

3.0 SWMM MODELING

Present and future pollutant loadings from the Lower Linganore Creek watershed were modeled to provide information on the types and quantities of pollutants likely to threaten water quality. This information will enable Frederick County officials to make better decisions about where to focus their efforts and resources to protect existing and future water quality. In this section, we document details of the modeling method, input data, and assumptions, along with results for Lower Linganore Creek watershed.

For this simulation, a modified version of USEPA's Stormwater Management Model (SWMM) was chosen. This model incorporates hydrological, topographical, and land use data from the watershed, and uses this information to calculate pollutant loads. Total pollutant loads over several representative years were simulated in order to give a more accurate picture of the watershed.

SWMM is made up of many different modules, or "blocks". For the Lower Linganore Creek simulation, only the RUNOFF block was used. RUNOFF is used to calculate the amount of runoff and pollutants that flow off the land during storm events. The goal of this study was to simulate the pollutant contributions of the land surface to the surface waters; therefore the transport of flow and pollutants downstream of each subwatershed was not simulated.

SWMM can simulate up to ten different pollutants at one time. The ten pollutants that were modeled were total nitrogen (TN), total phosphorus (TP), ortho phosphorus (OP), total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), lead (Pb), cadmium (Cd), copper (Cu), and zinc (Zn). Ten land uses can be simulated, and land uses were grouped accordingly. Event Mean Concentrations (EMCs) were calculated for each pollutant for each land use. These EMCs were used to calibrate the water quality of the simulation.

3.1 HYDROLOGICAL DATA

Historical rain information from BWI Airport for the period from 1980 to 1992 was examined. Simulations were run for three years, 1989, 1991, and 1992, respectively representing the wet, dry and average years, during that period. Monthly rainfall totals used in the simulations are summarized in Table 3-1. Rainfall data from BWI were used because it was the closest rain gauge to the study area that contained hourly rainfall data for the simulation period.

Monthly evaporation rates (Table 3-2) were calculated from both BWI and National Airport data, as well as National Oceanic and Atmospheric Association (NOAA) Technical Report 34. These data have been used in similar studies in Maryland (Tetra Tech 2000).

Table 3-1. Summary of monthly rainfall totals (inches) from BWI airport used for the Lower Linganore Creek SWMM simulation period. Simulations were run for wet (1989), dry (1991), and average (1992) years.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	2.58	0.49	3.37	2.21	1.96	2.03	2.16	5.85	3.24	3.07	3.71	3.54	1.27
Feb	1.06	2.93	4.04	4.81	3.9	3.03	3.78	2.22	3.25	3.36	1.48	0.73	2.49
Mar	5.46	1.14	3.03	6.8	5.79	2.37	0.96	0.99	2.35	4.24	2.54	5.65	4.58
Apr	4.24	2.04	3.61	6.55	2.95	0.39	2.64	1.86	2.44	3.16	4.23	1.68	1.76
May	3.58	3.63	1.85	5.47	4.29	6.01	0.37	4.16	4.37	8.71	4.92	1.16	2.92
Jun	3.04	5.4	5.7	5.23	1.65	2.44	1.46	2.63	0.84	5.98	2.55	1.08	1.89
Jul	3.25	4.59	2.16	1.31	3.27	2.53	4.12	5.05	3.78	7.35	5.68	1.76	5.07
Aug	4	1.93	0.95	1.57	4.11	3.72	4.26	1.61	2.64	3.38	6.17	2.54	2.19
Sep	1	2.89	3.63	1.76	2.38	6.22	0.58	7.34	2.05	3.64	1.07	3.05	5.96
Oct	3.08	2.57	2.31	3.58	1.94	2.48	1.86	2.25	1.59	4.9	2.57	3.2	2.19
Nov	2.72	0.31	3.13	5.02	3.01	4.71	5.96	5.05	4.78	1.97	2.1	1.69	3.44
Dec	0.7	3.3	2.39	6.72	1.71	0.84	5.52	2.07	0.97	2.12	4.86	4.08	4.63
TOTAL	34.71	31.22	36.17	51.03	36.96	36.77	33.67	41.08	32.3	51.88	41.88	30.16	38.39

Month	Evaporation	Month	Evaporation
Jan	0.0526	Jul	0.2442
Feb	0.0693	Aug	0.2233
Mar	0.1065	Sep	0.164
Apr	0.1627	Oct	0.1148
May	0.2023	Nov	0.0803
Jun	0.2326	Dec	0.0542

3.2 TOPOGRAPHICAL DATA

There are approximately 24,100 acres in the Lower Linganore Creek watershed. To improve the resolution of the model, the 10 subwatersheds shown in Figure 2-2 were subdivided into 52 catchments following methods outlined in Section 2.1.

GIS was used to calculate the area and flow length of each catchment. A central flow length was established that followed the stream network in the catchments. If there were no significant streams, a flow path was established following the appropriate contours of the map. Once the flow length was determined, the width and slope of each catchment were calculated. Table 3-3 shows the width, area, and slope of each of the 52 catchments.

