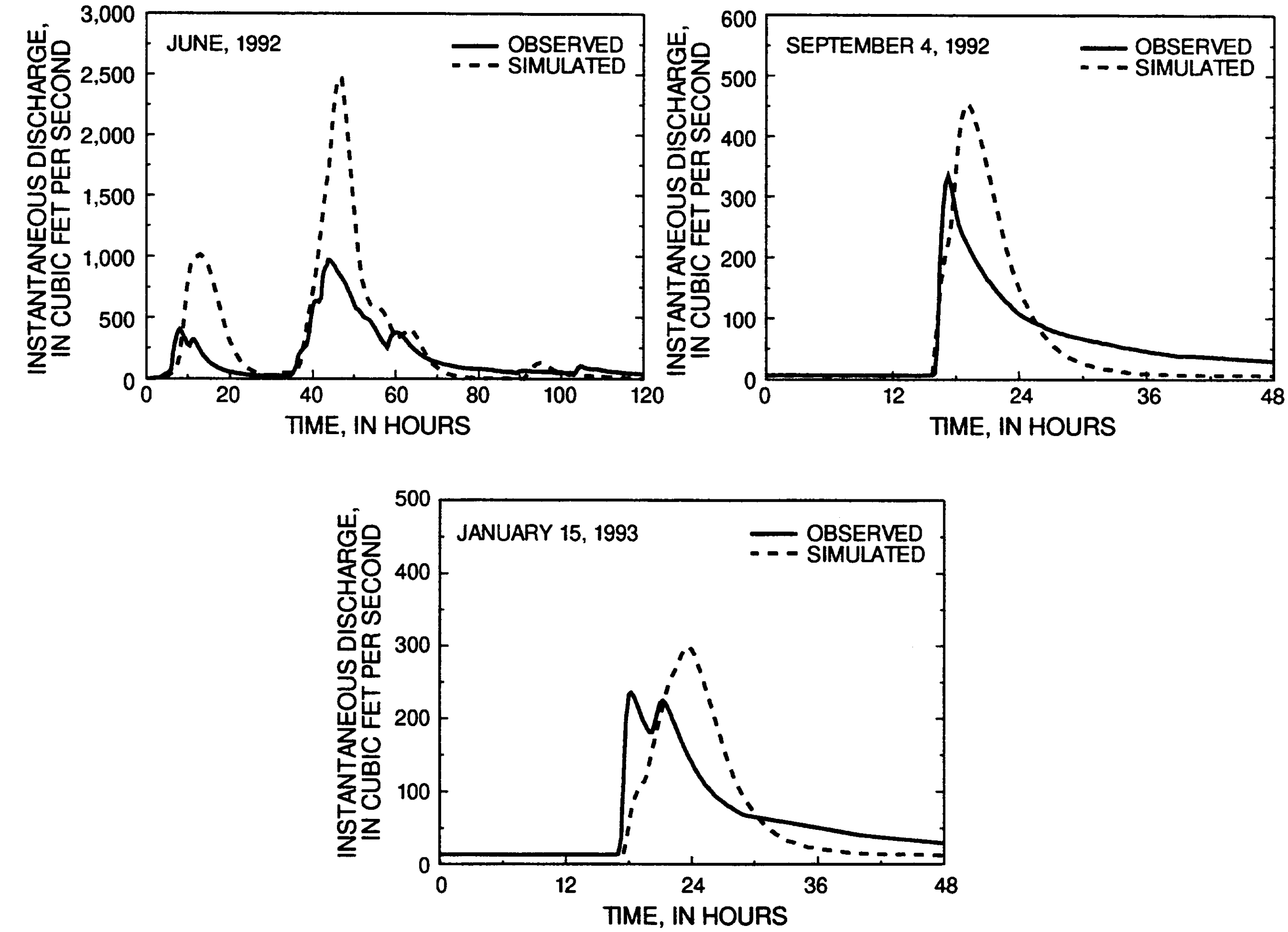

Figure 36. Typical observed hydrographs for storms occurring in the Walker Creek watershed and corresponding hydrographs simulated using the U.S. Army Corps of Engineers HEC-1 model.

had steeper rising and falling limbs and showed 2 distinct peaks corresponding to periods of heavier rainfall. The first observed peak occurred more than 5 hours before the model predicted a peak; the model also only predicted a single peak for the storm. A frontal storm that occurred on April 1, 1993 (not shown) produced a similar hydrograph. After the initial rapid decline, the later part of the recession limb of the observed hydrograph became flatter and remained higher than the simulated hydrograph, indicating a slower release of groundwater to the stream. The model, when applied to this watershed for frontal type storms, did not accurately match the observed storm hydrograph and does not appear to be sensitive to variable rainfall intensity.

The observed hydrographs for summer thunderstorms occurring in the Walker creek watershed had slightly steeper rising limbs than the simulated hydrographs. The recession limbs initially fell rapidly, than flattened and remained higher than the simulated hydrographs, indicating a ground water contribution to the stream. Peak discharges and runoff volumes were overestimated by about 34 and 16 percent, respectively and the predicted peaks occurred about 1.5 hours after observed peaks.

Typical observed and simulated hydrographs for the Catfish Creek and Gottfried Creek watersheds, also watersheds with mixed land use, are shown on figure 37. The model consistently overestimated the peak discharges and runoff volumes for the Catfish Creek watershed (table 7). The falling limb of the simulated hydrograph is steeper than the observed hydrograph and predicted peak discharges to occur between 1 to 2 hours after the observed peaks. There are numerous stormwater management practices in place in this watershed which include control structures and cultivation of aquatic plants in the stream channels. Such management practices slow streamflow and are probably the cause for the consistent overestimation of peak discharge and runoff volume by the model. The observed hydrograph for Gottfried Creek has a long time to peak and a long relatively flat recession limb. The simulated hydrograph peaks sooner, has a steep recession limb and has a peak discharge that is about twice the observed discharge. Low stream gradient, surface detention, subsurface storage and flow, aquatic weed growth and periodic tidal backwater conditions effect the shape of the storm hydrographs. The model predicted the peak to occur about 16 hours before the observed peak.

Typical observed and simulated hydrographs for storms occurring in the IMC, CFI-3, and Grace Creek watersheds, the three inland natural watersheds, are shown in figure 38. Simulated hydrographs for the these watersheds poorly match the observed hydrographs. The observed hydrographs have lower peaks and longer, flatter recession limbs, which indicates rainfall is being stored in the watershed, then released at a slower rate. Soil is permeable in these watersheds and there are no surface impoundments

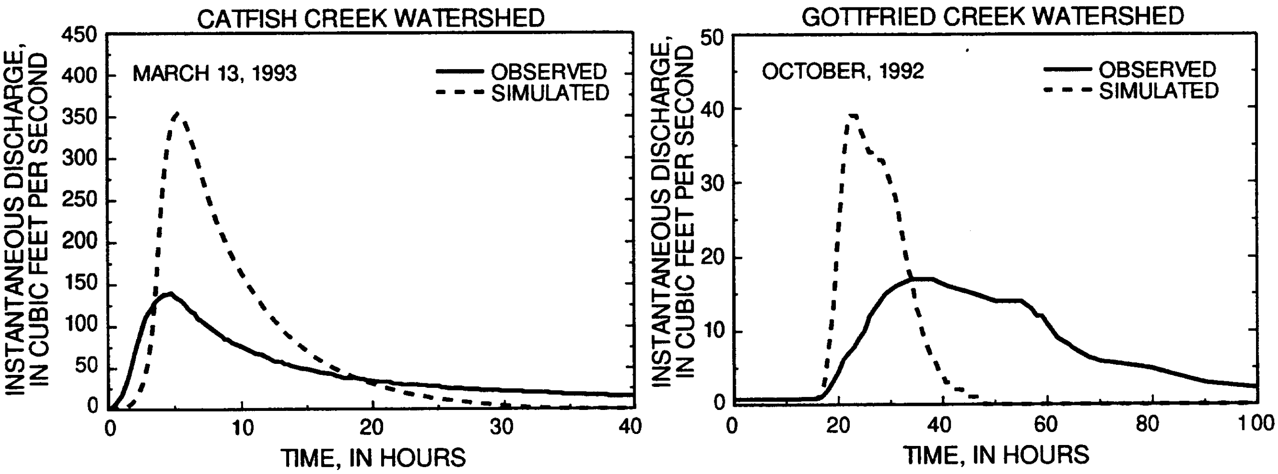

Figure 37. Typical observed hydrographs for storms occurring in the Catfish Creek and Gottfried Creek watershed and corresponding hydrographs simulated using the U.S. Army Corps of Engineers HEC-1 model.

