Benthic TMDLs for the Goose Creek Watershed

Submitted by

Virginia Department of Environmental Quality

Virginia Department of Conservation and Recreation

Prepared by

Interstate Commission on the Potomac River Basin

March 1, 2004
Revised April 27, 2004

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EXECUTIVE SUMMARY

Introduction

Goose Creek is the largest tributary to the Potomac River in Virginia downstream of the Shenandoah River. The Goose Creek watershed covers 386 square miles and is located in Northern Virginia. The headwaters of Goose Creek begin near the Blue Ridge Mountains in northwestern Fauquier County and flow east and slightly north for approximately 53 miles toward its confluence with the Potomac River in Loudoun County. The entire portion of the mainstem of Goose Creek in Loudoun County has been designated a scenic river under the state's Scenic River Act (Commonwealth of Virginia, 1984).

Loudoun County, on the edge of the Washington D. C. metropolitan area, is one of the fastest growing counties in the nation. Portions of the Goose Creek Watershed around Leesburg are rapidly being developed, although most of the watershed remains rural. Goose Creek lies in the heart of Virginia's horse country, and many of the state's wineries make their home there, but beef cattle production remains the dominant agricultural activity. Two active quarries just south of Leesburg mine diabase, which is used to make concrete and building material.

The City of Fairfax operates a water supply intake on Goose Creek just upstream of Leesburg. A 500 ft dam on Goose Creek creates a 200 million gallon reservoir on the mainstem of Goose Creek. A secondary reservoir with a capacity of 1.3 billion gallons is maintained just upstream from the Goose Creek Reservoir on Beaverdam Creek to supply additional water during low flows.

Impairment Listing

The lower mainstem of Goose Creek and a section of one of its larger tributaries, Little River, were listed as impaired on Virginia'a 1998 Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the General Standard (VADEQ, 1998). These impairments are characterized as "Benthic" because they were based on assessments of the benthic macroinvertebrate community performed under the Department of Environmental Quality's biological monitoring program. Table 1 characterizes the benthic impairments as listed in the 303 (d) report.

Table 1: Benthic Impairments in the Goose Creek Watershed

Waterbody	Stream Name	Location	Length (mi.)	Cause	Source	Years Listed
VAN-A08R	Goose Creek	From Goose Creek Impoundment to Confluence with Potomac River	4.91	General Standard (Benthic)	Unknown	1998, 2002
VAN-A08R	Little River	From Confluence with Hungry Run to Confluence with Goose Creek	6.13	General Standard (Benthic)	Unknown	1998, 2002

Stressor Identification

Stressor identification is the process by which the causes responsible for the benthic impairment are identified. Four potential stressors were examined to determine if they contributed to the impairment of aquatic life in Little River and Goose Creek. They are:

1. Heavy metals and toxic chemicals
2. Nutrients and excess algae
3. Hydromodification
4. Sediment

An analysis of water quality data collected by DEQ failed to identify any toxic chemicals or heavy metals in the water column, sediment, or fish tissue that are the likely cause of the benthic impairment. Nitrogen and phosphorus concentrations collected in VADEQ's ambient water quality monitoring program also failed to disclose significant differences in the nutrient concentrations between Little River and Goose Creek, on the one hand, and the monitoring sites on the Rapidan River and Catoctin Creek that were used as their biological references.

The highlights of the stressor identification are summarized below.

Heavy Metals and Toxic Chemicals
The growth and survival of fathead minnows (*Pimephales promelas*) and the survival and reproduction of water fleas (*Ceriodaphnia dubia*) were studied by the EPA Laboratory in Wheeling, WV, using samples of river water collected at four locations in the Goose Creek watershed by VADEQ in December 2002. Survival and reproduction of the water fleas in the water samples taken from any site in the Goose Creek watershed were not statistically different from the laboratory control. Subchronic effects on the growth of fathead minnows were detected in the samples taken from Little River, Tuscarora Creek, and Goose Creek above the confluence with Tuscarora Creek, but not in the sample taken below the confluence with Tuscarora Creek. Moreover, in the words of the report "…the weight reductions for the fish exposed to these sample sites might not be biologically significant." (Bailey et al, 2002). The results of the toxicity tests performed in Goose Creek may indicate an unknown source of toxicity, which bears further monitoring, but the ambiguous outcome of the tests suggests that even if there is an unknown source of toxicity in Goose Creek, it is not the primary cause of the impairment of the benthic community.

Nutrients
The observed diurnal DO fluctuations in Goose Creek and Little River, as measured by VADEQ in August 2003, do not indicate that excess primary production is causing DO concentrations to drop below Virginia's instantaneous minimum standard of 4 mg/l or the daily average standard of 5 mg/l.

Hydromodification
Both Little River and Goose Creek have dams above the biological monitoring sites. The dam on Goose Creek is used to create an impoundment for the City of Fairfax's water

supply. The dam on Little River is used to divert water into the mill race to power Aldie Mill.

Habitat assessment performed during biological monitoring indicates that under low flow conditions, there is sufficient flow in both Little River and Goose Creek. Observed water temperature, which may give an indication that low flows are having a negative impact on aquatic life, are well below the maximum temperature set for Piedmont streams under Virginia's water quality standards. There is no evidence that the presence of the dams on either Goose Creek or Little River is the primary cause of their benthic impairments.

Sediment

There is some direct evidence from an examination of the macroinvertebrate taxa observed in Little River and Goose Creek that these waterbodies have more sediment in their benthic environment than their biological references.

- Goose Creek has more crayfish, which are sediment tolerant, than Rapidan River;
- Goose Creek also shows consistently higher numbers of water striders and whirling beetles, and low numbers of riffle beetles, which taken together may suggest slow-moving water and/or less coarse substrate;
- Goose Creek has more narrow-winged damselflies, which may suggest some sediment deposition;
- Goose Creek lacks some sediment intolerant taxa, such as stoneflies or water pennies;
- Little River has high numbers of burrowing and sprawling mayflies, an increasing abundance of crayfish, and many Asian clams collected in Summer 1998; and
- Little River has few water pennies and almost no stoneflies.

Neither Goose Creek nor Little River, however, had an abundance of taxa that indicate severe sedimentation.

Conclusion of the Stressor Identification

Goose Creek and Little River are borderline cases of aquatic life impairments. For the most part, they are classified as slightly impaired when compared to their reference sites. The presence of sediment tolerant species in greater abundance in Goose Creek and Little River represents the clearest difference between the impaired sites and their references. It is therefore likely that sediment loads in excess of those found in their references are the cause of the differences observed in the macroinvertebrate communities in Goose Creek and Little River.

Selection of Reference Watersheds

Virginia does not currently have numeric criteria for sediment as part of its water quality standards. A TMDL requires, however, the determination of the maximum pollutant load compatible with water quality standards, and the allocation of that load among permitted and nonpoint sources. The reference watershed approach is used to determine the TMDL "endpoint," that is, in this case, the maximum sediment load that the impaired waterbodies can assimilate and still meet water quality standards.

In the reference watershed approach, the pollutant load for an unimpaired watershed, similar in other respects to the impaired watershed, is determined, usually by computer simulation. That load is then re-scaled in proportion to the comparative size of the impaired and unimpaired watersheds. The scaled load becomes the numeric TMDL endpoint for the impaired watershed.

Ideally, a reference watershed should be similar in size, soils, topography, geology, and ecoregion to the impaired watershed. It must also be assessed as unimpaired. Because it was difficult to find a reference watershed comparable in size to the Goose Creek watershed in the Piedmont region, it seemed that greater validity could be given to the reference watershed approach by choosing to use the catchment of the reference biological monitoring station as the reference watershed in this case. The Rapidan River was therefore selected as reference watershed for determining the TMDL endpoint for Goose Creek. For Little River, the catchment of the biological monitoring station on Catoctin Creek, which is the RBP reference station for Little River, was also chosen as the reference watershed. Selecting the catchment of the biological monitoring station as the reference watershed ties the TMDL sediment allocation to the biological yardstick by which impairment is measured.

Table 2 compares the characteristics of Goose Creek with the Rapidan River watershed and Little River with the Catoctin Creek watershed.

Table 2: Characteristics of Reference and Impaired Watersheds

	Goose Creek	Rapidan River	Little River	Catoctin Creek
Area (sq. mi.)	386.3	695.9	55.1	92.4
% Forest	40.5	63.2	42.4	33.3
% Agriculture	57.0	35.2	56.0	65.8
% Developed	2.0	1.2	1.4	0.7
Average Soil Erodibility (K)	0.35	0.31	0.32	0.35
Average Curve Number (CN)	67	66	67	68

Modeling of Sediment Loads

The water quality simulation model, Generalized Watershed Loading Functions (GWLF), was used to calculate sediment loads in the reference and impaired watersheds. The simulation period was 1990-2001, which represents the period during which the biological assessment of Goose Creek and Little River led to their placement on Virginia's 303(d) List of impaired waterbodies. Both the unadjusted reference watersheds and representations of the reference watersheds, adjusted for size, were also simulated for this period. The simulated average annual loads from the adjusted reference watersheds were then used to determine the TMDL endpoints for the impaired watersheds.

GWLF is a continuous simulation model that can be used to represent streamflow, sediment loads, and nitrogen and phosphorus loads from point and nonpoint sources on a watershed basis. GWLF's strength is that it uses accepted engineering practices and techniques, such as the NRCS curve numbers and the Universal Soil Loss Equation, to calculate key variables like runoff and erosion. AVGWLF, a version of GWLF developed by Pennsylvania State University (Evans et al., 2003a) for use in Pennsylvania's nonpoint source TMDLs, was used to calculate sediment loads for the Goose Creek benthic TMDLs because it added a streambank erosion component to the original GWLF model.

Sediment Source Assessment

Three types of sources were identified and represented in the GWLF models for the Goose Creek benthic TMDLs: (1) sediment loads from erosion on the land, (2) streambank erosion, and (3) sediment loads from permitted sources.

Four basic land uses were represented in the models: (1) Forest, (2) Pasture, (3), Cropland, and (4) Developed Land. Land disturbed by construction and timber harvests were also taken into account. The USLE is the basis of estimating erosion from the land surface.

Streambank erosion is calculated using the regression equation developed by Evans et al. (2003). Streambank erosion is a function of (1) percent developed land, (2) animal equivalent unit density, (3) average curve number, (4) average K- factor, (5) mean slope, (6) monthly runoff, and (7) total watershed streamlength.

Loads of TSS from permitted sources were generally calculated using information provided for the permits and from the Discharge Monitoring Reports. The following types of permits discharge TSS in the Goose Creek Watershed:

- Wastewater treatment plants;
- Wastewater discharges of less than 1,000 gallons from residences and businesses;
- Non-metallic mineral mining operations (quarries);
- Ready-mix concrete plants;
- Stormwater runoff form industrial activities;
- Construction sites; and
- Municipal separate storm sewer systems (MS4s).

Sediment trapping in the Goose Creek Reservoir and Beaverdam Reservoir was also taken into account.

Model Results

Table 3 compares the average annual simulated sediment load from Goose Creek and the Rapidan River. Table 4 compares the average annual simulated load from Little River and Catoctin Creek. Tables 3 and 4 also show sediment loads for the Rapidan River and Catoctin Creek, adjusted for size.

Table 3: Average Annual Sediment Loads From Goose Creek, Rapidan River, and Adjusted Rapidan River By Source (in tons/year)

Source	Goose Creek (1992-2001)	Goose Creek (current conditions)	Rapidan River	Adjusted Rapidan River
Construction	1,542	1,542	10	13
Crops	1,914	1,843	2,216	2,700
Forest	998	998	1,410	1,717
Clear-cut Timber	2	2	49	60
Select-cut Timber	72	72	93	114
Pasture	16,069	15,481	4,930	6,006
Developed Land	250	447	317	386
Streambank Erosion	44,915	55,502	177,079	36,089
WWTP	9.4	9.4	23.7	13.1
Business & Residences	0.5	0.5	0.4	0.2
Quarries	8.2	8.2	10.9	6.0
Reservoir Trapping	-6,578	-7,592	---	---
Total	59,202	68,341	186,142	47,106

Table 4: Average Annual Sediment Loads From Little River, Catoctin Creek, and Adjusted Catoctin Creek By Source (in tons/year)

Source	Little River	Catoctin Creek	Adjusted Catoctin Creek
Construction	155	268	211
Crops	457	1,335	1,054
Forest	266	290	229
Clear-cut Timber	0.4	0.0	0.0
Select-cut Timber	2	30	24
Pasture	4,444	3,213	2,537
Developed Land	25	16	13
Streambank Erosion	2,243	3,728	1,402
WWTP	0.1	1.2	0.7
Business & Residences	0.0	0.1	0.1
Quarries	0	0	0
Total	7,592	8,882	5,470

The dominant source of sediment in Goose Creek and the Rapidan River is streambank erosion. Streambank erosion accounts for almost 70% of the total sediment load in Goose Creek before adjusting for sediment trapping in the reservoir and a similar fraction in the adjusted Rapidan River. Erosion from pasture is the second largest source, accounting for about 25% of the total sediment load in Goose Creek and about half that percentage in the Rapidan River. Erosion from crops and construction sites are the next largest sources of sediment in Goose Creek, but neither accounts for more than 3% of the total sediment load. Other sources are less significant.

Sediment losses from pasture and streambank erosion are also the largest sources in Little River and Catoctin Creek. Erosion from pasture is the largest source of sediment, accounting for 60% of the total sediment load to Little River and almost 50% of the total sediment load in the adjusted Catoctin Creek. Streambank erosion is not as prominent in these smaller watersheds as in the larger watersheds. It accounts for 30% of the load in Little River and about 25% of the load in the adjusted Catoctin Creek. Erosion from cropland is a significant source of sediment in the adjusted Catoctin Creek but not in Little River.

Since the impact of development is probably the most important environmental issue in the Goose Creek watershed, additional simulations were performed to determine the sensitivity of sediment loads to development and the average annual load under current conditions. Table 3 also shows the simulated average annual sediment load under current conditions. Increased development leads to an increase in sediment loads primarily through an increase in streambank erosion. Overall, the average annual sediment load increases by 16%, primarily due to the 24% increase in streambank erosion. The delivered sediment load from developed land increases by 90%, but only constitutes about 1% of the total delivered load.

The Littler River Watershed has not seen rapid development, so conditions over the simulation period 1990-2001 remain a good representation of current conditions.

TMDL Allocations

The goal of any TMDL allocation is to determine the maximum pollutant load that is compatible with meeting water quality standards. Sediment has been identified as the pollutant preventing Goose Creek and Little River from meeting Virginia's General Water Quality Standard, which mandates that the waters of the state support aquatic life. The TMDL must be allocated among sources according to the following equation:

$$TMDL = WLA + LA + MOS$$

Where:
WLA = wasteload allocation for permitted sources
LA = load allocation for nonpoint sources
MOS = margin of safety

An explicit 10% margin of safety was used in the Goose Creek benthic TMDLs.

Load Reduction Scenarios

The goal of the analysis of load reduction scenarios is to determine an equitable allocation of loads among permitted and nonpoint sources that satisfies the requirements of the TMDL. One requirement of any TMDL is that it takes into account future growth of loads. This is a difficult task in Loudoun County, given its rate of development. The following three scenarios were analyzed to take into account future growth:

1. Current conditions
2. Development projected to occur by 2015

3. Full build-out on land zoned for development

Principles for Determining Wasteload Allocations

There are a wide variety of permitted sources of TSS in the Goose Creek watershed: wastewater treatment plants, construction sites, quarries, ready-made concrete plants, industrial stormwater systems, and MS4s. The following principles were used to determine the wasteload allocation for permitted sources:

- The allocated wasteload from WWTPs and WTPs under individual permits was set assuming that they were operating at five times their design flow at their permitted concentration.

- The wasteload for wastewater discharges from residences and businesses holding general permits was set assuming that they discharge at their maximum permitted flow of 1,000 gal/d and their permitted concentration of 30 mg/l.

- The wasteload allocation for the Leesburg and Loudoun County MS4s under each growth scenario was determined on the basis of the developed land and disturbed land within the MS4 boundary under each scenario. Under each scenario, these land uses were given the same reduction within the MS4 as they were given watershed-wide. The MS4 wasteload under each scenario is the load after the reductions from developed and disturbed land.

- Permitted industrial stormwater discharges within the Leesburg and Loudoun County MS4 boundaries were included under the MS4 allocated wasteload.

- The wasteload allocation for the Northern Virginia VDOT MS4 was included under the Leesburg and Loudoun County MS4 allocations.

- Permitted industrial stormwater discharges outside of MS4 boundaries were calculated based on facility size, average rainfall, and a maximum concentration of 70 mg/L.

- The wasteload allocation for quarries was determined by outfall. For outfalls discharging process water, or process water mixed with stormwater, the wasteload allocation was set equal to the largest reported quarterly flow times the permitted concentration of 30 mg/L. For outfalls discharging stormwater unmixed with process water, the wasteload concentration was calculated in the same manner as the wasteload allocation for industrial stormwater systems outside MS4 boundaries.

- Sediment loads from permitted construction sites were required to be reduced by 35%, which represents the maximum practical reduction of sediment from disturbed land under the Watershed Treatment Model (Caraco, 2001) achievable through better enforcement of Virginia's sediment and erosion control laws.

Principles for Determining Load Allocations
In general, load allocations to nonpoint sources were determined through an analysis of the load allocation scenarios, based on the load from each source predicted under the scenario, the reductions necessary to meet the TMDL, and equity considerations.

There are four controllable nonpoint sources subject to load allocations: (1) streambank erosion, (2) erosion from pasture, (3) erosion from cropland, and (4) erosion from developed land. Undisturbed forests are considered an uncontrollable load and are not subject to TMDL reductions. For all scenarios, full enforcement of the BMPs mandated under the Silviculture Act was assumed - that is, a 100% reduction in sediment loads above the background forest load was assumed for clear-cut and select-cut timber harvests. Reducing the timber harvest load to the backrgound forest load is equivalent to a 92% reduction. Therefore, in the allocation tables, timber harvests do not appear as sources distinct from forests.

Development Projections and Land Use Distributions for the Load Allocation Scenarios
The current Loudoun County General Plan (2003) was used to guide the construction of the future land use scenarios. Land use under full build-out was estimated on the basis of the principles guiding development in Loudoun County's Policy Areas. The estimates of the amount of developable land were taken from The Center for Watershed Protection (2001). Land use under the scenario for 2015 was estimated on the basis of projected housing units supplied by the Loudoun County Department of Economic Development. Table 5 shows the distribution of land uses in each scenario.

Table 5: Scenario Land Use Distributions in Loudoun County (acres)

Land Use	Simulation Period (1990-2001)	Current Conditions	2015	Full Build-out
Forest	99,375.3	99,375.3	99,375.3	99,375.3
Crops	3,728.7	3,594.0	3,258.2	3,017.8
Pasture	136,278.0	131,355.3	120,494.9	112,725.7
Developed	5,458.1	10,395.8	21,592.0	29,601.7
Construction	284.7	284.7	219.9	153.7
Total	245,113.8	245,005.1	246,955.3	245,113.8
% Developed	2%	4%	8%	12%

Load Reduction Scenario Results
The three load reduction scenarios were run using the land use distributions in Table 5 and the wasteload allocation principles discussed above. For each scenario, streambank erosion was adjusted to reflect the percent development as given in Table 5.

Table 6 shows the average annual sediment loads to Goose Creek by source for the three load reduction scenarios. As shown in the table, sediment loads increase as development increases, primarily due to the predicted increase in streambank erosion. Sediment loads from streambank erosion are predicted to double from current conditions to full build-out. The loads from developed land nearly triple from current conditions to full build-out, but the percent of the total load due to direct erosion from developed land remains less than 2%.

Sediment loads from land under construction declines because the amount of land under construction declines as development increases. Construction loads reflect the 35% reduction called for under the wasteload allocation.

Table 6: Average Annual Sediment Loads to Goose Creek (tons/yr) under Load Reduction Scenarios

Source	Current	2015	Full Build-out
Forest	1,072	1,072	1,072
Cropland	1,843	1,666	1,540
Pasture	15,481	14,185	13,257
Developed Land Inside MS4 Boundaries	299	357	435
Developed Land OutsideMS4 Boundaries	178	634	923
Construction	1,002	774	541
Streambank Erosion	55,502	83,842	110,277
Other Permitted Sources	456	456	456
Reservoir Trapping	-7,408	-10,140	-12,707
Total	68425	92,846	115,794
TMDL Target Load	42,396	42,396	42,396
Required Reduction	38%	54%	63%

Selection of the TMDL for Goose Creek

Because the planning horizon for TMDL implementation is about 10 years, it is appropriate to base the TMDL on the estimates of sediment loads in the 2015 Scenario.

The TMDL must determine how to divide the Load Allocation among sources. An equal percent reduction in nonpoint source loads among agriculture, developed land, and streambank erosion would call for a 55% reduction from these sources. The scenarios show, however, that development is responsible for an increase in sediment loads over time, and it is perhaps not equable to call for greater reductions over time from the agricultural sector despite the fact that the sediment load from agricultural sources and its share of the load overall are both decreasing. For that reason, the reduction from agricultural nonpoint sources was set at 30%, the level that would have been necessary had conditions remained as they were during the simulation period 1990-2001.

With a 30% reduction in sediment loads from cropland and pasture, a 61% reduction overall from developed land and streambank erosion is necessary to meet the TMDL. Because over 98% of the remaining load comes from streambank erosion, marginal reductions in sediment loads from developed land do not contribute significantly to the overall load reduction. The load reduction required from developed land was therefore set at 30%, and the load reduction required from streambank erosion was set at 62%.

Table 7 shows the elements of the sediment TMDL for Goose Creek. Table 8 shows the wasteload allocation. Table 9 shows the load allocation to nonpoint sources.

Table 7: Elements of the Benthic TMDL for Goose Creek

Waterbody ID	Parameter	TMDL (tons/yr)	WLA (tons/yr)	LA (tons/yr)	MOS (tons/yr)
Goose Creek	Sediment	47,106	1,587	40,808	4,711

Table 8: Sediment Wasteload Allocations For Goose Creek

Permit Number	Facility	Wasteload Allocation (tons/yr)
Wastewater Treatment Plants - Individual Permits		
VA0022802	Basham Simms WWF	91.5
VA0024112	Foxcroft School	9.0
VA0024759	US FEMA - Bluemont	16.0
VA0024775	Middleburg WWTP	14.5
VA0026212	Round Hill WWTP	38.0
VA0027197	Notre Dame Academy	3.5
VA0062189	St. Louis Community	19.5
VA0065200	Rehau Plastics	
VA0080993	Goose Creek Industrial Park	2.5
VA0089133	Aldie WWTP	3.5
Water Treatment Plants		
VA0002666	Goose Creek WTP	57.9
Wastewater Discharge - General Permits		
VAG406015	Residence	0.046
VAG406016	Business	0.046
VAG406018	Residence	0.046
VAG406019	Residence	0.046
VAG406020	Residence	0.046
VAG406047	Residence	0.046
VAG406069	Residence	0.046
VAG406101	Residence	0.046
VAG406113	Residence	0.046
VAG406115	Residence	0.046
VAG406116	Residence	0.046
VAG406121	Residence	0.046
VAG406135	Residence	0.046
VAG406143	Residence	0.046
VAG406146	Residence	0.046
VAG406149	Residence	0.046
VAG406170	Residence	0.046
VAG406172	Business	0.046
VAG406176	Residence	0.046
VAG406193	Residence	0.046
VAG406244	Residence	0.046
Quarries - General Permits		
VAG846011	Luck Stone—Leesburg	56.3

Permit Number	Facility	Wasteload Allocation (tons/yr)
VAG846016	Luck Stone—Goose Creek	90.1
VAG846012	Leesburg Iron and Metal	No longer operating
Industrial Stormwater Outside MS4 Boundaries - General Permits		
VAR051077	Loudoun County Sanitary Landfill	45.3
VAR051115	Waste Management of VA—Leesburg	0.7
VAR051442	Basham Simms WWF	2.1
Ready-Made Concrete Plants - General Permits		
VAG110123	Crider and Shockey	1.2
VAG110091	Virginia Concrete	3.8
Municipal Separate Storm Sewer Systems (MS4)		
VAR040059	**Town of Leesburg MS4**	287.4
VAR051426	Leesburg Municipal Airport	
VAR051427	Leesburg Water Pollution Control	
VAR050980	Leesburg Iron and Metal	
VAR101380	Airport Commerce Park - Phase 1	
VAR102543	Target - Battlefield Marketplace	
VAR101452	Stratford East	
VAR101399	Columbia Gas Transmission Corp. L	
VAR100810	Drymill	
VAR102991	Rokeby Hamlets	
VAR100796	Kincaid Forest	
VAR040062	VDOT - Northern VA MS4	
VAR040067	**Loudoun County MS4**	123.6
VAR051013	Superior Paving	
VAR101445	Belmont Glen	
VAR102855	Quail Pond	
VAR101530	Potomac Station - Sections 8B 8G 8I and 10	
VAR100797	Northlake Subdivision	
VAR102006	Riverside Parkway	
VAR100804	Broadlands - Section 22	
VAR100805	Broadlands - Sections 13 and 20	
VAR101478	Cedar Ridge - Parcel 37	
VAR101670	Potomac Station - Section 10 Parcel A and PI	
VAR040062	VDOT Northern VA MS4	
Erosion and Sediment Control Permits Outside MS4s		719.8
VAR102682	Hamilton Elementary School	
VAR102364	Dominion Virginia Power - Pleasant View	
VAR102736	Barclay Ridge	
VAR101520	Long Meadow Hamlet	
VAR100798	VDOT - 0733 053 P31 C502	
VAR102009	Purcellville Southern Collector	
VAR102008	Village Case The	
VAR102589	Oak Knoll Hamlet	
VAR102686	Dream Homes – William A Kelley Property	

Permit Number	Facility	Wasteload Allocation (tons/yr)
VAR100733	Patrick Henry College	
VAR100734	Patrick Henry College	
VAR102901	Courts of Saint Francis - Ferrell Addition	
VAR100748	Courts of St Francis	
VAR101411	Purcellville Property	
VAR100738	Purcellville WWQMF	
VAR101676	Round Hill - The Villages	
VAR101683	Greenwoods Common	
VAR101677	Hamlets of Blue Ridge	
VAR101615	Round Hill - Lake Point	
VAR101616	Round Hill - Mountain Valley	
VAR101624	Round Hill - West Lake	
VAR102854	Heronwood Farm	
VAR100732	Francis Tract	
VAR102474	Loudoun to Leesburg Tie-Over Gas Pipeline	
VAR101450	VDOT - 0015 053 125 PE101 C501	
Total Wasteload Allocation		**1,587**

Table 9: TMDL Load Allocation For Goose Creek

Land Use	Projected Load (tons/yr)	Load Allocation (tons/year)	Percent Reduction
Forest	998	998	0%
Clear-Cut Timber	2	0.2	92%
Select-Cut Timber	72	6	92%
Cropland	1,666	1,166	30%
Pasture	14,185	9,930	30%
Developed Land*	634	444	30%
Streambank Erosion	83,842	31,860	62%
Sediment Trapping	-10,140	-4,440	---
Total	91,259	39,963	56%

* Excludes developed land within MS4s

Selection of the TMDL for Little River

Little River does not face the same development pressures as the lower portions of the Goose Creek watershed. Much of the watershed lies in Fauquier County, and under the Loudoun County General Plan, the portion of the watershed within Loudoun county is expected to remain rural. The base 1990-2001 simulation, therefore, can be expected to reflect sediment loading rates and the distribution of sediment sources for some time to come. Under those conditions, it is necessary to reduce sediment loads from nonpoint sources by 37% to meet the TMDL load. The load reduction was made equally from cropland, pasture, developed land, and streambank erosion.

Table 10 shows the elements of the sediment TMDL for Little River. Table 11 shows the wasteload allocation. There are only two permitted WWTP sources in the watershed and two construction sites. Table 12 shows the load allocation to nonpoint sources.

Table 10: Elements of the Benthic TMDL for Little River

Waterbody ID	Parameter	TMDL (tons/yr)	WLA (tons/yr)	LA (tons/yr)	MOS (tons/yr)
Little River	Sediment	5,470	105	4,818	547

Table 11: Sediment Wasteload Allocation For Little River

Permit Number	Facility	Wasteload Allocation (tons/yr)
VA0089133	Aldie WWTP	3.5
VAG406019	Residence	0.05
VAR102736	Barclay Ridge	97
VAR102474	Loudoun to Leesburg Tie-Over Gas Pipeline	4
Total Wasteload Allocation		105

Table 12: TMDL Load Allocation For Little River

Land Use	Current Load (tons/yr)	Load Allocation (tons/year)	Percent Reduction
Forest	266	266	0%
Clear-Cut Timber	0.4	0.03	92%
Select-Cut Timber	2	0.16	92%
Cropland	457	288	37%
Pasture	4,444	2,800	37%
Developed Land	25	16	37%
Streambank Erosion	2,243	1,414	37%
Total	7,438	4,783	36%

TMDL Implementation

Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement. The iterative implementation of BMPs in the watershed has several benefits:

- It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
- It provides a measure of quality control, given the uncertainties inherent in
- Computer simulation modeling;

- It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
- It helps ensure that the most cost effective practices are implemented first; and
- It allows for the evaluation of the adequacy of the TMDL in achieving water
- quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

Stage 1 Scenario

The Goose Creek Benthic TMDL was developed to take into account future conditions that are anticipated to be realized in 2015 at the end of the planning horizon for implementation. Under current levels of development the average annual sediment loads from streambank erosion are expected to be considerably less than those predicted for 2015. A Stage 1 Scenario, based on current conditions, was developed for Goose Creek as an interim goal for TMDL implementation. The Stage 1 Scenario calls for a 45% reduction in streambank erosion, which is the level currently required to meet the TMDL allocations. The same wasteload allocation given under the TMDL is given in Stage I Scenario, except that the MS4 wasteload allocations reflect current loading rates.

Since the Little River Benthic TMDL is based on current conditions, no Stage 1 Scenario is required for Little River.

Public Participation

The development of the Goose Creek Benthic TMDLs relied on participation from the general public and various stakeholder groups. A series of public meetings were held to present the results of the TMDLs and to solicit comments and suggestions. Table 13 presents the specifics of the two public meetings held in support of the development of the benthic TMDLs. Meeting notices were published in the Virginia Register and in the community calendars of the Loudoun Times Mirror, Fauquier Times Democrat and Leesburg Today. A flyer announcing the meeting was also sent to interested parties, and the meeting dates were posted on the DEQ TMDL website at http://www.deq.state.va.us/tmdl/.

Table 13: Public participation in the Goose Creek TMDLs

Date	Location	Address	City	Attendance
4/10/03	First Floor Board Room Loudoun Co. Gov't Center	1 Harrison Street, SE	Leesburg, VA	18
12/11/03	First Floor Board Room Loudoun Co. Gov't Center	1 Harrison Street, SE	Leesburg, VA	13

In addition to keeping the public apprised of progress in the development of the Goose Creek TMDLs, a Technical Advisory Committee (TAC) was also established to help advise the TMDL developers. TAC meetings were used as a forum to review data and assumptions used in the modeling, and to provide local city and county government agencies an opportunity to raise concerns about the implications of the TMDL for their jurisdictions.