Catchment	Width (feet)	Area (acres)	Slope (ft/ft)
Bartonsville – A	3811	419	0.0334
Bartonsville – B	1306	135	0.0401
Bartonsville – C	2189	541	0.0223
Bartonsville – D	3831	449	0.0470
Bens Branch – A	3558	307	0.0160
Bens Branch – B	4679	341	0.0063
Bens Branch – C	5601	690	0.0149
Bens Branch – D	2259	263	0.0355
Bens Branch – E	2136	159	0.0432
Bens Branch - F	2651	527	0.0231
Chestnut Grove - A	3863	750	0.0284
Chestnut Grove - B	2553	504	0.0279
Detrick – A	4152	758	0.0176
Detrick - B	2553	476	0.0148
Detrick - C	2700	607	0.0245
Hazelnut Run - A	3603	273	0.0061
Hazelnut Run - B	1424	154	0.0404
Hazelnut Run - C	2963	679	0.0160
Hazelnut Run - D	2397	442	0.0249

Table 3-3. (Continued)			
	Width (feet)	Area (acres)	Slope (ft/ft)
Hazelnut Run - E	2209	417	0.0243
Hazelnut Run - F	3056	333	0.0295
Horseshoe Farms - A	4466	986	0.0125
Horseshoe Farms - B	4201	1037	0.0260
Linganore Creek - A	3079	565	0.0175
Linganore Creek - B	4535	691	0.0301
Linganore Creek - C	2825	665	0.0273
Linganore Creek - D	2975	629	0.0282
Linganore Creek - E	3117	110	0.1297
Linganore Creek - F	4318	298	0.0533
Linganore Creek - G	1991	207	0.0309
Linganore Creek - H	3674	216	0.0861
Linganore Creek - I	4532	892	0.0268
Linganore Creek - J	1869	131	0.0589
Linganore Creek - K	927	58	0.0444
Linganore Creek - L	6851	349	0.0992
Linganore Creek - M	3224	568	0.0130
Long Branch - A	3442	450	0.0141
Long Branch - B	3638	432	0.0039
Long Branch - C	5025	454	0.0102
Long Branch - D	2763	373	0.0221
Long Branch - E	3153	593	0.0195
Long Branch - F	2648	231	0.0264
New London - A	2861	804	0.0041
New London - B	2231	318	0.0258
New London - C	2589	506	0.0223
New London - D	3047	494	0.0071
New London - E	2568	593	0.0119
New London - F	3497	789	0.0142
Westwinds - A	3039	256	0.0491
Westwinds - B	2192	308	0.0424
Westwinds - C	2688	287	0.0517
Westwinds - D	3740	399	0.0430

3.3 LAND USE

Because land use is a major driving force in pollutant loadings, three scenarios were simulated for each year: pre-development, existing, and future land use. The pre-development scenario assumed the area was completely forested. Existing land use was determined using 1997 MOP land use. Future land use was based on zoning maps and projected build-out conditions, as described in Section 2.4.2. Current land uses represent a mixture of residential, agriculture, and forest types, varying by subwatershed (Table 3-4). Because of uncertainties in

preprojecting specific land uses, some categories were grouped in the future scenario (e.g., cropland and pasture were grouped together as agriculture). Future land uses by subwatershed are shown in Table 3-5.

SWMM used land use percentages directly to calculate how much pollutant buildup there will be in a catchment. Land use percentages by catchment were also used to determine percentage of impervious areas and Manning roughness coefficients, which were then used by SWMM to calculate the total runoff flow.

The Directly Connected Impervious Area (DCIA) is the amount of impervious area that is directly connected to a sewer system or water body. SWMM uses DCIA rather than the total impervious area in a subwatershed. SWMM employs two different Manning coefficients: the roughness of the pervious area and that of the impervious area. DCIA values for each land use were obtained from a recent assessment of the Patapsco River (Tetra Tech 2000). Manning coefficients for pervious and impervious surfaces were obtained from the Back River study (CDM 1997). DCIA and Manning coefficients assigned to each land use are shown in Table 3-6. The estimated percent DCIA and pervious and impervious Manning coefficients in each Lower Linganore catchment are listed in Table 3-7.

Depression storage represents the amount of low points in a watershed that must be filled before runoff can occur. Without further study, it was not possible to determine the actual depression storage within each subwatershed, therefore, literature values of 0.02 inches for impervious and 0.1 inches for pervious depression storage, as used in previous SWMM studies in central Maryland, were used (Tetra Tech 2000). These values do not account for existing SWM facilities.

3.4 SOILS

Hydrologic soil group data, as described in Section 2.2.3 and shown in Figure 2-5, were also used in the model. Each hydrologic soil group has a different infiltration rate. By determining the percentages of each group within a catchment, the maximum and minimum infiltration rates were calculated. Using the Horton infiltration method in SWMM, a constant decay rate of 0.00115 per second was set. The infiltration rates for each hydrologic soil group are shown in Table 3-8. The maximum and minimum infiltration rates calculated for each Lower Linganore catchment are listed in Table 3-9.

Table 3-4. Percentages of land use by subwatershed under current conditions

Subwatershed	Low-density Residential	Medium-density Residential	High-density Residential	Commercial	Open Urban Land	Cropland	Pasture	Forested	Bare Ground	Water
Bartonsville	23%	1%	0%	0%	4%	15%	24%	33%	0%	0%
Bens Branch	27%	1%	0%	1%	0%	24%	6%	40%	0%	0%
Chesnut Grove	3%	0%	0%	2%	0%	64%	4%	27%	0%	0%
Detrick	14%	0%	0%	0%	0%	67%	8%	11%	0%	0%
Hazelnut Run	6%	7%	0%	0%	0%	55%	10%	22%	0%	0%
Horseshoe Farms	14%	1%	0%	0%	1%	43%	8%	34%	0%	0%
Linganore Creek	6%	15%	2%	0%	0%	26%	11%	38%	1%	1%
Long Branch	20%	3%	0%	1%	8%	35%	11%	20%	3%	0%
New London	4%	2%	0%	0%	1%	60%	13%	20%	0%	0%
Westwinds	0%	8%	0%	0%	12%	30%	5%	45%	0%	0%