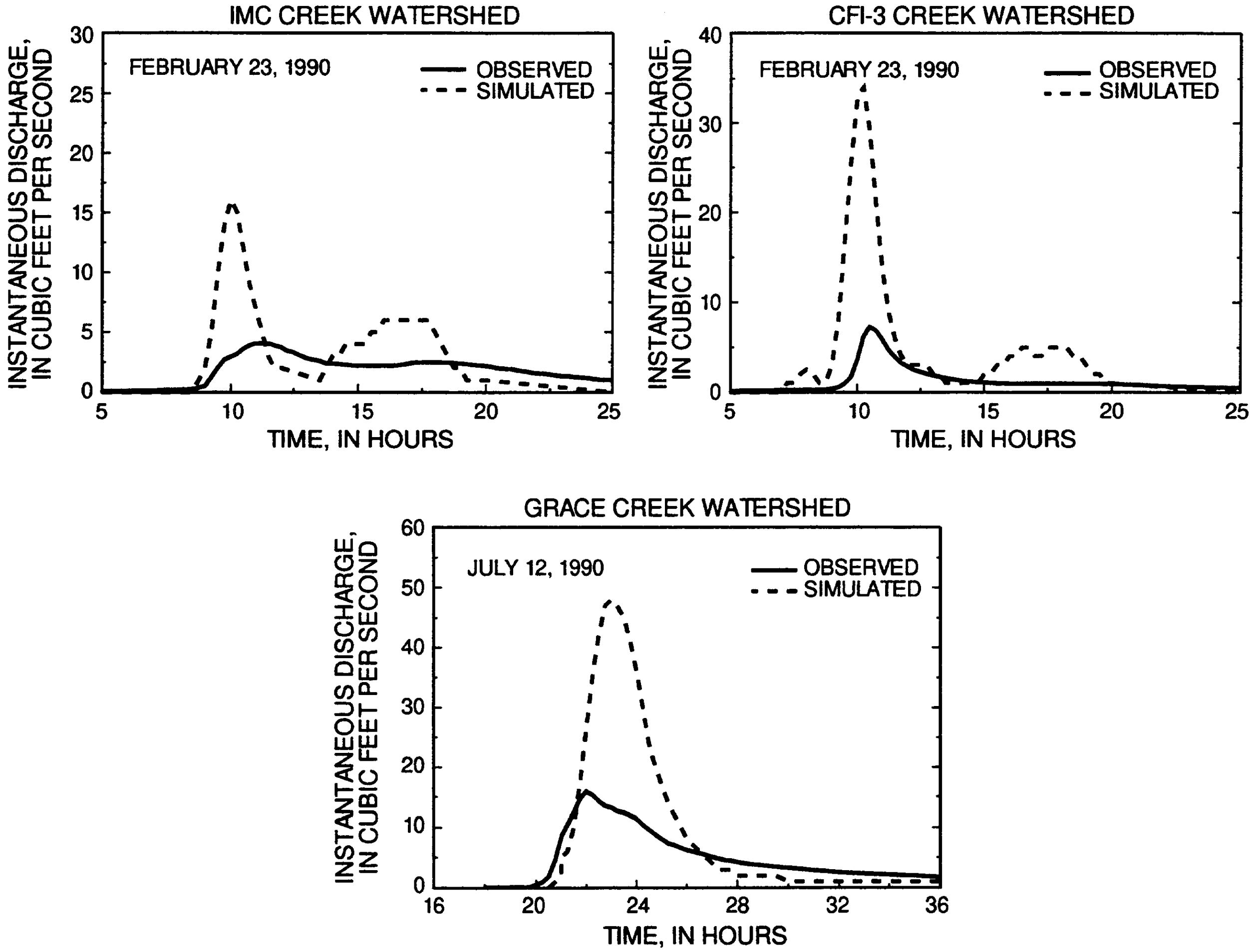

Figure 38. Typical observed hydrographs for storms occurring in the IMC, CFI-3, and Grace Creek watersheds and corresponding hydrographs simulated using the U.S. Army Corps of Engineers HEC-1 model.

or wetland areas. Attenuation of storm hydrographs is caused by storage in the permeable surficial deposits, subsurface flow, and gradual release of water from the surficial aquifer system to the stream.

Typical observed and simulated hydrographs for the South, Forked and Rock Creek watersheds are shown on figure 39. These watersheds are natural watersheds which are characterized by low slopes, large wetland areas and high water tables. Observed hydrographs in these 3 watersheds are similar in shape. Simulated hydrographs do not match the observed hydrographs in either size or shape. Peak discharges are overestimated in the South and Forked Creek watersheds and underestimated in the Rock Creek watershed. Simulated peak discharges occur before observed peak discharges. Surface detention, subsurface storage and flow, and discharge from the surficial aquifer system to the stream influence the shape of the observed hydrographs in these watersheds. The HEC-1 model does not calculate subsurface storage and flow.

The Environmental Protection Agency Storm Water Management Model

Uncalibrated model runs were used to simulate storm events. Selected input parameters for these model runs are listed in appendix II and III. Comparisons of estimated and observed peak discharges and runoff volumes, calculated with both the Green-Ampt and Horton infiltration methods (tables 8 and 9, figs. 40 and 41) show the similar results. Peak discharges for most storms were overestimated. Estimates of runoff volumes appear to better match measured runoff volumes. The model overestimated the peak discharge for 44 storms, underestimated the peak for 20 storms, and was the same for 2 storms, using the Green-Ampt method. When the Horton infiltration method was used, the model overestimated the peak discharge for 44 storms and underestimated the peak for 22 storms. Runoff volumes were overestimated for 22 storms, underestimated for 42 storms, and was the same for 2 storms, using the Green-Ampt infiltration method. When the Horton infiltration method was used, runoff volumes were overestimated for 25 storms, underestimated for 39 storms and was the same for 2 storms. Choice of the Green-Ampt or the Horton infiltration method did not greatly affect the estimates of peak discharges and runoff volumes, although the peaks and volumes calculated with the Horton method were slightly higher than those calculated with the Green-Ampt method.

When using the Green-Ampt infiltration method, the average error for the urban watersheds was 19 percent greater than observed peak discharges and 28 percent less than observed runoff volumes. The average error for the natural watersheds was about 105 percent greater than observed peak

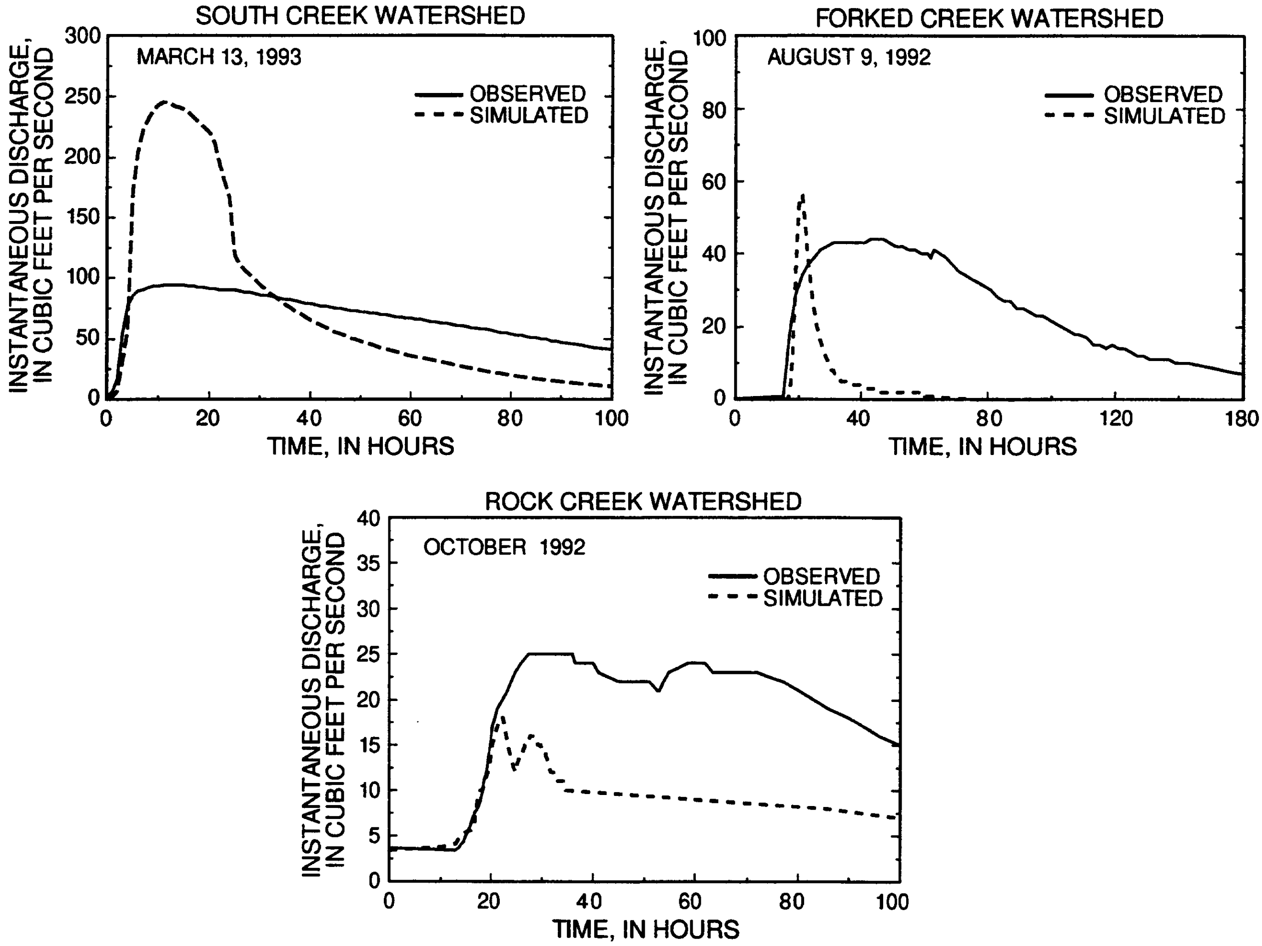

Figure 39. Typical observed hydrographs for storms occurring in the South, Forked, and Rock Creek watersheds and corresponding hydrographs simulated using the U.S. Army Corps of Engineers HEC-1 model.