ACKNOWLEDGEMENTS

The TMDL report for the Goose Creek watershed was prepared with the assistance of many private citizens and personnel from state agencies. Special acknowledgment is made to the following individuals and groups who made significant contributions toward the completion of this project:

Virginia Department of Environmental Quality

Virginia Department of Conservation and Recreation

Virginia Department of Forestry

Members of the Goose Creek Technical Advisory Committee

Loudoun County Soil and Water Conservation District

John Marshall Soil and Water Conservation District

Loudoun County Department of Building and Development

Louduon County Department of Economic Development

Loudoun County Environmental and Historic Resources Program

Loudoun County Office of Mapping and Geographic Information

Fauquier County Department of Community Development

Fauquier County Geographic Information Systems Office

Town of Leesburg

City of Fairfax Department of Utilities

Center for Watershed Protection

The Pennsylvania State University

Virginia Polytechnic Institute and State University

CHAPTER ONE: INTRODUCTION

1.1 TMDL Definition and Regulatory Information

The Clean Water Act (CWA) was established in 1972 to address widespread water pollution issues throughout the nation. Since its inception, one of the primary goals of the CWA has been to assure that waters are of sufficient quality to support designated uses such as fishing and swimming. Unfortunately, approximately 40 percent of all waters across the United States do not currently meet this goal, despite the fact that many pollution sources have implemented nationally required levels of pollution control.

Section 303(d) of the CWA requires states to identify waters that do not meet or are not expected to meet water quality standards after technology-based or other required controls are in place. States must establish a priority ranking for these waters, taking into account the pollution severity and designated uses of the waters. The 303(d) list of impaired waters is updated every two years, and plans must be developed to address identified impairments (US EPA, 1999).

The plans, required under section 303(d) of the CWA and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130), are called Total Maximum Daily Loads (TMDLs) and must be developed for all impaired waters. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (EPA, 1991).

1.2 Impairment Listing

Goose Creek and its tributaries are part of the Potomac River Basin (USGS Hydrologic Unit Code 02070008). The Goose Creek watershed covers 386 square miles and is located in Northern Virginia. The headwaters of Goose Creek begin near the Blue Ridge Mountains in northwestern Fauquier County and flow east and slightly north for approximately 53 miles toward its confluence with the Potomac River in Loudoun County. Figure 1.1 shows the location of the Goose Creek watershed.

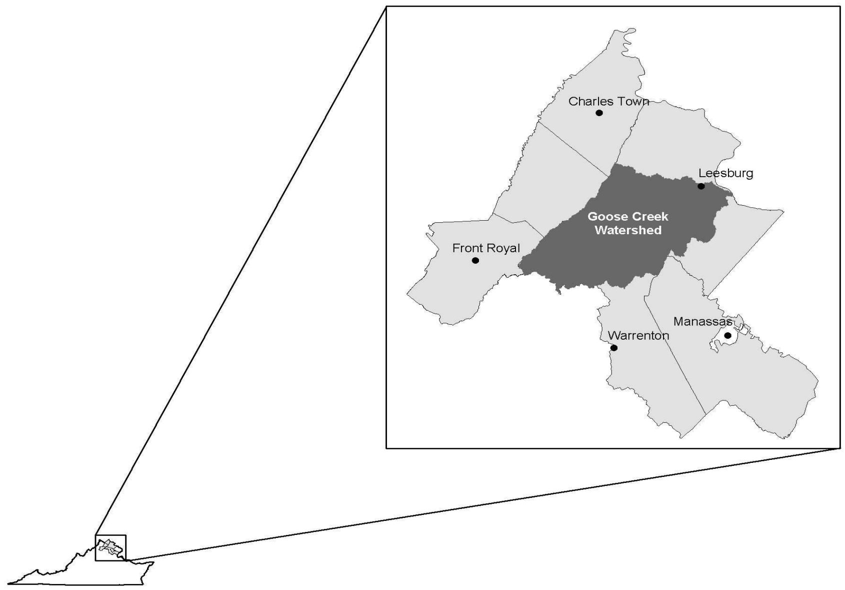

Figure 1.1: Location of the Goose Creek Watershed

The lower mainstem of Goose Creek and sections of one of its larger tributaries, Little River, were listed as impaired on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the General Standard (VADEQ, 1998). These impairments are characterized as "Benthic," because they were based on assessments of the benthic macroinvertebrate community performed under the Department of Environmental Quality's biological monitoring program. The impaired section of Goose Creek begins at the dam for the City of Fairfax's water supply reservoir and ends at Goose Creek's confluence with the Potomac. The benthic impairment on Little River begins at the confluence of Hungry Run and Little River and ends at Little River's confluence with Goose Creek. Figure 1.2 shows the location of the impaired segments. Table 1.1 characterizes the benthic impairments as listed in the 303(d) report.

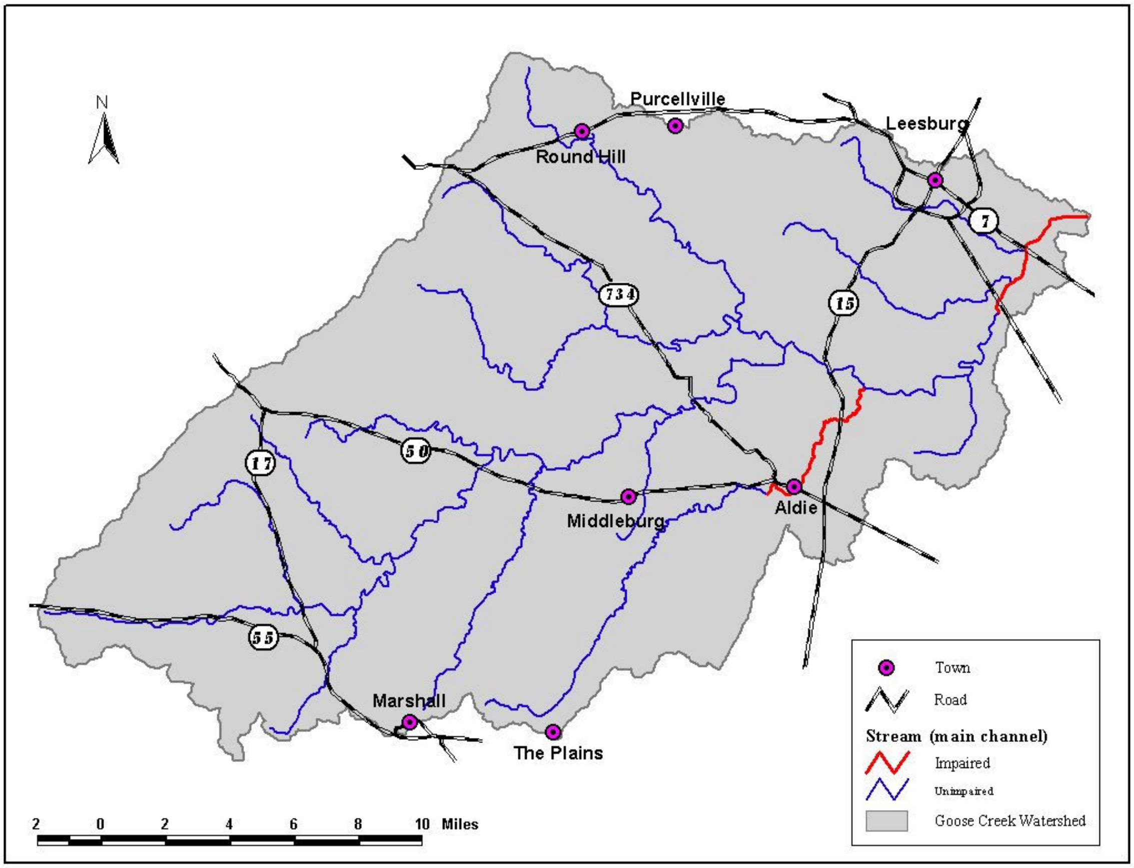

Figure 1.2: Location of Benthic Impairments in the Goose Creek Watershed

Table 1.1: Benthic Impairments in the Goose Creek Watershed

Waterbody	Stream Name	Location	Length (mi.)	Cause	Source	Years Listed
VAN-A08R	Goose Creek	From Goose Creek Impoundment to Confluence with Potomac River	4.91	General Standard (Benthic)	Unknown	1998, 2002
VAN-A08R	Little River	From Confluence with Hungry Run to Confluence with Goose Creek	6.13	General Standard (Benthic)	Unknown	1998, 2002

As will be explained in the subsequent chapter, VADEQ's biological assessment of both Goose Creek and Little River tended to find them only slightly impaired. In 2001 VADEQ proposed to USEPA Region III removing the benthic impairments in Goose Creek and Little River from the 303(d) TMDL Priority List. EPA Region III did not agree to the proposed delisting of the impairments.

The same sections of Goose Creek and Little River, along with sections of five other tributaries to Goose Creek, were listed as impaired on Virginia's 1998 and 2002 TMDL Priority Lists due to violations of the fecal coliform standards. TMDLs addressing the bacteria impairments have already been developed (VADEQ, 2003) and were accepted by EPA Region III in May 2003.

1.3 Applicable Water Quality Standards

The Virginia Water Quality Standards (9 VAC 25-260-5) define "water quality standards" as:

> *provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC 1251 et seq.).*

The Virginia Water Quality Standards (9 VAC 25-260-10 A) go on to say that:

> *All state waters are designated for the following uses: recreational uses e.g., swimming and boating; the propagation and growth of a balanced indigenous population of aquatic life including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*

Further the general criteria, which are the basis of the aquatic life use impairments in the Goose Creek watershed, are defined in the Virginia Water Quality Standards (9 VAC 25-260-20 A) as follows:

> *All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*
>
> *Specific substances to be controlled include, but are not limited to: floating debris, oil, scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life.*

CHAPTER TWO: WATERSHED CHARACTERIZATION

2.1 General Description of the Goose Creek Watershed

Goose Creek is the largest tributary to the Potomac River in Virginia downstream of the Shenandoah River. The Goose Creek watershed lies in Loudoun and Fauquier Counties on the edge of the Washington D. C. metropolitan area. Loudoun County is one of the fastest growing counties in the nation. Although portions of the watershed around Leesburg are rapidly being developed, most of the watershed remains rural. Goose Creek lies in the heart of Virginia's horse country, and many of the state's wineries make their home there, but beef cattle production remains the dominant agricultural activity. Two active quarries just south of Leesburg mine diabase, which is used to make concrete and building material.

The City of Fairfax operates a water supply intake on Goose Creek just upstream of Leesburg. A 500 ft dam on Goose Creek creates a 200 million gallon reservoir on the mainstem of Goose Creek. A secondary reservoir with a capacity of 1.3 billion gallons is maintained just upstream from the Goose Creek Reservoir on Beaverdam Creek (not to be confused with the larger Beaverdam Creek which is a tributary to the North Fork of Goose Creek) to supply additional water during low flows. The City of Fairfax withdraws approximately 11 million gallons a day, a portion of which is delivered to customers of the Loudoun County Sanitation Authority (Mohsenin, 2002; Boryschuk, 2002).

The entire portion of the mainstem of Goose Creek in Loudoun County has been designated a scenic river under the state's Scenic River Act (Commonwealth of Virginia, 1984).

For the purposes of this report, the Goose Creek watershed has been divided into the subwatersheds shown in Figure 2.1.

2.2 Climate

The Goose Creek watershed has the typical humid climate that characterizes the Piedmont region of the Middle Atlantic States. There are three meteorological stations in the watershed, at The Plains (448396), Lincoln (444909), and Mt. Weather (445851), and a fourth station at the Dulles International Airport (448903) lies just to the east of the watershed. Average annual precipitation for these stations is 42.4, 41.6, 41.2, and 41.8 inches, respectively, indicating that precipitation is spread fairly evenly over the watershed. Table 2.1 contrasts average monthly precipitation, maximum and minimum temperatures at Lincoln, which lies just west of Leesburg, and Mt. Weather, which is located near the top of the Blue Ridge in the southwest corner of Loudoun County. Mt. Weather has cooler maximum temperatures in the winter, but otherwise there are not great differences in average temperature and precipitation between the stations. Annual snowfall at Mt. Weather is 23.4 inches compared to 22.6 inches at Lincoln (Southeast Regional Climate Center, 2002).

Table 2.1: Average Monthly Temperature, Precipitation, and Potential Evapotranspiration in the Goose Creek Watershed

Month	Lincoln (444909) 1930-2000			Mt. Weather (445851) 1948-2000			Dulles Airport (448903
	Precipitation (in)	Temperature Max (^oF)	Temperature Min (^oF)	Precipitation (in)	Temperature Max (^oF)	Temperature Min (^oF)	PET (in)
Jan	3.02	43.9	24.7	2.76	36.8	21.2	0.00
Feb	2.63	47.1	25.8	2.34	39.4	23.1	0.04
Mar	3.63	56.1	32.8	3.33	47.5	30.0	0.68
Apr	3.40	67.5	42.0	3.38	59.7	40.3	1.96
May	4.09	77.2	51.8	4.27	69.1	50.5	3.53
Jun	3.84	85.0	60.6	4.22	77.1	59.4	4.95
Jul	3.87	88.9	64.9	3.81	81.2	63.7	5.91
Aug	4.11	87.5	63.1	3.56	79.5	62.4	5.33
Sep	3.56	81.0	56.5	3.78	72.8	55.6	3.68
Oct	3.16	70.2	45.0	3.40	62.0	44.9	1.92
Nov	3.17	57.9	36.1	3.39	50.6	35.2	0.74
Dec	3.12	46.3	27.4	2.91	40.1	25.2	0.10
Total	41.59	---	---	41.15	---	---	28.84

Table 2.1 also shows the Virginia State Climatology Office (2002) estimate of average monthly potential evapotranspiration at Dulles Airport. The estimate is based on the Thornthwaite Method. As Table 2.1 shows, precipitation is fairly even throughout the year but evapotranspiration is significantly higher in the summer months.

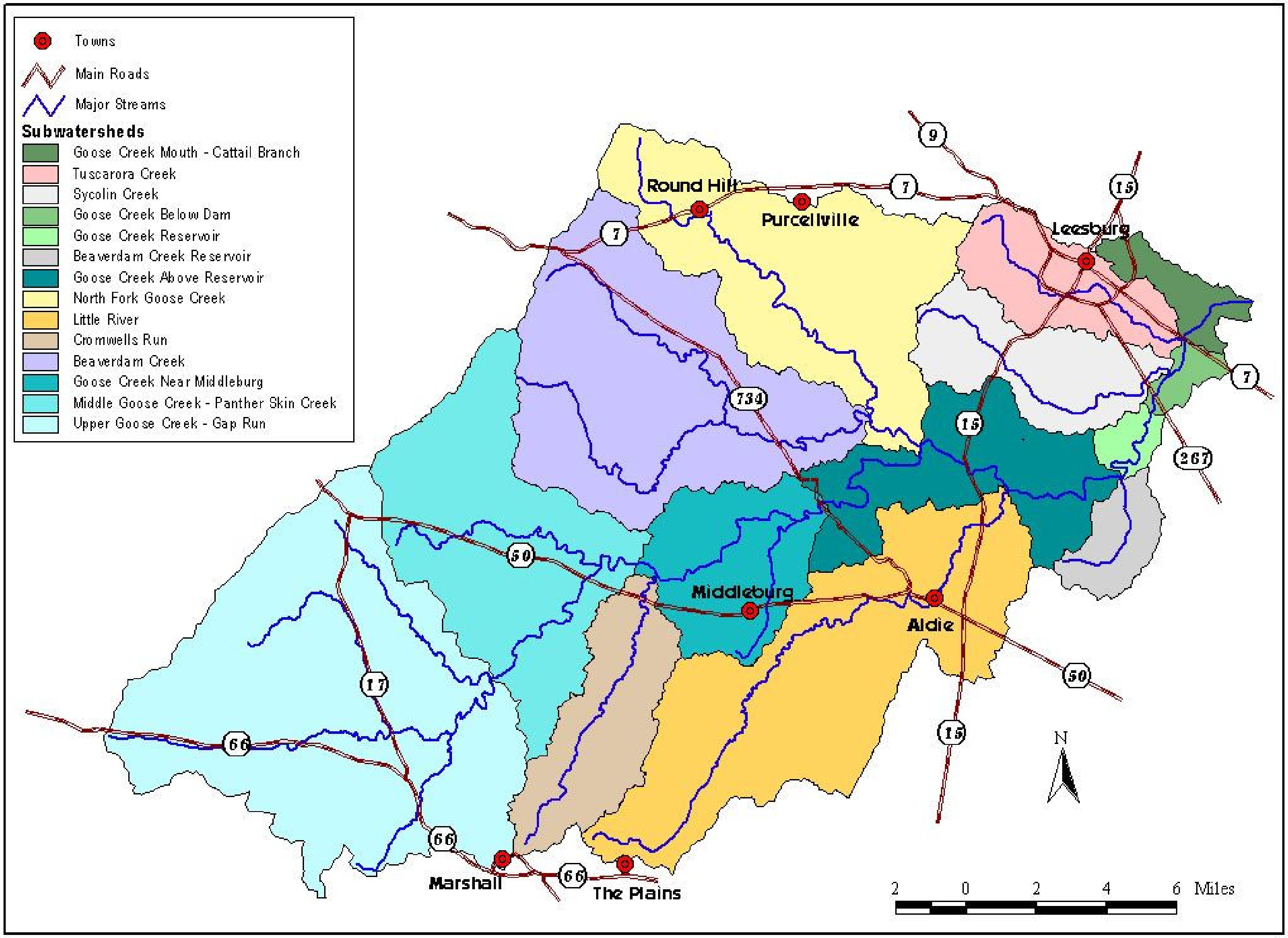

Figure 2.1: Goose Creek Subwatersheds

2.3 Geology and Soils

Goose Creek is located within the Blue Ridge and Piedmont Physiographic Provinces. The dividing line between these two provinces is the Catoctin Ridge /Bull Run Mountains that runs just west of Route 15. The watershed is characterized by diverse soil series and bedrock geology. Soil surveys have recently been updated for Loudoun (Blackburn, 2000) and Fauquier (Hatch and Branford, 2001) Counties. The information in this section is mostly drawn from those reports.

Elevation in the Blue Ridge Mountains proper reaches over 2,100 feet in the southwest corner of the Goose Creek watershed. On the highest ridges the underlying bedrock is quartzite and metabasalt. Slopes in the Blue Ridge are characterized by large areas of boulders and rock outcrops. The dominant soil association is the Catoctin-Myersville-Fauquier Association. It consists of well-drained, moderately deep soils. The predominant hydrologic soil group of these soils is C. The Catoctin-Myersville-Fauquier Association is also the dominant soil of the Catoctin Ridge where Little River has its headwaters. The underlying bedrock is greenstone schist.

Between the Blue Ridge Mountains and the Catoctin Ridge lies an area of more gentle relief underlain by gneisses and metasediments intruded with metadiabase. Elevations range from 450 to 800 feet. The majority of the Goose Creek drainage lies in this area of moderately well-drained, deep soils. The dominant associations are the Eubanks and Purcellville-Tankerville-Middleburg Associations. The predominant hydrologic soil groups in this region are B and B/C soils.

Goose Creek passes into the Piedmont Physiographic Province downstream of Oatlands at Route 15. Little River passes into the Piedmont Province downstream of Aldie. The underlying bedrock is metasedimentary rock of the Triassic lowlands. The dominant association in the upper portion of the drainage is the Sudley-Leedsville-Oatlands Association, which consists of deep well-drained soils over red sandstones and conglomerates. B and C soils are the dominant hydrologic soil groups. The dominant associations in the lower portion of the drainage near Leesburg are the Haymarket-Elbert-Waxpool Association and the Sycoline-Kelley-Catlett Association. Soils in both associations are characterized by seasonal wetness and shrink-swell clays. D soils are the dominant hydrologic soil group.

2.4 Ecoregion

Most of Goose Creek, and all of Little River lies in the Northern Piedmont Level III Ecoregion. The headwaters of Goose Creek lie in the Blue Ridge Mountains. The Northern Piedmont is characterized by low hills, irregular plains, and open valleys. The natural vegetation is predominately Appalachian oak forest. The Blue Ridge Mountains are, of course, more mountainous. The slopes are forested with cool, clear, high-gradient streams (USEPA, 2002).

2.5 Land Use and Population

Land use patterns in the Goose Creek watershed were identified using results from the 1997 version of the Multi-Resolution Land Characteristics (MRLC) Consortium study (EPA, 2002). The MRLC data were developed using 30-meter resolution satellite imagery collected as part of the Landsat Thematic Mapper program. Cooperating agencies included the U.S. Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), the U.S. Forest Service (USFS), and the National Oceanic and Atmospheric Administration (NOAA). The MRLC classification scheme includes 21 different land use classifications. Of those 21 different classifications, 13 were represented in the Goose Creek watershed. Table 2.2 lists the 13 MRLC land uses found within Goose Creek watershed.

To simplify the modeling process, the MRLC categories represented in the Goose Creek watershed were aggregated into 6 land use classes. The classes and methods used to aggregate the MRLC data are presented in Table 2.3.

Table 2.2: MRLC Land Use Categories Found in the Goose Creek Watershed

Class Number	Land Use Type	Abbreviation
21	Low Intensity Residential	LIR
22	High Intensity Residential	HIR
23	Commercial/Industrial/Transportation	CIT
32	Quarries/Strip Mines/Gravel Pits	QSG
33	Transitional	TR
41	Deciduous Forest	DF
42	Evergreen Forest	EF
43	Mixed Forest	MF
81	Pasture/Hay	PH
82	Row Crops	RC
85	Urban/Recreational Grasses	URG
91	Woody Wetlands	WW
92	Emergent Herbaceous Wetlands	EHW

Table 2.3: Model Land Use Classes Used in the Goose Creek Watershed

Land Type	Model Land Use Class	Aggregated MRLC Land Use Classes
Pervious Land	Forest	= DF + EF + MF +WW + EHW
	Cropland	= RC
	Pasture	= PH
	Developed	= 0.15*(HIR+CIT) + 0.6*(LIR) + URG
Impervious Land	Developed Impervious	= 0.85*(HIR+CIT) + 0.4*(LIR)
	Barren	= QSG + TR

Table 2.4 shows the land use distribution in each modeling segment. Overall, pasture and forest are the two dominant land use classes in the Goose Creek watershed. Pasture

represents about 55% of the total watershed area while forest accounts for about 41%. The remaining 4% of the Goose Creek watershed is comprised of cropland (1.5%), urban pervious (1%), urban impervious (1%), and barren land (0.5%). This general distribution holds true for many of the large subwatersheds in Goose Creek, with pasture making up more than 50% of the watershed area, and pasture and forest together usually comprising at least 92% of the total watershed area.

According to the 2000 Census, approximately 60,000 people live in the Goose Creek watershed. More than half live in Leesburg and the surrounding area. As was mentioned earlier, Loudoun County is one of the fastest growing counties in the nation. During the 1990's the population doubled to about 170,000. Most of this growth occurred east of the watershed, but the area south of Leesburg and west along the Route 7 corridor also saw significant growth. The population of Leesburg doubled from 1990 to 2002, from 16,202 to 32,003. Purcellville and the surrounding area is currently the fastest growing portion of the county. The population of Purcellville increased from 3,584 to 4,394 the last two years alone.

The population of Loudoun County is expected to increase by 75% over this decade and by 44% between 2010 and 2020 (Department of Economic Development, 2002). More of the Goose Creek watershed around Leesburg and along the Route 7 corridor is expected to be developed. Loudoun County is currently trying to preserve the rural character of the western portion of the county, including much of the Goose Creek watershed. The portion of the watershed in Fauquier County, currently rural in character, is not expected to experience significant growth in the near future (Center for Watershed Protection, 2002).

Table 2.4: Land Use (acres) by Subwatershed

Subwatershed	Forest	Crops	Pasture	Pervious Developed	Impervious Developed	Quarries	Transitional	Total Acres
Beaverdam Creek	11,474	364	22,689	36	16	0	9	34,587
Beaverdam Creek Reservoir	1,899	98	1,674	7	8	0	0	3,686
Cromwells Run	3,256	23	8,727	106	60	0	8	12,179
Goose Creek Above Reservoir	7,848	219	7,624	23	14	0	5	15,732
Goose Creek Below Dam	789	12	438	18	94	162	18	1,530
Goose Creek Mouth Cattail Branch	1,847	223	653	198	288	2	20	3,231
Goose Creek Near Middleburg	4,276	91	7,955	254	174	0	1	12,751
Goose Creek Reservoir	1,009	56	553	3	15	0	0	1,637
Little River	14,992	477	19,348	340	215	0	9	35,381
Middle Goose Creek Panther Skin Creek	8,680	296	18,095	246	182	0	28	27,526
North Fork Goose Creek	9,824	502	17,649	395	209	0	5	28,583
Sycolin Creek	3,980	422	6,274	66	79	68	174	11,063
Tuscarora Creek	3,276	597	3,651	743	792	97	43	9,199
Upper Goose Creek Gap Run	27,394	394	22,550	357	463	0	89	51,246
Total	100,543	3,773	137,879	2,791	2,610	329	409	248,333

2.6 Streamflow

Daily streamflow records are currently available from two USGS gaging stations on the mainstem of Goose Creek. Two additional gaging stations were initiated in October 2001, one on Beaverdam Creek and one on the North Fork of Goose Creek, but because the period of record is so short, streamflow records from these stations were not used in the development of these TMDLs. Table 2.5 presents all four USGS stations and provides information on the location and period of record of each.

Table 2.5: Active USGS Streamflow Gages in the Goose Creek Watershed

Stream	Station ID	Location	Area (mi^2)	Period of Record
Goose Creek	01643700	Near Middleburg	123	10/01/65 - 1/28/97 6/28/01 - Present
Goose Creek	01644000	Near Leesburg	332	07/12/09 - Present
NF Goose Creek	01643805	Route 729 Bridge	39	10/01/01 - Present
Beaverdam Creek	01643880	Route 734 Bridge	19	10/01/01 - Present

Streamflow data during the model calibration period (1990 to 2001) were used to characterize the hydrological conditions in the Goose Creek watershed. Table 2.6 shows mean monthly streamflow in cubic feet per second (cfs) for Goose Creek from 1990 through 2001.

Table 2.6: Mean Monthly Streamflow (cfs) at Long Term USGS Gages in the Goose Creek Watershed

1990 to 2001 (Leesburg) and 1990 to 1996 (Middleburg)

Month	Middleburg Gage (01643700)	Leesburg Gage (01644000)
January	241	580
February	159	488
March	323	826
April	223	531
May	127	305
June	106	217
July	53	114
August	59	140
September	80	167
October	78	174
November	95	248
December	182	411

From the table it is evident that the highest mean monthly flows in Goose Creek occur during the months of December through April, which is typical for watersheds in the Eastern United States. The lower flows typically occur during the months of May through November.

Table 2.7 shows the mean annual streamflow at the Goose Creek gages from 1990 through 2001. For the period of record at each gage, mean streamflow at Middleburg is approximately 136 cfs and at Leesburg the mean streamflow is approximately 318 cfs. These represent "average" conditions at the respective gaging stations.

Table 2.7: Mean Annual Streamflows (cfs) at the USGS Gages in the Goose Creek Watershed

Year	Middleburg Gage (01643700)	Leesburg Gage (01644000)	Flow Status
1990	132	343	Average
1991	89	227	Low
1992	133	362	Average
1993	174	472	High
1994	140	393	High
1995	101	264	Low
1996	270	751	High
1997	---	259	Low
1998	---	518	High
1999	---	183	Low
2000	---	211	Low
2001	---	272	Low

The period of 1990 through 2001 recorded near-average streamflow conditions for the years of 1990 and 1992. Streamflow conditions during 1991, 1995, 1997, 1999, 2000, and 2001 were all slightly below or well below average conditions. Streamflow conditions during 1993, 1994, 1996, and 1998 were all slightly above or well above average conditions.

2.7 VADEQ's Biological Assessment

Goose Creek and Little River were assessed as impaired on the basis of benthic macroinvertebrate surveys conducted by VADEQ starting in 1994. VADEQ uses the EPA's Rapid Bioassessment Protocol, 1989 version. Each monitored site is paired with a single reference site, which represents a healthy benthic macroinvertebrate community for that ecoregion, stream order, etc. The reference site for Goose Creek is the Rapidan River (RAP006.53), and the reference site for Little River is Catoctin Creek (CAX004.57). Tables 2.8 and 2.9 show the results of the surveys for Goose Creek and Little River, respectively. Table 2.8 also shows the results of sampling at GOO003.18 in September 2002, in which Catoctin Creek was used as the reference site.