Table 3-5. Percentages of land use by subwatershed under future conditions

Subwatershed	Low-density Residential	Medium-density Residential	High-density Residential	Commercial	Open Urban Land	Agriculture	Forested	Water
Bartonsville	31%	1%	0%	0%	4%	61%	2%	0%
Bens Branch	39%	1%	0%	1%	0%	59%	0%	0%
Chesnut Grove	7%	0%	0%	2%	0%	91%	0%	0%
Detrick	15%	0%	0%	0%	0%	85%	0%	0%
Hazelnut Run	11%	30%	0%	1%	5%	53%	0%	0%
Horseshoe Farms	18%	3%	0%	0%	1%	78%	0%	0%
Linganore Creek	7%	49%	2%	0%	0%	38%	3%	1%
Long Branch	47%	10%	0%	2%	8%	31%	1%	0%
New London	6%	8%	0%	2%	1%	83%	0%	0%
Westwinds	0%	29%	0%	0%	12%	59%	0%	0%

Land Use	DCIA (%)	Manning Coefficients	
		Impervious	Pervious
Low Density Residential (LDR)	15.0%	0.015	0.250
Medium Density Residential (MDR)	25.0%	0.015	0.250
High Density Residential (HDR)	60.0%	0.015	0.250
Commercial/Industrial	90.0%	0.015	0.250
Open Urban	4.0%	0.015	0.300
Croplands	3.0%	0.015	0.400
Pasture	5.0%	0.015	0.400
Forest	1.5%	0.015	0.300
Barren	1.5%	0.015	0.300
Water/Wetlands	100.0%	0.100	0.400

Catchment	Current			Future		
	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients
Bartonsville - A	4%	0.0150	0.3603	5%	0.0150	0.3801
Bartonsville - B	10%	0.0150	0.3244	10%	0.0150	0.3218
Bartonsville - C	6%	0.0150	0.3060	9%	0.0150	0.3278
Bartonsville - D	6%	0.0150	0.3222	9%	0.0150	0.3413
Bens Branch - A	10%	0.0150	0.2991	12%	0.0150	0.2933
Bens Branch - B	3%	0.0150	0.3594	7%	0.0150	0.3618
Bens Branch - C	3%	0.0150	0.3311	6%	0.0150	0.3814
Bens Branch - D	12%	0.0150	0.2972	13%	0.0150	0.3259
Bens Branch - E	2%	0.0150	0.3415	4%	0.0150	0.3986
Bens Branch - F	10%	0.0150	0.2782	13%	0.0150	0.2808
Chestnut Grove - A	3%	0.0150	0.3637	5%	0.0150	0.3816
Chestnut Grove - B	6%	0.0150	0.3709	8%	0.0150	0.3936
Detrick - A	4%	0.0150	0.3849	4%	0.0150	0.3941
Detrick - B	4%	0.0150	0.3747	5%	0.0150	0.3884
Detrick - C	7%	0.0150	0.3411	8%	0.0150	0.3478
Hazelnut Run - A	4%	0.0150	0.3503	12%	0.0150	0.3398
Hazelnut Run - B	3%	0.0150	0.3899	8%	0.0150	0.3643
Hazelnut Run - C	4%	0.0150	0.3637	8%	0.0150	0.3621
Hazelnut Run - D	3%	0.0150	0.3696	13%	0.0150	0.3314

Table 3-7. (Continued)

Catchment	Current			Future		
	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients	DCIA	Impervious Manning Coefficients	Pervious Manning Coefficients
Hazelnut Run - E	3%	0.0150	0.3767	14%	0.0150	0.3253
Hazelnut Run - F	16%	0.0150	0.3022	20%	0.0150	0.2581
Horseshoe Farms - A	4%	0.0150	0.3354	6%	0.0150	0.3744
Horseshoe Farms - B	5%	0.0150	0.3516	7%	0.0150	0.3608
Linganore Creek - A	3%	0.0150	0.3677	6%	0.0150	0.3777
Linganore Creek - B	3%	0.0150	0.3313	12%	0.0150	0.3284
Linganore Creek - C	3%	0.0150	0.3401	10%	0.0150	0.3529
Linganore Creek - D	8%	0.0150	0.3551	12%	0.0150	0.3415
Linganore Creek - E	6%	0.0150	0.2996	17%	0.0150	0.3075
Linganore Creek - F	28%	0.0217	0.2803	35%	0.0217	0.2619
Linganore Creek - G	20%	0.0150	0.2674	25%	0.0150	0.2536
Linganore Creek - H	24%	0.0268	0.2972	34%	0.0268	0.2823
Linganore Creek - I	7%	0.0150	0.3413	19%	0.0150	0.2829
Linganore Creek - J	7%	0.0150	0.2993	12%	0.0150	0.3194
Linganore Creek - K	4%	0.0150	0.2918	18%	0.0150	0.2842
Linganore Creek - L	4%	0.0150	0.2998	18%	0.0150	0.2734
Linganore Creek - M	15%	0.0150	0.3023	27%	0.0150	0.2536
Long Branch - A	7%	0.0150	0.2948	15%	0.0150	0.2697
Long Branch - B	15%	0.0150	0.2986	26%	0.0150	0.2740
Long Branch - C	6%	0.0150	0.3501	8%	0.0150	0.3402
Long Branch - D	6%	0.0150	0.3535	10%	0.0150	0.3353
Long Branch - E	5%	0.0150	0.3453	11%	0.0150	0.2748
Long Branch - F	6%	0.0150	0.3774	8%	0.0150	0.3535
New London - A	4%	0.0150	0.3578	11%	0.0150	0.3421
New London - B	4%	0.0150	0.3836	5%	0.0150	0.3905
New London - C	5%	0.0150	0.3743	6%	0.0150	0.3860
New London - D	3%	0.0150	0.3695	13%	0.0150	0.3801
New London - E	4%	0.0150	0.3678	5%	0.0150	0.3888
New London - F	4%	0.0150	0.3774	6%	0.0150	0.3835
Westwinds - A	10%	0.0150	0.2932	18%	0.0150	0.2675
Westwinds - B	4%	0.0150	0.3180	17%	0.0150	0.2872
Westwinds - C	2%	0.0150	0.3469	4%	0.0150	0.4000
Westwinds - D	3%	0.0150	0.3519	4%	0.0150	0.3984