Table 8. Comparison of peak discharges and runoff volumes estimated using the Environmental Protection Agency Storm Water Management model with the Green-Ampt infiltration method, and observed peak discharges and runoff volumes

[cfs, cubic feet per second; in, inches; E, early; L late; -, negative values represent underestimations; U, urban; N, natural; M, mixed]

		Peak discharge (cfs)				Runoff volume (in)				
				Error				Error		
Watershed name	Watershed classification	Estimated	Observed	cfs	Percent	Estimated	Observed	Inches	Percent	Date of storm
Arctic Street storm drain	U	121	120	1	0.83	1.01	0.76	0.25	32.9	08/03/76
		174	133	41	30.8	.84	.97	-.13	-13.4	08/04/76
		182	137	45	32.8	.73	.58	.15	25.9	09/26/77
		241	142	99	69.7	1.49	1.30	.19	14.6	05/20/78
Kirby Street drainage ditch	U	92	57	35	61.4	.15	.30	-.15	-50.0	07/19/75
		139	95	44	46.3	.33	.77	-.44	-57.1	08/30/75
		100	96	4	4.17	.13	.76	-.63	-82.9	08/15/78
St. Louis Street drainage ditch	U	128	357	-229	-64.1	.96	.92	.04	4.35	05/15/76
		117	226	-109	-48.2	.39	.40	-.01	-2.50	06/18/76
		76	326	-250	-76.7	.45	.45	0	0.00	06/29/77
Gandy Boulevard drainage ditch	U	251	223	28	12.6	.34	.50	-.16	-32.0	06/18/75
		285	301	-16	-5.32	.45	1.19	-.74	-62.2	07/11/75
		203	207	-4	-1.93	.25	.71	-.46	-64.8	08/07/75
		537	692	-155	-22.4	.98	2.46	-1.48	-60.2	05/15/76
		354	410	-56	-13.7	.43	.87	-.44	-50.6	05/17/76
Allen Creek	U	171	341	-170	-49.9	.16	.69	-.53	-76.8	07/28/76
		362	379	-17	-4.49	.32	.60	-.28	-46.7	07/01/77E
		475	819	-344	-42.0	.52	1.64	-1.12	-68.3	07/01/77L
		156	335	-179	-53.4	.17	.51	-.34	-66.7	07/03/77
		125	89	36	40.4	.21	.18	.03	16.7	12/02/77
		374	286	88	30.8	.40	.71	-.31	-43.7	02/18/78
IMC Creek	N	2	11	-9	-81.8	.03	.66	-.63	-95.5	11/23/88
		29	5	24	480	.39	.17	.22	129	07/12/89
		4	4	0	0.00	.06	.36	-.30	-83.3	02/23/90
		13	9	4	44.4	.13	.47	-.34	-72.3	07/21/90
Grace Creek	N	111	59	52	88.1	.55	1.00	-.45	-45.0	08/07/88
		40	40	0	.0	.16	.72	-.56	-77.8	08/23/88
		51	16	35	219	.14	.23	-.09	-39.1	07/12/90
		31	25	6	24.0	.42	.54	-.12	-22.2	07/14/90
CFI-3 Creek	N	0.1	19	-18.9	-99.5	.01	.44	-.43	-97.7	07/05/89
		10	7	3	42.9	.12	.29	-.17	-58.6	02/23/90
		52	6	46	767	.86	.10	.76	760	06/02/90
Walker Creek	M	1650	971	679	69.9	9.57	6.89	2.68	38.9	June 92
		1270	438	832	190	.90	.91	-.01	-1.10	07/23/92

Table 8. Comparison of peak discharges and runoff volumes estimated using the Environmental Protection Agency Storm Water Management model with the Green-Ampt infiltration method, and observed peak discharges and runoff volumes

[cfs, cubic feet per second; in, inches; E, early; L late; -, negative values represent underestimations; U, urban; N, natural; M, mixed] (Continued)

		Peak discharge (cfs)				Runoff volume (in)				
				Error				Error		
Watershed name	Watershed classification	Estimated	Observed	cfs	Percent	Estimated	Observed	Inches	Percent	Date of storm
		649	398	251	63.1	.59	.96	-.37	-38.5	08/07/92
		970	334	636	190	.80	.77	.03	3.90	09/04/92
		783	278	505	182	.63	.41	.22	53.7	09/05/92
		533	199	334	168	.65	.56	.09	16.1	09/25/92
Walker Creek (cont.)		496	292	204	69.9	.47	.74	-.27	-36.5	09/26/92
		420	235	185	78.7	.70	.76	-.06	-7.89	01/15/93
		729	319	410	129	.94	.94	0	0.00	04/01/93
		664	237	427	180	.84	.46	.38	82.6	07/01/93
Clower Creek	U	99	77	22	28.6	.94	1.45	-.51	-35.2	02/05/92
		463	205	258	126	15.30	17.08	-1.78	-10.4	June 92
		89	66	23	34.8	.68	1.07	-.39	-36.4	09/02/92
		227	110	117	106	1.84	2.31	-.47	-20.3	09/13/92
		75	42	33	78.6	.75	.67	.08	11.9	09/14/92
		105	60	45	75.0	1.26	1.37	-.11	-8.03	03/13/92
		294	116	178	153	3.15	2.90	.25	8.62	04/01/92
Catfish Creek	M	79	70	9	12.9	.18	.21	-.03	-14.3	01/14/93
		55	76	-21	-27.6	.13	.25	-.12	-48.0	01/15/93
		137	140	-3	-2.14	.34	.49	-.15	-30.6	03/13/93
		300	300	0	0.00	1.03	1.41	-.38	-27.0	04/01/93
South Creek	N	651	442	209	47.3	9.29	4.30	4.99	116	June 92
		154	143	11	7.69	.16	.13	.03	23.1	09/06/92
		132	96	36	37.5	.30	.39	-.09	-23.1	09/13/92
		207	94	113	120	.76	.69	.07	10.1	03/13/32
		193	168	25	14.9	.68	1.27	-.59	-46.5	04/01/93
Forked Creek	N	263	287	-24	-8.36	8.84	8.54	.34	3.51	June 92
		39	45	-6	-13.3	1.29	.82	.47	57.3	08/09/92
Gottfied Creek	M	244	119	125	105	11.70	6.70	5.00	74.6	June 92
		23	21	2	9.50	.15	.32	-.17	-53.1	08/11/92
		17	18	-1	-5.60	.29	.50	-.21	-42.0	October 92
Rock Creek	N	272	109	163	150	12.50	5.64	6.86	122	June 92
		17	24	-7	-29.2	.10	.24	-.14	-58.3	09/25/92
		12	25	-13	-52.0	.37	.78	-.41	-52.6	October 92

Table 9. Comparison of peak discharges and runoff volumes estimated using the Environmental Protection Agency Storm Water Management model with the Horton infiltration method, and observed peak discharges and runoff volumes

[cfs, cubic feet per second; in, inches; E, early; L, late; -, negative values represent underestimations; U, urban; N, natural; M, mixed]

Watershed name	Watershed classification	Peak discharge (cfs)				Runoff volume (in)				Date of storm
		Estimated	Observed	Error		Estimated	Observed	Error		
				cfs	Percent			Inches	Percent	
Arctic Street storm drain	U	124	120	4	3.33	1.06	0.76	0.30	39.5	08/03/76
		174	133	41	30.8	.87	.97	-.10	-10.3	08/04/76
		182	137	45	32.8	.74	.58	.16	27.6	09/26/77
		244	142	102	71.8	1.61	1.30	.31	23.8	05/20/78
Kirby Street drainage ditch	U	92	57	35	61.4	.17	.30	-.13	-43.3	07/19/75
		142	95	47	49.5	.42	.77	-.35	-45.5	08/30/75
		99	96	3	3.13	.14	.76	-.62	-81.6	08/15/78
St. Louis Street drainage ditch	U	144	357	-213	-59.7	1.59	.92	.67	72.8	05/15/76
		125	226	-101	-44.7	.76	.40	.36	90.0	06/18/76
		86	326	-240	-73.6	.88	.45	.43	95.6	06/29/77
Gandy Boulevard drainage ditch	U	256	223	33	14.8	.41	.50	-.09	-18.0	06/18/75
		289	301	-12	-3.99	.57	1.19	-.62	-52.1	07/11/75
		208	207	1	.48	.28	.71	-.43	-60.6	08/07/75
		544	692	-148	-21.4	1.22	2.46	-1.24	-50.4	05/15/76
		361	410	-49	-12.0	.55	.87	-.32	-36.8	05/17/76
Allen Creek	U	176	341	-165	-48.4	.18	.69	-.51	-73.9	07/28/76
		370	379	-9	-2.37	.39	.60	-.21	-35.0	07/01/77E
		488	819	-331	-40.4	.69	1.64	-.95	-57.9	07/01/77L
		161	335	-174	-51.9	.18	.51	-.33	-64.7	07/03/77
		127	89	38	42.7	.21	.18	.03	16.7	12/02/77
		374	286	88	30.8	.44	.71	-.27	-38.0	02/18/78
IMC Creek	N	3	11	-8	-72.7	.05	.66	-.61	-92.4	11/23/88
		33	5	28	560	.60	.17	.43	253	07/12/89
		3	4	-1	-25.0	.06	.36	-.30	-83.3	02/23/90
		16	9	7	77.8	.23	.47	-.24	-51.1	07/21/90
Grace Creek	N	125	59	66	112	.67	1.00	-.33	-33.0	08/07/88
		42	40	2	5.00	.57	.72	-.15	-20.8	08/23/88
		62	16	46	288	.23	.23	.00	0.00	07/12/90
		29	25	4	16.0	.41	.54	-.13	-24.1	07/14/90
CFI-3 Creek	N	10	19	-9	-47.4	.05	.44	-.39	-88.6	07/05/89
		5	7	-2	-28.6	.05	.29	-.24	-82.8	02/23/90
		57	6	51	850	1.16	.10	1.06	1060	06/02/90
Walker Creek	M	1650	971	679	69.9	9.60	6.89	2.71	39.3	June 92
		1270	438	832	190	.92	.91	.01	1.10	07/23/92

Table 9. Comparison of peak discharges and runoff volumes estimated using the Environmental Protection Agency Storm Water Management model with the Horton infiltration method, and observed peak discharges and runoff volumes

[cfs, cubic feet per second; in, inches; E, early; L, late; -, negative values represent underestimations; U, urban; N, natural; M, mixed] (Continued)