Table 2.8: Rapid Bioassessment Protocol Results for Goose Creek (GOO002.38)

Station ID	Metric	04/22/97	08/27/97	7/15/98	09/28/98	06/07/99	09/11/00	GOO003.18 9/19/02
GOO002.38	Taxa Richness	12	17	20	15	16	17	15
	MFBI	4.73	5.15	4.81	5.42	5.43	5.17	4.46
	SC/CF	0.85	0.24	0.47	0.15	0.29	0.89	0.27
	EPT/Chi Abund	16.50	12.78	6.93	10.14	12.50	19.25	87.00
	% Dominant	32.60	28.57	19.76	26.71	24.36	20.74	21.62
	EPT Index	4	6	5	5	3	4	6
	Comm. Loss Index	0.83	0.53	0.25	0.67	0.75	0.47	0.67
	SH/Tot	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Station ID	**Metric**	04/17/97	09/02/97	CAX004.57 6/30/98	09/14/98	04/27/99	09/13/00	CAX004.57 10/01/02
RAP006.53 - Ref	Taxa Richness	20	21	17	22	20	21	19
	MFBI	4.12	3.57	3.41	4.26	3.82	4.05	4.08
	SC/CF	1.46	1.50	0.57	1.08	3.92	0.69	1.30
	EPT/Chi Abund	12.45	38.50	28.50	33.00	15.00	100.00	29.00
	% Dominant	26.61	15.67	17.00	14.36	28.57	14.72	29.00
	EPT Index	6	8	7	7	7	8	5
	Comm. Loss Index	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SH/Tot	0.00	0.17	0.02	0.02	0.03	0.07	0.07
	Ref Bio Score	40	48	48	48	46	48	46
	Metric							
Ratio: Comparability to Ref	Taxa Richness	60	81	118	68	80	81	79
	MFBI	87	69	71	79	70	78	91
	SC/CF	58	16	82	14	7	128	21
	EPT/Chi Abund	132	33	24	31	83	19	300
	% Dominant	33	29	20	27	24	21	22
	EPT Index	67	75	71	71	43	50	120
	Comm. Loss Index	1	1	0	1	1	0	1
	SH/Tot	0	0	60	30	0	0	0
	Metric							
RBP II Metric Scores	Taxa Richness	2	6	6	4	4	6	4
	MFBI	6	2	4	4	4	4	6
	SC/CF	6	0	6	0	0	6	2
	EPT/Chi Abund	6	2	0	2	6	0	6
	% Dominant	2	4	6	4	4	4	4
	EPT Index	0	2	2	2	0	0	6
	Comm. Loss Index	4	4	6	4	4	6	4
	SH/Tot	0	0	6	2	0	0	0
Biological Condition Score		26	20	36	22	22	26	32
% of Reference		65.00	41.67	75.00	45.83	47.83	54.17	69.57
RBP II Assessment		**Slight**	**Moderate**	**Slight**	**Moderate**	**Moderate**	**Slight**	**Slight**

Table 2.9: Rapid Bioassessment Protocol For Little River (LIV004.78)

Station ID	Metric	04/04/97	10/01/97	07/01/98	11/23/98	04/21/99	10/07/99	05/15/00
LIV004.78	**Taxa Richness**	13	16	15	15	19	14	19
	MFBI	4.65	4.29	3.99	4.27	4.10	5.56	3.25
	SC/CF	0.79	0.63	0.20	0.95	0.76	0.38	0.17
	EPT/Chi Abund	39.00	14.50	14.14	25.00	31.25	4.00	25.14
	% Dominant	26.79	20.51	35.42	24.00	45.66	24.00	52.23
	EPT Index	4	5	5	5	5	3	6
	Comm. Loss Index	0.54	0.50	0.47	0.40	0.26	0.64	0.32
	SH/Tot	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Station ID	**Metric**	04/04/97	10/01/97	05/26/98	11/02/98	04/14/99	12/09/99	04/11/00
CAX004.57 – Ref	**Taxa Richness**	18	22	17	17	22	18	21
	MFBI	3.76	3.58	3.41	4.06	4.01	4.44	3.55
	SC/CF	0.40	0.57	0.57	0.52	0.81	0.49	0.48
	EPT/Chi Abund	85.00	13.86	28.50	35.00	35.00	19.50	21.25
	% Dominant	21.77	16.87	17.00	22.63	16.44	17.07	33.57
	EPT Index	6	7	7	7	6	6	6
	Comm. Loss Index	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	SH/Tot	0.00	0.05	0.02	0.04	0.01	0.01	0.00
	Ref Bio Score	40	48	48	46	48	48	38
	Metric							
Ratio: Comparability to Ref	**Taxa Richness**	72	73	88	88	86	78	90
	MFBI	81	83	86	95	98	80	109
	SC/CF	197	112	36	181	94	77	35
	EPT/Chi Abund	46	105	50	71	89	21	118
	% Dominant	27	21	35	24	46	24	52
	EPT Index	67	71	71	71	83	50	100
	Comm. Loss Index	1	1	0	0	0	1	0
	SH/Tot	0	0	0	30	84	109	0
	Metric							
RBP II Metric Scores	**Taxa Richness**	4	4	6	6	6	4	6
	MFBI	4	4	6	6	6	4	6
	SC/CF	6	6	4	6	6	6	4
	EPT/Chi Abund	2	6	2	4	6	0	6
	% Dominant	4	4	2	4	0	4	0
	EPT Index	0	2	2	2	4	0	6
	Comm. Loss Index	4	4	6	6	6	4	6
	SH/Tot	0	0	0	2	6	6	0
Biological Condition Score		24	30	28	36	40	28	34
% of Reference		60.00	62.50	58.33	78.26	83.33	58.33	89.47
RBP II Assessment		**Slight**	**Slight**	**Slight**	**Slight**	**No Impact**	**Slight**	**No Impact**

Based on the results of the RBP, Goose Creek and Little River were classified as slightly to moderately impaired, when compared to the Rapidan River and Catoctin Creek. Figure 2.2 shows the trend in Goose Creek's RBP scores. RBP scores tend to be worse in the fall and worse after periods of prolonged low flows, such as occurred in the summers of 1998 and 1999. Figure 2.3 shows the trend in Little River's RBP scores. One of the lowest scores took place in the fall of 1999. The survey that year took place three weeks after Hurricane Floyd, and the results may reflect the scour of benthic macroinvertebrates caused by unusually high flows following a period of prolonged dry weather.

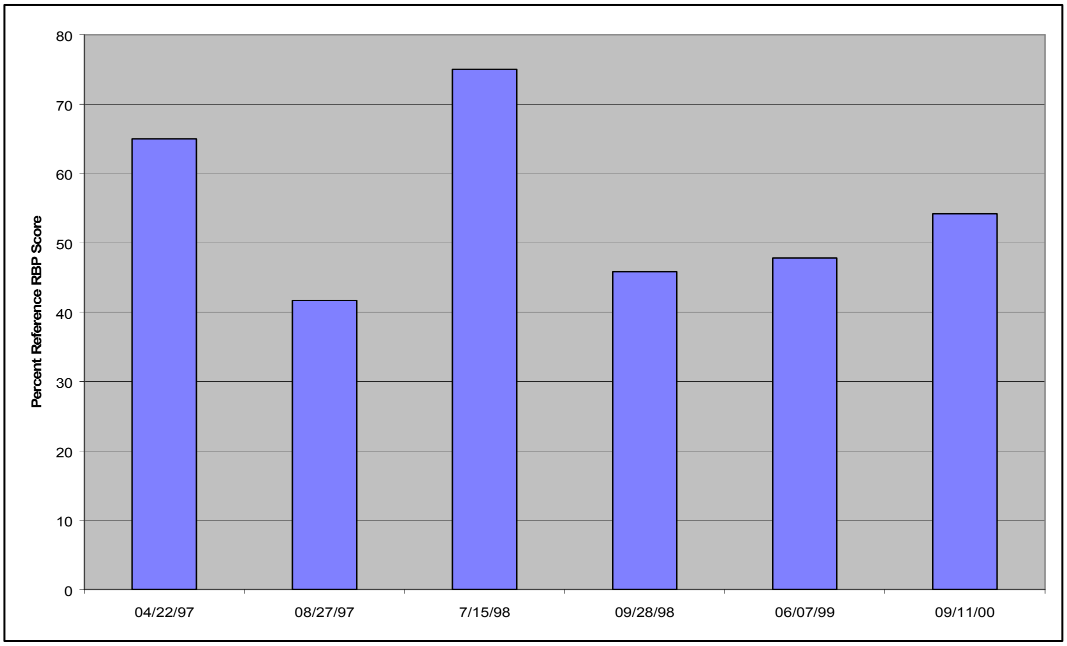

Figure 2.2: Goose Creek Rapid Bioassessment Protocol Scores

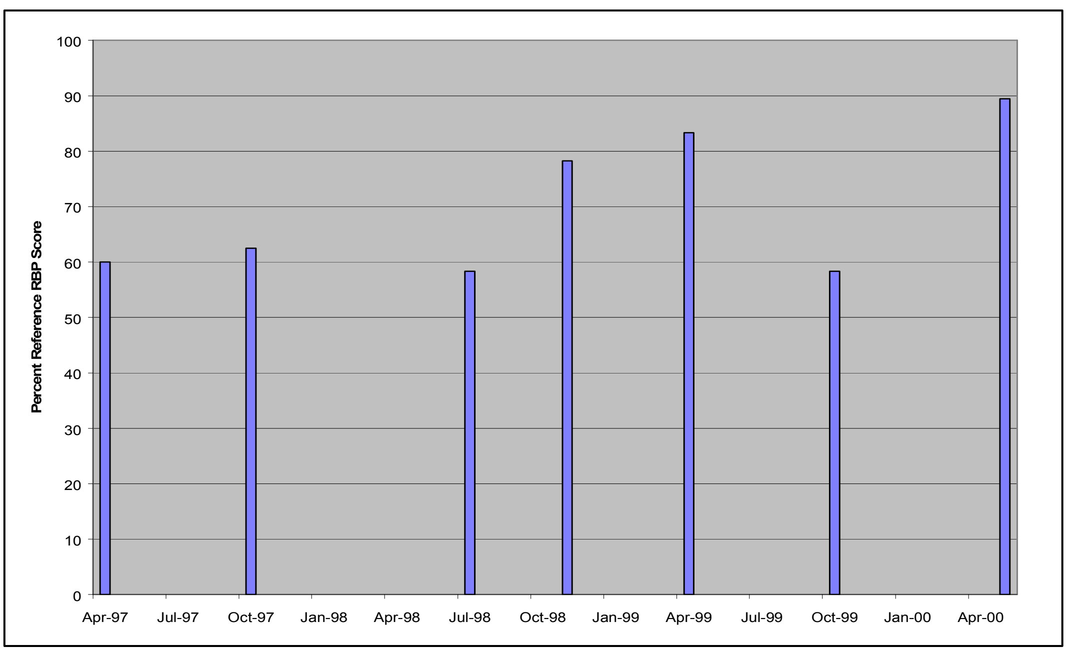

Figure 2.3: Little River Rapid Bioassessment Protocol Scores

2.8 Biological Assessment By Other Organizations

Two recent studies have assessed the ecological health of the Goose Creek watershed. The Metropolitan Washington Council of Governments (MWCOG) evaluated Goose Creek as part of a baseline study of Loudoun County watersheds (Trieu et al., 2003). The MWCOG study integrated the assessment of the macroinvertebrate community, the evaluation of habitat conditions, and the assessment of physical and chemical water quality parameters in their survey of Loudoun County streams. The Natural Resource Conservation Service (NRCS) developed a regional index of biotic integrity (IBI), based on the assessment of fish populations, to evaluate three Northern Virginia watersheds: Occoquan River, the Upper Rappahannock River, and Goose Creek (Teels and Danielson, 2001). Habitat and the physical condition of stream reaches were also evaluated using the NRCS's Stream Visual Assessment Protocol (SVAP).

There are also several active citizen's monitoring groups that conduct macroinvertebrate surveys in the Goose Creek watershed. The results of their studies are discussed below.

2.8.1 Loudoun County Baseline Biological Monitoring Survey

Trieu et al. (2003) evaluated nine stream reaches in the Goose Creek watershed using MWCOG's Rapid Stream Assessment Technique (RSAT) in 2002. RSAT rates streams in six categories: bank stability, scouring and deposition, instream habitat, water quality, riparian conditions, and biological indicators. The biological indicator rating is based in part on an evaluation the benthic macroinvertebrate community using metrics from Fairfax County's Stream Protection Strategy Index of Biological Indicators.

One site evaluated by Trieu et al. was the lower mainstem of Goose Creek at Golf Course Lane, the approximate location of VADEQ station GOO002.38. The reach was rated Excellent with respect to biological indicators and Good for its overall RSAT rating. The IBI score for the site was 99.2 out of 100.

Little River was evaluated just above its confluence with Goose Creek. It was rated Good with respect to biological indicators, receiving a IBI score of 89.7. Little River was rated Fair overall, mostly because bank stability only received a Fair rating due to evidence of bank erosion in the reach.

Six of the seven remaining Goose Creek sites received RSAT rating of Good. The exception was Beaverdam Creek, which received a Fair RSAT rating. All of the sites were rated Good or Excellent with respect to biological indicators.

2.8.2 Northern Virginia Regional Index of Biotic Integrity

The goal of Teels and Danielson (2001) was to construct a fish IBI for Northern Virginia and use it to evaluate the impact of human activities on the aquatic ecosystem. Their primary concern was to evaluate the Occoquan watershed, a major source of drinking water for Northern Virginia, which is rapidly undergoing development. Because so much of the

Occoquan watershed had been severely impacted by development, the Goose Creek and Rappahannock River watersheds were also evaluated to provide a wider rage of sites.

Teels and Danielson constructed a human disturbance index, based on land use, the presence or absence of fish barriers, and the SVAP scores. The following 12 fish metrics were selected as components of the IBI, based on their ability to distinguish the most from the least impaired sites:

1. Number of native species
2. Number of darter species
3. Number of minnow species
4. Percent of dominant species
5. Number of intolerant species
6. Percent tolerant individuals
7. Percent omnivores
8. Percent benthic invertivores
9. Percent specialist carnivores
10. Percent lithophilic spawners
11. Number of late-maturing species
12. Percent diseased individuals

Teels and Danielson evaluated 42 sites in the Goose Creek watershed. Sampling locations tended to be on smaller streams. There was no sampling site on the mainstem of Goose Creek below the confluence of Goose Creek and Little River. There were five sampling sites in the Little River watershed, including one just below Route 50, the approximate location of VADEQ monitoring station LIV004.78. The remaining sites in the Little River watershed were upstream of this location and upstream of the confluence of Little River and Hungry Run. Two of the sites are on the mainstem of Little River, one site is on Hungry Run, and one site is on Burnt Mill Run, a small tributary to Little River.

The IBI score for the Route 50 site was in the Fair range. Sites upstream received lower scores. The site on Hungry Run and the most upstream site on Little River scored in the Fair range. The site on Little River just above its confluence with Hungry Run scored Poor, as did the site on Burnt Mill Run. The SVAP scores for the mainstem of Little River were all rated Good; the sites on the tributaries were rated Poor.

In general, 52.4% of the Goose Creek sites were classified as Poor and 23.8% were classified as Good or Excellent. Of the three watersheds, Goose Creek had the largest percentage of sites rated Poor and the smallest percentage of sites rated Good or Excellent. The sites rated Good or Excellent tended have their headwaters in the Blue Ridge, in the western portion of the watershed. The site rate Poor tended to be clustered around Leesburg, along Route 7 corridor west of Leesburg, and along Route 66. Teels and Danielson speculate that development is responsible for low biotic integrity around Leesburg and in the Route 7 corridor, while livestock are responsible for the impacts along Route 66.

2.8.3 Citizen Monitoring

The Loudoun County Soil and Water Conservation District (LCSWCD), the Loudoun Wildlife Conservancy, the North Fork of Goose Creek Watershed Committee, and the Friends of Bull Run all conduct benthic macroinvertebrate surveys within the Goose Creek Watershed. For the most part, these organizations follow the Save Our Streams (SOS) protocols for biological assessment.

None of the organizations monitor on the mainstem of Goose Creek. From 1999 to 2001 LCSWCD monitored at two locations on Little River, one at Route 629 above the confluence of Hungry Run and Little River and one just below the Aldie Dam. The water quality ratings of the samples at both locations were either Good or Excellent.

Elsewhere in the watershed citizen monitoring presents a mixed picture of the health of aquatic ecosystems. Tuscarora Creek, from Town Branch to its confluence with Goose Creek, has been listed by VADEQ as threatened on the basis of benthic surveys by the Loudoun Wildlife Conservancy. Sections of the North Fork of Goose Creek and Beaverdam Creek are also listed as threatened on the basis of citizen monitoring. Other sections of the North Fork watershed are routinely assessed as Good or Excellent. Schwalm (2002), in his review of the state of Loudoun County streams, noted the variability in the condition of the benthic community across monitoring sites and across time at the same site. He pointed out that the highest average score on benthic assessments occurred at a site on Crooked Run with poor habitat scores, and suggested the need for further study to determine the good reference sites and to calculate regional reference conditions for biological assessments in Loudoun County.

2.8.4 Summary of Benthic Monitoring Data from Other Sources

It is difficult to summarize the results reported in the biotic surveys, in part because they are not comparable with each other. Benthic monitoring using the SOS protocol does not identify invertebrates consistently even at the family level. The MWCOG baseline study identified invertebrates at the genus and even the species level. The NRCS study uses fish, not invertebrates, to measure water quality. At best it can be said that the condition of aquatic life in the Goose Creek watershed is neither uniformly good nor bad, but shows considerable variability over time and by location.

CHAPTER THREE: STRESSOR IDENTIFICATION OF THE IMPAIRMENTS TO THE BENTHIC COMMUNITYIN LITTLE RIVER AND LOWER GOOSE CREEK

3.1 Introduction

Biological assessment can determine that a waterbody is not fully supporting aquatic life, but it doesn't explicitly identify the causes of the impairment. An additional analysis is necessary to determine what factors are responsible for the impairment. Stressor identification is the process by which potential causes are examined to determine which of them, perhaps jointly, are the actual cause.

3.1.1 Potential Stressors

Four potential stressors were examined to determine if they contributed to the impairment of aquatic life in Little River and Goose Creek. They are

1. Heavy metals and toxic chemicals
2. Nutrients and excess algae
3. Hydromodification
4. Sediment

3.1.2 Sources of Data

The primary sources of data for evaluating potential stressors were (1) VADEQ's biological monitoring program and (2) VADEQ's ambient water quality monitoring program. VADEQ also conducted several special water quality studies, some of which targeted identifying the source of the impairments in Goose Creek and Little River.
In addition to the information provided by VADEQ's monitoring programs, several other sources of information were available to help identify potential stressors, including MWCOG's recently completed baseline biological monitoring survey of Loudoun County (Trieu et al, 2003), and NRCS's regional IBI study of Northern Virginia watersheds (Teels and Danielson, 2001).

3.2 Description of Biological Monitoring Sites

The source of the stressors of the benthic community at a biological monitoring station may be localized, or the impairment may be an integrated effect of activities throughout the upstream catchment. In the interest of identifying potential local sources, the significant features in the vicinity of the biological monitoring stations are described below.

3.2.1 Description of Significant Features in Vicinity of the Lower Goose Creek Impairment

The impaired segment of Goose Creek runs from the City of Fairfax's water supply impoundment on the mainstem of Goose Creek to the confluence with the Potomac River. Biological monitoring took place in the vicinity of the Keep Loudoun Beautiful Park where

Route 7 crosses Goose Creek, so the source of the impairment must be located at or above that point. VADEQ also conducts ambient water quality monitoring at this location (1AGOO002.38).

Two major tributaries enter Goose Creek between the impoundment and Route 7. Sycolin Creek, south of Leesburg, remains heavily agricultural. A significant number of acres of agricultural land receive biosolid applications. The Leesburg Executive Airport is located in the Sycolin Creek watershed, and there is one permitted point source, the Goose Creek Industrial Park, which discharges to Sycolin Creek. There are several operating quarries along Goose Creek between the impoundment and Route 7.

Tuscarora Creek drains the town of Leesburg. The Town of Leesburg's wastewater treatment plant discharged to Tuscarora Creek until 1994, when the outfall was moved to the Potomac River. The Goose Creek Golf Course sits at the mouth of Tuscarora Creek where it joins Goose Creek just above Route 7. There is a VADEQ ambient monitoring stations at the mouth of Tuscarora Creek (1ATUS000.37). A site on Goose Creek just above the confluence with Tuscarora Creek (1AGOO003.18) was surveyed in September 2002 to help determine if Tuscarora Creek was the source of the impairment on the lower Goose Creek.

Figure 3.1 shows the location of the monitoring stations and the significant features in the vicinity of the impaired segment of Goose Creek.

3.2.2 Description of Significant Features in Vicinity of the Little River Impairment

The impaired segment of Little River runs from the confluence of Little River and Hungry Run, above the Town of Aldie, to the confluence of Little River and Goose Creek. Biological monitoring took place upstream of where Little River crosses Route 50, just downstream of Aldie. VADEQ also conducts ambient water quality monitoring at this location (1ALIV004.78).

The Aldie Mill is a historically significant nineteenth century mill operated by the Virginia Outdoors Foundation. It has recently been restored and is open to the public. Prior to the restoration of the mill in the late 90's, the mill race was closed off from Little River. Raw sewage from several residences and businesses in Aldie discharged directly into the mill race. Plans to restore the mill and open the mill race led to the construction of a wastewater treatment plant for the town of Aldie, which became operational in 1998. The plant is located on Little River downstream of Route 50. The mill race is fed by a dam upstream of Aldie and just downstream of the confluence of Little River and Hungry Run.

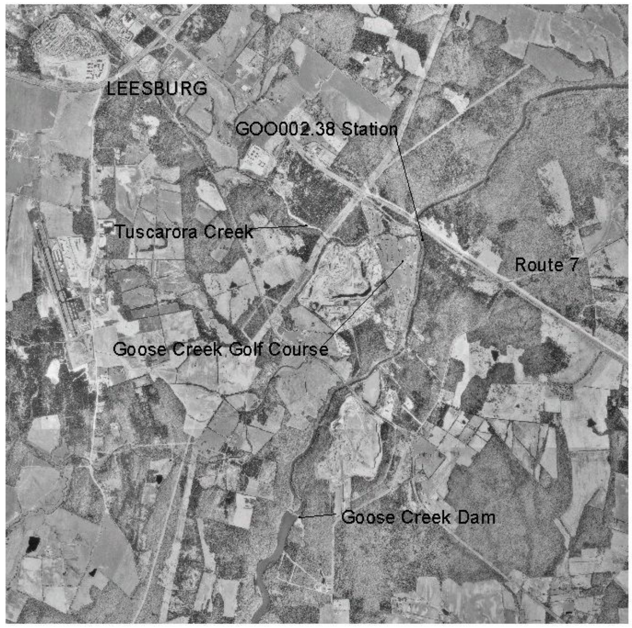

Figure 3.1: Aerial Photo of Lower Goose Creek

Upstream of Aldie, the Little River watershed is rural. Figure 3.2 shows the location of the monitoring stations and the significant features in the vicinity of the impaired segment of Little River.

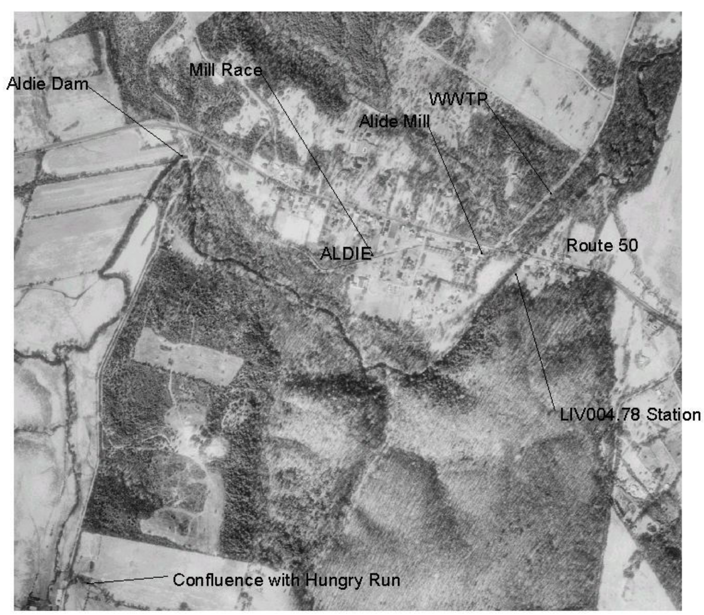

Figure 3.2: Aerial Photo of Little River Near Aldie

3.3 Toxics and Heavy Metals

3.3.1 Chronic Toxicity Study of Little River and Goose Creek

In December 2002, VADEQ collected samples for a chronic toxicity study of Little River and Goose Creek. The purpose of the study was to detect any unknown toxicity that may be having an adverse effect on aquatic life. The growth and survival of fathead minnows (*Pimephales promelas*) and the survival and reproduction of water fleas (*Ceriodaphnia dubia*) were studied by the EPA Laboratory in Wheeling, WV, using samples of river water collected in the Goose Creek watershed. For Little River, the sample was taken just above Route 50. For Goose Creek, the study was designed to detect sources of toxicity in Tuscarora Creek that might be having an impact on the mainstem of Goose Creek. Samples were taken on Goose Creek just above and below the confluence with Tuscarora Creek and at the mouth of Tuscarora Creek.

Survival and reproduction of the water fleas in the water samples taken from any site in the Goose Creek watershed were not statistically different from the laboratory control. Subchronic effects on the growth of fathead minnows were detected in the samples taken from Little River, Tuscarora Creek, and Goose Creek above the confluence with Tuscarora Creek, but not in the sample taken below the confluence with Tuscarora Creek. Moreover, in the words of the report "…the weight reductions for the fish exposed to these sample sites might not be biologically significant." (Bailey et al, 2002)

3.3.2 Monitoring of Toxic Chemicals and Metals in the Water Column

VADEQ tested three water column samples for toxic chemicals and metals at 1AGOO002.38 over the last ten years. Two samples were taken at 1ATUS000.37 and 1ALIV004.78. No toxic chemicals were detected in the water column samples at any station. Table 3.1 shows the metals detected in the water quality samples. None of the metals detected violated Virginia's water quality standards.

Table 3.1: Metals Detected in Goose Creek Water Column Samples (ug/l)

Station ID	**1AGOO002.38**			**1ALIV004.78**		**1ATUS000.37**	
Collection Date	4/7/93	7/6/94	9/28/98	2/2/93	8/3/94	1/13/93	7/7/94
Arsenic, dissolved			0.33				
Chromium, dissolved			0.11				
Copper, dissolved			1.22				
Iron, total	449.48	737		267.92	679	1736.74	275
Manganese, total		105		41.16	91	45.99	54
Manganese, dissolved			31				
Nickel, dissolved			0.61				
Zinc, dissolved			2.49				
Zinc, total	U	U		U	U	19.57	U
Aluminum, dissolved			4.63				
Selenium, dissolved			0.19				

3.3.3 Monitoring Toxic Chemicals and Metals in Sediment

VADEQ also monitored the levels of toxic chemicals and metals in sediments at their ambient monitoring stations. No toxic chemicals were detected in sediment samples at any station. Table 3.2 shows the metals detected in sediment samples. The observed values are compared to the Threshold Effects Level (TEL) and Probable Effects Level (PEL) developed by NOAA. The following definitions of TEL and PEL have been given by NOAA:

> *The TEL is calculated as the geometric mean of the 15th percentile concentration of the toxic effects data set and the median of the no-effect data set; as such, it represents the concentration below which adverse effects are expected to occur only rarely. The PEL, as the geometric mean in the 50% of impacted, toxic samples and the 85% of the non-impacted samples, is the level above which adverse effects are frequently expected. Freshwater TEL/PELs are based on benthic community metrics and toxicity tests results. (NOAA, 1999)*

Table 3.2: Metals Detected in Goose Creek Sediment Samples (mg/kg)

Station	Date	Aluminum 1108	Antimony 1098	Arsenic 1003	Chromium 1029	Copper 1043	Iron 1170	Lead 1052	Manganese 1053	Nickel 1068	Zinc 1093
1AGOO002.38	6/20/95	11800	16		39	32	27300	15	523	18	19
1AGOO002.38	4/6/99	9500			35.2	32.4	21500	14.3	410	13.2	46.8
1ALIV004.78	8/3/92				41	41		7		26	75
1ALIV004.78	7/6/95	14300	25		34	38	40900	9	1260	21	70
1ALIV004.78	9/30/97	19400			19.66	20	34490	7.84	484	12.55	12.55
1ALIV004.78	5/19/99	22400			41.9	46.7	49200	12.1	1330	23.6	79.6
1ATUS000.37	7/16/92				62	69		14		28	70
1ATUS000.37	4/27/95	19500	29	23	56	88	39100	31	729	28	119
1ATUS000.37	4/1/99	17100			63	45	28500	13.5	180	21.4	54.3
NOAA SQRT	TEL			5.9	37.3	35.7		35		18	123.1
	PEL			17	90	197		91.3		35.9	315

As Table 3.2 shows, no sample exceeds the PEL of any detected metal, except for arsenic. Arsenic was found in concentrations above the PEL in one sediment sample from Tuscarora Creek in 1995. Arsenic was not detected in subsequent sediment sampling from Tuscarora Creek in 1999 and was never detected in any sediment samples from Goose Creek or Little River. Sediment samples collected from Tuscarora Creek all exceed the TEL for copper, as do most of the samples from Little River. All sediment samples from Tuscarora Creek also exceed the TEL for chromium, as do some samples from Little River and the mainstem of Goose Creek.

A separate VADEQ study of contaminants in sediment by the Fish Tissue and Sediment Monitoring Program in 1997 found that a sediment sample from 1AGOO012.38, upstream of the reservoir, exceeded the low effects range threshold for mercury of 150 ppb with a concentration of 170 ppb dry weight. The observed concentration was below the medium effects level of 710 ppb.

3.3.4 Monitoring Toxic Chemicals and Metals in Fish Tissue

VADEQ analyzed fish tissues samples from Goose Creek and Tuscarora Creek for metals, halogenated organics, and non-halogenated organics. Table 3.3 shows the results for Goose Creek and Table 3.4 shows the results for Tuscarora Creek. The only metal detected in fish tissue was mercury. Observed concentrations were below the VADEQ screening value. No observed concentration of organic chemicals exceeded the VADEQ screening value.