Soil Group	Maximum Infiltration Rate (in/hr)	Minimum Infiltration Rate (in/hr)
A	2	0.065
B	1.5	0.05
C	1	0.035
D	0.5	0.02

Catchment	Maximum infiltration (in/hr)	Minimum infiltration (in/hr)	Catchment	Maximum infiltration (in/hr)	Minimum infiltration (in/hr)
Bartonsville – A	0.74	0.02	Linganore Creek - D	0.66	0.02
Bartonsville – B	0.80	0.03	Linganore Creek - E	0.68	0.02
Bartonsville – C	0.68	0.02	Linganore Creek - F	0.67	0.02
Bartonsville – D	0.56	0.02	Linganore Creek - G	0.63	0.02
Bens Branch – A	0.66	0.02	Linganore Creek - H	0.43	0.02
Bens Branch – B	0.70	0.02	Linganore Creek - I	0.51	0.02
Bens Branch – C	0.68	0.02	Linganore Creek - J	0.68	0.02
Bens Branch – D	0.71	0.02	Linganore Creek - K	0.74	0.02
Bens Branch – E	0.71	0.02	Linganore Creek - L	0.63	0.02
Bens Branch – F	0.73	0.02	Linganore Creek - M	0.68	0.02
Chestnut Grove - A	0.67	0.02	Long Branch – A	0.69	0.02
Chestnut Grove - B	0.63	0.02	Long Branch – B	0.60	0.02
Detrick – A	0.64	0.02	Long Branch – C	0.59	0.02
Detrick – B	0.66	0.02	Long Branch – D	0.66	0.02
Detrick – C	0.75	0.02	Long Branch – E	0.64	0.02
Hazelnut Run - A	0.52	0.02	Long Branch – F	0.64	0.02
Hazelnut Run - B	0.55	0.02	New London – A	0.75	0.02
Hazelnut Run - C	0.49	0.02	New London – B	0.75	0.03
Hazelnut Run - D	0.67	0.02	New London – C	0.58	0.02
Hazelnut Run - E	0.57	0.02	New London – D	0.61	0.02
Hazelnut Run - F	0.53	0.02	New London – E	0.68	0.02
Horseshoe Farms - A	0.61	0.02	New London – F	0.65	0.02
Horseshoe Farms - B	0.65	0.02	Westwinds – A	0.76	0.03
Linganore Creek - A	0.68	0.02	Westwinds – B	0.84	0.03
Linganore Creek - B	0.55	0.02	Westwinds – C	0.69	0.02
Linganore Creek - C	0.63	0.02	Westwinds - D	0.83	0.03

3.5 BUILDUP AND WASHOFF

SWMM uses buildup and washoff algorithms to determine how much pollution will be washed off the land surface during a storm. Each pollutant has a land use specific buildup rate. Initial maximum pollutant accumulation values from the Back River study were calibrated using the EMCs selected for the Linganore Creek watershed. This algorithm uses the following equation:

$$PSHED = QFACT(1)*(1.0-\exp(-QFACT(2)*t))$$

PSHED = pollutant mass available for washoff at time "t," pounds per acre
QFACT(1) = maximum pollutant accumulation, pounds per acre
QFACT(2) = daily pollutant accumulation growth rate, per day
t = time, days

The washoff algorithm used constant values, with the washoff coefficient set to 4.6 per inch and the power exponent for runoff rate at 1.0. The following equation was used by SWMM:

$$POFF = PSHED0*(1.0-\exp(-K*t))$$

$$K = RCOEFF*(r^{WASHPO})$$

POFF = cumulative pollutant load washed off at time t, lbs/ac
K = first order decay rate
RCOEFF = washoff coefficient, per inch
WASHPO = power exponent for runoff rate
PSHED0 = pollutant mass available for washoff, lbs/ac
r = runoff rate during time interval, in/hr
t = time interval, hr

Calibrated QFACT(1) values are shown in Table 3-10.

3.6 EVENT MEAN CONCENTRATIONS

EMCs are the mean pollutant loads that can be expected to run off from an average sized storm. The EMCs used in calibration of the Linganore Creek simulation (Table 3-11) were taken from the Patapsco study and adjusted according to Winer (2000).

3.7 CALIBRATION

Rainfall data from 1980 to 1986 was used in the calibration of the Lower Linganore Creek model. One simulation was created, incorporating all seven years of rainfall data. For this simulation, ten watersheds, each with an identical area, slope, and width were created. A different land use was assigned to each watershed, and was used to calculate an

	TN	TP	OP	BOD	COD	TSS	Pb	Cu	Zn	Cd
LDR	0.3183	0.0459	0.02524	1.423	6.812	13.658	0.002065	0.005565	0.00909	0.000416
MDR	0.3578	0.0582	0.03201	2.9245	9.875	20.563	0.00328	0.002523	0.01741	0.000582
HDR	0.3888	0.0622	0.0342	4.456	11.299	25.528	0.006142	0.00324	0.02637	0.000804
Comm/Ind	0.6744	0.06745	0.03711	5.911	14.439	25.286	0.01255	0.01875	0.06117	0.000877
Open	0.3391	0.04915	0.02703	0.8165	6.281	26.078	0.000479	0.01041	0.00566	0.000353
Crop	0.9647	0.1009	0.0555	1.646	6.143	52.556	0.000603	0.02182	0.004713	0.000295
Pasture	0.4458	0.05205	0.02863	1.064	4.108	42.797	0.000534	0.01556	0.003885	0.000334
Forest	0.2857	0.02857	0.01571	0.8885	3.884	14.285	0.000443	0.01714	0.003414	0.000229
Barren	0.3532	0.0718	0.0395	0.6964	5.727	49.103	0.000718	0.02182	0.005084	0.000488
Water	0.1965	0.00728	0.004	0.3128	1.371	7.533	0.004	0.00542	0.00895	0.000146