Watershed name	Watershed classification	Peak discharge (cfs) Estimated	Peak discharge (cfs) Observed	Error cfs	Error Percent	Runoff volume (in) Estimated	Runoff volume (in) Observed	Error Inches	Error Percent	Date of storm
		671	398	273	68.6	.62	.96	-.34	-35.4	08/07/92
		967	334	633	190	.81	.77	.04	5.19	09/04/92
		816	278	538	193	.68	.41	.27	65.9	09/05/92
		540	199	341	171	.65	.56	.09	16.1	09/25/92
Walker Creek (cont.)		513	292	221	75.7	.48	.74	-.26	-35.1	09/26/92
		421	235	186	79.1	.70	.76	-.06	-7.89	01/15/93
		746	319	427	134	.98	.94	.04	4.26	04/01/93
		674	237	437	184	.85	.46	.40	84.8	07/01/93
Clower Creek	U	96	77	19	24.7	.91	1.45	-.54	-37.2	02/05/92
		463	205	258	126	15.30	17.08	-1.78	-10.4	June 92
		87	66	21	31.8	.67	1.07	-.40	-37.4	09/02/92
		223	110	113	103	1.82	2.31	-.49	-21.2	09/13/92
		74	42	32	76.1	.74	.67	.07	10.4	09/14/92
		102	60	42	70.0	1.24	1.37	-.13	-9.49	03/13/92
		290	116	174	150	3.13	2.90	.23	7.93	04/01/92
Catfish Creek	M	75	70	5	7.14	.21	.21	.00	0.00	01/14/93
		56	76	-20	-26.3	.15	.25	-.10	-40.0	01/15/93
		132	140	-8	-5.71	.41	.49	-.08	-16.3	03/13/93
		316	300	16	5.33	1.25	1.41	-.16	-11.3	04/01/93
South Creek	N	662	442	220	49.8	9.24	4.30	4.94	115	June 92
		148	143	5	3.50	.15	.13	.02	15.4	09/06/92
		113	96	17	17.7	.27	.39	-.12	-30.8	09/13/92
		199	94	105	112	.75	.69	.06	8.70	03/13/32
		196	168	28	16.7	.70	1.27	-.57	-44.9	04/01/93
Forked Creek	N	264	287	-23	-8.01	8.88	8.54	.34	3.98	June 92
		36	45	-9	-20.0	1.41	.82	.59	72.0	08/09/92
Gottfied Creek	M	244	119	125	105	11.80	6.70	5.10	76.1	June 92
		19	21	-2	-9.50	.14	.32	-.18	-56.3	08/11/92
		17	18	-1	-5.60	.30	.50	-.20	-40.0	October 92
Rock Creek	N	269	109	160	147	12.60	5.64	6.96	123	June 92
		17	24	-7	-29.2	.10	.24	-.14	-58.3	09/25/92
		12	25	-13	-52.0	.37	.78	-.41	-52.6	October 92

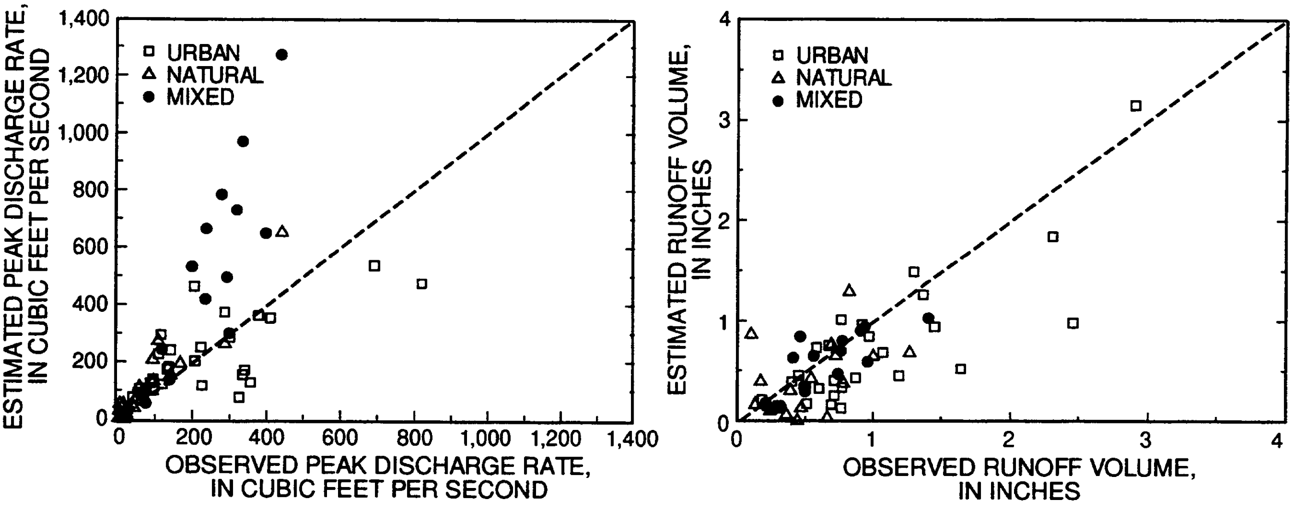

Figure 40. Comparison of observed and estimated peak discharge rates and runoff volumes for the Environmental Protection Agency Storm Water Management model, using the Green-Ampt infiltration method.

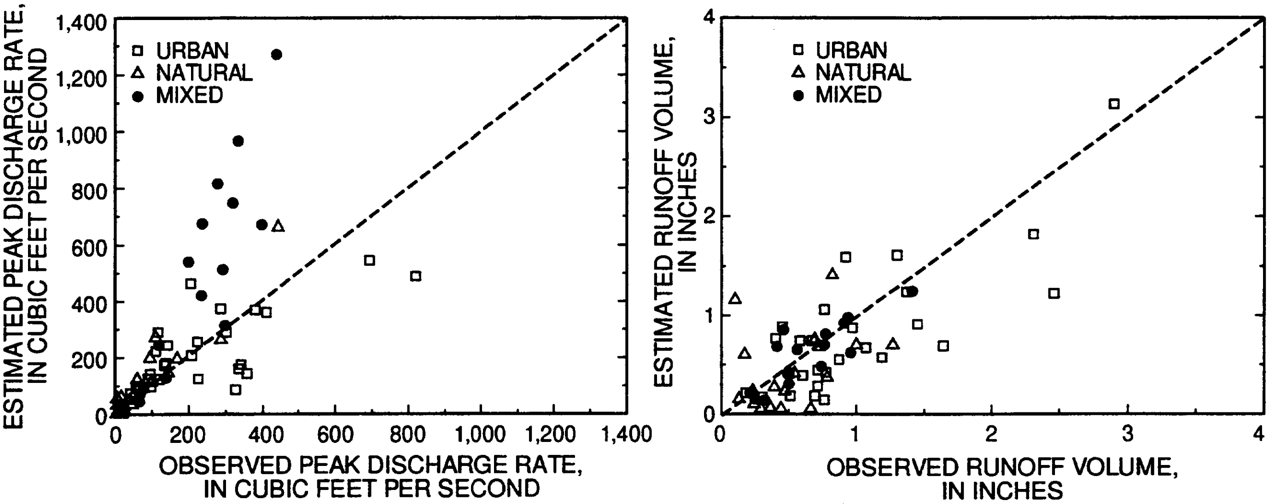

Figure 41. Comparison of observed and estimated peak discharge rates and runoff volumes for the Environmental Protection Agency Storm Water Management model, using the Horton infiltration method.

discharges and 26 percent greater than observed runoff volumes. The average error for the three mixed land use watersheds was 67 percent greater than observed discharges and 4 percent less than observed runoff volumes. When using the Horton infiltration method, the average error for the urban watersheds was 26 percent greater than observed peak discharges and 14 percent greater than observed runoff volumes. The average error for the natural watersheds was about 137 percent greater than observed peak discharges and 59 percent greater than observed runoff volumes. The average error for the three mixed land use watersheds was 67 percent greater than observed peak discharges and 9 percent greater than observed runoff volumes.

Figures 42 and 43 show the percent error between estimated and observed peak discharges, as a function of the percent impervious area, watershed slope, and watershed size calculated using the Green-Ampt and Horton infiltration methods, respectively. Very little correlation between these basin characteristics and the percent error in peak discharges is evident. The percent error between estimated and observed runoff volumes, as a function of the percent impervious area, watershed slope and watershed size calculated using the Green-Ampt and Horton infiltration methods are shown in figures 44 and 45, respectively. The range in errors generally decreased with increasing impervious area. No direct correlation between the percent error and the watershed slope or size is apparent.

Observed and simulated hydrographs typical of storms occurring in the Gandy Boulevard and Clower Creek watersheds are show in figure 46. The watersheds are urban and drain through underground storm sewers. Simulated hydrographs for the Gandy Boulevard watershed closely matched the observed peak; however, runoff volume was underestimated. In the Clower Creek watershed, the simulated peaks exceeded the observed peaks by more than 100 percent. The time of the peaks and the runoff volumes was similar.

The observed and simulated hydrograph for the Arctic Street watershed, also an urban watershed, had similar shapes (fig. 47). The first peak on the simulated hydrograph matched the observed peak. Subsequent peaks were greater than the observed peaks; however, the timing of each peak was simulated accurately.