Table 3.3: Contaminants Detected in Fish Tissue in Goose Creek

Constituent	Units	Screening Value	Redbreast Sunfish	Rock Bass	Yellow Bullhead Catfish	American Eel
As	ppb	0.072	<0.5	<0.5	<0.5	<0.5
Cd	ppb	11	<0.01	<0.01	<0.01	<0.01
Cr	ppb	32	<0.05	<0.05	<0.05	<0.05
Hg	ppb	0.3	<0.01	0.011	0.015	0.015
Pb	ppb		<0.1	<0.1	<0.1	<0.1
Se	ppb	50	<0.5	<0.5	<0.5	<0.5
sum PAH	ppb	NA	6.99	6.49	7.13	10.75
sum PEC	ppb	15	0.0608	0.0204	0.0296	0.0660
naphthalene	ppb		2.64	3.03	0.71	0.86
2-methyl naphthalene	ppb		0.76	0.84	0.70	1.11
1-methyl naphthalene	ppb		0.27	0.51	0.38	0.86
biphenyl	ppb		0.30	0.42	0.43	0.68
2,6 dimethyl naphthalene	ppb		0.00	0.00	0.23	0.42
ace~naphthylene	ppb		0.00	0.00	0.27	0.24
ace~naphthalene	ppb	650000	0.04	0.05	0.18	0.57
2,3,5-trimethyl naphthalene	ppb		0.00	0.00	0.32	0.21
fluorene	ppb	430000	0.17	0.08	0.00	0.00
phenanthrene	ppb		0.73	0.41	1.55	1.78
anthracene	ppb	3200000	0.16	0.14	0.23	0.68
1-methyl phenanthrene	ppb		0.00	0.00	0.39	0.00
fluoranthene	ppb	430000	0.64	0.33	0.55	1.34
pyrene	ppb	320000	0.52	0.35	0.55	0.95
benz(a) anthracene	ppb	15	0.41	0.13	0.19	0.44
chrysene	ppb	15	0.35	0.20	0.45	0.60
benzo(b) fluoranthene	ppb	15	0.00	0.00	0.00	0.00
benzo(k) fluoranthene	ppb	15	0.00	0.00	0.00	0.00
benzo(e) pyrene	ppb		0.00	0.00	0.00	0.00
benzo(a) pyrene	ppb	15	0.00	0.00	0.00	0.00
perylene	ppb		0.00	0.00	0.00	0.00
Indeno(1,2,3-cd) pyrene	ppb	15	0.00	0.00	0.00	0.00
dibenzo(a,h) anthracene	ppb	15	0.00	0.00	0.00	0.00
benzo(ghi) perylene	ppb		0.00	0.00	0.00	0.00
Total PCB	ppb	54	6.31	6.99	8.52	51.41
Total Chlordane	ppb	310	1.78	0.82	2.64	17.51
sum DDE	ppb	320	1.19	0.90	1.38	9.54
sum DDD	ppb	450	0.36	0.21		0.87
sum DDT	ppb	320		0.16		
Total DDT	ppb	320	1.55	1.28	1.38	10.41
Total BDE	ppb	5000	0.24			3.57
Heptachlor epoxide	ppb	10				2.12
HCB	ppb	70				0.33

Table 3.4: Contaminants Detected in Fish Tissue in Tuscarora Creek

Constituent	Units	Screening Value	Redbreast Sunfish	White Sucker	Yellow Bullhead Catfish
As	ppb	0.072	<0.5	<0.5	<0.5
Cd	ppb	11	<0.01	<0.01	<0.01
Cr	ppb	32	<0.05	<0.05	<0.05
Hg	ppb	0.3	<0.01	0.019	<0.01
Pb	ppb		<0.1	<0.1	<0.1
Se	ppb	50	<0.5	<0.5	<0.5
sum PAH	ppb	NA	11.64	12.18	4.56
sum PEC	ppb	15	1.9649	1.3563	0.2633
naphthalene	ppb		0.00	0.00	0.54
2-methyl naphthalene	ppb		0.00	0.00	0.10
1-methyl naphthalene	ppb		0.00	0.00	0.12
biphenyl	ppb		0.26	0.00	0.20
2,6 dimethyl naphthalene	ppb		0.00	0.00	0.00
ace~naphthylene	ppb		0.00	0.00	0.00
ace~naphthene	ppb	650000	0.17	0.21	0.17
2,3,5-trimethyl naphthalene	ppb		0.00	0.00	0.23
fluorene	ppb	430000	0.00	0.00	0.00
phenanthrene	ppb		1.35	1.45	0.72
anthracene	ppb	3200000	0.34	0.68	0.23
1-methyl phenanthrene	ppb		0.00	0.00	0.00
fluoranthene	ppb	430000	0.93	1.61	0.45
pyrene	ppb	320000	0.97	1.43	0.40
benz(a) anthracene	ppb	15	0.96	0.85	0.13
chrysene	ppb	15	0.89	1.64	0.28
benzo(b) fluoranthene	ppb	15	0.90	0.89	0.19
benzo(k) fluoranthene	ppb	15	0.00	0.00	0.00
benzo(e) pyrene	ppb		0.00	0.00	0.00
benzo(a) pyrene	ppb	15	0.00	0.00	0.00
perylene	ppb		0.00	0.00	0.00
Indeno(1,2,3-cd) pyrene	ppb	15	0.00	0.00	0.00
dibenzo(a,h) anthracene	ppb	15	0.00	0.00	0.00
benzo(ghi) perylene	ppb		0.00	0.00	0.00
Total PCB	ppb	54	4.38	31.53	18.13
Total Chlordane	ppb	310	1.44	8.39	3.74
sum DDE	ppb	320	0.68	4.70	2.18
sum DDD	ppb	450	0.44		1.33
sum DDT	ppb	320			0.26
Total DDT	ppb	320	1.12	4.70	3.77
Total BDE	ppb	5000			0.61
Heptachlor epoxide	ppb	10	0.23	0.78	0.17
HCB	ppb	70			

3.3.5 Pesticide Use at the Goose Creek Golf Course

Attempts were made, unsuccessfully, to interview the groundskeeper of the Goose Creek Golf Course and determine the pest management practices of the golf course. However, because of the presence of pollutant-sensitive species of mayflies and caddis flies, it is unlikely that the impairment identified at 1AGOO002.37 is caused by toxicity from pesticides.

3.3.6 Summary of the Evidence for the Identification of Toxics and Heavy Metals as Stressors

There is no significant evidence linking heavy metals or toxic chemicals to the impairment of the benthic community in Goose Creek or Little River. Observed concentrations of toxic chemicals and heavy metals do not suggest they are the cause of impairment. The results of the toxicity tests performed in Goose Creek may indicate an unknown source of toxicity, which bears further monitoring, but the ambiguous outcome of the tests suggests that even if there is an unknown source of toxicity in Goose Creek, it is not the primary cause of the impairment of the benthic community.

3.4 Nutrients

Excess nitrogen and phosphorus can lead to excess algal growth, which in turn can impair other aquatic life through two pathways. First, excess algae and other primary producers lead to greater fluctuations in dissolved oxygen concentrations. During the daytime, primary producers release oxygen as a byproduct of photosynthesis, but during the night, they respire, consuming oxygen. Their oxygen consumption can reduce dissolved oxygen concentrations below the levels necessary to support other life. Second, excess algae can foul the habitat of benthic macroinvertebrates.

3.4.1 Benthic Macroinvertebrate Monitoring

In none of the macroinvertebrate surveys conducted in Little River or the lower Goose Creek, was there evidence of the prevalence of any macroinvertebrate taxa that indicate either excess algae or low oxygen associated with excess primary production by algae.

3.4.2 Physical Characterization and Habitat Assessment

VADEQ's habitat assessment does not directly assess the presence of excess algae. Field data for the physical characterization of the monitoring site were recorded only for recent sampling. Rooted submerged plants and attached algae were observed at 1AGOO03.18, just above the confluence of Goose Creek with Tuscarora Creek, under low flow conditions in September 2002.

Trieu et al. (2003) evaluated the lower Goose Creek for substrate fouling, the formation of organic slimes on the underside of substrate. Such slimes might be evidence for excess organic matter and anaerobic conditions. Trieu et al. recorded the percent of cobble-sized stones covered in by substrate. Thirty-two percent of the cobbles in the lower Goose Creek were fouled, warranting it a Fair rating. That percentage, however, is among the lowest observed by Trieu et al. in Loudoun County. Little River was rated Poor, because 85% of the cobbles observed at a site near its confluence with Goose Creek were fouled. The level of substrate fouling in Little River is comparable to that observed in Catoctin Creek, which was also rated Poor.

Teels and Danielson (2001) conducted a habitat evaluation using NRCS's Stream Visual Assessment Protocol at five sites in Little River as part of their application of a regional IBI to Northern Virginia watersheds. The SVAP assesses nutrient enrichment, bank stability, riffle embeddedness, among other factors. All three sites on the mainstem of Little River were evaluated as Good, according to the SVAP. Hungry Run, a tributary of Little River, was evaluated as Poor, based on evidence of nutrient enrichment and the presence of cattle in the stream just above the monitoring site. These factors no longer had any impact at the NRCS's monitoring site on Little River at Route 50 (B. Teels, personal communication, 2003) where station 1ALIV004.78 is also located.

3.4.3 Water Quality Monitoring Data

Nitrogen and phosphorus concentrations observed on the Lower Goose Creek (1AGOO002.38) and Little River (1ALIV004.78) were compared with observations taken at water quality monitoring stations located on the Rapidan River (3-RAP006.53), the biological reference for lower Goose Creek, and Catoctin Creek, (1ACAX004.57), the biological reference for Little River. Table 3.5 shows the summary statistics for the observed monitoring data for the period 1992-2002. There are no violations of Virginia's water quality standard for ammonia in either of the impaired waterbodies.

Figure 3.3 shows the cumulative distribution of observed total nitrogen concentrations at the biological monitoring stations. The distribution of observed total nitrogen concentrations in the Rapidan River is generally lower than those in Goose Creek, except for the largest observed concentrations. Observed total nitrogen concentrations in Little River and Catoctin Creek are comparable.

Figure 3.4 shows the cumulative distribution of observed nitrate concentrations at the biological monitoring stations. Observed nitrate concentration in Goose Creek are larger than those in the Rapidan River. The highest concentrations observed in Little River are higher than the highest observed concentrations in Catoctin Creek, but Catoctin Creek frequently has higher overall nitrate concentrations than any of the four stations.

Figure 3.5 shows the cumulative distribution of observed total phosphorus concentrations at the biological monitoring stations. Total phosphorus concentrations observed in the Rapidan River dominate all other stations, including Goose Creek. Observed total phosphorus concentrations in Catoctin Creek tend to dominate those observed in Little River, except at the highest values.

Table 3.5: Summary Statistics of Observed Water Quality Data in Goose Creek, Tuscarora Creek, Little River, Catoctin Creek, and Rapidan River

Station	Statistic	Temp	Turb	DO	BOD	pH	TSS	Ammonia	Nitrite	Nitrate	TKN	TP
1AGOO002.38	Count	113	4	112	108	112	116	116	112	114	113	123
	Mean	13.211	6.450	10.151	2.044	7.395	9.328	0.064	0.021	0.918	0.609	0.101
	Median	13	6.85	10.25	2	7.425	7	0.04	0.01	0.905	0.4	0.1
Lower Goose Creek	Min	0.05	2.6	4.96	0.5	6.4	1	0.006	0.01	0.04	0.1	< 0.0003
	Max	28.3	9.5	14.8	15	10	57	0.55	0.34	6.11	17	1.4
	Std. Dev.	8.307	2.919	2.436	2.066	0.446	8.705	0.071	0.036	0.673	1.582	0.138
1ATUS000.37	Count	51	2	50	42	49	52	51	52	52	52	61
	Mean	12.693	12.100	10.081	2.900	7.500	45.038	0.298	0.104	2.060	0.773	0.177
	Median	11.8	12.1	9.905	2	7.5	4.5	0.04	0.01	1.135	0.35	0.1
Tuscarora Creek	Min	1.4	4.2	5.1	0.3	5.6	1	0.04	0.01	0.04	0.1	0.0014
	Max	26.7	20	14.91	12	8.4	1626	4.6	0.93	17.9	5	1.6
	Std. Dev	7.136	11.172	2.665	2.379	0.493	225.576	0.784	0.201	2.911	0.991	0.334
3-RAP006.53	Count	102	---	101	105	100	108	106	106	106	106	108
	Mean	14.677	---	10.042	1.616	7.313	16.222	0.087	0.021	0.517	0.407	0.106
	Median	14.65	---	9.8	1.5	7.3	5	0.04	0.01	0.53	0.3	0.1
Rapidan River	Min	0.3	---	4.8	0	6	1	0.01	0.01	0.04	0.1	< 0.0015
	Max	28.9	---	15.2	5	8.8	148	4	0.63	1.3	3.5	0.4
	Std. Dev	8.309	---	2.317	0.781	0.501	28.440	0.384	0.061	0.253	0.400	0.066
1ALIV004.78	Count	54	2	54	43	53	53	53	51	52	53	63
	Mean	12.398	4.600	10.085	1.993	7.175	18.528	0.053	0.014	0.618	0.459	0.074
	Median	12.6	4.6	9.84	2	7.2	4	0.04	0.01	0.64	0.4	0.1
Little River	Min	0.01	4	6.2	0.8	5.7	3	0.01	0.01	0.02	0.04	0.0024
	Max	25.1	5.2	15.6	4	8.2	508	0.21	0.05	1.72	2	0.6
	Std. Dev	7.603	0.849	2.298	0.811	0.502	69.459	0.034	0.008	0.342	0.337	0.080
1ACAX004.57	Count	101	---	100	103	100	107	105	105	105	105	107
	Mean	12.329	---	10.163	1.867	7.288	9.785	0.051	0.013	0.899	0.443	0.095
	Median	11.8	---	9.85	2	7.3	4	0.04	0.01	0.91	0.4	0.1
Catoctin Creek	Min	0	---	5.13	1	6.4	1	0.04	0.01	0.04	0.1	0.0143
	Max	26.9	---	15	12	8.3	206	0.25	0.06	2.37	1.5	0.4
	Std. Dev	7.969	---	2.349	1.250	0.363	22.152	0.033	0.007	0.556	0.206	0.048

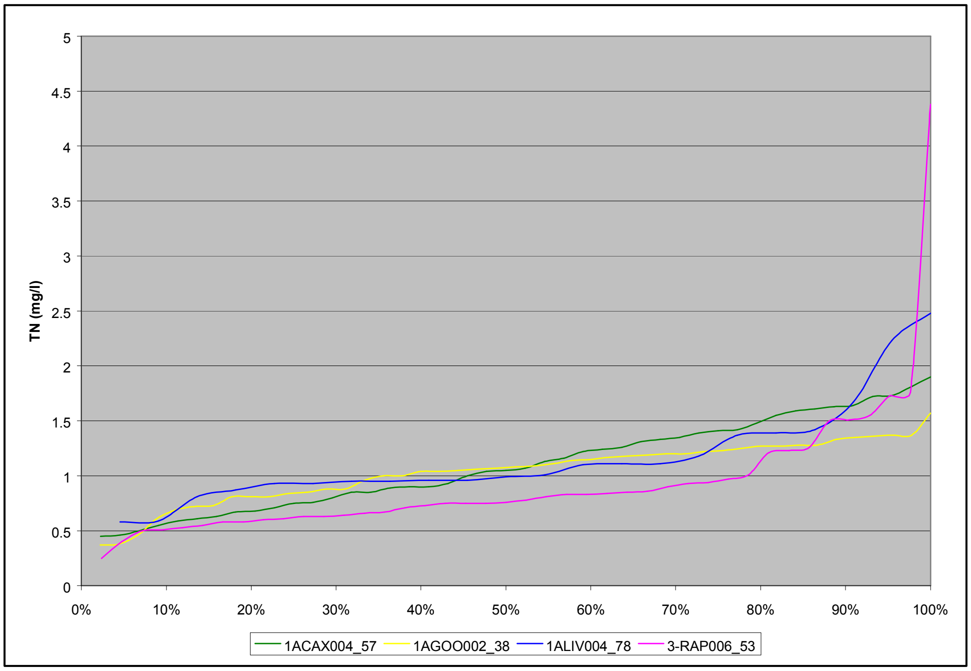

Figure 3.3: Cumulative Distribution of Observed Total Nitrogen Concentrations in Goose Creek, Little River, Catoctin Creek, and Rapidan River

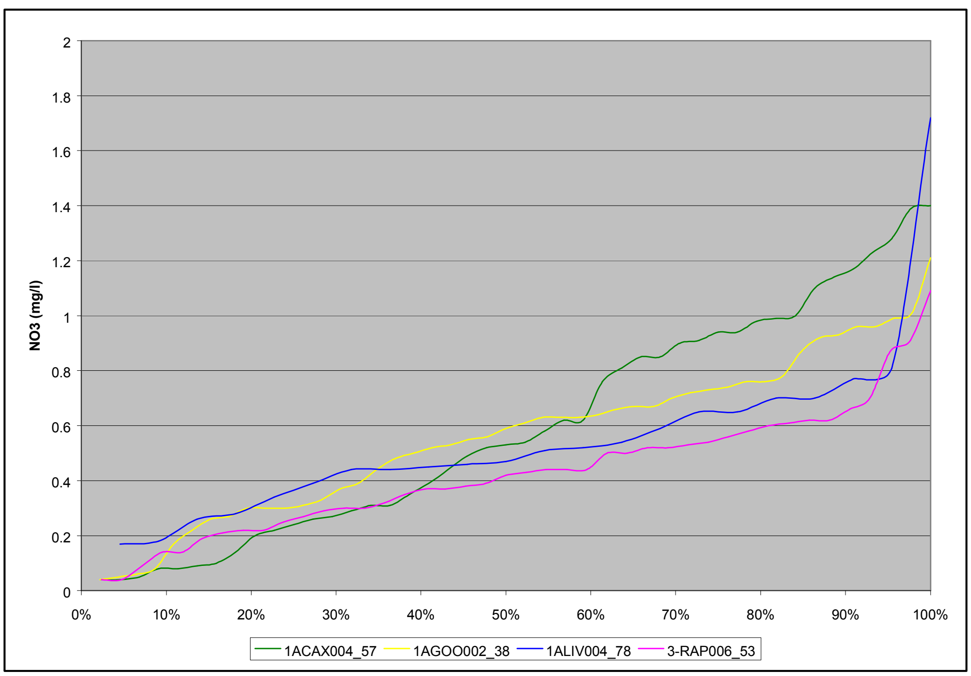

Figure 3.4: Cumulative Distribution of Observed Nitrate Concentrations in Goose Creek, Little River, Catoctin Creek, and Rapidan River

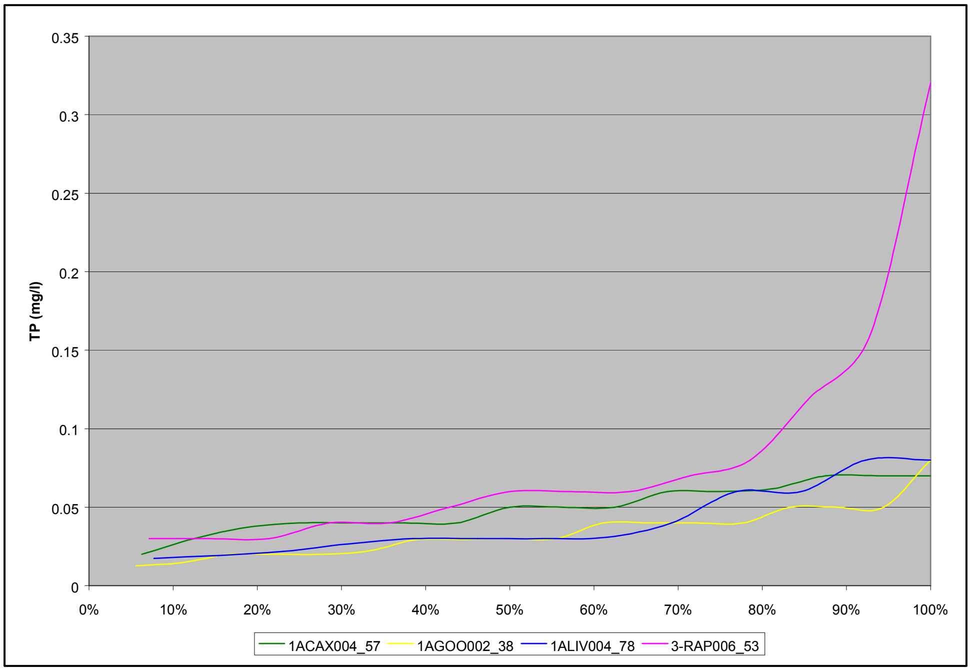

Figure 3.5: Cumulative Distribution of Observed Total Phosphorus Concentrations in Goose Creek, Little River, Catoctin Creek, and Rapidan River, 1998-2002

3.4.3.1 Trophic State Classification

Using the cumulative frequency distribution of average TN and TP concentrations for over 1000 sites, Dodds et al. (1998) suggested that the boundary between oligotrophic and mesotrophic streams be drawn at the first tri-tile TN and TP concentrations (0.7 and 0.025 mg/l, respectively) and the boundary between mesotrophic and eutrophic streams be drawn at the second tri-tile concentrations (1.5 mg/l TN and 0.075 mg/l TP). Only concentrations taken from the growing season (April to October) are included in the calculations. Since the TP boundary concentrations were below the detection limit used by VADEQ before July, 1999, Table 3.6 shows the average growing season TN and TP concentrations for the impaired waterbodies and their references calculated for observations made after July 1999. (One outlier TKN concentration was excluded from the Goose Creek sample.) All of the waterbodies except the Rapidan River can be classified as mesotrophic; the average TP concentration for the Rapidan River exceeds the phosphorus eutrophic boundary. Since the July 1999 cutoff date may impose an arbitrary limit on TN concentrations, Table 3.6 also shows the average growing season TN concentration after 1995, when the Town of Leesburg stopped discharging their wastewater to Tuscarora Creek. Average TN concentrations for the impaired waterbodies for this period exceed their reference sites, but not significantly. Goose Creek, Little River, and Catoctin Creek are most likely phosphorus limited, but the Rapidan River may be nitrogen limited.

Table 3.6: Average Growing Season (April – October) Nutrient Concentrations (mg/l)

Waterbody	TN (1995-2001)	TN (1999-2001)	TP (1999-2001)
Goose Creek	1.04	0.91	0.034
Little River	1.13	1.05	0.040
Rapidan River	1.10	1.18	0.082
Catoctin Creek	0.94	1.04	0.049

3.4.4 2002 Nonpoint Source Assessment

Virginia's 305(b) Report includes an assessment of nonpoint source loads for Virginia's 14-digit watersheds. Goose Creek and Rapidan River occupy several 14-digit watersheds, Catoctin Creek occupies one 14-digit watershed, and Little River occupies a fraction of one the watersheds that constitute Goose Creek. Nutrient and sediment loads are estimated at this scale by land use. For the 2002 report, the GWLF model, which is the same model used to estimate loads for Virginia's benthic TMDLs, was used to help estimate loads. The GWLF models of the 14-digit watersheds were calibrated to match the loads from the Chesapeake Bay Program's Phase 4.3 Watershed Model. The Watershed Model is calibrated on a grosser scale than the GWLF models: the model segment containing Goose Creek, for example, is calibrated against data collected at Chain Bridge, and the Rappahannock River, including the Rapidan River, is only calibrated at Fredericksburg.

An average annual loading rate of total nitrogen and total phosphorus was calculated for the impaired and reference watersheds by determining the loading rate for each watershed by land use and weighting the loading rates for each land use by the area in the watershed in that land use. Table 3.7 shows the results. According to these calculations, nutrient loading rates for Little River are significantly smaller than those for Catoctin Creek. The TN loading rate for Goose Creek is larger than that for the Rapidan River, but the TP loading rate is smaller. The TN:TP ratio is less than 10:1 for all watersheds.

Table 3.7: Estimated Average Annual Nutrient and Sediment Loads (lbs/ac/yr) Nonpoint Source Assessment for Virginia's 2002 305(b) Report

Waterbody	TN	TP	TSS
Goose Creek	5.88	0.62	0.13
Little River	3.11	0.42	0.10
Rapidan River	5.01	0.71	0.18
Catoctin Creek	7.64	0.86	0.22

3.4.5 Diurnal DO Measurements

VADEQ directly monitored dissolved oxygen concentrations in Goose Creek and Little River over the diurnal cycle in August 2003. Table 3.8 shows the results. In neither case did the DO concentrations approach Virginia's instantaneous minimum standard of 4 mg/l. The fluctuation in Little River was approximately 0.75-1.25 mg/l and Goose Creek 2.2- 2.5 mg/l.

Table 3.8: Diurnal DO Observations in Goose Creek Watershed

Station	Date	Time	Temp (°C)	DO (mg/L)	Sat DO (mg/L)	DO (%)
1ALIV004.78	08/20/03	13:00	23.25	8.74	8.54	102%
1ALIV004.78	08/20/03	20:45	23.44	7.58	8.51	89%
1ALIV004.78	08/21/03	4:50	22.53	7.48	8.66	86%
1ALIV004.78	08/21/03	13:00	23.64	8.25	8.48	97%
1AGOO002.38	08/20/03	13:30	25.47	9.23	8.19	113%
1AGOO002.38	08/20/03	21:15	26.89	8.27	7.98	104%
1AGOO002.38	08/21/03	5:25	24.85	6.77	8.29	82%
1AGOO002.38	08/21/03	13:25	25.95	8.54	8.12	105%

The methodology used by Tetra Tech in the Blacks Run and Cooks Creek Benthic TMDL (2002) was applied to Goose Creek to determine whether the DO fluctuation in Goose Creek was large enough to produce violations of Virginia's water quality standards. An estimate was obtained of the minimum daily DO for each observed DO concentration by assuming that DO varied by 2.5 mg/l over the diurnal cycle with a minimum at 5:30 AM and a maximum at 1:30 PM. The time of the observed concentration was used to fix the maximum and minimum DO concentrations for that day. Of the 112 observations of DO taken at GOO002.38 since 1992, only one observed value, a reading of 4.96 mg/l on October 10, 2000, was below 5 mg/l. This was the only value that led to a calculated minimum DO concentration of less than 4 mg/l, and a calculated average daily concentration below the Virginia standard of 5 mg/l.

3.4.6 Summary of Analysis of Available Evidence Concerning Nutrients

An analysis of the macroinvertebrates collected at the monitoring stations on Goose Creek and Little River showed no evidence that the benthic community was impaired by excess algae.

Outside of evidence of substance fouling at Little River and the observation of benthic algae and submerged aquatic vegetation in September 2002 at 1AGOO003.18 on Goose Creek above the confluence with Tuscarora Creek, there is little direct evidence, based on habitat assessment or the physical characterization of the waterbodes, that either Little River or the lower Goose Creek are impaired by excess algal growth caused by nutrients.

Observed nutrient concentrations in the impaired waterbodies are comparable to those observed in their biological references during the growing season. Estimates of nutrient loads from 2002 Nonpoint Source Pollution Assessment suggest that Catoctin Creek has larger nutrient loads than either Goose Creek or Little River, and that the Rapidan River has a larger total phosphorus load than Goose Creek.

The observed diurnal DO fluctuations in Goose Creek and Little River do not indicate that excess primary production is causing DO concentrations to drop below Virginia's instantaneous minimum standard of 4 mg/l or the daily average standard of 5 mg/l.

3.5 Hydromodification

Both Little River and Goose Creek have dams above the biological monitoring sites. The dam on Goose Creek is used to create an impoundment for the City of Fairfax's water supply. The dam on Little River is used to divert water into the mill race to power Aldie Mill. Figures 3.1 and 3.2 show the location of the dams.

The dam on Goose Creek was built in 1960. It is 39 feet high and 715 feet long. It was designed to create a reservoir of 4,373 acre-feet of storage. The dam on Little River is over one hundred years old. No information was available on its design specifications.

Both of the dams are overflow dams, and under most flow regimes the presence of the dams do not significantly alter downstream flows. Under low flow conditions, however, downstream flows can be significantly reduced. In the summers of 1998, 1999, and 2002, water supply withdrawals from Goose Creek exceeded observed flow at the USGS gage near Leesburg. During those periods, water supply needed to be augmented by releases from the Beaverdam Creek Reservoir.

Under most flow conditions, the dams on Little River and Goose Creek can be expected to have positive impact on water quality. Both dams can be expected to trap sediment and other constituents in particulate form from upstream sources. Because water is released from the impoundments over the top of the dam, the dams probably facilitate reaeration and help increase dissolved oxygen concentrations. Under low flow conditions, however, the dams may exacerbate water quality problems.

3.5.1 Physical Characterization and Habitat Assessment

VADEQ's habitat assessments of Goose Creek at 1AGOO002.38 and Little River at 1ALIV004.78 do not show negative impacts from low flows in either 1998 or 1999. According to the assessments, flow was sufficient to cover the channel and bed substrate in 1998 and 1999. Channel flow status scores for Goose Creek and Little River were almost always in the optimal range, and on average were greater than those for the reference sites.

The habitat assessment at 1AGOO003.18 in September 2002 did record that flow occupied less than half the channel width. Flows were uniformly low along Goose Creek during that period, however. The habitat assessment at 1AGOO22.44, upstream of the confluence of Goose Creek and the North Fork, also shows the same level of exposure of the channel and substrate. The presence of the dam is therefore not the primary cause of the suboptimal assessment of the channel flow status at 1AGOO3.18.

3.5.2 Water Quality Data

Water temperature may give an indication that low flows are having a negative impact on aquatic life. Table 3.9 shows the water temperature observed in VADEQ's ambient monitoring program in the summer months and the monthly average over the last 10 years. Temperatures in the lower Goose Creek tend to be somewhat higher than in the Rapidan River, but are well below the maximum temperature standard of 32º C set for Piedmont streams under Virginia's water quality standards. Observed temperatures in Little River tend to be less than temperatures observed in Catoctin Creek.

3.5.3 Impact of Hydromodification

There is no evidence that the presence of the dams on either Goose Creek or Little River is the primary cause of their benthic impairments. They may exacerbate the impacts of low flow conditions, but are probably neither a necessary nor sufficient cause of the impairment of the benthic community in Goose Creek or Little River. In so far as the dams tend to trap sediment and particulate organic matter, they may tend to improve water quality downstream under most flow regimes.

Table 3.9: Average Summer Observed Water Temperature (^oC)

Month	Year	Goose Creek	Rapidan River	Little River	Catoctin Creek
June	1992	18.00			17.30
	1993	21.60			21.40
	1994	24.80			23.10
	1995	19.50			
	1996	18.00			17.70
	1997	15.90		15.20	15.40
	1998	17.60		15.30	15.80
	1999	23.40			22.60
	2000	20.80			18.50
	2001	21.24	21.06	22.90	19.91
	2002	23.48	20.69	22.50	
June Average		20.39	20.88	18.98	19.08
July	1992	27.60	26.70		26.00
	1993	27.80	23.20		26.90
	1994	26.70	24.40		25.50
	1995	22.60	23.90		21.80
	1996	24.30	23.20		23.40
	1997	24.90			22.90
	1998	27.80		25.10	25.80
	1999	21.80	20.30		21.10
	2000	26.51	19.87	19.73	24.05
	2002	26.33	23.44	24.98	
July Average		25.16	22.88	22.20	23.65
August	1992	22.00		20.90	20.80
	1993	22.60		23.40	23.80
	1994			23.40	
	1995	28.30		21.30	26.10
	1996	22.00		18.60	21.10
	1997	21.40	22.30		20.20
	1998	24.90	23.20	22.00	24.00
	1999	23.20		23.50	19.80
	2000	26.48			25.75
August Average		24.24	22.95	22.25	22.80
September	1992	21.70			19.30
	1993	19.30			18.00
	1994	20.60			17.90
	1995	20.30			18.80
	1996	20.80			20.20
	1997	22.70		16.10	22.80
	1998	23.90			
	1999		18.30		
	2000	20.90	14.97	17.30	18.03
	2001	22.13	19.33	18.83	
September Average		21.66	18.89	18.62	19.73

3.6 Sediment

3.6.1 Benthic Macroinvertebrate Monitoring

An examination of the taxa observed during the benthic macroinvertebrate surveys of Goose Creek and the Rapidan River yielded the following observations:

- Goose Creek has more crayfish, which are sediment tolerant, than Rapidan River;
- Goose Creek also shows consistently higher numbers of water striders and whirling beetles, and low numbers of riffle beetles, which taken together may suggest slow-moving water and/or less coarse substrate;
- Goose Creek has more narrow-winged damselflies, which may suggest some sediment deposition; and
- Goose Creek lacks some sediment intolerant taxa, such as stoneflies or water pennies.

On the other hand, Goose Creek does not have unusually higher numbers of sediment-tolerant taxa (worms, Asian clams, midges) that would suggest excessive sedimentation. Goose Creek has comparable numbers of certain "good" taxa such as mayflies and some caddisflies, and in fact has more free-living caddisflies than the Rapidan River.

The differences between Goose Creek and the Rapidan River may indicate that there is relatively more sediment in the aquatic environment in Goose Creek. This does not necessarily mean that Goose Creek is impaired by sediments. The differences between Goose Creek and the Rapidan River may be due to natural differences in the rivers caused by differences in physiographic province and geological setting.