	TN	TP	OP	BOD	COD	TSS	Pb	Cu	Zn	Cd
LDR	2.22	0.32	0.176	9.92	47.5	95.22	0.0144	0.0388	0.0634	0.0029
MDR	2.03	0.33	0.1815	16.58	55.99	116.63	0.0186	0.0143	0.0987	0.0033
HDR	1.5	0.24	0.132	17.19	43.6	98.46	0.0237	0.0125	0.1018	0.0031
Comm/Ind	2	0.2	0.11	17.53	42.81	75	0.0372	0.0556	0.1814	0.0026
Open	2.69	0.39	0.2145	6.48	49.85	206.91	0.0038	0.0826	0.0449	0.0028
Crop	7.84	0.82	0.451	13.38	49.92	427	0.0049	0.1774	0.0383	0.0024
Pasture	3.34	0.39	0.2145	7.97	30.78	320.52	0.004	0.1166	0.0291	0.0025
Forest	2	0.2	0.11	6.22	27.2	100	0.0031	0.12	0.0239	0.0016
Barren	2.46	0.5	0.275	4.85	39.87	342.17	0.005	0.152	0.0354	0.0034
Water	0.54	0.02	0.011	0.86	3.77	20.71	0.011	0.0149	0.0246	0.0004

infiltration value specific to that type of land use. The infiltration values for each land use were calculated by overlaying the soils map on the land use map. The proportion of soil types to land use was then used to determine an infiltration rate for each land use. Thus, each watershed had a unique land use and infiltration rate, but was otherwise identical to all the other watersheds.

The SWMM model uses QFACT(1) to define how much of each pollutant will run off during a storm event. SWMM uses these variables to determine the mean pollutant loads, in mg/L. These mean pollutant loads are the EMCs for that watershed. Initially, QFACT(1) values from the Back River study were used in SWMM to calculate the mean pollutant loads for each of the calibration watersheds. Since each watershed was made up of a single land use, mean pollutant loads were compared to the Linganore Creek EMCs for that land use. After running the calibration, the loads were compared to the Linganore Creek EMCs, and QFACT(1) values were adjusted as necessary. This process was repeated until the difference between the mean pollutant loads and the EMCs was 0.0%. The calibrated QFACT(1) values were then used for the simulations for the Lower Linganore Creek watershed.

3.8 MODELED POLLUTANT LOADS

Once all the simulations were run, the total yearly pollutant loads were analyzed and mapped for the wet year. Results for wet year conditions are presented here because they have the highest loadings and represent a worst-case scenario. To facilitate overall comparison of the subwatersheds, the pollutant loads per acre were calculated. The ten subwatersheds were ranked by wet-year pollutant loadings, with larger loadings receiving a higher rank. For example, an area with the highest loadings would be ranked 10 and an area with the lowest loadings would be ranked 1. Rankings for both current and future scenarios, are shown in Tables 3-12 and 3-13. Those pollutants with the highest rankings have the highest pollutant loads per acre, and vice versa. To simplify comparisons, individual pollutants were grouped into agricultural or urban pollutant categories. Average rankings for both agricultural and urban pollutants were then calculated for each subwatershed. These averages were used to provide an overview of which subwatersheds are the most heavily impacted by pollutants. Pollutant removals provided by existing SWM facilities have been factored into the following scenarios.

3.8.1 Current Scenario

For the current scenario, pollutant loadings for total nitrogen, total phosphorus, BOD, TSS, copper and zinc, are shown in Figures 3-1 through 3-6. Since Total and ortho phosphorus have similar results, as do BOD and COD, only figures for TP and BOD were included. Copper is shown because it is an agricultural pollutant, while zinc is used to illustrate the impact urban pollutant metals may have on the watershed.

The three subwatersheds that contain the highest agricultural pollutant loadings are Chestnut Grove, Detrick and Hazelnut Run. As shown in the land use map (Figure 2-9), these subwatersheds have the highest amounts of agricultural lands. Forested areas produce relatively

Table 3-12. Lower Linganore Creek subwatershed rankings by pollutant loadings for a current wet year scenario

	Agricultural Pollutant Rankings					Average Agricultural Score	Agricultural Rank	Urban Pollutant Rankings					Average Urban Score	Urban Rank
	TN	TP	OP	TSS	CU			BOD	COD	PB	ZN	CD		
Bartonsville	1	1	1	3	1	1.4	1	2	4	6	6	7	5.0	6
Bens Branch	3	3	3	1	2	2.4	3	5	7	8	8	8	7.2	7
Chestnut Grove	9	9	9	9	10	9.2	9	7	5	5	4	3	4.8	5
Detrick	10	10	10	10	9	9.8	10	6	6	4	3	4	4.6	4
Hazelnut Run	8	8	8	8	8	8.0	8	9	8	7	7	6	7.4	8
Horseshoe Farms	5	4	4	5	5	4.6	5	1	2	2	2	2	1.8	2
Linganore Creek	4	5	5	4	4	4.4	4	10	10	10	10	10	10.0	10
Long Branch	6	6	6	6	6	6.0	6	8	9	9	9	9	8.8	9
New London	7	7	7	7	7	7.0	7	3	1	1	1	1	1.4	1
Westwinds	2	2	2	2	3	2.2	2	4	3	3	5	5	4.0	3

Table 3-13. Lower Linganore Creek subwatershed rankings by pollutant loadings for a future wet year scenario