Simulated storm hydrographs for the remaining 3 urban watersheds in Pinellas and western Hillsborough Counties did not accurately match the observed hydrographs (fig. 47). Peak discharge on the simulated hydrograph for the Kirby Street watershed was 49.5 percent greater than on the observed hydrograph (table 9), although the time to peak was predicted accurately. The falling limb of the simulated hydrograph was much steeper than that of the observed hydrograph. The rising limb of the

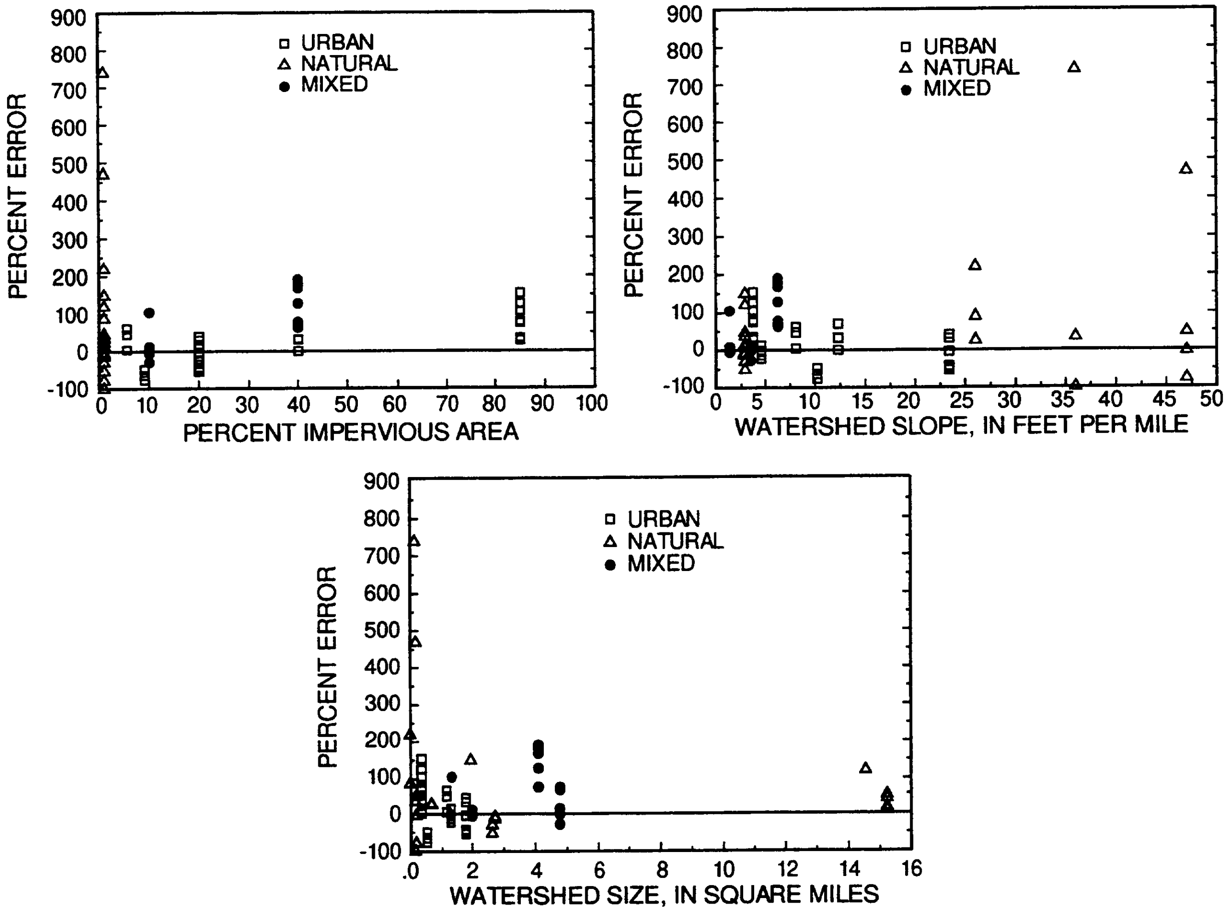

Figure 42. Comparison of the percent error between estimated and observed peak discharge rates with percent impervious area, average watershed slope, and watershed size, for the Environmental Protection Agency StormWater Management model, using Green-Ampt infiltration method.

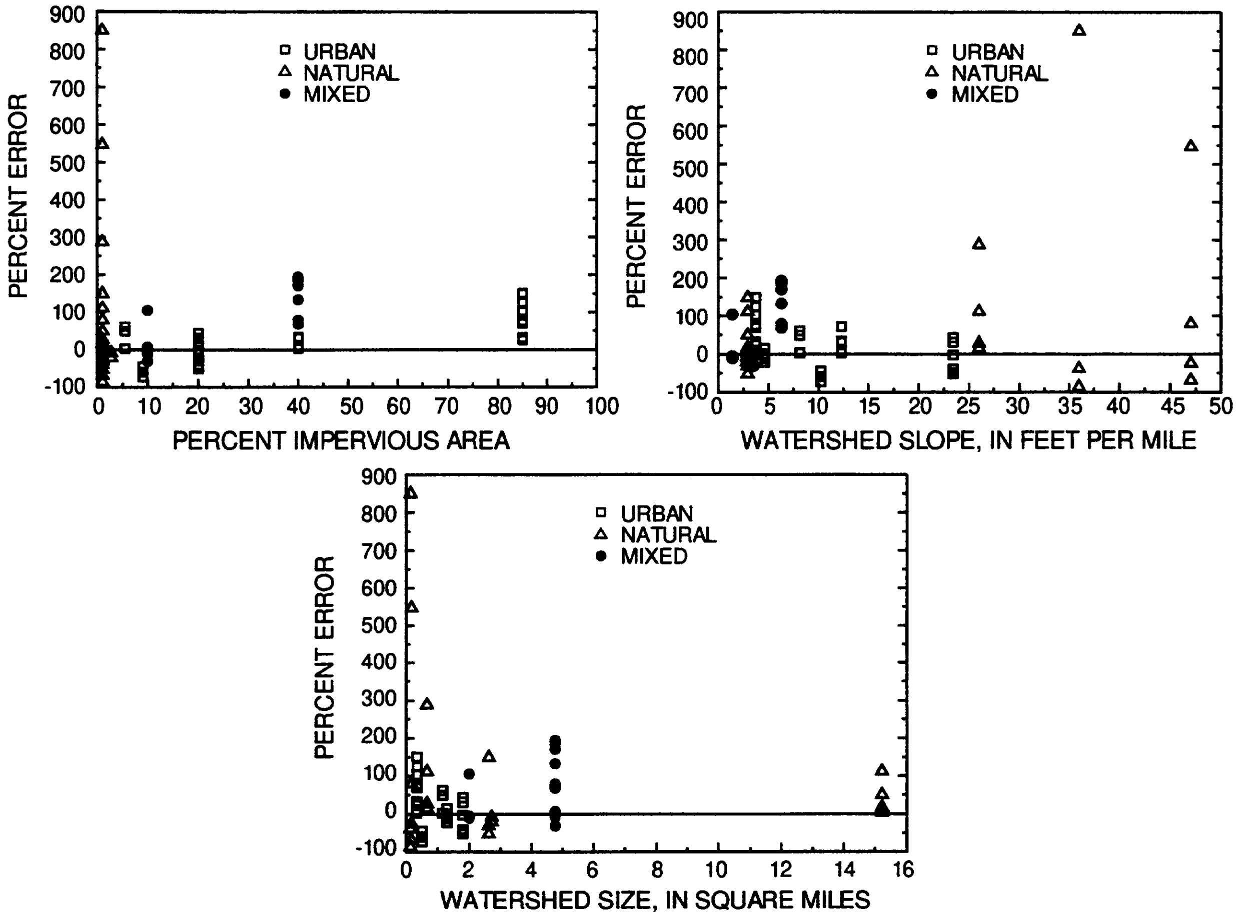

Figure 43. Comparison of the percent error between estimated and observed peak discharge rates with impervious area, average watershed slope, and watershed size, for the Environmental Protection Agency Storm Water Management model, using the Horton infiltration method.

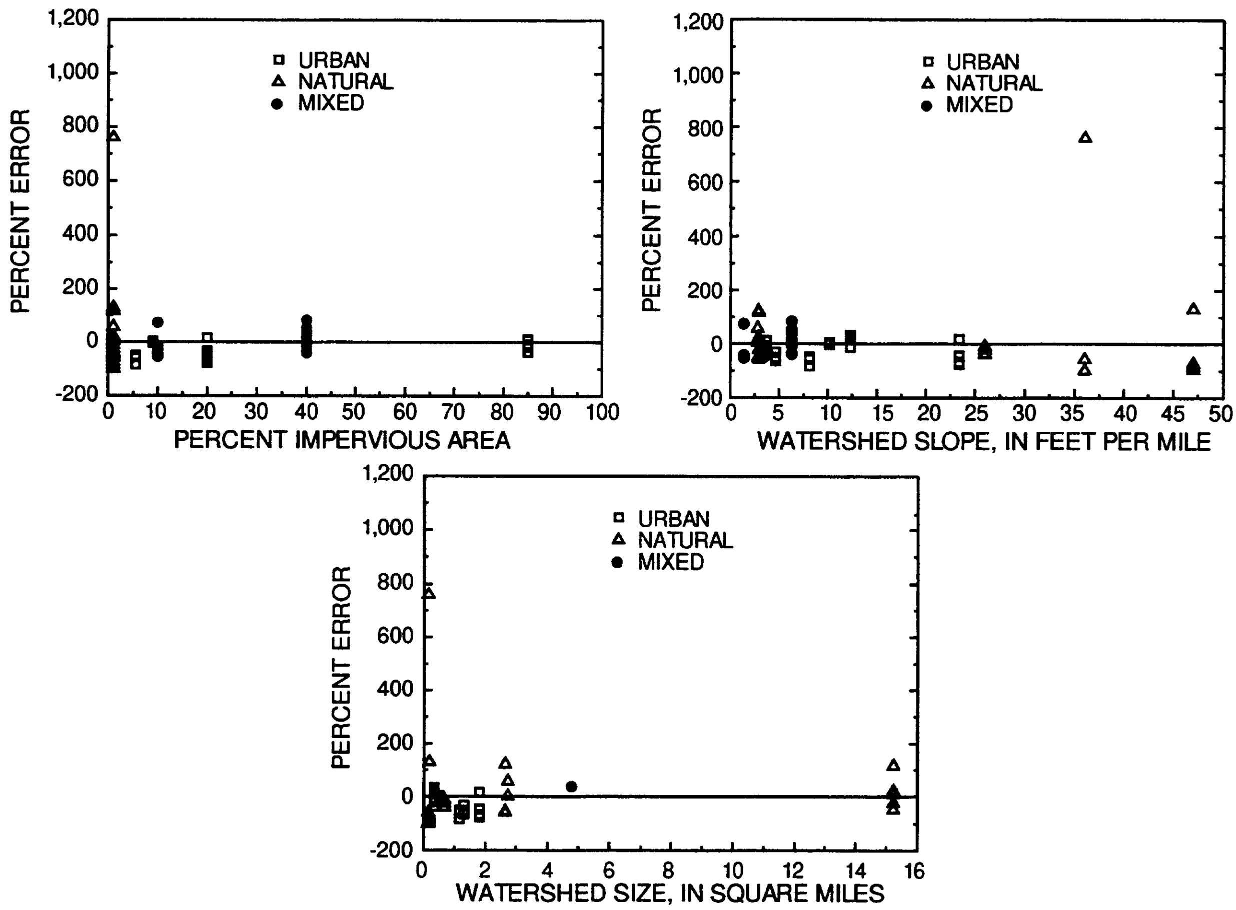

Figure 44. Comparison of the percent error between estimated and observed runoff volumes with percent impervious area, average watershed slope, and watershed size, for the Environmental Protection Agency Storm Water Management model, using the Green-Ampt infiltration method.