An examination of the raw taxa counts from Little River's macroinvertebrate surveys also shows comparatively more sediment tolerant species in Little River than Catoctin Creek, though not all the evidence points in that direction. More specifically:

- Little River had high numbers of burrowing and sprawling mayflies, an increasing abundance of crayfish, and many Asian clams collected in Summer 1998;
- Little River had few water pennies and almost no stoneflies;

both of which may suggest a difference in substrate quality between Little River and Catoctin Creek. On the other hand,

- Little River did not contain excessively high abundances of other sediment-tolerant taxa such as worms or bloodworm midges;
- Little River has fewer narrow-winged damselflies, a lotic-erosional taxon, than Catoctin Creek; and
- Little River has a comparable abundance of riffle beetles to Catoctin Creek.

3.6.2 Physical Characterization and Habitat Assessment

In VADEQ's habitat assessment, Goose Creek at 1AGOO002.38 on average outscored the Rapidan River reference site in the embeddedness and sedimentation categories; and both streams were in the optimal range. Suboptimal sediment deposition was observed in September 2002 at 1AGOO003.18, above Tuscarora Creek. Embeddedness scores remained in the optimal range. Trieu et al. (2003) also rated lower Goose Creek as good to excellent for sedimentation and embeddedness.

On average Little River also outscored the Catoctin Creek reference site in the embeddedness and sedimentation categories in VADEQ's habitat assessment. Teels and Danielson (2001) rated the Little River site at 1ALIV004.74 Good according to the SVAP, which includes an evaluation of riffle embeddedness and bank stability. Trieu et al. (2003) evaluated embeddedness and other habitat parameters on a reach of Little River near its confluence with Goose Creek. They found little evidence of embeddedness, but the did observe, however, that 88% of the streambank soils at the site they evaluated were highly erodible, and that over half of the 0.44 mile segment of the river they examined suffered from severe or moderately severe bank erosion.

3.6.3 Water Quality Monitoring Data

It is difficult to assess sediment loads on the basis of observed sediment concentrations from an ambient water quality monitoring program, because most of the sediment load is transported during storm flow events and few observations are made during storms. Figure 3.6 shows the observed sediment concentrations in Goose Creek and the Rapidan River plotted against the percent of flow exceeded on the observation date by the USGS gages downstream of the monitoring site. Higher concentrations are observed in the Rapidan River at higher flows, but there are also more observations at higher flows. Sediment concentrations in Goose Creek may exceed those in the Rapidan River for flow less than the 85th percentile flow, but they rarely exceed 30 mg/l.

Figure 3.7 shows the observed sediment concentrations in Little River and the Catoctin Creek plotted against the percent of flow exceeded on the observation date at the nearest USGS gage to the monitoring site. One sediment concentration over 450 mg/l was observed in Little River under high flow conditions. Otherwise, few observations were taken there under high flow conditions. More observations under high flow conditions were taken at Catoctin Creek, but because there are no corresponding observations taken in Little River it is difficult to draw any conclusions. Observed sediment concentrations at flows below the 85th percentile are generally low.

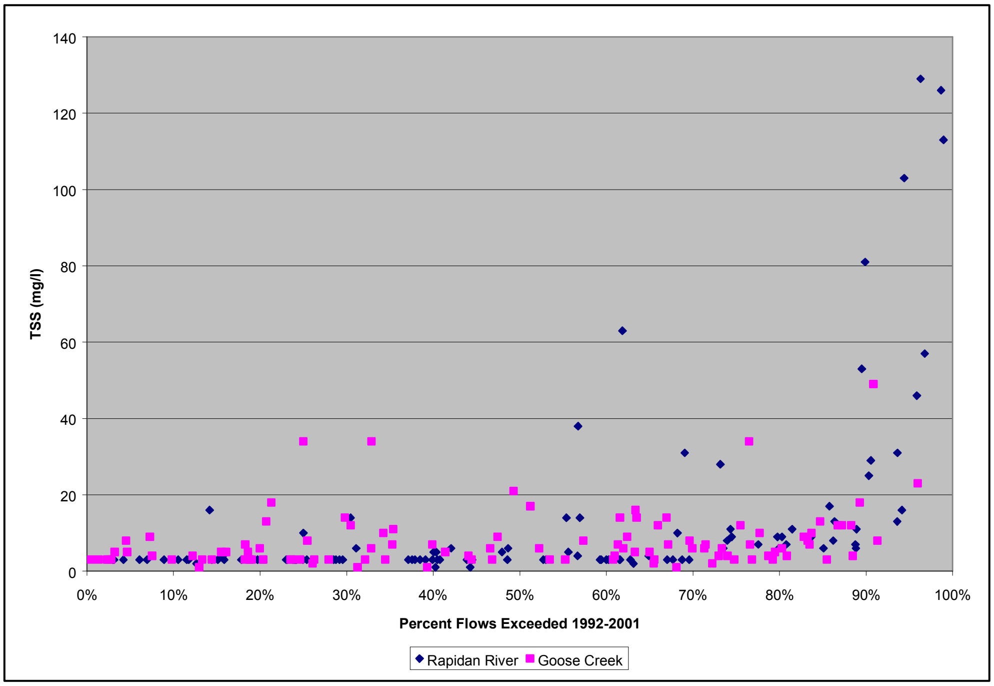

Figure 3.6: Observed Sediment Concentrations as a Function of Percentile of Observed Flow for the Goose Creek and Rapidan River

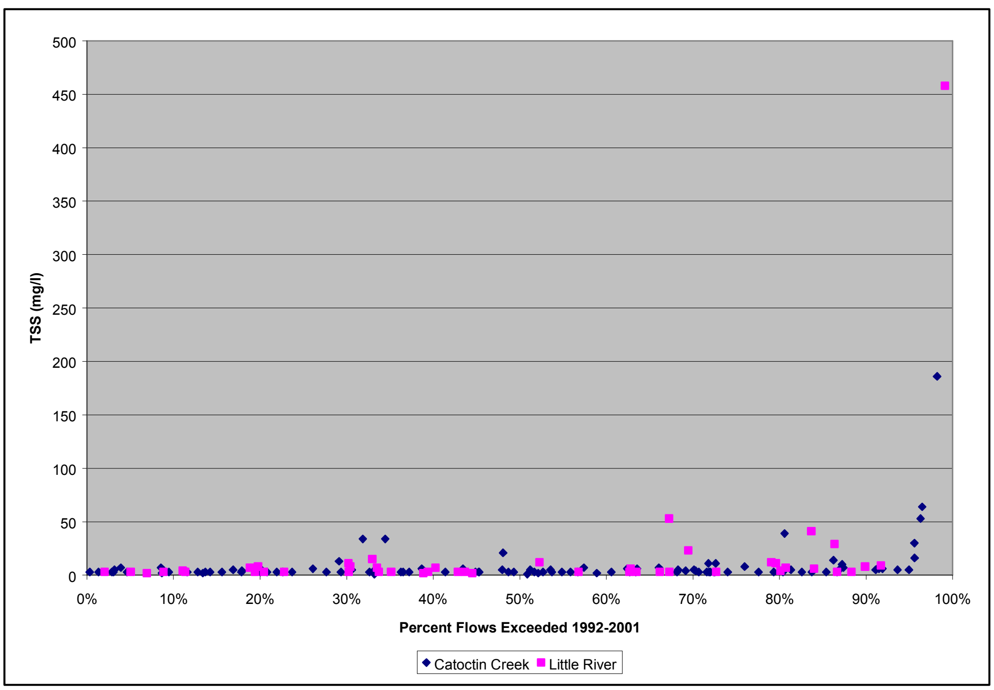

Figure 3.7: Observed Sediment Concentrations as a Function of Percentile of Observed Flow for the Little River and Catoctin Creek

3.6.4 2002 Nonpoint Source Assessment

Table 3.7 shows the average annual sediment loading rates estimated from the 2002 Nonpoint Source Assessment. According to the modeling performed for the assessment, the loading rates for the reference sites are considerably larger than those for the impaired sites.

3.6.5 Summary of Available Evidence Concerning Sediment

There is some direct evidence from an examination of the macroinvertebrate taxa observed in Little River and Goose Creek that these waterbodies have more sediment in their benthic environment than their biological references. On the other hand, habitat assessment, water quality monitoring, and the modeling performed for the 2002 Nonpoint Source Assessment do no indicate significant differences in sediment loadings between the impaired and reference watersheds.

3.7 Conclusion of the Stressor Identification For Goose Creek and Little River

Goose Creek and Little River are borderline cases of aquatic life impairments. For the most part, they are classified as slightly impaired when compared to their reference sites. The presence of sediment tolerant species in greater abundance in Goose Creek and Little River represents the clearest difference between the impaired sites and their references.

It is therefore likely that sediment loads in excess of those found in their references are the cause of the differences observed in the macroinvertebrate community in Goose Creek and Little River. Toxics, excess nutrients, and hydromodification have all been ruled out as the primary cause of any impairment to the benthic community in Goose Creek.

Habitat assessment and the physical characterization of the waterbodies, water quality monitoring, and planning-level modeling results all indicate that the differences in sediment loads in the impaired waterbodies and their biological references is likely to be small, and it can be anticipated that only a minimal reduction in sediment loads in Goose Creek and Little River will be necessary for these waterbodies to meet Virginia’s water quality standard for aquatic life.

CHAPTER FOUR: REFERENCE WATERSHED SELECTION

4.1 Reference Watershed Approach

Virginia does not currently have numeric criteria for sediment as part of its water quality standards. A TMDL requires, however, the determination of the maximum pollutant load compatible with water quality standards, and the allocation of that load among permitted and nonpoint sources. The reference watershed approach is used to determine the TMDL "endpoint," that is, in this case, the maximum sediment load that the impaired waterbodies can assimilate and still meet water quality standards.

In the reference watershed approach, the pollutant load for an unimpaired watershed, similar in other respects to the impaired watershed, is determined, usually by computer simulation. That load is then re-scaled in proportion to the comparative size of the impaired and unimpaired watersheds. The scaled load becomes the numeric TMDL endpoint for the impaired watershed. In other words, it is assumed that if the areal loading rate of the impaired watershed were equal to that of the unimpaired watershed, it would meet water quality standards.

As mentioned earlier, the reference watershed - the unimpaired watershed used to set the TMDL endpoint - should be similar in other respects to the impaired watershed. The characteristics most often examined in this regard are:

1. Size
2. Ecoregion
3. Physiographic province
4. Soils
5. Land use

Of course, the reference watershed must be assessed as unimpaired. The reference watershed can be the catchment of the biological monitoring station used in the macroinvertebrate RBP, but it need not be.

4.2 Screening Procedure for Reference Watersheds

It was anticipated that it would be difficult to find a reference watershed comparable in size to the Goose Creek watershed in the Piedmont region. A screening procedure was developed to identify potential candidate reference watersheds for Goose Creek.

Potential reference watersheds were first screened from watersheds assessed by VADEQ using physical habitat assessment criteria developed by Tetra Tech (2002) to select candidate biological monitoring stations as part of their effort to develop for VADEQ regional bioassessment criteria. These regional bioassessment criteria would be used to replace the reliance on a single biological monitoring station in the determination of RBP scores. It is anticipated that VADEQ will adopt this methodology in the near future.

The following physical habitat criteria were first applied to the results of sampling events, and then used to select biological monitoring stations whose samples consistently met the criteria:

- Dissolved oxygen concentrations > 6.0 mg/L
- pH between 6.0 and 9.0
- Conductivity < 500 µmhos/cm
- Epifaunal substrate score greater or equal to 10
- Channel alteration score greater or equal to 10
- Sediment deposition score greater or equal to 10
- Bank disruptive pressure score greater or equal to 10
- Riparian vegetation zone width score greater or equal to 6
- Total habitat score greater or equal to 120

In addition, stations were restricted to the Piedmont and Northern Piedmont ecoregions with stream order greater or equal to three. Table 4.1 shows the stations, their location, assessment status, and, for unimpaired stations, the relative size of the upstream catchment. If a watershed had multiple stations, only the stations whose catchments are closest in size to Goose Creek are shown.

As Table 4.1 shows, there are only two watersheds in the Piedmont ecoregion of comparable size to Goose Creek that are unimpaired: the Rapidan River, Goose Creek's biological reference, and the Rappahannock River. In both cases there is a considerable difference in size between the Goose Creek watershed (386 sq. mi.) and the potential references. Given the discrepancy in the size of the potential reference watersheds, it seemed that greater validity would be given to the reference watershed approach by choosing to use the catchment of the reference biological monitoring station as the reference watershed in this case. The Rapidan River was therefore selected as reference watershed for determining the TMDL endpoint for Goose Creek.

Table 4.1: Potential Candidate Reference Watersheds for Goose Creek

Watershed	VADEQ Station	Major Basin	County	Assesment	Size (sq. mi.)
Accotink Creek	1AACO006.10	Potomac River	Fairfax	Impaired	
Bull Run	1ABUL010.28	Potomac River	Prince William	Impaired	
Catoctin Creek	1ACAX004.57	Potomac River	Loudoun	Unimpaired	<92
Difficult Run	1ADIF010.57	Potomac River	Fairfax	Impaired	
Mountain Run	3-MTN000.59	Rappahannock River	Culpeper	Delisted 2002	73
Piney River	2-PNY005.30	James River	Nelson	Impaired	
Popes Head Creek	1APOE002.00	Potomac River	Fairfax	Impaired	
Rapidan River	3-RAP006.53	Rappahannock River	Culpeper	Unimpaired	695
Rappahannock River	3-RPP147.10	Rappahannock River	Culpeper	Unimpaired	620
Rappahannock River	3-RPP150.32	Rappahannock River	Culpeper	Unimpaired	257
Rivanna River	2-RVN035.67	James River	Albemarle	Impaired	
Robinson River	3-ROB001.90	Rappahannock River	Culpeper	Unimpaired	< 179
Rockfish River	2-RKF023.33	James River	Nelson	Delisted 2002	About 100
SF Rivanna River	2-RRS010.30	James River	Albemarle	Impaired	
SF Tye River	2-TYS000.85	James River	Nelson	Unimpaired	< 100
Smith River	4ASRE019.00	Roanoke River	Henry	Impaired	
Tye River	2-TYE020.67	James River	Nelson	Unimpaired	98

For Little River, the catchment of the biological monitoring station on Catoctin Creek, which is the RBP reference station for Little River, was also chosen as the reference watershed, to keep the treatment of Little River similar to Goose Creek. Selecting the catchment of the biological monitoring station as the reference watershed in both cases gives the reference watershed approach greater clarity and validity for stakeholders: it ties the TMDL sediment allocation to the biological yardstick by which impairment is measured. Catoctin Creek, being the neighboring watershed to Goose Creek, is also familiar to stakeholders. Good quality data is also available for Catoctin Creek. In many cases the same data sets used to estimate loads for Goose Creek can be used for Catoctin Creek, which again helps add validity to comparing the loads from these watersheds. Finally, as will be shown below, the Catoctin Creek and Little River watersheds are similar in almost all characteristics, except for size.

4.3 Comparison of Goose Creek and Little River With Their Reference Watersheds

Figure 4.1 shows location of the Rapidan River and Catoctin Creek with respect to the Goose Creek watershed, against the background of the ecoregions of Northern Virginia. Little River is entirely in the Northern Piedmont Ecoregion. Goose Creek, Catoctin Creek, and the Rapidan River have their headwaters in the Blue Ridge Ecoregion, while the bulk of their watershed is in the Northern Piedmont Ecoregion. The outlet to the Rapidan River catchment at monitoring station RAP006.53 is on the boundary between the Piedmont and Northern Piedmont Ecoregions.

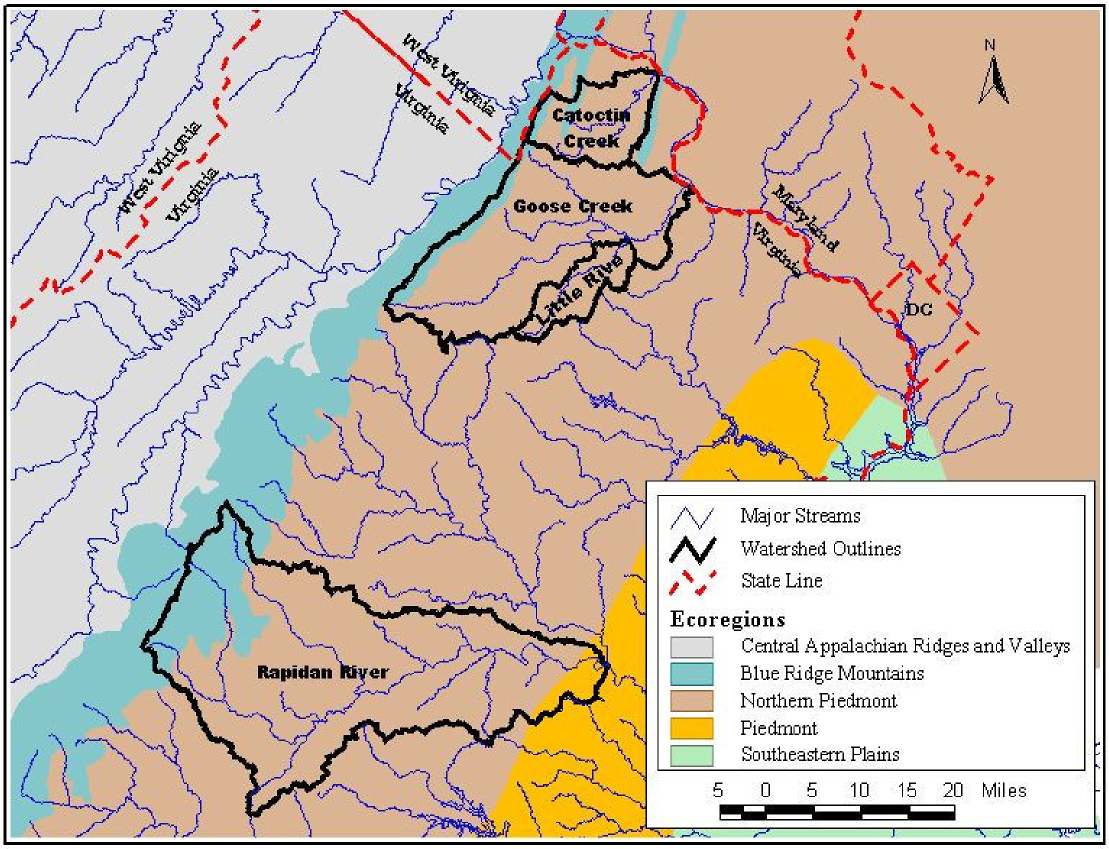

Figure 4.1: Location of Reference Watersheds

Table 4.2 compares the characteristics of Goose Creek with the Rapidan River watershed and Little River with the Catoctin Creek watershed.

Table 4.2: Characteristics of Reference and Impaired Watersheds

Characteristic	Goose Creek	Rapidan River	Little River	Catoctin Creek
Area (sq. mi.)	386.3	695.9	55.1	92.4
% Forest	40.5	63.2	42.4	33.3
% Agriculture	57.0	35.2	56.0	65.8
% Developed	2.0	1.2	1.4	0.7
Average Soil Erodibility (K)	0.35	0.31	0.32	0.35
Average Curve Number (CN)	67	66	67	68

With respect to soil and hydrological properties, the reference and impaired watersheds are very similar. The primary difference between the reference and impaired watersheds is size.

In both cases, the reference watershed is considerably larger than the impaired watershed. The Rapidan River watershed is also more forested than the Goose Creek watershed, and the Catoctin watershed is less forested than the Little River watershed. Whatever the differences between Goose Creek and Rapidan River watersheds, it must be kept in mind that the Rapidan River at Station RAP006.56 is similar enough to Goose Creek at GOO003.28 to serve as the reference for RBP.

CHAPTER FIVE: DETERMINATION OF SEDIMENT LOADS FOR THE IMPAIRED AND REFERENCE WATERSHEDS

The water quality simulation model, Generalized Watershed Loading Functions (GWLF), was used to calculate sediment loads in the reference and impaired watersheds. The simulation period was 1990-2001. This represents the period during which the biological assessment of Goose Creek and Little River led to their placement on Virginia's 303(d) List of impaired waterbodies. Both the unadjusted reference watersheds and representations of the reference watersheds, adjusted for size, were also simulated for this period. The simulated average annual loads from the adjusted reference watersheds were then used to determine the TMDL endpoints for the impaired watersheds.

The Goose Creek watershed is rapidly changing its character. The rapid growth in suburban development is transforming Goose Creek from a largely rural watershed to one where the pressures of development have the potential for significant environmental impacts. It is important to understand the not only the factors that led to Goose Creek's impairment but also the current and future conditions that may interfere with its recovery. Sensitivity analysis will be used to determine average annual sediment loads under current conditions and the impact of the increase in development.

5.1 The GWLF Model

GWLF is a continuous simulation model that can be used to represent streamflow, sediment loads, and nitrogen and phosphorus loads from point and nonpoint sources on a watershed basis. It has played a key role in the reference watershed approach to the development of sediment and nutrient TMDLs to address benthic impairments in Virginia and other states, such as Pennsylvania.

GWLF's strength is that it uses accepted engineering practices and techniques to calculate key variables like runoff and erosion. It is best characterized as a planning level model that does not require as much input data as many continuous simulation models, nor does it require the calibration of model parameters. GWLF operates on a daily timestep, although flow and loads are most often reported on a monthly or annual basis. Runoff, erosion, and the nutrients transported in them are simulated by land use; groundwater flows and their loads are simulated on a watershed scale.

GWLF was originally developed at Cornell University (Haith and Shoemaker, 1990; Haith et al., 1992). AVGWLF, a version of GWLF developed by Pennsylvania State University (Evans et al., 2003a) for use in Pennsylvania's nonpoint source TMDLs, was used to calculate sediment loads for the Goose Creek benthic TMDLs because it added a channel erosion component to the original GWLF model.

The key elements in GWLF's simulation of watershed hydrology and sediment transport are discussed below. For more details on the GWLF model, see Haith et al. (1992) and Evans et al. (2003a).

5.1.1 Simulation of Watershed Hydrology

GWLF represents all phases of the hydrological cycle: precipitation, runoff, infiltration, percolation, evapotranspiration, and groundwater discharge. It requires daily times series of average temperature and rainfall.

The cornerstone of the hydrology model is use of the NRCS (formerly SCS) Curve Number method for computing runoff from daily rainfall. Curve numbers for each land use represented are adjusted on a daily basis according to precipitation over the previous five days. Snowfall, snowpack, and snowmelt are also simulated.

While runoff is computed on a distributed basis over the land uses represented in the watershed, subsurface processes are lumped on a watershed scale. Precipitation that does not runoff infiltrates into the shallow unsaturated zone. There it is subject to evapotranspiration. Potential evapotranspiration is calculated daily according to Hamon's method, on the basis of average temperature and latitude. Monthly cover coefficients determine how much of potential evapotranspiration can be satisfied by the vegetative cover.

When the unsaturated zone reaches its maximum water capacity, additional inflow enters saturated storage. Saturated storage is modeled as a linear reservoir; the recession coefficient is the ratio of the change in storage, discharged as baseflow, and the saturated storage. Total streamflow is the sum of baseflow and runoff. There is no hydraulic routing in GWLF.

The key parameters that characterize a hydrology simulation are (1) curve numbers for each land use represented, (2) maximum unsaturated storage, (3) cover coefficients, and (4) the recession coefficient. More details on the hydrology component of GWLF can be found in Haith et al. (1992).

5.1.2 Simulation of Erosion and Sediment Transport

Just as curve numbers are the cornerstone of the hydrology simulation, the universal soil loss equation (USLE) forms the cornerstone of the representation of erosion and sediment transport. The USLE was modified to calculate erosion on an event basis by calculating the erosivity factor (R) for daily precipitation. Other factors in the USLE - the soil erodibility factor (K), the cover factor (C), the length-slope factor (LS), and the practice factor (P) - are input to the model for each land use.

Not all the sediment eroded in a watershed is transported out of the watershed. The sediment delivery ratio, the proportion of the eroded sediment transported out of the watershed, is a function of watershed size. The delivery of sediment is proportional to the relative size of the monthly runoff that occurs over the remainder of the year from the time the erosion took place. Again, for more details, see Haith et al. (1992).

Evans et al. (2003b) introduced a channel erosion component into GWLF. Channel erosion is the product of a total stream length in the watershed, bank height, the bulk density of the bank soil, and a lateral erosion rate. The lateral erosion rate (LER), in cm/month, is a function of average monthly streamflow (Q), in m^3/s, and a factor "a"

$$LER = a*Q^{0.6}$$

The “a” factor was determined by regression as a function of the following watershed characteristics: (1) percent developed land, (2) animal equivalent unit density, (3) average curve number, (4) average K-factor, and (5) mean slope.

Sediment loads from point sources can also be represented in GWLF. These are not subject to the sediment delivery ratio.

5.1.3 Seasonal Variability and Critical Conditions

Any TMDL is required to take into account the seasonal factors that impact loading rates and critical conditions that exacerbate the impact of the pollutant in question, in this case sediment. The GWLF model can incorporate seasonal variability and critical conditions into its simulation of watershed sediment loads.

First, several GWLF parameters, including rainfall erosivity and evaporation cover coefficients, are modified on a monthly basis to take into account their seasonal variation. Second, using a daily model over a twelve-year simulation period represents a wide variety of meteorological and hydrological conditions and seasonal effects. Wet springs, dry hot summers, or even wet cool summers are represented over a long simulation period.

With respect to sediment, critical conditions are (1) heavy rainfalls that erode sediment from fields and (2) high flows that scour streambanks. Both types of events are represented in GWLF if the simulation period includes a sufficient variety of meteorological and hydrological conditions.

5.2 Hydrology Simulation and Calibration of the Impaired and Reference Watersheds

The GWLF model was run for a twelve-year simulation period, 1990-2001. The MRLC land use cover, discussed in Chapter 2, was used to set the land use for the model. The MRLC represents the best available estimate of land use on average for the simulation period.

As a planning level model, GWLF can be run without calibration by using default parameters or locally-derived information to estimate parameters. Initial values for curve numbers, cover coefficients, maximum unsaturated storage, recession coefficients, and other parameters were obtained for local data or by using the guidance in the GWLF manual. Following the precedent set by previous Virginia TMDLs that used GWLF, the hydrology simulations of Goose Creek, Catoctin Creek, and Rapidan River were calibrated against monthly flows observed at USGS gages in those watersheds. Table 5.1 shows the USGS gages used in the calibration. Figures 5.1 and 5.2 show the location of the gages.

Table 5.1: NOAA Weather Stations and USGS Gaging Stations Used in Hydrology Calibration

Watershed	USGS Gage	NOAA Weather Station
Goose Creek (calibration)	Goose Creek near Leesburg (01644000)	Dulles Airport (448903)
Goose Creek (verification)	Goose Creek near Middleburg (01643700)	Dulles Airport (448903)
Catoctin Creek	Catoctin Creek at Taylorstown (01638480)	Dulles Airport (448903)
Rapidan River	Rapidan River near Culpeper (01667500)	Piedmont Research Station (446712)

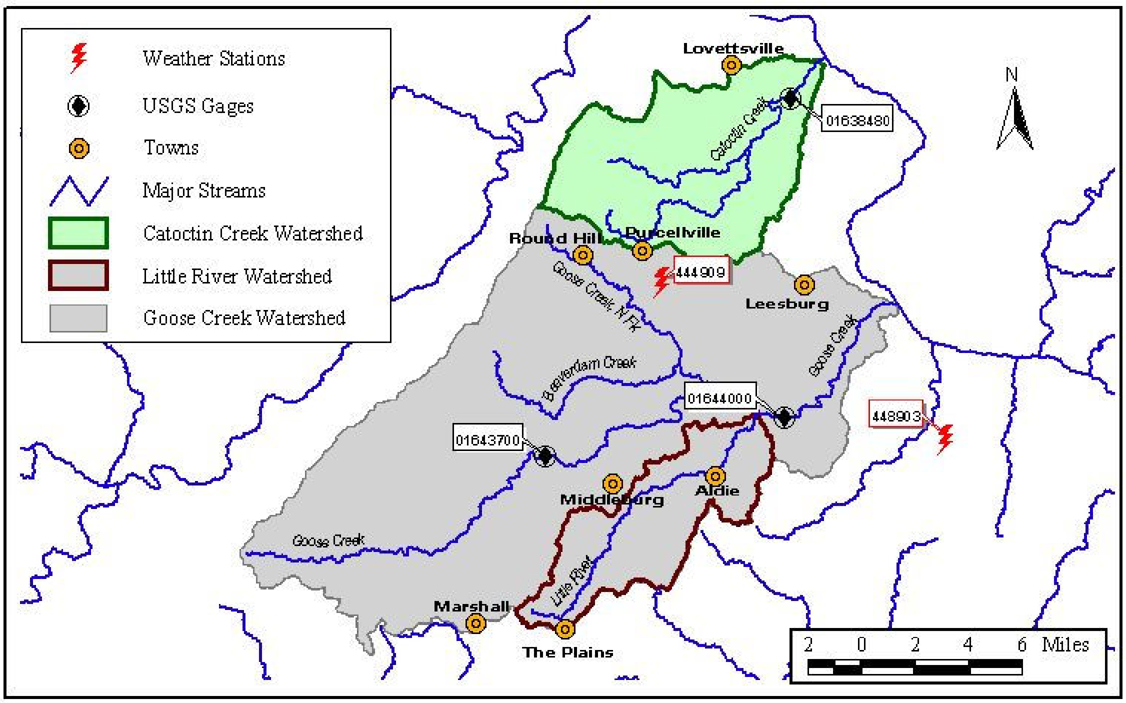

Figure 5.1: Locations of USGS Gages and Weather Stations in the Catoctin and Goose Creek Watersheds

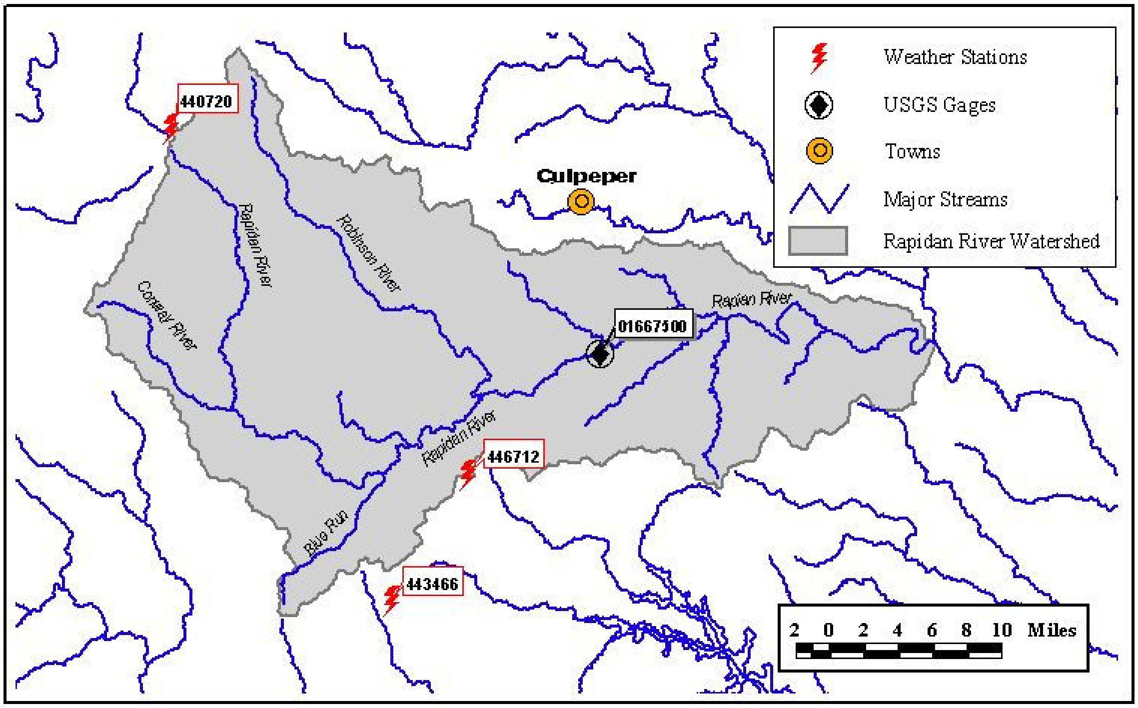

Figure 5.2: Locations of USGS Gages and Weather Stations in the Rapdian River Watershed

5.2.1 Meteorological Data

Table 5.1 also shows for each watershed the NOAA Cooperative Station from which precipitation and average temperature records were used in the hydrology simulation. Dulles Airport and the Piedmont Research Station were chosen because of the consistency of their observations, the length of available record, and the fact that fewer observations were missing in their records than at neighboring stations.