	Agricultural Pollutant Rankings					Average Agricultural Score	Agricultural Rank	Urban Pollutant Rankings					Average Urban Score	Urban Rank
	TN	TP	OP	TSS	CU			BOD	COD	PB	ZN	CD		
Bartonsville	5	2	2	4	6	3.8	4	3	5	5	4	5	4.4	4
Bens Branch	4	3	3	3	5	3.6	3	5	6	6	6	6	5.8	6
Chestnut Grove	10	10	10	10	10	10.0	10	4	3	2	3	2	2.8	3
Detrick	8	7	7	8	8	7.6	8	1	1	1	1	1	1.0	1
Hazelnut Run	6	8	8	6	4	6.4	6	9	9	8	8	8	8.4	8
Horseshoe Farms	7	6	6	7	7	6.6	7	2	2	3	2	3	2.4	2
Linganore Creek	2	5	5	2	1	3.0	2	10	10	10	10	10	10.0	10
Long Branch	1	1	1	1	2	1.2	1	7	8	9	9	9	8.4	9
New London	9	9	9	9	9	9.0	9	6	4	4	5	4	4.6	5
Westwinds	3	4	4	5	3	3.8	5	8	7	7	7	7	7.2	7

Figure 3-1. Pollutant loadings (lb/ac) for TN in the Lower Linganore Creek watershed, for the current scenario

Figure 3-2. Pollutant loadings (lb/ac) for TP in the Lower Linganore Creek watershed, for the current scenario

Figure 3-3. Pollutant loadings (lb/ac) for BOD in the Lower Linganore Creek watershed, for the current scenario

Figure 3-4. Pollutant loadings (lb/ac) for TSS in the Lower Linganore Creek watershed, for the current scenario

Figure 3-5. Pollutant loadings (lb/ac) for copper in the Lower Linganore Creek watershed, for the current scenario

Figure 3-6. Pollutant loadings (lb/ac) for zinc in the Lower Linganore Creek watershed, for the current scenario

smaller agricultural pollutant loads, and as such, subwatershed with larger proportions of forest were ranked lower. The three subwatersheds with the least agricultural pollutant loadings are Bartonsville, Bens Branch, and Westwinds. All of these have more forested than agricultural land, so the low rankings were expected.

Urban pollutant rankings were highest for the Mainstem Linganore Creek and Long Branch subwatersheds. Both contain a high percentage of medium-density and high-density residential land, as well as some commercial lands. The next highest ranked subwatersheds for urban pollutants are Hazelnut Run and Bens Branch. Hazelnut Run contains a large amount of medium-density residential and commercial land, while Bens Branch contains more low-density residential along with some medium-density residential lands. Horseshoe Farms and New London subwatersheds have the least amount of urban pollutants, because both have very little residential land, and no commercial land.

In general, if a subwatershed has a high ranking for one group of pollutants, it has a lower matching ranking for the other group of pollutants. For example, Mainstem Linganore Creek may have the highest urban loadings, but has less than average agricultural loadings. However, Long Branch and Hazelnut Run subwatersheds both have high agricultural and urban rankings because they have large amounts of residential and commercial lands, as well as a high percentage of agricultural lands.

3.8.2 Future Scenario

Pollutant loadings for the future scenario are shown in Figures 3-7 through 3-12. As outlined for the current scenario, maps include total nitrogen, total phosphorus, BOD, TSS, copper and zinc.

In the future scenario, the Chestnut Grove and New London subwatersheds have the highest concentration of agricultural pollutants. Future land use projections indicate that in both of these subwatersheds, along with several others, considerable amounts of forested land will be converted to agricultural land uses. Chestnut Grove and New London subwatersheds also had high agricultural pollutant rankings in the current scenario. The two other subwatersheds that had high agricultural rankings in the current scenario, Detrick, and Hazelnut Run, had very little new agricultural land in the future, and therefore are ranked lower than Chestnut Grove and New London. They continue to have higher agricultural pollutant rankings than the other six subwatersheds.

Figure 3-7. Pollutant loadings (lb/ac) for TN in the Lower Linganore Creek watershed, for the future scenario

Figure 3-8. Pollutant loadings (lb/ac) for TP in the Lower Linganore Creek watershed, for the future scenario

Figure 3-9. Pollutant loadings (lb/ac) for BOD in the Lower Linganore Creek watershed, for the future scenario

Figure 3-10. Pollutant loadings (lb/ac) for TSS in the Lower Linganore Creek watershed, for the future scenario

Figure 3-11. Pollutant loadings (lb/ac) for copper in the Lower Linganore Creek watershed, for the future scenario

Figure 3-12. Pollutant loadings (lb/ac) for zinc in the Lower Linganore Creek watershed, for the future scenario

The Long Branch subwatershed has the lowest agricultural pollutant loadings in the future scenario. In the current scenario, it had a higher than average rank. The Bartonsville, Westwinds and Bens Branch subwatersheds had the least agricultural pollutants in the current scenario, and were still ranked very low in the future scenario. The Long Branch subwatershed lost forested and agricultural lands to low-density residential development in the future scenario, and therefore has less agricultural pollutants.

Urban pollutant loadings in the future scenario were highest for the mainstem Linganore Creek and Long Branch subwatersheds. The Hazelnut Run subwatershed is also ranked highly. In all three subwatersheds, agricultural lands had been converted into medium density residential lands, which increased urban pollutant loadings.

The three subwatersheds in the future scenario that have the least urban pollutant loadings are Chestnut Grove, Detrick, and Horseshoe Farms subwatersheds. Although urban pollutant loadings increased for all subwatersheds, these three subwatersheds had the smallest increase because most of the other subwatersheds had much more development.