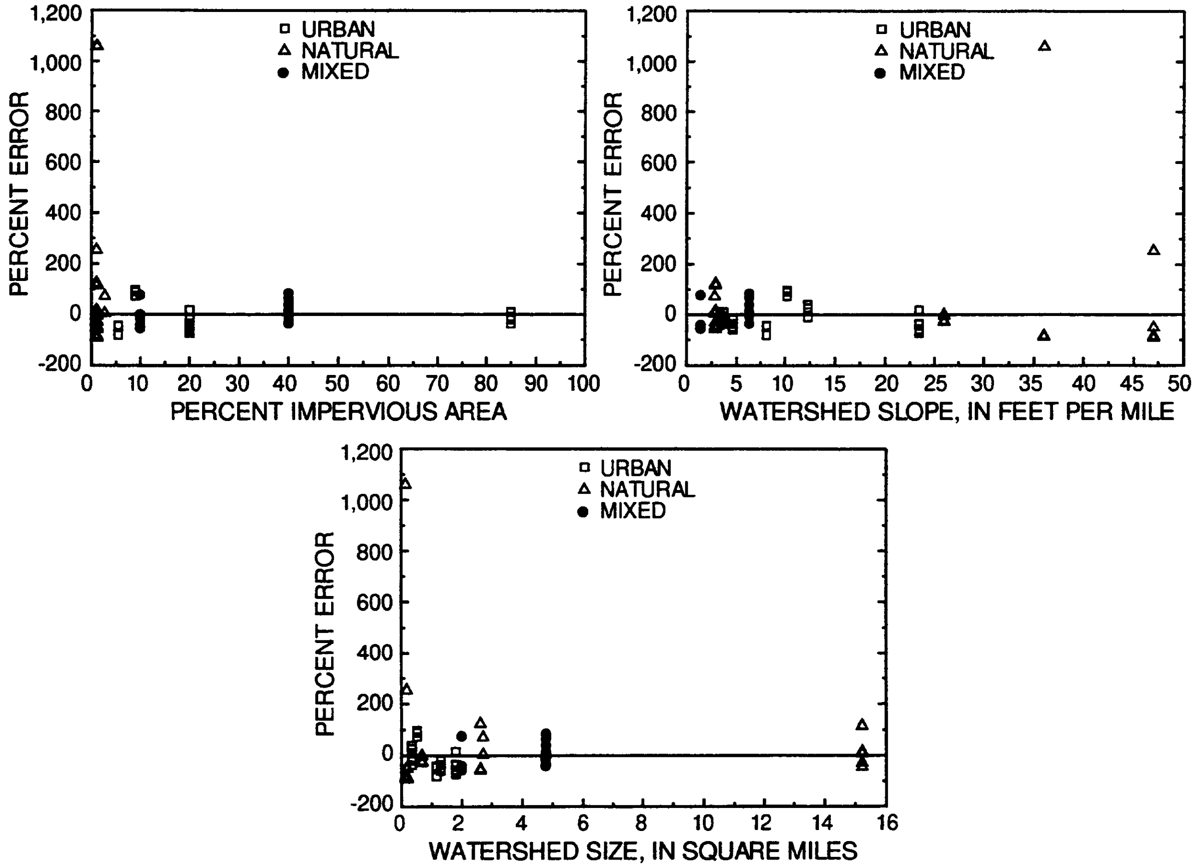

Figure 45. Comparison of the percent error between estimated and observed runoff volumes with percent impervious area, average watershed slope, and watershed size, for the Environmental Protection Agency Storm Water Management model, using the Horton infiltration method.

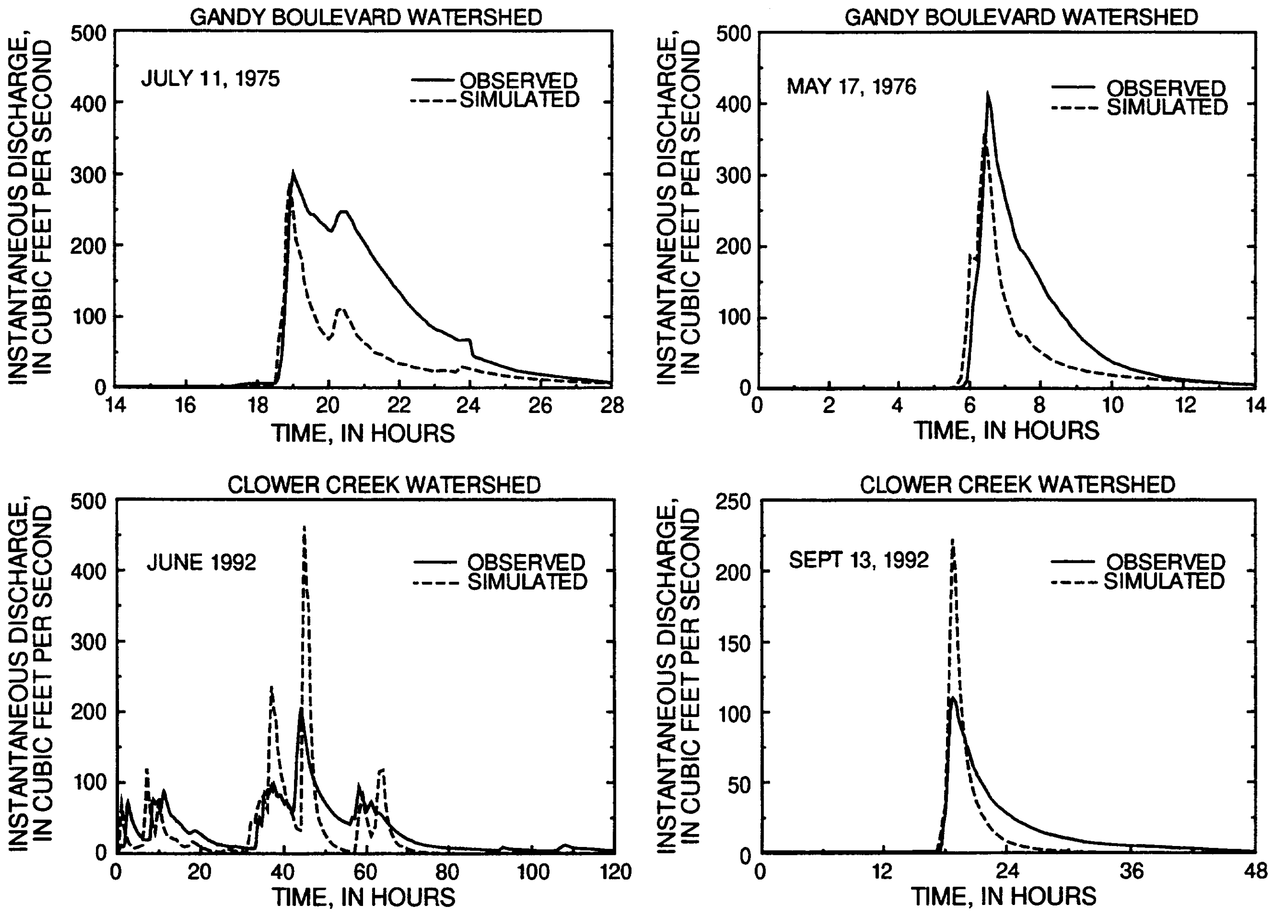

Figure 46. Typical observed hydrographs for storms occurring in the Gandy Boulevard and the Clower Creek watersheds and corresponding hydrographs simulated using the Environmental Protection Agency Storm Water Management model.