The choice of meteorological stations was confirmed by attempting to calibrate Goose Creek with precipitation data from Lincoln, and to calibrate the Rapidan River with precipitation data from Big Meadows. The calibration of neither Goose Creek nor the Rapidan River could be improved by using data from the alternative weather station. Figures 5.1 and 5.2 show the locations of all the weather stations used in the hydrology calibration.

5.2.2 Initial Parameter Values

Initial values for the key hydrological parameters were chosen as follows:

- Land use was determined using the MRLC coverage, as described in Chapter Two, not only for the Goose Creek and Little River watersheds but also for the reference watersheds. Tables 5.2 through 5.5 show the land use distribution in the watersheds at the calibration points.

- Curve numbers were determined by overlaying the digitized soil maps on the land use layers. For the Rapidan River watershed, the VIRGIS soil layer for the Culpeper Conservation District was used. For Goose Creek and Catoctin Creek, digitized soil layers from Loudoun and Fauquier County's soil scientists were used. Tables 5.2 through 5.5 show the distribution of Hydrologic Soil Groups by land use for the watersheds at the calibration points.

- Recession coefficients were estimated by first performing a base flow separation on the observed daily flow records at each station using HYSEP, the USGS's automated base flow separation program. The local minimum method was used to perform the separation. Using all days that were on a falling limb of the hydrograph, the average value of the ratio of base flow on successive days was calculated for each station. The GWLF recession constant is minus the natural log of this average value. For Goose Creek and Catoctin Creek, the initial value of the recession constant calculated in this fashion was 0.02; for the Rapidan River, the initial value was 0.04.

- The maximum unsaturated zone storage was set at the default value of 10 cm.

- Monthly cover coefficients were determined according to the guidance of the GWLF manual.

Table 5.2: Land Use and Soils Distribution Upstream of USGS Site 01644000 (Goose Creek near Leesburg)

Land Use	%Area	A	B	B/D	C	C/D	D
Barren	0%	0%	44%	3%	47%	0%	6%
Crops	1%	0%	62%	16%	17%	0%	6%
Developed	1%	0%	66%	11%	18%	0%	5%
Forest	40%	0%	41%	8%	44%	0%	7%
Pasture	57%	0%	58%	15%	21%	0%	6%
Total	84,641 (ha)	0%	51%	12%	30%	0%	7%

Table 5.3: Land Use and Soils Distribution Upstream of USGS Site 01643700 (Goose Creek near Middleburg)

Land Use	% Area	A	B	B/D	C	C/D	D
Barren	0%	0%	44%	1%	54%	1%	0%
Crops	1%	0%	79%	7%	13%	1%	0%
Developed	2%	0%	73%	2%	21%	4%	0%
Forest	46%	0%	51%	3%	39%	7%	0%
Pasture	52%	0%	70%	8%	17%	5%	0%
Total	31,086 (ha)	0%	61%	6%	27%	0%	0%

Table 5.4: Land Use and Soils Distribution Upstream of USGS Site 01638480 (Catoctin Creek at Taylorstown)

Land Use	% Area	A	B	B/D	C	D
Crops	3%	1%	54%	30%	12%	3%
Developed	1%	2%	64%	18%	11%	4%
Forest	33%	1%	23%	10%	50%	16%
Pasture	64%	1%	45%	24%	23%	7%
Total	7,813 (ha)	1%	23%	10%	50%	16%

Table 5.5: Land Use and Soils Distribution Upstream of USGS Site 01667500 (Rapidan River near Culpeper)

Land Use	% Area	A	B	B/D	C	C/D	D
Barren	0%	0%	65%	0%	35%	0%	0%
Crops	3%	2%	46%	0%	46%	1%	5%
Developed	1%	2%	54%	0%	37%	1%	5%
Forest	59%	7%	57%	0%	30%	2%	3%
Pasture	36%	4%	49%	0%	42%	1%	4%
Total	107,838 (ha)	6%	54%	0%	35%	2%	4%

5.2.3 Hydrology Calibration

All hydrology calibrations were performed using Version 5 of PEST, the model-independent parameter estimation software developed by J. Doherty (Doherty, 2001). PEST determines the values of parameters that optimize a user-specified objective function. In these simulations, the objective function was the sum of the squares of the differences between monthly observed and simulated flows. This is equivalent to maximizing the coefficient of determination (R^2) between observed and simulated flows.

Table 5.6 shows the parameters that were optimized by PEST. The optimization of the recession constant and the maximum unsaturated storage is straightforward.

Table 5.6: Parameters Optimized in PEST Calibrations

Parameter	Definition
Recession constant	Baseflow discharge per unit saturated zone storage
Maximum unsaturated storage	Maximum storage in the unsaturated zone; field capacity
Winter cover coefficient	Evaporation cover coefficient for winter months
Summer cover coefficient	Evaporation cover coefficient for winter months
Hydrological condition index	Degree to which soil hydrologic conditions are good (0) or poor (1)

Two monthly cover coefficients were estimated using PEST, a winter coefficient and a summer coefficient. A transitional coefficient was calculated for April and November on the basis of the estimated coefficients. The coefficients for May and June were set to 1.0. The summer coefficient was allowed to drop below 1.0 to simulate the impact of hot, dry weather. Table 5.7 shows how the coefficients were applied over the calendar year.

Table 5.7: Evaporation Cover Coefficients

Month	Calibration/Calculation
January	Winter
February	Winter
March	Winter
April	(Summer + Winter)/2
May	1.0
June	1.0
July	Summer
August	Summer
September	Summer
October	(Summer + Winter)/2
November	Winter
December	Winter

Curve numbers for forest and pasture were optimized by constructing a hydrologic condition index. As the index varied from 0 to 1, curve numbers were linearly adjusted from good hydrologic conditions to poor conditions, based on the percent of the hydrologic groups in each land use.

PEST produced a satisfactory calibration of Goose Creek near Leesburg and Catoctin Creek without further adjustment. Table 5.8 shows the optimum parameter set. Table 5.9 shows the coefficient of determination between observed and simulated monthly flows and the total observed and simulated flow volume over the 12-year calibration period. The coefficient of determination is greater than 0.8 and the water balance is within 2% of total observed flow. Figures 5.3 and 5.4 show the time series and scatter plots comparing observed and simulated monthly flows for Goose Creek near Leesburg. Figures 5.5 and 5.6 show the same plots for Catoctin Creek.

Table 5.8: Optimized Parameter Sets

Parameter	Goose Creek	Catoctin Creek	Rapidan River
Recession constant	0.066	0.084	0.044
Maximum unsaturated storage	19.97	19.52	11.97
Winter cover coefficient	0.5	0.5	0.5
Summer cover coefficient	0.926	1.0	0.9
Hydrologic index	0.927	0.724	1.0
Forest CN	71.8	73.4	68.6
Pasture CN	79.7	78.6	82.1

Table 5.9: Calibration Results

Watershed	Coefficient of Determination	Total Simulated Flow as Percent of Observed Flow
Goose Creek near Leesburg	0.86	99%
Catoctin Creek at Taylorstown	0.84	98%
Rapidan River near Culpeper	0.81	100%
Goose Creek near Middleburg	0.87	98%

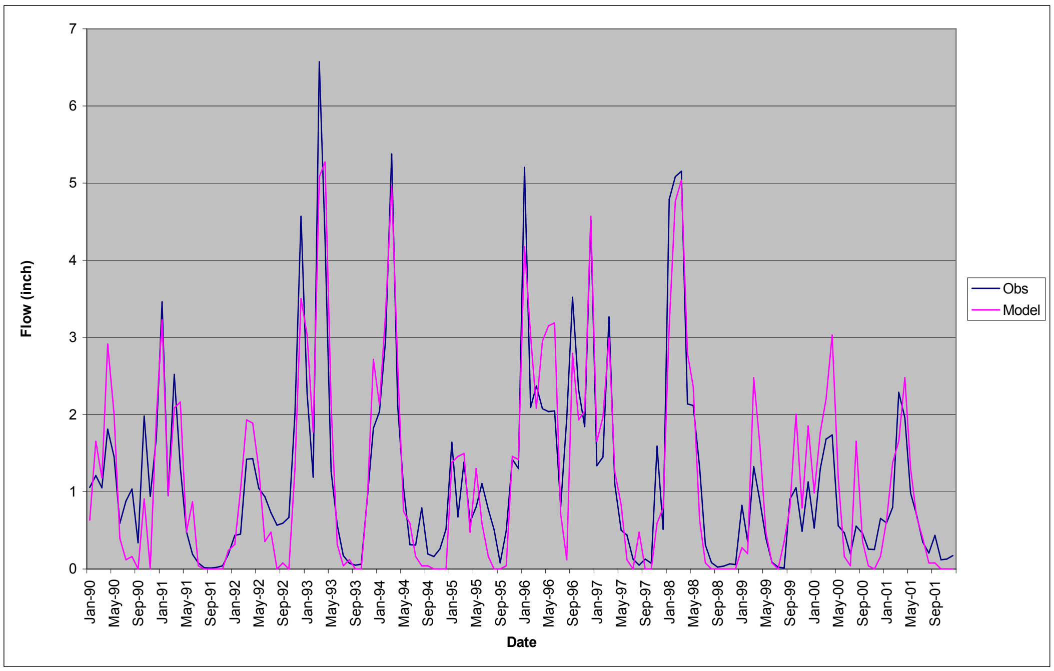

Figure 5.3: Time Series: Observed and Simulated Monthly Flow at USGS Site 01643700, Goose Creek Near Leesburg

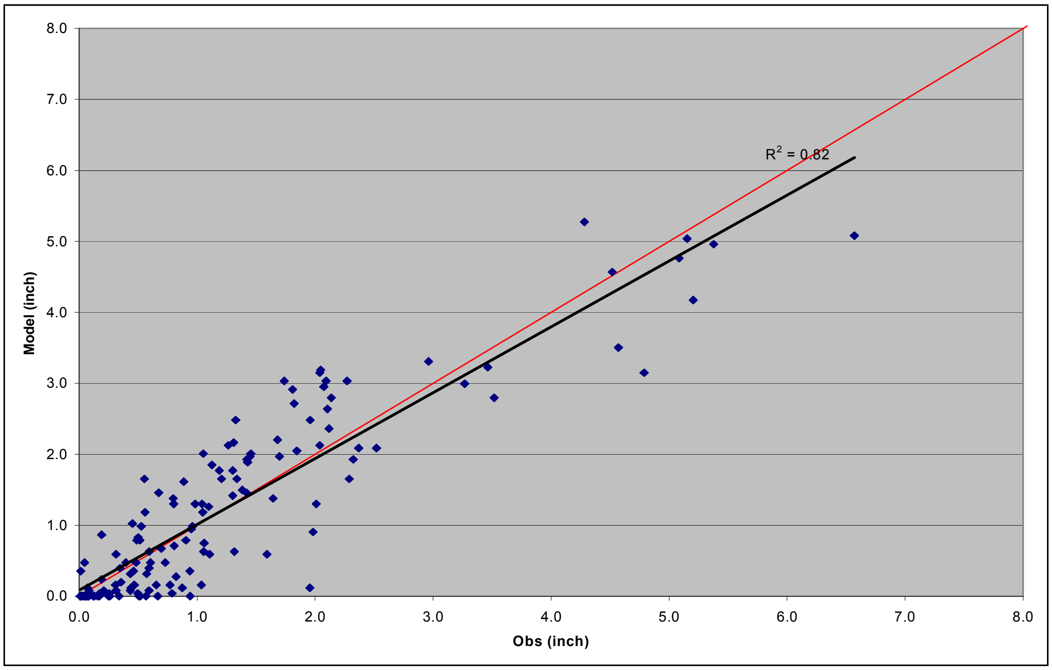

Figure 5.4: Scatter Plot: Observed vs. Simulated Monthly Flow at USGS Site 01643700, Goose Creek Near Leesburg

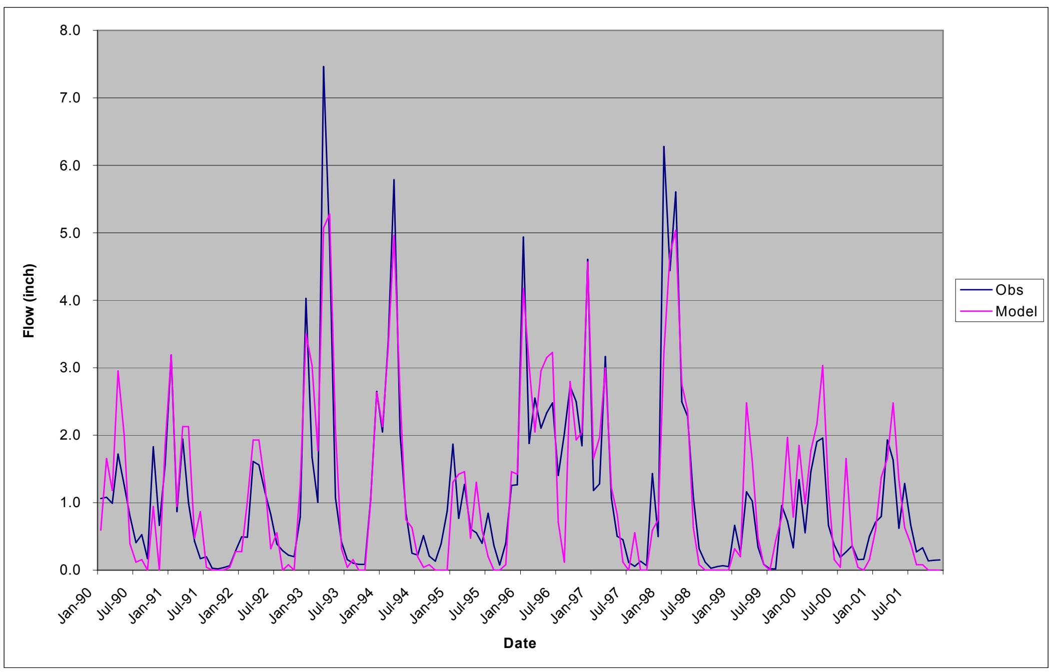

Figure 5.5: Time Series: Observed and Simulated Monthly Flow at USGS Site 01638480, Catoctin Creek Near Taylorstown

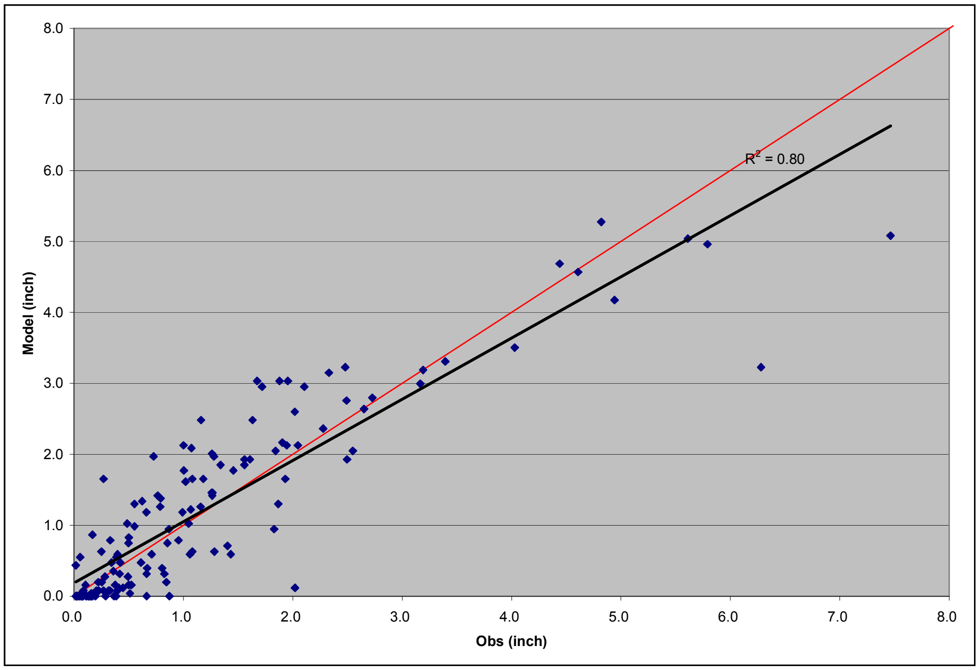

Figure 5.6: Scatter Plot: Observed vs. Simulated Monthly Flow at USGS Site 01638480, Catoctin Creek Near Taylorstown

A comparison of monthly observed and simulated flows for the USGS gage near Middleburg (01643700), performed for validation, also showed good agreement between the model and observations, as Table 5.8 shows. Figures 5.7 and 5.8 show the time series and scatter plots comparing observed and simulated monthly flows for the validation study.

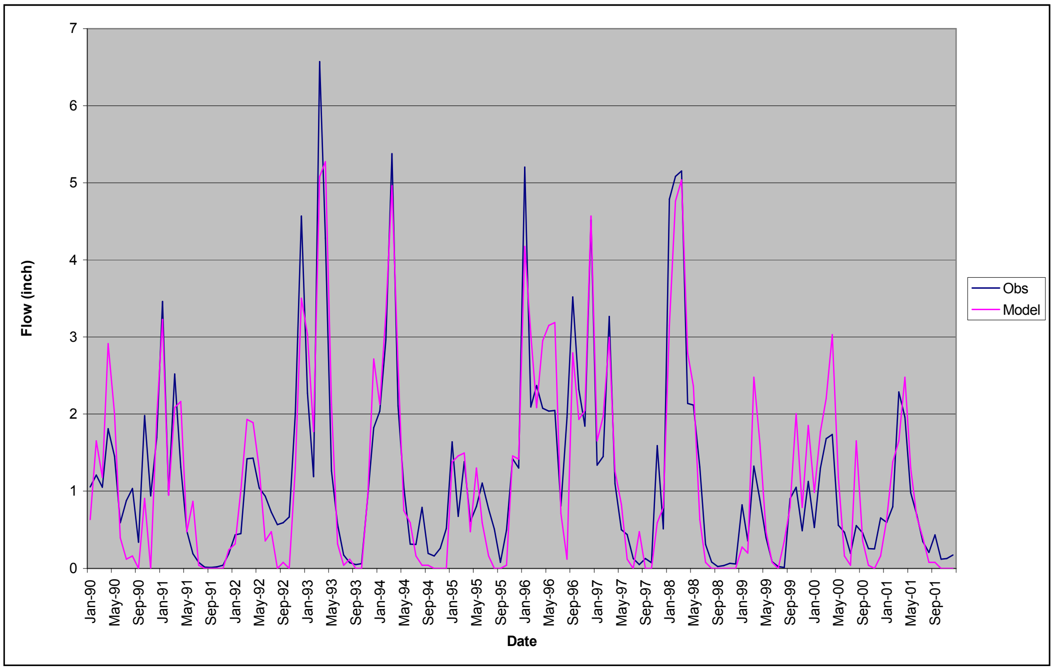

Figure 5.7: Time Series: Observed and Simulated Monthly Flow at USGS Site 01643700, Goose Creek Near Middleburg

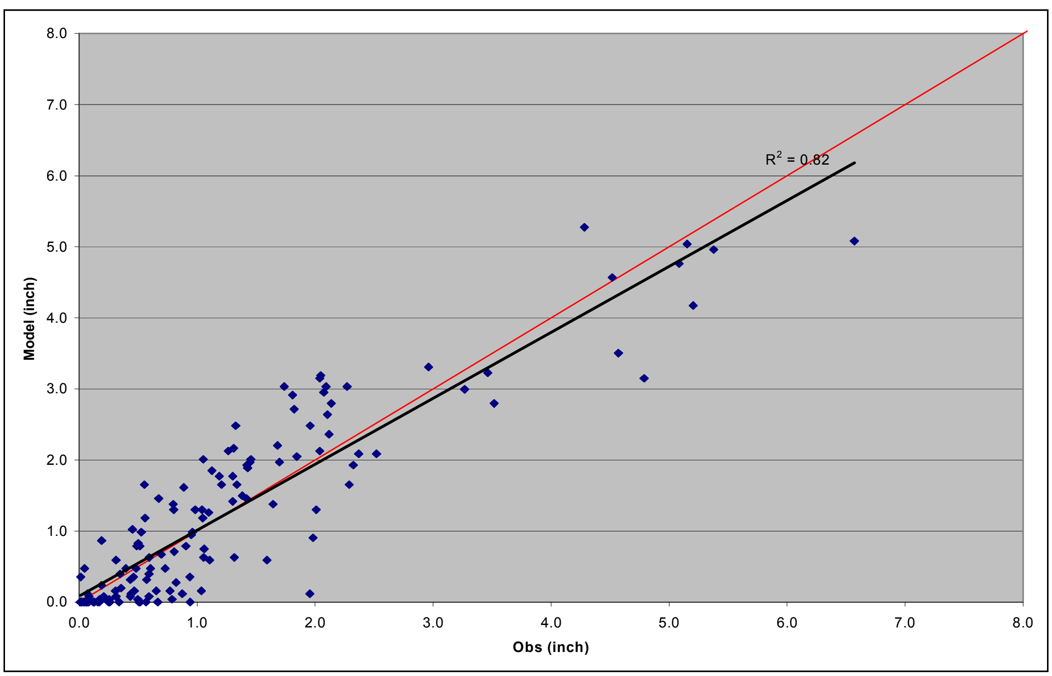

Figure 5.8: Scatter Plot: Observed vs. Simulated Monthly Flow at USGS Site 01643700, Goose Creek Near Middleburg

Initially, PEST could not find a parameterization of the simulation of the Rapidan River watershed with a coefficient of determination greater than 0.76. The problem was traced to two storms, one in June 1995 and one in September 1996. The observed flows for these months are the maximum for the period of record at this gage, and the simulation underpredicted flows during these two months. The problem most likely lay in the precipitation time series. The possibility of using the Thiessen method to estimate precipitation for the model was investigated, but rejected, because many of the stations in this region have discontinuous records or are missing data for the critical storms. Big Meadows has a good precipitation record, but because it is on the Blue Ridge, probably tends to represent topographic impacts rather than general trends in the watershed. The meteorological station at Gordonsville, just southwest of the Piedmont Research Station, recorded more precipitation during the June 1995 storm than the Piedmont Research Station. The precipitation record from this station was used to represent the June storm, as shown in Table 5.10. For the September storm, the precipitation time series was constructed as the weighted sum of 0.3 of the precipitation recorded at Big Meadows and 0.7 of the rainfall at the Research Station. Table 5.11 shows the precipitation record used for the September storm. The optimum parameter set for the Rapidan River is shown in Table 5.8. The results of the simulation are shown in Table 5.9. Figures 5.9 and 5.10 show the time series and scatter plots comparing observed and simulated monthly flows for Rapidan River near Culpeper.

Table 5.10: Precipitation for June 1995 Storm in Rapidan River Watershed (cm)

Date	Piedmont Research Station	Gordonsville
6/26/95	1.32	0.48
6/27/95	14.40	4.11
6/28/95	0.69	23.62
6/29/95	0.33	0.58
6/30/95	1.02	1.14

Table 5.11: Precipitation for September 1996 Storm in Rapidan River Watershed (cm)

Date	Piedmont Research Station	Big Meadows	Model Input
9/4/96	2.54	9.14	4.52
9/5/96	5.84	2.03	4.70
9/6/96	5.08	4.82	5.00
9/7/96	4.06	25.4	10.46

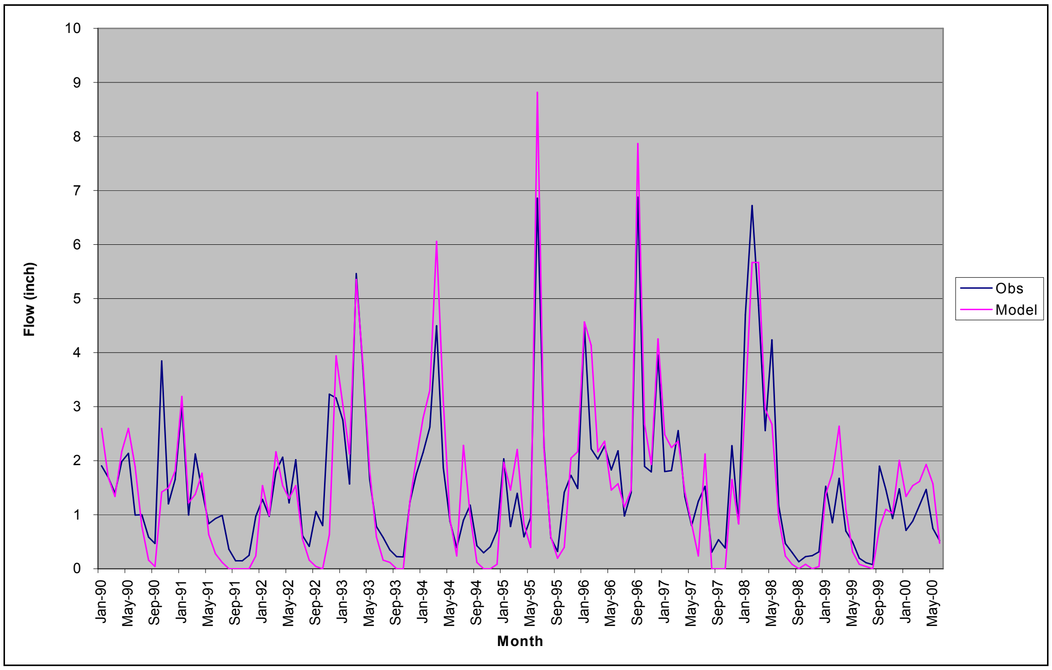

Figure 5.9: Time Series: Observed and Simulated Monthly Flow at USGS Site 01667500, Rapidan River near Culpeper

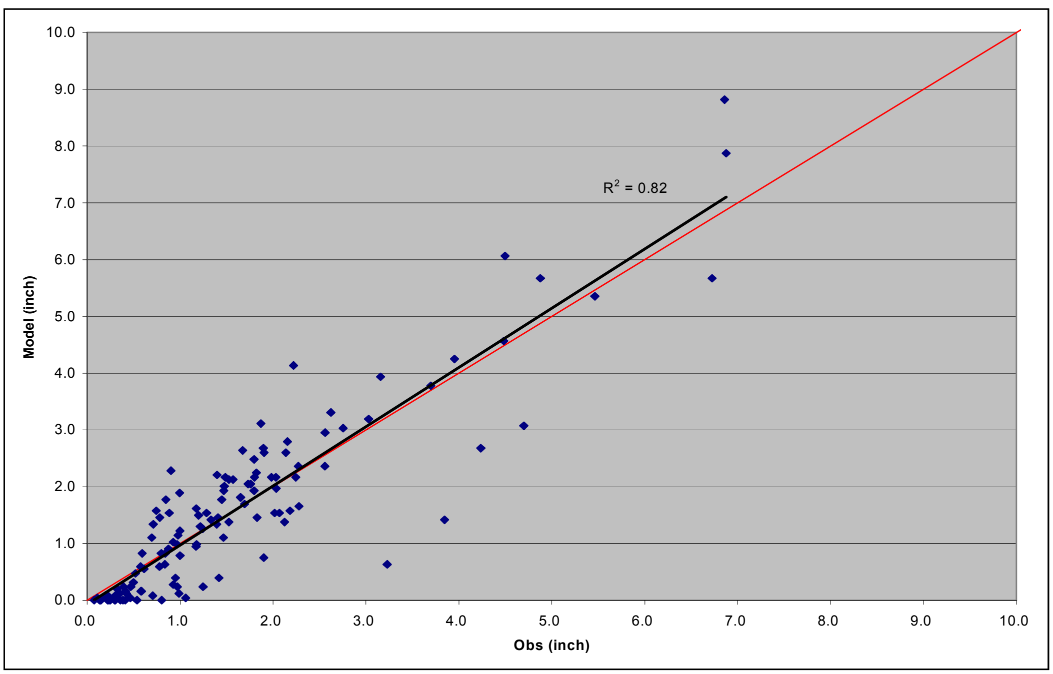

Figure 5.10: Scatter Plot: Observed vs. Simulated Monthly Flow at USGS Site 01667500, Rapidan River near Culpeper

It should be noted that the index of hydrological condition in optimum parameter sets tended towards poor. To what extent this reflects actual conditions is unknown. Forests on the slopes of the Blue Ridge tend to be covered with boulders that can hinder infiltration, which may explain why higher curve numbers produce a better calibration. In the end, however, the agreement with observed flows is the most important factor in judging the calibration, especially when the hydrology simulation is put in the context of calculating sediment loads. In GWLF precipitation, not runoff, determines erosion rates. Runoff and streamflow have no impact on erosion or even the average annual sediment load delivered from erosion; they only impact the intra-annual timing of the delivery of sediment loads. Channel erosion, on the other hand, is determined from monthly streamflow rates on a watershed basis.

5.3 Sediment Source Assessment

GWLF was run to simulate sediment loads for the period 1990-2001. This simulation period encompasses the assessment period within which Goose Creek and Little River were listed as impaired. The twelve-year simulation period also takes into account the full variety of hydrological and meteorological conditions. Section 5.5 discusses the impact of development and gives the best estimate of sediment loads under current conditions.

Three types of sources were identified and represented in the GWLF models for the Goose Creek benthic TMDLs: (1) sediment loads from erosion on the land, (2) streambank erosion, and (3) sediment loads from permitted sources. The loads from each type of source are derived in a different way. The USLE is the basis of estimating erosion from the land surface. Streambank erosion is calculated using the regression equation developed by Evans et al. (2003). Loads from permitted sources were calculated using information provided for the permits and from the Discharge Monitoring Reports (DMRs) that are often a permit requirement.