In general, pollutant loadings increased for most subwatersheds in the future scenario (Figures 3-7 to 3-12). Only the pollutants dependent on agricultural and forested land uses decreased as those land uses were converted to residential uses. This trend occurred with copper, total and ortho phosphorus, total nitrogen, and total suspended solids. Copper loadings decreased in most subwatersheds, including Long Branch, Hazelnut Run, and Linganore Creek subwatersheds, which are projected to lose much forested area to residential development. The four remaining pollutants (TP, OP, TN, and TSS) decreased in Long Branch E, Hazelnut Run F and Linganore Creek M catchments, due to conversions of current agricultural land to future residential lands.

3.9 POLLUTANT REMOVAL BY STORMWATER FACILITIES

Currently, there are 33 stormwater facilities in the Lower Linganore Creek watershed. Several of these have very small drainage areas (i.e., less than nine acres), and therefore, would have little impact on the pollutant loadings within the watershed as a whole. From the remaining stormwater facilities, with a drainage area of more than nine acres, 25 were chosen for more in-depth analysis. The 25 facilities are located within seven subwatersheds.

Each SWM pond was analyzed separately in SWMM to determine the impact it had on its subwatershed. First, the drainage area of each facility was delineated on a topographic map so that the shape of the drainage area could be determined. These shapes were then digitized into a GIS and overlaid onto land use maps to find the type and amount of land draining into each pond. Slopes for each drainage area were calculated using the topographic map, and the land use data were used to calculate imperviousness and Manning coefficients for each facility. Once these values were determined, SWMM simulations were run under the assumption that each drainage area was a separate subwatershed.

Once the pollutant loadings flowing into each pond were calculated, removal efficiencies were used to calculate loading removals by each facility. Each type of facility had different removal efficiencies, based on values from Winer (2000) and Schueler (1997).

The largest pond in the watershed (Structure ID 459 in the Mainstem Linganore Creek subwatershed) was much larger than all the other facilities, and several smaller ponds, and their drainage areas, were located entirely within its drainage area. To properly analyze this pond, only the area that was not covered by the other ponds was used to find the pollutant loadings. To find the total pollutant loadings entering the largest pond, the loadings from SWMM were combined with the loadings coming out of the ponds inside of the drainage area of the large pond after they had removed a percentage of the pollutants. The total pollutants were then multiplied by the removal efficiency for that pond.

Once the pollutant removals were calculated for each of the 25 ponds, they were compared to the pollutant loadings for each subwatershed. The percent of pollutants removed from each associated catchment and subwatershed were calculated, and are presented in Tables 3-14 and 3-15 for the current scenario, and in Tables 3-16 and 3-17 for the future scenario. Over 50 percent of some pollutants were removed from the Linganore Creek M catchment for the current scenario. Linganore Creek M and Hazelnut Run F catchments both exhibited greatly reduced loadings due to existing SWM ponds. Long Branch A and F, and Westwinds B catchments also had large removals. Once the catchments were aggregated at the subwatershed level (Table 3-14), the impacts of the stormwater facilities were not as dramatic. Nevertheless, individual subwatersheds had up to thirteen percent of pollutants removed by the SWM facilities.

Hazelnut Run and Long Branch subwatersheds, as shown in Table 3-12, had high rankings for both agricultural and urban pollutant loadings. Tables 3-14 through 3-17 demonstrate that both of these subwatersheds also had some of the highest pollutant removals by SWM facilities.

In the future scenario (Table 3-16), pollutant removals by catchment followed a similar pattern to the current scenario. However, a maximum of 40 percent of some pollutants were removed. When catchment removals were aggregated by subwatershed (Table 3-17), SWM facilities removed up to nine percent of pollutants.

3.10 CONCLUSION

SWMM modelling provided useful results for comparing nonpoint pollutant loadings originating from various areas within Lower Linganore watershed. In the current scenario, subwatersheds with the highest urban pollutant loadings were Mainstem Linganore Creek and Long Branch (Table 3-12). Those subwatersheds with the least urban pollutants are New London and Horseshoe Farms. The subwatersheds with the highest agricultural pollutant loadings are Chestnut Grove and Detrick, while the lowest agricultural loadings are Bartonsville,

Table 3-14. Percentage of removals by stormwater facilities in each catchment for the wet year, current scenario. Area (acres) indicates the total surface treated by SWM facilities.

	Catchment Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville - A	419	2%	3%	4%	2%	2%	6%	6%	2%	5%	2%
Bens Branch - C	690	1%	1%	1%	1%	1%	2%	2%	2%	2%	3%
Bens Branch - F	527	3%	2%	-1%	3%	3%	5%	5%	2%	3%	6%
Hazelnut Run - B	154	4%	2%	-1%	3%	3%	7%	5%	3%	3%	6%
Hazelnut Run - F	333	25%	15%	-8%	15%	16%	48%	25%	24%	17%	34%
Linganore Creek - F	298	4%	3%	-1%	3%	3%	8%	4%	4%	3%	7%
Linganore Creek - I	892	3%	3%	-2%	7%	6%	5%	17%	1%	10%	12%
Linganore Creek - L	349	1%	1%	-1%	2%	2%	2%	7%	1%	3%	4%
Linganore Creek - M	568	14%	27%	6%	10%	9%	25%	56%	17%	24%	58%
Long Branch - A	450	8%	6%	-3%	8%	7%	23%	20%	8%	13%	18%
Long Branch - B	432	4%	2%	-1%	4%	3%	7%	8%	3%	5%	6%
Long Branch - E	593	3%	2%	-1%	2%	2%	6%	3%	3%	2%	4%
Long Branch - F	231	15%	8%	4%	16%	16%	15%	23%	12%	20%	18%
New London - A	804	1%	2%	3%	1%	1%	3%	3%	1%	4%	1%
Westwinds - B	308	6%	10%	12%	5%	5%	14%	19%	5%	16%	5%

Table 3-15. Percentages of removals by stormwater facilities in each subwatershed for the wet year, current scenario