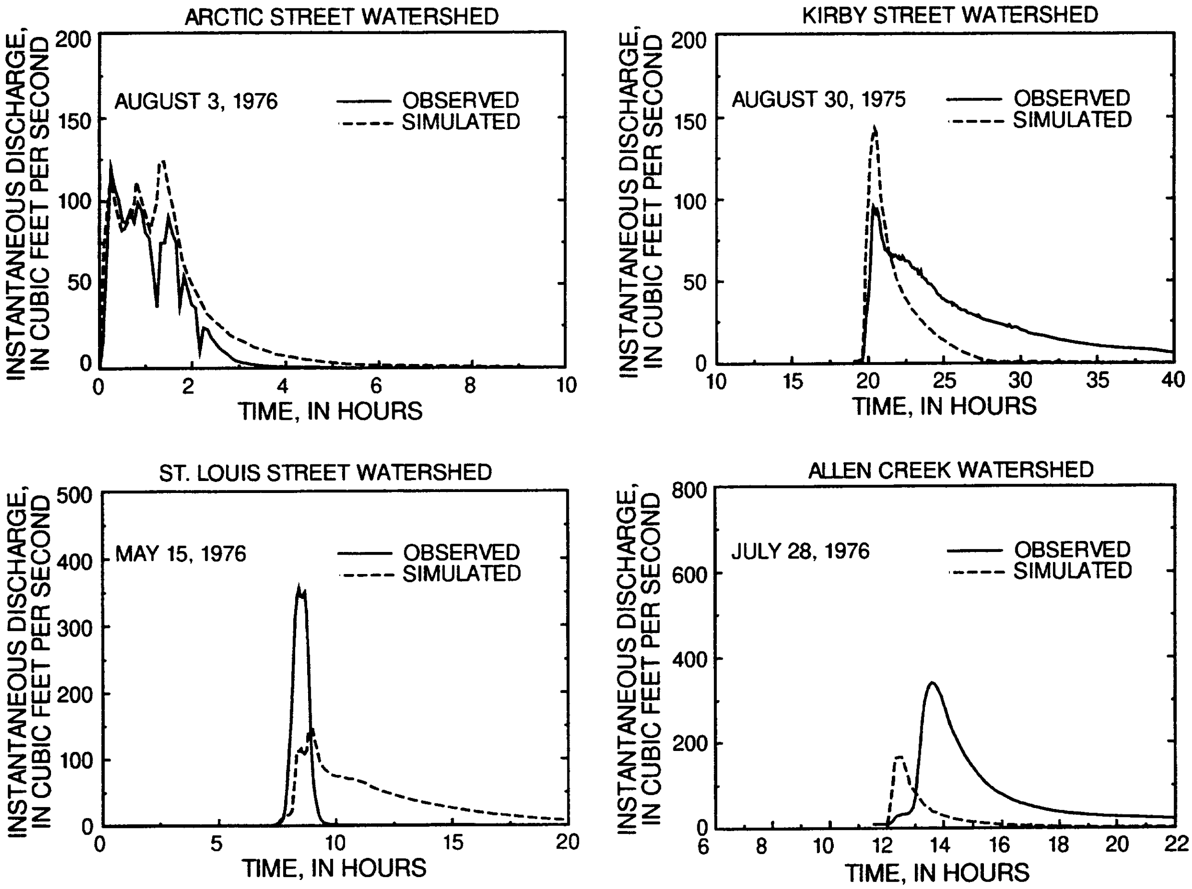

Figure 47. Typical observed hydrographs for storms occurring in the Arctic Street, Kirby Street, St. Louis Street and Allen Creek watersheds and corresponding hydrographs simulated using the Environmental Protection Agency Storm Water Management model.

simulated hydrograph for the St. Louis Street watershed was steep and matched the observed hydrograph; however, neither the peak discharge or the falling limb of the simulated hydrograph matched the observed hydrograph. The general shape of the simulated hydrograph for the Allen Creek watershed matched the observed hydrograph; however, the peak occurred about 1.5 hours before the observed peak and the runoff volume was underestimated by about 48 percent.

Observed and simulated hydrographs resulting from three different types of storms in the Walker Creek watershed are shown on figure 48. Land use in the Walker Creek watershed is mixed. The simulated hydrograph for a 4 day, high intensity storm (June, 1992) matched the observed hydrograph more accurately than the short duration, high intensity, summer thunderstorm (Sept 4, 1992), or the winter frontal storm (Jan 15, 1993). Peak discharges were overestimated for all three type storms; however, overestimations were greater for the summer thunder storms than for the other two storm types. The time to peak between the simulated and observed hydrographs differed by less than one hour for the three storm types. The falling limbs of the simulated hydrographs for the summer thunderstorms and the winter frontal storms did not match the observed hydrographs.

Observed and simulated hydrographs for the Catfish Creek and Gottfried Creek watersheds, also mixed land use watersheds are shown in figure 49. Peak discharge was only slightly underestimated for both watersheds, but the shape of the simulated hydrograph better matched the observed hydrograph for the Catfish Creek watershed than for the Gottfried Creek watershed. The predicted peak discharge occurred 1 hour before the observed discharge in the Catfish Creek watershed and 13.5 hours before the observed peak in the Gottfried Creek watershed.

Typical observed and simulated hydrographs for storms occurring in the three natural watersheds of IMC Creek, CFI-3 Creek and Grace Creek are shown on figure 50. The simulated hydrographs for the IMC Creek and CFI-3 Creek watersheds had lower peak discharges and runoff volumes than the observed hydrographs; whereas in the Grace Creek watershed, peak discharge was greater than the observed. All three simulated hydrographs had steep rising and falling limbs, while the observed hydrographs had long flat recession limbs. The long recession limbs on the observed hydrographs indicate that rainfall is being stored in the watershed and released to the stream at a slow rate.

Typical observed and simulated hydrographs for the South Creek, Forked Creek, and Rock Creek watersheds, natural watersheds, characterized by low slopes, large wetlands, and high water tables, are shown on figure 51. The shape of the observed hydrographs in all three watersheds are similar, with long, flat recession limbs. The simulated hydrographs for these watersheds do not match the observed

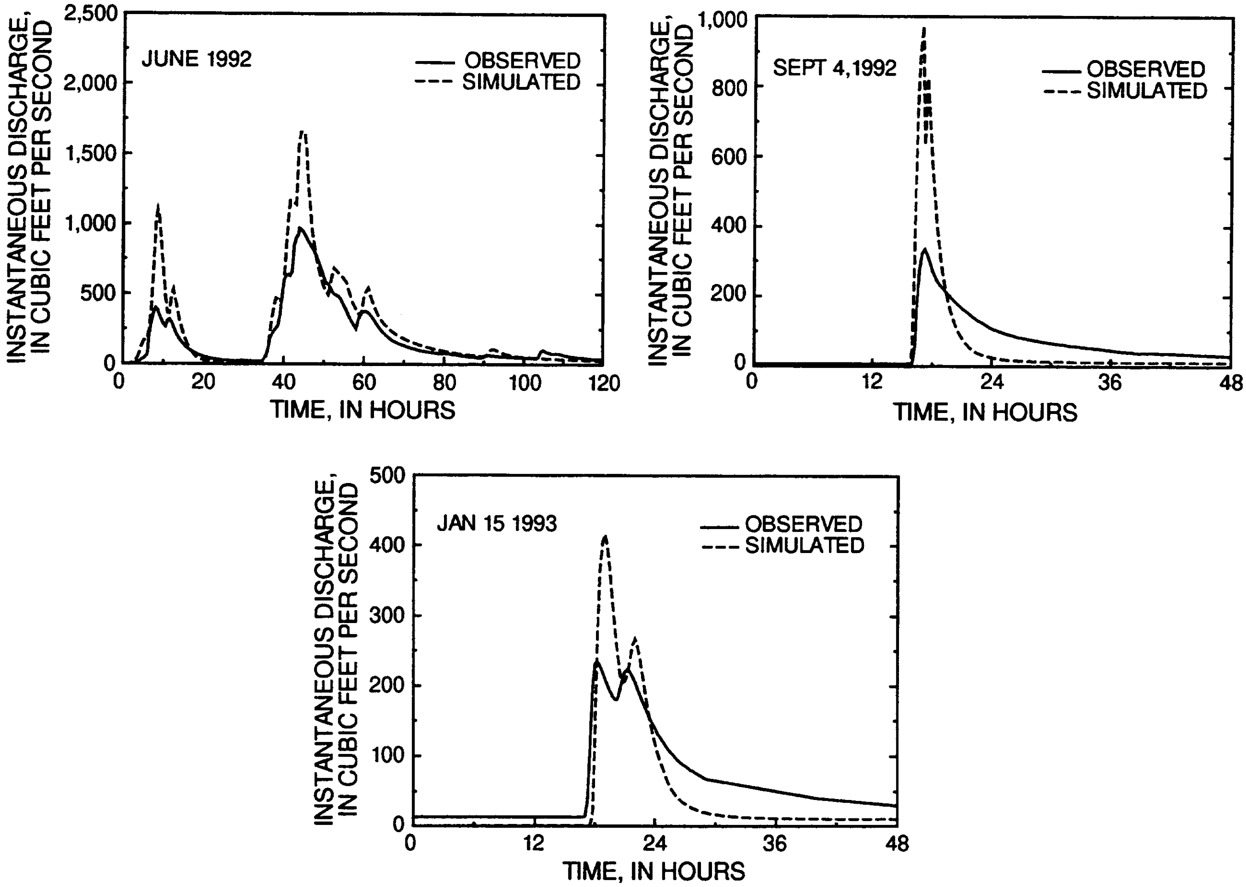

Figure 48. Typical observed hydrographs for storms occurring in the Walker Creek watershed and corresponding hydrographs simulated using the Environmental Protection Agency Storm Water Management model.

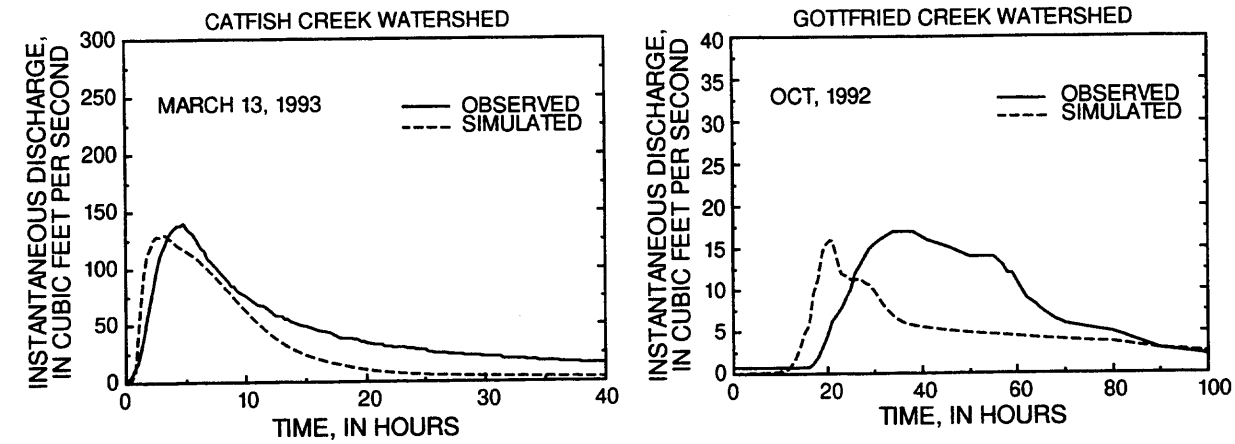

Figure 49. Typical observed hydrographs for storms occurring in the Catfish Creek and Gottfried Creek watersheds and corresponding hydrographs simulated using the Environmental Protection Agency Storm Water Management model.