5.3.1 Erosion From the Land Surface

Four basic land uses were represented in the models

1. Forest
2. Pasture
3. Crops
4. Developed land

The MRLC land cover, adjusted as described below, was used to calculate the distribution of land uses in each watershed.

Erosion from the land is calculated using the Universal Soil Loss Equation

$$A = R*K*LS*C*P$$

Where

R = Rainfall erosivity

K = Soil erodibility
LS = Topographic factor, base on slope and slope length
C = Cover and management factor
P = Support practice factor
A = Soil loss per unit of time

USLE was originally intended to provide annual or seasonal estimates of erosion from fields. In GWLF, erosion is calculated on a daily basis by calculating the rainfall erosivity on the basis of daily precipitation. Soil erodibility is a soil property and was calculated from digitized soil maps. Both Loudoun County and Fauquier County provided recently digitized soil maps. The digitized soil map from VIRGIS was used for the Rapidan River watershed.

Slopes for the topographic factor were calculated using digitized elevation maps (DEMs). Slopes for Catoctin Creek and Goose Creek were also calculated using digitized five-foot contours from Loudoun County and ten-foot contours from Fauquier County. The resulting slopes agreed overall with the slopes derived from the DEMs, but tended to produce poor results in very steep or very flat areas. Slope lengths were taken from the VIRGIS system, based on field surveys.

The KLS portion of the USLE was calculated as follows. The topographic factor and the soil erodibility factor were calculated on separate grids. The K-factor was combined with information on land use and watershed or subwatershed. The average value of the "LS" factor for each combination of watershed, land use, and K-factor was then calculated and combined with the K-factor to give the K* LS product by watershed and land use. Table 5.12 shows the KLS products by watershed and land use.

Table 5.12: KLS Products by Watershed and Land Use

Land Use	Rapidan River	Goose Creek	Little River	Catoctin Creek
Crops	0.3294	0.5793	0.4929	0.6594
Pasture	0.3856	0.7376	0.6657	0.6850
Forest	1.0149	1.1277	0.9330	1.0064
Developed	0.3574	0.5915	0.6384	0.5582

The cover and management factor is a function of, among other things, the vegetative cover associated with land use. A base "C" factor was assigned to each land use, based on the vegetative cover for each land use. Table 5.13 shows the base "C" factors. Because no-till corn is the dominant crop in Goose Creek and Catoctin Creek, the crop "C" factor was selected to represent this type of cover. The base "C" factor was adjusted to take into account management practices.

Table 5.13: Base C-Factors

Forest	Crops	Pasture	Developed Land
0.001	0.1	0.01	0.01

The support practice factor applies mostly to cropping practices like contouring and strip cropping. In this project it was used to track BMPs installed on cropland, forest, and pasture. The P factor was calculated based on the following formula:

P = (1- BMP efficiency for sediment removal)* area under BMP/total area

Where the area in question is pasture, cropland, or forest depending on the BMP.

Adjustments to the "C" factor and the incorporation of BMPs into load estimates are described below for each land use.

5.3.1.1 Pasture and Cropland

For pasture, "C" values were adjusted from the base value to reflect animal density. Table 5.14 shows the animal populations for each subwatershed of Goose Creek, and the reference watersheds, Catoctin Creek and Rapidan River, number of acres of pasture, and adjusted "C" values. No adjustment was made to the C-factor for crops. Table 5.15 shows the adjusted C-factors.

Table 5.14: Animal Populations by Watershed

Watershed	Pasture (acres)	Number of Animals			
		Dairy	Beef	Horse	Sheep
Beaverdam Creek	22,425.81	0	3,500	2,900	0
Beaverdam Creek Reservoir	1,654.14	0	50	20	0
Cromwells Run	8,625.40	0	675	2,122	120
Goose Creek above Reservoir	7,535.91	0	1,100	720	200
Goose Creek below Dam	433.22	0	0	0	0
Goose Creek Mouth - Cattail Branch	645.82	0	20	20	10
Goose Creek near Middleburg	7,862.60	0	3,993	2,000	0
Goose Creek Reservoir	546.86	0	10	10	0
Little River	19,123.54	244	3,700	4,000	85
Middle Goose Creek - Panther Skin Creek	17,884.83	0	10,914	923	249
North Fork Goose Creek	17,443.83	200	3,000	2,000	0
Sycolin Creek	6,201.35	0	500	560	200
Tuscarora Creek	3,608.72	0	250	200	100
Upper Goose Creek Gap Run	22,287.93	0	11,000	400	50
Total Goose Creek	**136,279.92**	**444**	**38,712**	**15,875**	**1,014**
Little River	19,123.54	0	3,700	4,000	85
Catoctin	37,514.08	170	5,340	3,120	1,180
Rapidan	141,498.08	11,114	63,720	15	2,625

Table 5.15: Adjusted C-Factors and P-Factors for Impaired and Reference Watersheds

	Goose Creek	Rapidan River	Little River	Catoctin Creek
Adjusted pasture C-Factor	0.0178	0.02	0.0178	0.01
Pasture P-factor	0.99	0.89	0.98	0.83
Crop P-Factor	1.0	0.93	1.0	0.95

Table 5.16 shows the types of agricultural BMPs installed with cost-share funding from federal or state agencies, as identified in the VADCR BMP Cost-Share Database. It also shows the expected reduction in sediment loads from the installed practices. The efficiencies are taken from VADCR's TMDL implementation manual (VADCR, 2003). For streambank fencing, the acres reported assume that 208 linear feet of streambank fencing reduce sediment loads by 75% on three acres of pasture (Palace et al, 1998). Table 5.15 shows the P-values calculated on the basis of the area in BMPs and efficiencies.

Table 5.16: Agricultural BMPs on Impaired and Reference Watersheds

BMP Code	Description	Sediment Reduction Efficiency	Goose Creek	Rapidan River	Catoctin Creek	Little River
SL-3	Stripcropping system	70%	0	572	50	0
SL-6	Grazing land protection	14%	2,892	7,405	561	207
WP-2	Streambank protection	75%	418	32	21	41

Not all agricultural BMPs are accounted for in VADCR Cost-Share Database. Additional BMPs, such as existing farm ponds, can be credited against the necessary reductions in load from agricultural land during implementation.

5.3.1.2 Forests

The Virginia Department of Forestry (VADOF) has records of timber harvests since 1993. Table 5.17 shows the average annual number of acres of forest harvested by clearcutting, selected cutting, or thinning in the impaired and reference watersheds. Since 1993, VADOF also has monitored the implementation and effectiveness of silvaculture BMPs mandated under Virginia's Silviculture Act. Random timber harvesting sites are inspected, and VADOF biannually reports on the results.

Table 5.17: Average Annual Timber Harvests (acres)

Watershed	Unharvested	Clear-cut	Select-cut	Total
Goose Creek	98,813.6	13.6	548.0	99,375.2
Little River	14,751.4	5.1	61.2	14,817.6
Rapidan River	279,169.6	744.5	1,423.7	281,337.7
Catoctin Creek	19,313.9	0.6	155.0	19,469.5

To model the sediment load associated with timber harvesting, clear-cut and select-cut harvested forest were modeled as separate land uses. C-factors were calculated for each type of harvest, following the guidance of Dissmeyer and Foster (1984). According to Dissmeyer and Foster, the C-factor for soils with timber harvests are a function of (1) the percent of soil left bare, (2) the degree of disturbance in the fine-root mat of the forest, (3) canopy cover, (4) the amount of depression storage, (5) the impacts of any tillage that may be performed after harvesting, and (6) the “steps” that are formed by the debris washed down a slope that act like small dams, ponding runoff and facilitating deposition. The greater the slope, the more debris steps hinder sediment transport.

It is difficult, if not impossible to generalize about the impacts of the type of harvesting on sediment loads (S. Austin, VADOF; personal communication). The following characterizations were used to calculate C-factors for clear-cut and select-cut harvests:

- Clear-cutting harvests 90% and select-cut harvests 50% of the trees;
- The amount of bare soil after harvesting is equal to half the percentage of trees harvested;
- No tillage is performed after harvesting;
- Depression storage is formed from tracks of logging vehicles;
- The canopy over bare soil is equal to the fraction of trees not harvested;
- 50% of the fine-root mass is left on bare soil; and
- The amount of debris that forms steps is equal to the fraction of trees cleared.

Table 5.18 shows how C-factors were calculated from subfactors associated with assumptions, based on Haan et al.’s (1994) simplification of Dissmeyer and Foster.

Table 5.18: C-Factors for Clear-cut and Select-cut Timber Harvests

Subfactor	Clear-Cut	Select-Cut
Bare-soil/root mat	0.063	0.03
Steps	0.26	0.59
Canopy	0.98	0.93
Depression storage	0.8	0.8
Calculated C-Factor	0.013	0.013

The bi-annual DOF surveys of compliance and implementation of forestry BMPs show that on average 95% of sites are attempting to comply with the Silviculture Act. While the level at which all BMPs are being implemented according to the technical specifications of the BMP design manual is much lower, DOF inspectors found that the potential for water quality problems existed only at 12.6% of inspected sites. The reduction efficiency for forest BMPs was therefore set to 0.87, and the P-factor for clear-cut and select-cut harvest was set to 0.13.

5.3.1.3 Developed Land

Two types of developed land were modeled: (1) already developed land and (2) land disturbed by construction. Properties under construction are subject to discharge permits for sediment and erosion control, but will be discussed here because they are modeled using the USLE. Table 5.19 shows the area under sediment and erosion control permits by watershed during the 1999 - 2004 permit period. The average annual area under permit was taken to be the representative value of land under construction, except in Catoctin Creek, where one recent project accounts for two-thirds of the permitted area and skews the general trend.

Table 5.19: Land Under Sediment and Erosion Control Permits (acres)

Watershed	Goose Creek	Little River	Rapidan River	CatoctinCreek
Disturbed Land	576.1	55.0	14.0	64.4

The MRLC category land in transition is often thought to represent land under construction. Land in transition is by nature transient, and it is unlikely that the transitional land in the MRLC can be identified with the current permitted sites. Nevertheless, the land under construction was subtracted from the transitional land category. If land under construction was larger than transitional land, the difference was taken from developed land.

Erosion from developed land was modeled using ULSE as described in Section 5.1. Developed land includes both pervious and impervious surfaces, and it is not physically realistic to use the USLE to model solids transport from impervious surfaces. The best information on sediment loads from developed land, however, tends to report concentrations or loads for areas including both types of surfaces. In this project, the KLSCP factor for developed land was calibrated so that the concentration of solids in runoff from developed land was equal to 100 mg/L, the concentration recommended for use in planning for urban runoff (Caraco, 2001).

The representation of erosion from construction sites was taken from The Center for Watershed Protection's Watershed Treatment Model (Caraco, 2001). Erosion from a construction site is the product of five factors:

$$L = (1 - C*M*T*E)*A$$

Where

L = Net load from land disturbed by construction, tons/year
C = Compliance factor
M = Maintenance factor
T = Treatability factor
E = Sediment reduction efficiency
A = Untreated sediment load, tons/year

In this project, the untreated sediment load is modeled in GWLF using the USLE for bare soil. The sediment reduction efficiency under optimum conditions is 70%, based on the following assumptions (Caraco, 2001):

- Phased or limited clearing at the site reduces the exposure of bare soil by 25%
- The use of sedimentation ponds and other BMPs reduces losses from disturbed surfaces by 60%.

The treatability factor represents the percent of land under construction subject to permits. In Virginia, sites under one acre in size do not need erosion and sediment control permits. Loudoun County does require permits for grading for disturbed areas greater than 10,000 square feet. Using the records for grading permits, it was estimated that the disturbed land under one acre in size was no more than 95% of the disturbed land under erosion and sediment control permits.

The maintenance factor is a measure of how well BMPs are installed and maintained. The compliance factor measures what fraction of BMPs in the control plan is actually implemented. Both are a function of the frequency of inspections. In Loudoun County, the Center for Watershed Protection found that there were too few inspectors to adequately enforce erosion control permits (Winer et al, 2002), so both the “C” and “M” factors were set at 0.5.

Little information was available on the extent of urban BMPs or stormwater controls, so their effect is not represented in the model. Sediment loads from the Town of Leesburg are probably being reduced by 10% through monthly street sweeping (Caraco, 2001). These and other reductions in sediment loads from urban BMPs or stormwater controls can be can be credited against the necessary reductions in loads from developed land during implementation.

5.3.2 Streambank Erosion

As described in Section 5.1.1, the lateral erosion rate is proportional to monthly runoff. The proportional coefficient, the “a’ factor, is a function of (1) percent developed land, (2) animal equivalent unit density, (3) average curve number, (4) average K- factor, and (5) mean slope. Table 5.20 gives the value of these variables for the impaired and reference watersheds and the calculated “a” factor.

Table 5.20: Characteristics of Reference and Impaired Watersheds

Characteristic	Rapidan River	Catoctin Creek	Little River	Goose Creek
Percent Developed Land	0.72	1.49	1.18	1.98
Animal Density (AEUs/acre)	0.15	0.22	0.18	0.22
Area-weighted Curve Number	68.27	66.86	66.04	67.37
Area-weighted K-factor	0.35	0.32	0.31	0.35
Mean Topographic Slope Percent	8.42	8.89	6.37	9.12
“a” Factor	0.000077	0.000079	0.000070	0.000099

Observers have found the banks of the Little River to be highly erodible, due to the nature of the soils composing them (Galli and Trueng, 2003). The erodibility of the banks was not apparent in the mean K-factor for the Little River watershed, so the a-factor for Little River was increased.

Monthly streambank erosion (SE) is the product of the lateral erosion rate (LER), bank bulk density (BD), average bank height (BH), and total length of "blue line" streams in the watershed. Following Evans et al. (2003), bulk density was assumed to be 1500 kg/m^3 and bank height was assumed to be 1.5 m. Table 5.21 gives the total stream length in each watershed, based on the National Hydrologic Database (NHD). An analysis of USGS topographical maps for the Rapidan River shows that the NHD overestimates blue line streams, which are the perennial streams represented on the USGS quads.

Table 5.21: Total Stream Length per Watershed

Watershed	Total Stream Length (miles)
Little River	68.8
Catoctin Creek	133.7
Goose Creek	515.7
Rapidan River	1,829.2

5.3.3 Permitted Sources

For the purposes of this TMDL, total suspended solids (TSS) was assumed to be equivalent to sediment. All permitted sources of TSS were considered.

5.3.3.1 Individual and General Permits

Under the Virginia Pollutant Discharge Elimination Program (VPDES), two classes of permits can be distinguished: individual permits and general permits. Individual permits are tailored to a specific facility or operation. Individual permits cover both major and minor municipal and industrial wastewater treatment plants (WWTPs). Major plants are those that discharge more than one million gallon per day (MGD).

General permits set out general requirements for types of facilities or operations. They may set limits on discharges or the concentration of constituents in discharges, and they may set requirements for monitoring discharges. The following types of facilities have general permits that regulate the discharge of TSS:

- Non-metallic mineral mining operations (quarries);
- Ready-mix concrete plants;
- Stormwater runoff form industrial activities; and
- Wastewater discharges from residences and businesses of less than 1000 gallons/day

Table 5.22 shows the number of permitted systems by watershed.

Table 5.22: Permitted Systems By Watershed

Type	Class	Goose Creek	Little River	Rapidan River	Catoctin Creek
Major Municipal WWTP	Individual	1	0	2	0
Minor Municipal WWTP	Individual	9	1	15	2
Major Industrial WWTP	Individual	0	0	1	0
Minor Industrial WWTP	Individual	3	0	7	3
Residence/Business Wastewater	General	29	1	22	5
Concrete	General	2	0	1	1
Quarries	General	3	0	4	0
Industrial Stormwater	General	3	0	3	0

Municipal separate stormwater systems (MS4) can be permitted under either an individual or general permit.

5.3.3.2 Load Estimates for Permitted Facilities

The average monthly load and average annual loads from permitted facilities were calculated on the following basis:

- For water and wastewater treatment plants holding individual permits, the average monthly load was estimated from the product of monthly flows and average concentrations reported on the Discharge Monitoring Reports (DMRs). WTPs and WWTPs in Goose Creek were estimated from DMRs over the period 1990-2001. WWTPs in the reference watersheds were estimated on the basis of DMRs from 1999-2002.

- In the Goose Creek watershed, average annual loads from residences and businesses holding general permits for wastewater discharge were estimated on the basis of the product of the reported average daily flow and permitted average concentration of 30 mg/L. It was then assumed that the loads per permit of businesses and residences in the reference watersheds were equal to the average of the annual loads from the Goose Creek dischargers.

- The average annual and monthly loads from quarries in the Goose Creek watershed were calculated on the basis of the quarterly flows and average concentrations reported in the DMRs. The average load of the Goose Creek quarries was used to estimate the load from quarries in the Rapidan River.

- Currently, no discharges are associated with ready-mix concrete plants.

- Loads from industrial stormwater are already implicitly represented in the simulation of developed land.

Table 5.23 shows the total average annual load loads from permitted point sources by type of facility. Table 5.24 shows the average annual flow and TSS load for each permitted facility in the Goose Creek watershed.

Table 5.23: Average Annual Sediment Load By Permit Type (tons/yr)

Watershed	WTP and WWTP	Business and Residences	Quarries and Concrete Plants	Total
Goose Creek	9.4	0.5	8.2	18.1
Little River	0.06	0.03	0.00	0.09
Rapidan River	23.7	0.4	10.9	35.0
Catoctin Creek	1.2	0.1	0.0	1.3

Table 5.24: Permitted Facilities in the Goose Creek Watershed

Permit Number	Facility	Average Flow	TSS Load
Wastewater Treatment Plants—Individual Permits		**MGD**	**tons/yr**
VA0022802	Purcellville WWTP (Basham Simms)	0.344	3.799
VA0024112	Foxcroft School	0.031	0.248
VA0024759	US FEMA	0.031	0.271
VA0024775	Middleburg WWTP	0.102	1.094
VA0026212	Round Hill WTTP	0.085	0.213
VA0027197	Notre Dame Academy	0.003	0.049
VA0062189	St. Louis Community	0.0058	1.425
VA0080993	Goose Creek Industrial Park	0.008	0.151
VA0089133	Aldie WWTP	0.003	0.065
Water Treatment Plants—Individual Permits		**MGD**	**tons/yr**
VA002666	Goose Creek WTP	0.253	2.848
Wastewater Discharge—General Permits		**Gallons/day**	**tons/yr**
VAG406015	Residence	800	0.037
VAG406016	Business	200	0.009
VAG406018	Residence	500	0.023
VAG406019	Residence	400	0.019
VAG406020	Residence	500	0.023
VAG406047	Residence	200	0.009
VAG406069	Residence	1000	0.045
VAG406101	Residence	450	0.021
VAG406113	Residence	600	0.028
VAG406115	Residence	400	0.019
VAG406116	Residence	800	0.037
VAG406121	Residence	50	0.002
VAG406135	Residence	580	0.027
VAG406143	Residence	450	0.021
VAG406146	Residence	500	0.023
VAG406149	Residence	300	0.013
VAG406170	Residence	700	0.032

Permit Number	Facility	Average Flow	TSS Load
VAG406172	Business	900	0.041
VAG406176	Residence	400	0.019
VAG406193	Residence	300	0.013
VAG406244	Residence	1000	0.045
Quarries—General Permits		**MGD**	**tons/yr**
VAG846011	Luck Stone—Leesburg	0.075	5.110
VAG846016	Luck Stone—Goose Creek	0.007	2.851
VAG846012	Leesburg Iron and Metal	0.0007	0.580
Industrial Stormwater - General Permits		**MGD**	**tons/yr**
VAR050980	Leesburg Iron and Metal	Represented under Developed Land Use	
VAR051013	Superior Paving		
VAR051077	Loudoun County Sanitary Landfill		
VAR051115	Waste Management of VA - Leesburg		
VAR051426	Leesburg Municipal Airport		
VAR051427	Leesburg Water Pollution Control		
VAR051442	Basham Simms Wastewater Facilitiy		
Ready-Made Concrete Plants—General Permits		**MGD**	**tons/yr**
VAG110123	Crider and Shockey	No discharge	
VAG110091	Virginia Concrete	No discharge	

5.3.3.3 Municipal Separate Storm Sewer Systems

There are three MS4 permitted systems in the Goose Creek watershed, the Town of Leesburg, Loudoun County and the Virginia Department of Transportation (VDOT). The VDOT MS4 system is coextensive with the Leesburg and Loudoun County systems. It covers all public roads in the metropolitan areas of Northern Virginia. Figure 5.11 shows the location of the Leesburg and Loudoun systems. Neither of the systems is completely inside the Goose Creek watershed.

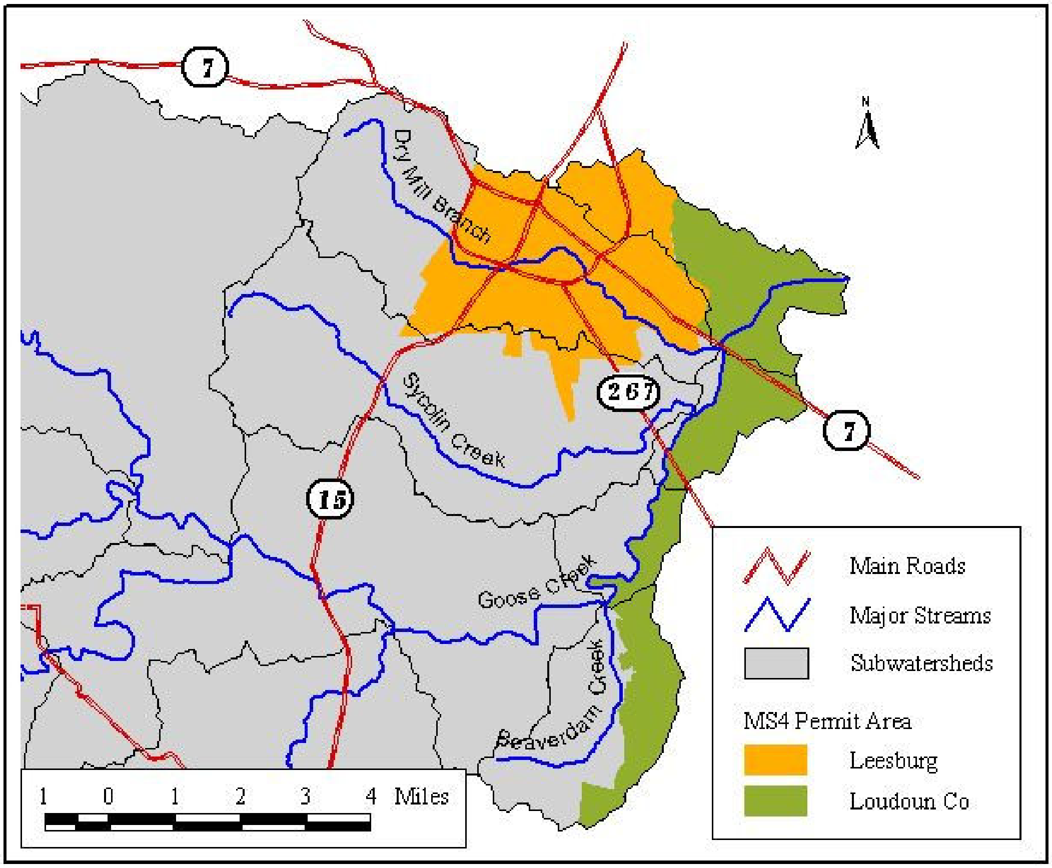

Figure 5.11: Location of MS4 Areas within the Goose Creek Watershed

Sediment loads from the MS4 systems were calculated on the basis of the sediment loads simulated by GWLF for the developed land uses within the MS4 boundaries. Table 5.25 gives the area of each developed land use within the MS4 boundaries, both for the mid-90's and under current conditions. The 1995 land used is based on the MRLC land coverage; the current estimate is based on Leesburg's MS4 Permit, a digitized map of Loudoun County's parcel layer, and a windshield survey of the portion of Loudoun County's MS4 lying within the Goose Creek watershed. It demonstrates the explosive growth that the Leesburg area has seen during the last decade.

Table 5.25: Developed Land and Land Under Construction With MS4 Boundaries

		Town of Leesburg		Loudoun County (excluding Beaverdam Reservoir)	
Scenario	**Land Use**	**Area (acres)**	**Percent of Watershed**	**Area (acres)**	**Percent of Watershed**
1990-2001	Developed	3,008	55%	55.6	1%
	Construction	68.3	24%	74.0	26%
Current Conditions	Developed	5,560	53%	921.7	9.6%
	Construction	68.3	24%	74.0	26%

5.3.4 Sediment Trapping in the Goose Creek Reservoir and Beaverdam Reservoir

The Goose Creek Reservoir is a major sink for sediment generated in the Goose Creek watershed. The reservoir, created in 1961, had to be dredged in 1998 because it had lost almost half its storage capacity. Dynamic Corporation (1992) calculated that the reservoir accumulated sediment at a rate of 8.2 acre-ft/yr. Roberge (1994) reports that the moisture content of the sediments averaged about 60%, which implies that sediment was deposited in the reservoir at a rate of approximately 10,000 tons/year.

Another approach to calculating the sediment trapping efficiency of a reservoir is to calculate the ratio of storage capacity to average inflow. The average annual flow at the USGS gage near Leesburg, just upstream of the reservoir, is 13.12 in/year, or 232,311 acre-ft/year. The storage capacity of the reservoir when built was 536 acre-ft, and the initial C/I ratio was therefore 0.0023. According to the NRCS's National Engineering Handbook, the median value of trapping efficiency for a reservoir with that C/I ratio is approximately 10%. The maximum value is approximately 25%. The trapping efficiency could be expected to decline as the reservoir filled with sediment.

Beaverdam Reservoir is used as a storage reservoir by the City of Fairfax. Water is released from the reservoir during low flow periods when the flow in Goose Creek threatens to fail to satisfy withdrawals. At other times little water leaves the reservoir. Sediment trapping was therefore assumed to be 100% in the Beaverdam Reservoir. This impacts only the small watershed draining into it, which was effectively excluded from load calculations.

5.4 Modeling Results and Load Estimates

The GWLF models were run for a simulation period of twelve years, 1990-2001. Table 5.26 compares the average annual simulated sediment load from Goose Creek and the Rapidan River. Table 5.27 compares the average annual simulated load from Little River and Catoctin Creek. Tables 5.26 and 5.27 also show the adjusted sediment loads for the Rapidan River and Catoctin Creek. These sediment loads were adjusted for size in the following manner:

- The area of each land use in the reference watershed was multiplied by the ratio of the impaired watershed to the reference watershed, so that the adjusted reference watershed was equal in size to the impaired watershed;
- Point source loads from the reference watershed were also multiplied by the ratio of the area of the impaired watershed to the reference watershed; and
- The total stream length of the impaired watershed was used to model streambank erosion in the adjusted reference watershed. This is equivalent to assuming equal drainage density between the reference and drainage watersheds.

Table 5.26: Average Annual Sediment Loads From Goose Creek, Rapidan River, and Adjusted Rapidan River By Source (in tons/year)

Source	Goose Creek	Rapidan River	Adjusted Rapidan River
Construction	1,542	10	13
Crops	1,914	2,216	2,700
Forest	998	1,410	1,717
Clear-cut Timber	2	49	60
Select-cut Timber	72	93	114
Pasture	16,069	4,930	6,006
Developed Land	250	317	386
Streambank Erosion	44,915	177,079	36,089
WWTP	9.4	23.7	13.1
Business & Residences	0.5	0.4	0.2
Quarries	8.2	10.9	6.0
Reservoir Trapping	-6,578	---	---
Total	59,202	186,142	47,106

Table 5.27: Average Annual Sediment Loads From Little River, Catoctin Creek, and Adjusted Catoctin Creek By Source (in tons/year)

Source	Little River	Catoctin Creek	Adjusted Catoctin Creek
Construction	155	268	211
Crops	457	1,335	1,054
Forest	266	290	229
Clear-cut Timber	0.4	0.0	0.0
Select-cut Timber	2	30	24
Pasture	4,444	3,213	2,537
Developed Land	25	16	13
Streambank Erosion	2,243	3,728	1,402
WWTP	0.1	1.2	0.7
Business & Residences	0.0	0.1	0.1
Quarries	0	0	0
Total	7,592	8,882	5,470

The average sedimentation rate of 10,000 tons/year calculated from the dredging studies would represent a trapping efficiency of 15%. Because the amount of deposition in the reservoir was probably higher when the reservoir was first built, the sediment trapping efficiency of the Goose Creek Reservoir was set at 10% as a conservative assumption.

The dominant source of sediment in Goose Creek and the Rapidan River is streambank erosion. Streambank erosion accounts for almost 70% of the total sediment load in Goose Creek before adjusting for sediment trapping in the reservoir and for a similar fraction in the adjusted Rapidan River. Erosion from pasture is the second largest source, accounting for about 25% of the total sediment load in Goose Creek and about half that percentage in the

Rapidan River. Erosion from crops and construction sites are the next largest sources of sediment in Goose Creek, but neither accounts for more than 3% of the total sediment load. Other sources are less significant.

Sediment losses from pasture and streambank erosion are also the largest sources in Little River and Catoctin Creek. Erosion from pasture is the largest source of sediment, accounting for 60% of the total sediment load to Little River and almost 50% of the total sediment load in the adjusted Catoctin Creek. Streambank erosion is not as prominent in these smaller watersheds as in the larger watersheds. It accounts for 30% of the load in Little River and about 25% of the load in the adjusted Catoctin Creek. Erosion from cropland is a significant source of sediment in the adjusted Catoctin Creek but not in Little River.

Table 5.28 shows the erosion rates from land sources. These are the rates calculated from the USLE without taking into account the sediment delivery ratio. As should be expected, disturbed land has the highest rate of erosion, followed by cropland. The difference in the pasture erosion rate for Little River and Catoctin Creek is a function both of soil type and animal density. Little River has a higher animal density than Goose Creek, and its soils in pasture are on average slightly more erodible. The difference in erosion rates between Goose Creek and the Rapidan River is due to slope and erodibility of soils. The animal density on pasture in the Rapidan River is greater than in Goose Creek.

Table 5.28: Erosion Rates from Land Sources (tons/acre/yr)

Source	Goose Creek	Rapidan River	Little River	Catoctin Creek
Construction	98.5	74.8	---	93.7
Crops	9.6	5.9	8.1	9.1
Forest	0.18	0.20	0.15	0.17
Clear-cut Timber	0.78	0.86	0.66	0.93
Select-cut Timber	0.71	0.77	0.59	0.63
Pasture	2.17	1.39	1.94	0.95
Developed Land	1.25	1.62	1.15	1.20

The difference in sediment load between Little River and Catoctin Creek, adjusted for size, is 35%. That difference is primarily due to greater streambank erosion and erosion from pasture. Greater streambank erosion in Little River is due to the erodibilty of bank soils. Greater erosion from pasture is due primarily to greater animal density.

The difference in sediment load between Goose Creek and the Rapidan River is 28%. The difference is primarily due to land use. Goose Creek is more developed and less forested than the Rapidan River. The slopes and soils of agricultural land in Goose Creek also lead to greater erosion.