	Subwatershed Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville	1545	0.6%	1.0%	1.2%	0.4%	0.4%	2.0%	1.0%	0.8%	1.0%	0.5%
Bens Branch	2286	0.8%	0.8%	0.0%	0.9%	1.0%	1.6%	2.2%	0.9%	1.4%	2.4%
Hazelnut Run	2297	4.2%	2.9%	-1.6%	4.3%	4.3%	7.7%	11.6%	3.1%	6.6%	9.4%
Linganore Creek	5379	2.4%	4.1%	0.4%	2.8%	2.5%	4.4%	13.5%	2.1%	6.0%	11.3%
Long Branch	2532	4.0%	2.5%	-0.4%	4.1%	3.7%	7.1%	8.4%	3.7%	5.8%	6.9%
New London	3504	0.2%	0.4%	0.5%	0.2%	0.3%	0.6%	0.5%	0.3%	0.7%	0.3%
Westwinds	1250	1.2%	2.1%	2.6%	1.2%	1.2%	2.9%	4.2%	1.1%	3.6%	1.1%

	Catchment Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville - A	419	2%	3%	4%	2%	2%	5%	8%	3%	6%	2%
Bens Branch - C	690	1%	2%	2%	1%	1%	5%	2%	2%	2%	3%
Bens Branch - F	527	2%	2%	-1%	2%	2%	4%	5%	2%	3%	6%
Hazelnut Run - B	154	2%	2%	-1%	5%	4%	4%	14%	1%	8%	10%
Hazelnut Run - F	333	22%	14%	-7%	17%	17%	38%	32%	21%	20%	37%
Linganore Creek - F	298	4%	3%	-2%	4%	4%	9%	5%	3%	4%	8%
Linganore Creek - I	892	3%	2%	-1%	4%	3%	6%	7%	1%	4%	8%
Linganore Creek - L	349	1%	1%	0%	1%	1%	2%	3%	1%	2%	2%
Linganore Creek - M	568	13%	22%	5%	7%	7%	22%	41%	16%	18%	39%
Long Branch - A	450	8%	5%	-3%	10%	8%	15%	22%	6%	15%	17%
Long Branch - B	432	2%	1%	-1%	3%	2%	4%	6%	3%	4%	5%
Long Branch - E	593	3%	2%	-1%	2%	2%	6%	3%	3%	2%	4%
Long Branch - F	231	13%	8%	4%	21%	20%	13%	33%	9%	29%	22%
New London - A	804	1%	1%	1%	0%	1%	2%	1%	1%	2%	1%
Westwinds - B	308	3%	5%	6%	3%	3%	7%	7%	4%	7%	3%

	Subwatershed Area (ac)	TN	TP	OP	BOD	COD	TSS	PB	CU	ZN	CD
Bartonsville	1545	0.6%	1.0%	1.2%	0.5%	0.5%	1.5%	1.2%	0.8%	1.1%	0.4%
Bens Branch	2286	0.9%	1.1%	0.4%	0.8%	0.9%	2.3%	2.0%	0.9%	1.3%	2.4%
Hazelnut Run	2297	2.1%	1.7%	-0.9%	3.3%	3.4%	3.7%	8.9%	1.5%	5.2%	8.2%
Linganore Creek	5379	1.6%	2.6%	0.2%	2.1%	1.9%	3.0%	9.0%	0.9%	4.3%	7.8%
Long Branch	2532	3.6%	2.3%	-0.3%	4.7%	3.9%	5.3%	8.6%	2.8%	6.2%	6.9%
New London	3504	0.1%	0.2%	0.3%	0.1%	0.2%	0.4%	0.3%	0.2%	0.5%	0.2%
Westwinds	1250	0.6%	1.2%	1.4%	0.9%	0.9%	1.5%	3.2%	0.6%	2.9%	0.9%

Westwinds and Bens Branch. In general, stormwater facilities are already located in subwatersheds that have higher pollutant loadings. However, the existing facilities may not be sufficient for each subwatershed because their removals do not considerably lower the pollutant loadings within subwatersheds. Only when the subwatersheds are broken down into smaller areas, and analyzed at a localized level do the benefits of the existing stormwater facilities become apparent.

As expected, future loadings of many pollutants were predicted to increase as a result of land use changes (Figures 3-1 to 3-12). In the future scenario, the Mainstem Linganore Creek, Long Branch and Hazelnut Run subwatersheds are projected to have the highest urban pollutant loadings (Table 3-13). This was due to an increase in the percentage of residential lands in each subwatershed. In contrast, the Chestnut Grove, Detrick, and Horseshoe Farms subwatersheds contained the lowest urban pollutant loads, as they are expected to have less residential or commercial land. Chestnut Grove and New London subwatersheds are projected to have the highest agricultural pollutant loads, assuming much existing forested land will be used for agriculture in the future. Long Branch subwatershed will lose both forested and agricultural lands to future residential development, and therefore is expected to have the lowest agricultural pollutant loadings.

These SWMM results, when integrated with other watershed assessment findings, provide valuable information for targeting general areas (subwatersheds) where water quality improvement opportunities would be most effective. This will assist the County in identifying potential areas for implementing new structural BMPs, retrofits to existing structures, stream restoration projects, or other site-specific improvements. Further application of the SWMM model would involve modeling to help select specific locations and types of structural BMPs for implementation. In this extended application, the baseline model presented here (which estimates current and future pollutant loads) would be augmented with simulations of pollutant loading reductions from potential BMPs in new locations or from retrofitting existing structures. Running various "what-if" scenarios would help identify specific locations for the most cost-effective BMPs that would result in the greatest improvement in water quality in watershed streams and lakes. This extended application would refine the SWMM model output and support more detailed recommendations and cost estimates for watershed planning.