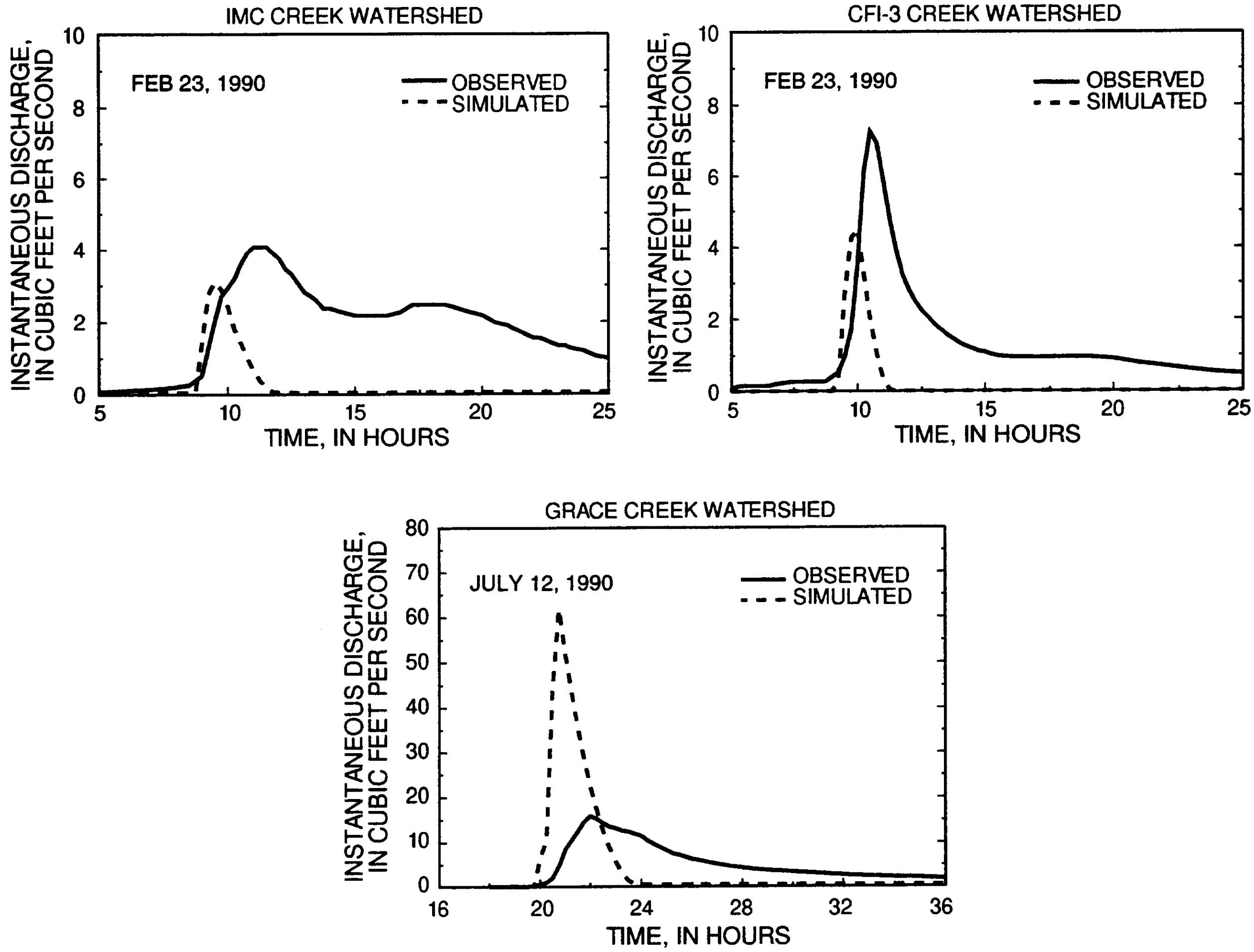

Figure 50. Typical observed hydrographs for storms occurring in the IMC, CFI-3 and Grace Creek watersheds and corresponding hydrographs simulated using the Environmental Protection Agency Storm Water Management model.

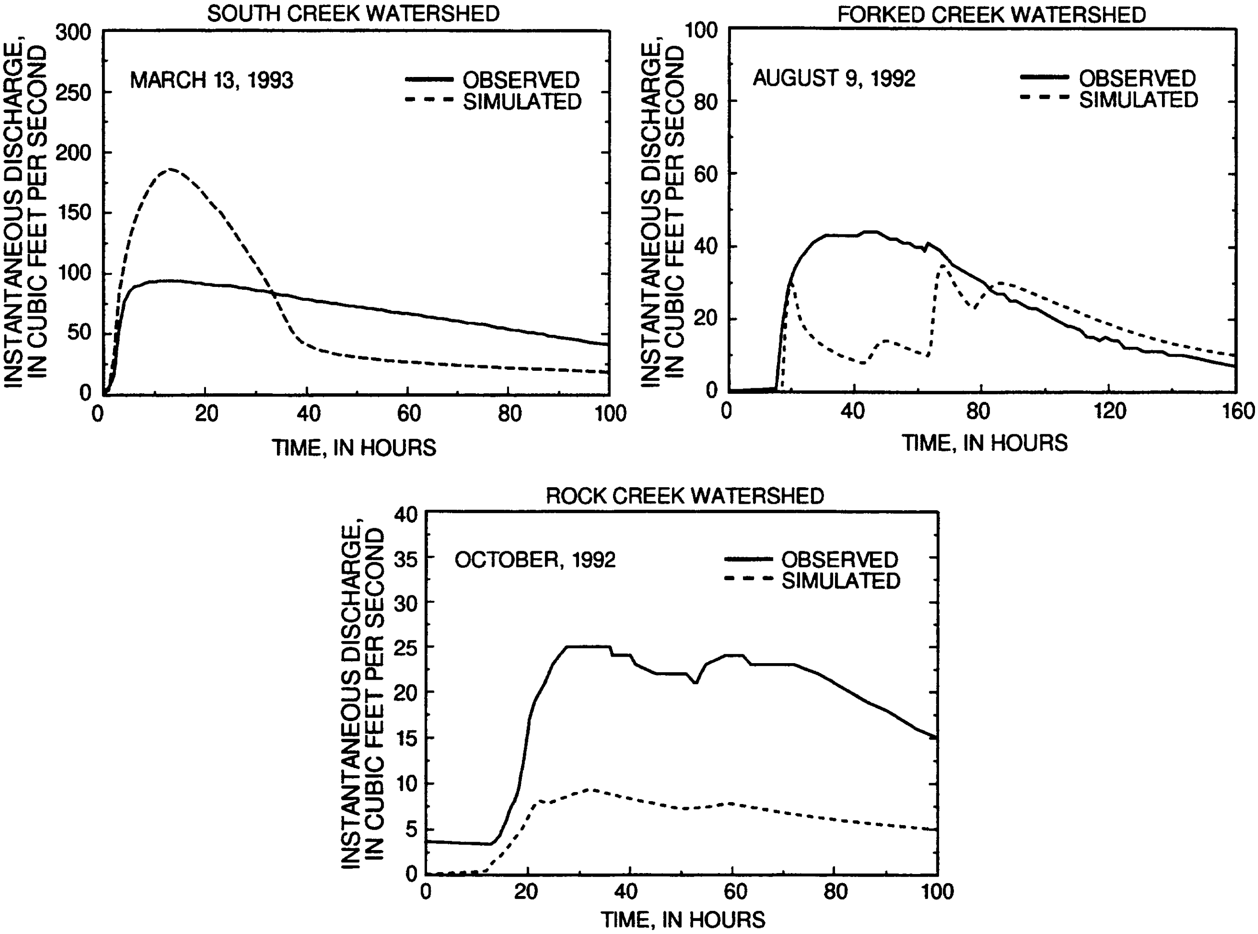

Figure 51. Typical observed hydrographs for storms occurring in the South, Forked, and Rock Creek watersheds and corresponding hydrographs simulated using the Environmental Protection Agency Storm Water Management model.

hydrographs in either size or shape. Peak discharges are overestimated for the South Creek watershed and underestimated for the Forked Creek and Rock Creek watersheds. Surface detention, subsurface storage and flow, and discharge from the surficial aquifer system influence the shape of the observed hydrographs in these watersheds.

STATISTICAL ANALYSIS OF DATA

The mean estimation error indicates the tendency of a method to under- or overestimate observed data. The mean estimation error, in percent, was calculated for each watershed, all urban watersheds, all natural watersheds, all mixed watersheds, and for all watersheds for each method using the following equation:

$$\xi = 100\left[\frac{\sum_{i=1}^{n}\left(\frac{est_i - obs_i}{obs_i}\right)}{n}\right] \qquad (8)$$

where:

ξ = mean estimation error, in percent;

est_i = estimated peak discharge for event i, in cubic feet per second or runoff volume, in inches;

obs_i = observed peak discharge for event i, in cubic feet per second or runoff volume, in inches;

n = number of storm events.

Mean estimation errors for peak discharge for all storms in each watershed for the rational method ranged from an underestimation of 31 percent to an overestimation of 767 percent. The smallest mean estimation error was calculated for storms in the urban watershed of Allen Creek. The largest was for storms in the natural watershed of South Creek (table 10). The mean estimation error for all storms occurring in the urban watersheds was an overestimation of about 67 percent. The error was an