5.5 Sensitivity of Sediment Loads to Development and Estimate of Current Loads

Sensitivity analysis was used to examine two issues related to development in the Goose Creek watershed.

First, Goose Creek is an almost 400 square mile watershed. The impairment segment of Goose Creek runs from the Goose Creek Reservoir to the confluence of Goose Creek and the Potomac River. Development is also concentrated around Leesburg below the reservoir. It is reasonable to assume that sources closer to the impaired segment have a greater impact than sources farther upstream. To what extent does the distribution of sources throughout the watershed impact the delivered load from those sources, and to what extent should geographic distribution of sources be taken into account in the allocation of the load among sources?

Second, Loudoun County is one of the fastest growing regions in the nation. For the most part, development has occurred outside of the Goose Creek watershed in the eastern portion of the county, but Leesburg and the surrounding area, as well as the Route 7 corridor, have seen significant growth that is expected only to increase. To what extent will an increase in development impact sediment loads in the Goose Creek watershed?

5.5.1 Heuristic Geographic Analysis

GWLF calculates sediment loads on a watershed scale. It can calculate erosion from distinct land uses but the delivered load from these land uses is calculated through the sediment delivery ratio at the watershed scale. To better understand the potential role that the distribution of sources plays in delivered sediment loads, a method of calculating delivery factors by subwatershed was devised to try to identify the impact of location on the contribution of sources to the total sediment load. A delivery factor gives the percent of erosion in a subwatershed that contributes to the total sediment load in the watershed. It is important to recognize that delivery factors do not apply to streambank erosion, which can only be approached on a watershed basis.

The following assumptions were made in estimating delivery factors:

1. For each subwatershed, a sediment delivery ratio, determined by the size of the subwatershed, can be used to calculate the erosion delivered to the outlet of the subwatershed. That is, the sediment delivery ratio captures the sediment stored at the foot of slopes and in tributary channels in a subwatershed, as well as potential deposition in the main channel.

2. For each upstream subwatershed, there is a sediment loss associated with transport through a downstream watershed, embodied in a transport reduction factor. The transport reduction factor is the fraction of sediment lost passing through a downstream subwatershed from the outlet of the upstream watershed.

3. The delivery factor of a subwatershed is the product of the sediment delivery ratio of the subwatershed and the transport reduction factor for all segments downstream of the subwatershed.

The transport factor, TF is calculated by solving the following equation:

$$TF * SDR_{upstream} * E_{upstream} + SDR_{downstream} * E_{downstream} = SDR_{total} * E_{total}$$

Where "SDR" is the sediment delivery ratio, "E" is the average annual erosion from the subwatershed, and the "total" subscript refers to the watershed consisting of the combined upstream and downstream watersheds.

This approach is only heuristic because the first assumption is perhaps not, strictly speaking, valid, because the sediment delivery ratio is calculated for whole watersheds. Nevertheless, the approach embodied here is compatible with the downward sloping log-log relationship between watershed size and the sediment delivery ratio as used in GWLF.

Table 5.29 gives the calculated delivery factors for each watershed. Figure 5.12 shows the same information geographically. As the table and figure show, by this analysis, eroded sediment in Tuscarora Creek is seven times more likely to contribute to the delivered sediment load in the impaired segment of Goose Creek than eroded sediment in the most upstream subwatershed. When used with caution, this information may be useful in determining where sediment reductions are most cost-effective during the implementation phase of the TMDL.

Table 5.29: Geographic Delivery Factors By Subwatershed

Subwatershed	Geographic Delivery Factor
Beaverdam Creek	0.042
Beaverdam Creek Reservoir	0.000
Cromwells Run	0.042
Goose Creek Above Reservoir	0.099
Goose Creek Below Dam	0.190
Goose Creek Mouth - Cattail Branch	0.190
Goose Creek Near Middleburg	0.057
Goose Creek Reservoir	0.170
Little River	0.040
Middle Goose Creek - Panther Skin Creek	0.035
North Fork Goose Creek	0.046
Sycolin Creek	0.117
Tuscarora Creek	0.121
Upper Goose Creek - Gap Run	0.017

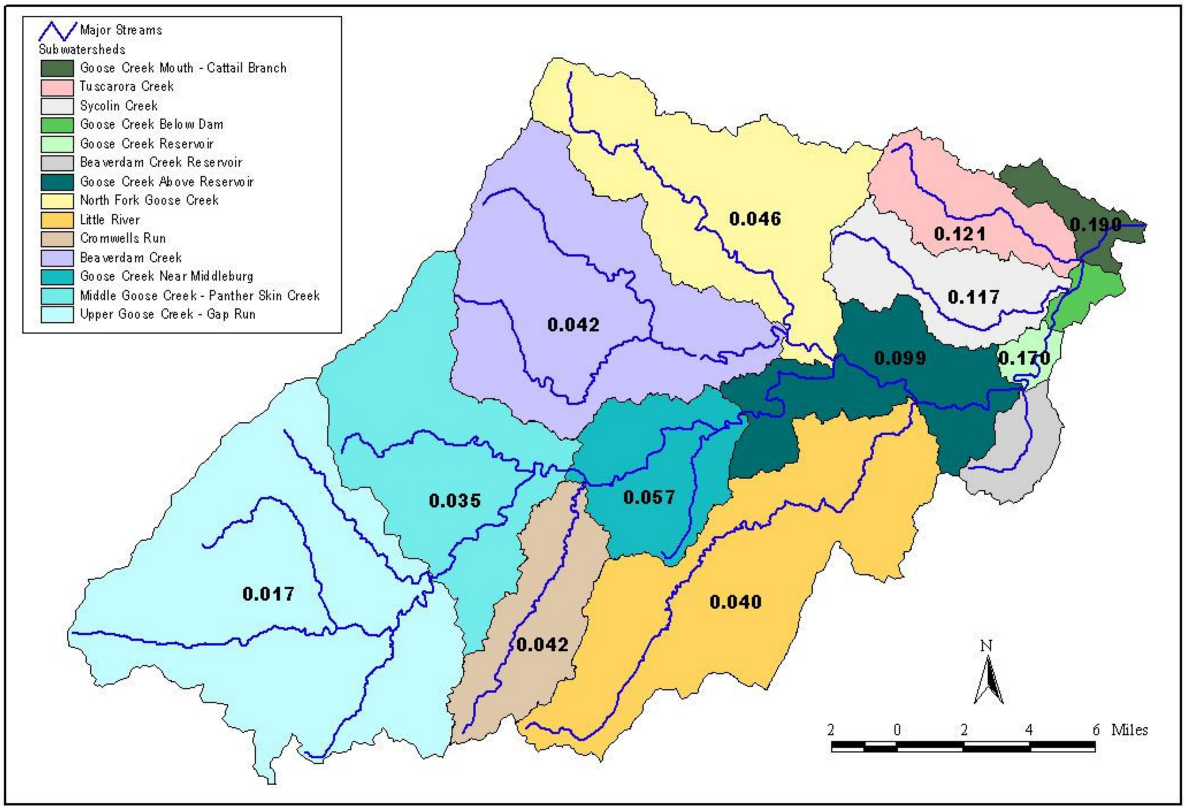

Figure 5.12: Geographic Delivery Factors

The primary purpose of the geographical sensitivity analysis, however, is to determine the impact of the geographic distribution of sources on the contribution of each source type to the total sediment load. Table 5.30 shows the percent contribution of each source to total load, first using the overall sediment delivery ration in Goose Creek of 0.055, and second, using the delivery factors to calculate delivered sediment loads. As might be expected, there is a decrease in the sediment delivered from pasture and an increase in the sediment delivered from developed land and construction sites. Surprisingly, there is an increase also in the delivered load from cropland. The load from construction almost doubles and the developed land increases by 33%, but their overall share of the total load remains small. The delivered load from pasture decreases by 12%, but its share of the total load decreases by only 3%. The large contribution from streambank erosion, which is unaffected by the change in delivery rates, buffers any changes in delivery rates.

Table 5.30: Geographic Sensitivity Analysis: Percent Contribution of Sources

SourceSource	Sediment Delivery Ratio	Geographic Delivery Factor
Construction	2.6%	4.7%
Crops	3.3%	4.6%
Forest	1.7%	1.4%
Clear-cut timber	<1%	<1%
Select-cut timber	<1%	<1%
Pasture	27.3%	23.9%
Developed land	0.6%	0.9%
Streambank Erosion	75.6%	75.6%
Permitted Sources	<1%	<1%

5.5.2 Increases in Developed Land

The impact of development is probably the most important environmental issue in the Goose Creek watershed. The Town of Leesburg population doubled between 1990 and 2000, and the area surrounding Leesburg continues to grow. Significant growth is also occurring in the Route 7 corridor west of Leesburg, especially around Purcellville.

As developed land in the watershed increases, the total sediment load changes. The following impacts occur:

- Sediment loads from developed land increase;
- Sediment loads from other sources - forest, cropland, and pasture - decrease;
- Sediment loads from construction may increase or decrease, depending on whether the rate of development is increasing or decreasing; and
- Streambank erosion rates will increase with increases in developed land, all other factors being held equal.

To elaborate, if land is developed from pasture or cropland, sediment loads will decrease once the land is developed. If the land is developed from forest, overall loads will increase. These effects are small compared to the impact of development on streambank erosion. Assuming that there is no decrease in the animal density in Goose Creek and that other watershed factors, such as the average curve and number slope, are not affected by development, the increase in streambank erosion will dominate other impacts. Figure 5.13 shows the predicted average annual sediment load as a function of the percent of developed land in the watershed. For this analysis, it has been assumed that land is developed from pasture and the rate of development is proportional to the change in percent developed land under current conditions.

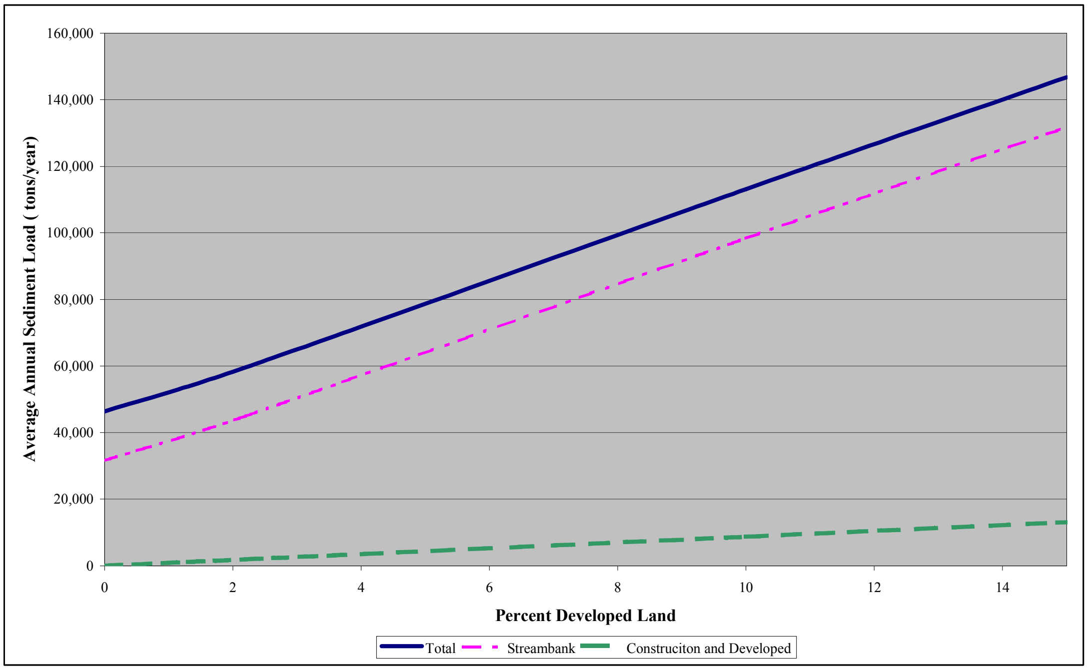

Figure 5.13: Average Annual Sediment Load (tons/yr) vs. Percent Developed Land

The impact of development can best be seen if the average annual sediment load during the simulation period is contrasted with the average annual load estimated on the basis of current land use. Table 5.31 shows the loads by source associated with current conditions if the increase in developed land in the Town of Leesburg, the Loundoun County MS4 District, and Purcellville is taken into account. The growth rate in other parts of the watershed remain low, except in the drainage to the Beaverdam Reservoir, which does not contribute loads to Goose Creek.

Table 5.31: Average Annual Sediment Loads (tons/yr) Under Current Conditions

Source	Simulation Period	Current Conditions
Construction	1,542	1,542
Crops	1,914	1,843
Forest	998	998
Clear-cut Timber	2	2
Select-cut Timber	72	72
Pasture	16,069	15,481
Developed Land	250	477
Streambank Erosion	44,915	55,502
WWTP	9.4	9.4
Business & Residences	0.5	0.5
Quarries	8.2	8.2
Reservoir Trapping	-6,578	-7,592
Total	59,203	68,341

Overall, the average annual sediment load increases by 15%, primarily due to the 24% increase in streambank erosion. The delivered sediment load from developed land increases by 90%, but only constitutes about 1% of the total delivered load.

CHAPTER SIX: BENTHIC TMDL ALLOCATIONS FOR GOOSE CREEK AND LITTLE RIVER

6.1 Elements of the Benthic TMDLs

The goal of any TMDL allocation is to determine the maximum pollutant load that is compatible with meeting water quality standards. Sediment has been identified as the pollutant preventing Goose Creek and Little River from meeting Virginia's General Water Quality Standard, which mandates that the waters of the state support aquatic life. Because there are no numeric criteria for sediment in Virginia, the reference watershed approach was used to determine the maximum sediment load in Goose Creek and Little River compatible with supporting aquatic life. Table 6.1 shows the TMDL endpoints calculated for Goose Creek and Little River based on the average annual sediment loads calculated for their adjusted reference watersheds.

Table 6.1: Sediment TMDLs for Goose Creek and Little River (tons/yr)

Waterbody	Adjusted Reference Watershed Load	Margin of Safety (10%)	Target Load	Current Load	Percent Reduction
Goose Creek	47,106	4,711	42,396	68,341	38%
Little River	5,470	547	4,923	7,592	35%

The TMDL must be allocated among sources according to the equation:

$$TMDL = WLA + LA + MOS$$

Where
WLA = wasteload allocation for permitted sources
LA = load allocation for nonpoint sources
MOS = margin of safety

An explicit 10% margin of safety was used in the Goose Creek benthic TMDLs. Table 6.1 shows the current annual average sediment load, the margin of safety, and the percent reduction from the current load necessary to meet the TMDL allocation. The wasteload allocation and the load allocation were determined through an analysis of the load reduction scenarios described below.

6.2 Description of the Load Reduction Scenarios

The goal of the analysis of load reduction scenarios is to determine an equitable allocation of loads among permitted and nonpoint sources that satisfies the requirements of the TMDL. One requirement of any TMDL is that it takes into account future growth of loads. This is a difficult task in Loudoun County, given its rate of development. The following three scenarios were analyzed to take into account future growth:

1. Current conditions
2. Development projected to occur by 2015
3. Full build-out on land zoned for development

For each growth scenario, several different allocations among sources were examined. The allocations for some sources, like WWTPs, were based on permit limits and fixed independently of the scenario. Other allocations were calculated to determine how best to meet the TMDL endpoint under the conditions specified by the scenario. The principles for determining load and wasteload allocations are described in the following sections.

6.2.1 Principles for Determining Wasteload Allocations

There is a wide variety of permitted sources of TSS in the Goose Creek watershed: wastewater treatment plants, construction sites, quarries, ready-made concrete plants, industrial stormwater systems, and MS4s.

6.2.1.1 Wastewater Treatment Plants

The allocated load from WWTPs under individual permits was set assuming that they were operating at five times their design flow at their permitted maximum average concentration. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed on a first-come, first-served basis. All current permit limits remain in effect and can only be altered through the VADEQ permitting process.

Table 6.2 shows the load allocation for WWTPs with individual permits.

Table 6.2: Wasteload Allocation for Wastewater Treatment Plants

VPDES	Facility	Design Flow (MGD)	Permitted Concentration (mg/L)	WLA (tons/yr)
VA0022802	Basham Simms WWF	1.000	12	91.5
VA0024112	Foxcroft School	0.075	16	9.0
VA0024759	US FEMA – Bluemont	0.090	23	16
VA0024775	Middleburg WWTP	0.135	14	14.5
VA0026212	Round Hill WWTP	0.500	10	38.0
VA0027197	Notre Dame Academy	0.015	30	3.5
VA0062189	St. Louis Community	0.086	30	19.5
VA0065200	Rehau Plastics, Inc.	No longer active		
VA0080993	Goose Creek Industrial Park WWTP	0.010	30	2.5
VA0089133	Aldie WWTP	0.015	30	3.5
Total				197.5

6.2.1.2 Water Treatment Plants

There is one individual permit for a water treatment plant in the Goose Creek Watershed: the City of Fairfax's Goose Creek Water Treatment Plant. Its wasteload allocation was set at five times the average annual flow at its permitted maximum average concentration of 30 mg/L TSS. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed on a first-come, first-served basis. All current permit limits remain in effect and can only be altered through the VADEQ permitting process.

Table 6.3 shows the load allocation for the WTP.

Table 6.3: Wasteload Allocation for Water Treatment Plant

VPDES	Facility	Average Annual Flow (MGD)	Permitted Concentration (mg/L)	WLA (tons/yr)
VA002666	Goose Creek WTP	0.253	30	57.9

6.2.1.3 Small Municipal Wastewater Discharges under General Permits

Wastewater discharges from residences and businesses holding general permits were set assuming that they discharge at their maximum permitted flow of 1000 gal/d and their permitted maximum average concentration of 30 mg/l. Table 6.4 shows the resulting allocations.

Table 6.4: Design Flow, Permitted Outflow Concentrations, and Wasteload Allocations of Sediment for Wastewater Dischargers Holding General Permits

Permit No.	Facility	Permitted Flow (gallons/day)	Permitted Concentration (30 mg/L)	WLA (tons/yr)
VAG406015	Residence	1000	30	0.046
VAG406016	Business	1000	30	0.046
VAG406018	Residence	1000	30	0.046
VAG406019	Residence	1000	30	0.046
VAG406020	Residence	1000	30	0.046
VAG406047	Residence	1000	30	0.046
VAG406069	Residence	1000	30	0.046
VAG406101	Residence	1000	30	0.046
VAG406113	Residence	1000	30	0.046
VAG406115	Residence	1000	30	0.046
VAG406116	Residence	1000	30	0.046
VAG406121	Residence	1000	30	0.046
VAG406135	Residence	1000	30	0.046
VAG406143	Residence	1000	30	0.046
VAG406146	Residence	1000	30	0.046
VAG406149	Residence	1000	30	0.046
VAG406170	Residence	1000	30	0.046
VAG406172	Business	1000	30	0.046
Total				0.828

6.2.1.4 Industrial Stormwater and MS4s

The wasteload allocation for the MS4s under each growth scenario was determined based on the acres of developed land and disturbed land within the MS4 boundary under each scenario. Under each scenario, these land uses were given the same reduction within the MS4 as they were given watershed-wide. The MS4 wasteload under each scenario is the load after the reductions from developed and disturbed land.

Permitted industrial stormwater discharges within the MS4 boundaries were included under the MS4 allocated load. The VDOT MS4 was also included under the Loudoun and Leeburg MS4s. Given the fact that there is spatial overlap between several stormwater permits, it was not practical to separate out individual allocations. Table 6.5 shows the existing permits included in each MS4 boundary.

Table 6.5: Industrial Stormwater System Permits within MS4 Boundaries

MS4	Industrial Stormwater VPDES	Facility
Leesburg	VAR051426	Leesburg Municipal Airport
	VAR051427	Leesburg Water Pollution Control
	VAR050980	Leesburg Iron and Metal
Loudoun	VAR051013	Superior Paving

Permitted industrial stormwater discharges outside of MS4 boundaries were calculated based on the Simple Method (Sheuler, 1987), as adapted by TVA (2003):

$$L = P * Rv * A * C * 0.0001135$$

where

L	=	load (tons per year)
P	=	average annual precipitation (inches)
A	=	facility area (acres)
C	=	average concentration in runoff (mg/L)
0.0001135	=	unit conversion factor
Rv	=	runoff coefficient (unitless)

and

Rv	=	0.050 + 0.009 *I
I	=	percent impervious area

The facility area was obtained from Loudoun County's digitized parcel map. Industrial facilities were assumed to be 85% impervious. The average TSS concentration in runoff was determined by the percent load reduction on developed land as determined in the Load Allocation Scenarios, as described below. Table 6.6 shows the industrial stormwater facilities outside of MS4 boundaries and their load allocations.

Table 6.6: Industrial Stormwater System Permits Outside of MS4 Boundaries

VPDES	Facility	Area (acres)	Concentration (mg/L)	Wasteload Allocation (tons/yr)
VAR051077	Loudoun County Sanitary Landfill	186.3	70 mg/L	45.3
VAR051115	Waste Management of VA - Leesburg	3.0	70 mg/L	0.7
VAR051442	Basham Simms Wastewater Facility	8.8	70 mg/L	2.1
			Total	48.1

6.2.1.5 Quarries and Ready-Mix Concrete Plants

The wasteload allocation for quarries was determined by outfall. For outfalls discharging process water, the wasteload allocation was set equal to 365 times the largest reported quarterly flow times the permitted maximum average concentration of 30 mg/l. Table 6.7 shows the wasteload allocation for quarries.

Table 6.7: Wasteload Allocation for Permitted Non-Metallic Mineral Mining (Quarries)

VDPES	Facility Area (acres)	Number of Process Outfalls	Maximum Reported Flow (MGD)	Permitted Concentration (mg/L)	Wasteload Allocation (tons/yr)
VAG8460011 Luck Stone Leesburg	130	2	0.27	30 mg/L	56.3
VAG846016 Luck Stone Goose Creek	235	1	0.721	30 mg/L	90.1
Total					146.4

For outfalls discharging stormwater unmixed with process water, the wasteload concentration was calculated in the same manner as the wasteload allocation for industrial stormwater systems outside MS4 boundaries.

To date, there have been no discharges under the concrete plant permits.

Table 6.8: Wasteload Allocation for Ready-Mix Concrete Plants

VDPES	Facility Area (acres)	Number of Process Outfalls	Maximum Reported Flow (MGD)	Permitted Concentration (mg/L)	Wasteload Allocation (tons/yr)
VAG110123 Crider and Shockey	5	1	No flows reported	30 mg/L	1.2
VAG110091 Virginia Concrete	15	1	0.004	30 mg/L	3.8
Total					5.0

6.2.1.6 Construction Sites

Under all scenarios, sediment loads from permitted construction sites were required to be reduced by 35%. This reduction represents the maximum practical reduction of sediment from disturbed land under the Watershed Treatment Model achievable through better enforcement of Virginia's sediment and erosion control laws. The amount of disturbed land, and therefore the load, varies with the growth scenarios.

Table 6.9 shows the construction sites currently permitted by DEQ for sediment and erosion control. The table also shows which sites lie within the boundaries of a municipal separate storm sewer system. The loads from sites within the MS4 boundaries will be included in the wasteload allocation for the MS4 permit. The permitted construction sites outside MS4 boundaries will be given a wasteload allocation as a group.

Table 6.9: Construction Sites Permitted for Sediment and Erosion Control

Permit No.	Facility Name	Disturbed Area (acres)
Within Town of Leesburg MS4 Boundary		
VAR101380	Airport Commerce Park - Phase 1	32.56
VAR102543	Target – Battlefield Marketplace	32.96
VAR101452	Stratford East	70.00
VAR102474	Loudoun to Leesburg Tie-Over Gas Pipeline	2.30
VAR101399	Columbia Gas Transmission Corp. Line VC Replacement	35.00
VAR100810	Drymill	6.50
VAR102991	Rokeby Hamlets	81.70
VAR100796	Kincaid Forest	80.00
Within Loudoun County MS4 Boundary		
VAR101445	Belmont Glen	26.30
VAR102855	Quail Pond	15.20
VAR101530	Potomac Station - Sections 8B 8G 8I and 10	39.79
VAR100797	Northlake Subdivision	150.00
VAR102006	Riverside Parkway	1.77
VAR100804	Broadlands - Section 22	32.00
VAR100805	Broadlands - Sections 13 and 20	35.00
VAR101478	Cedar Ridge - Parcel 37	26.30
VAR101670	Potomac Station - Section 10 Parcel A and PI	45.78
Outside of MS4 Boundaries		
VAR101414	Park Meadows Property	45.00
VAR102682	Hamilton Elementary School	2.61
VAR102364	Dominion Virginia Power - Pleasant View Substation	2.70
VAR102736	Barclay Ridge	57.70
VAR101520	Long Meadow Hamlet	16.80
VAR100798	VDOT - 0733 053 P31 C502	6.50
VAR102009	Purcellville Southern Collector	46.20
VAR102008	Village Case, The	46.20
VAR102589	Oak Knoll Hamlet	11.20
VAR102686	Dream Homes - William A Kelley Property	22.00

Permit No.	Facility Name	Disturbed Area (acres)
VAR100733	Patrick Henry College	14.60
VAR100734	Patrick Henry College	18.60
VAR102901	Courts of Saint Francis - Ferrell Addition	3.98
VAR100748	Courts of St Francis	9.03
VAR101411	Purcellville Property	23.80
VAR100738	Purcellville WWQMF	7.20
VAR101676	Round Hill - The Villages	20.00
VAR101683	Greenwoods Common	17.84
VAR101677	Hamlets of Blue Ridge	30.39
VAR101615	Round Hill - Lake Point	120.00
VAR101616	Round Hill - Mountain Valley	95.00
VAR101624	Round Hill - West Lake	42.80
VAR102854	Heronwood Farm	33.50
VAR100732	Francis Tract	6.30
VAR101450	VDOT - 0015 053 125 PE101 C501	10.35

6.2.2 Principles for Determining Load Allocations

In general, load allocations to nonpoint sources were determined through an analysis of the load allocation scenarios, based on the load from each source predicted under the scenario, the reductions necessary to meet the TMDL, and equity considerations.

There are four controllable nonpoint sources subject to load allocations: (1) streambank erosion, (2) erosion from pasture, (3) erosion from cropland, and (4) erosion from developed land. Undisturbed forests are considered an uncontrollable load and are not subject to TMDL reductions. For all scenarios, full enforcement of the BMPs mandated under the Silviculture Act was assumed - that is, a 100% reduction in sediment loads above the background forest load was assumed for clear-cut and select-cut timber harvests. Therefore, in the allocation tables, timber harvests do not appear as sources distinct from forests.

6.2.3 Development Projections and Land Use Distributions for the Load Allocation Scenarios

The current Loudoun County General Plan (2003) was used to guide the construction of the future land use scenarios. The General Plan divides the county into five policy areas:

1. Towns
2. Joint Land Management Areas (JLMA)
3. Suburban
4. Transitional
5. Rural

Figure 6.1 shows the extent of each policy area within the Goose Creek watershed.

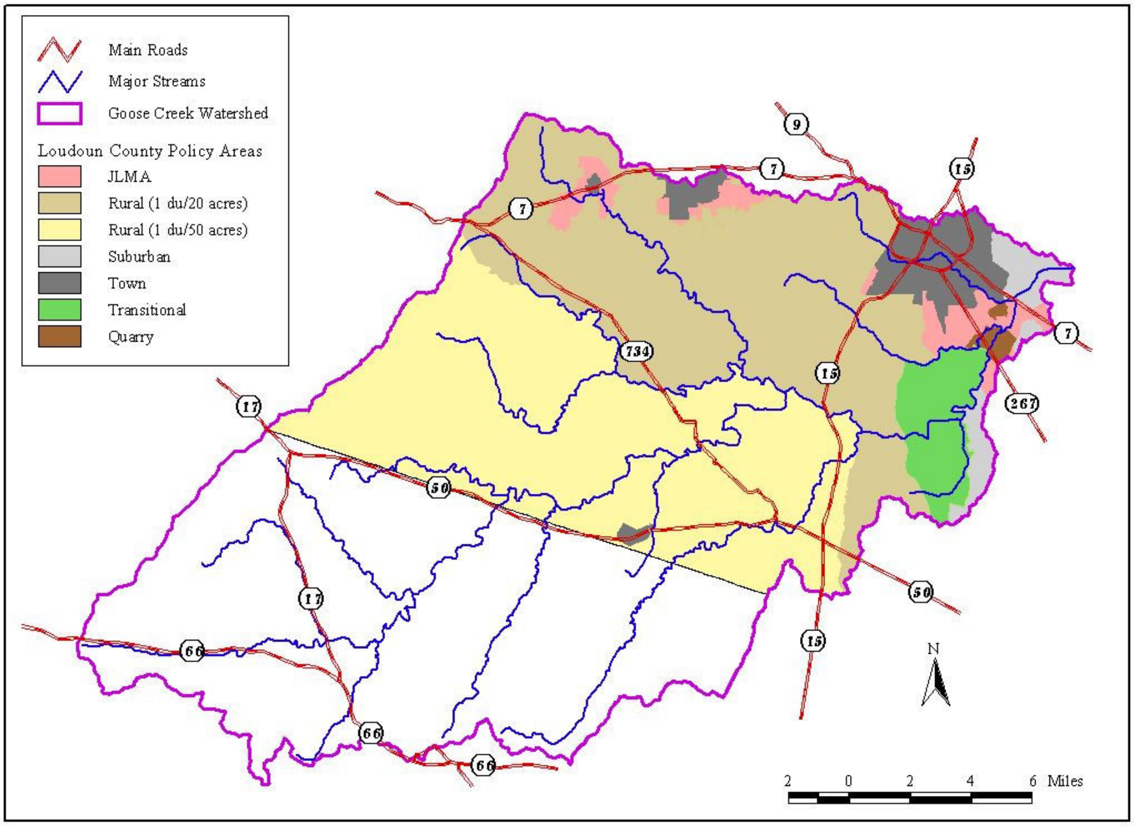

Figure 6.1: Policy Areas Under the Loudoun County General Plan

Towns represent independent incorporated political entities that are primarily responsible for their own planning and zoning. Five of the county's seven towns are located in the Goose Creek watershed: Leesburg, Hamilton, Purcellville, Round Hill, and Middleburg. Leesburg is by far the largest of the towns. The JLMAs are areas surrounding the towns where significant development is planned to occur. The towns and the county cooperate in planning the development of these areas.

The Suburban Policy Area covers eastern Loudoun County. It is characterized by the familiar pattern of suburban development. Only the portion of the Goose Creek watershed within the Loudoun County MS4 boundary falls within the Suburban Policy Area. The Transitional and Rural Policy Areas are intended to help preserve the rural character of western Loudoun County, including most of the Goose Creek watershed. The General Plan envisions restricting the density of residential development in the Rural Policy Area to one dwelling per 20 acres in the northern portion of the area and one dwelling per 50 acres in the southern portion of the area, roughly south of the North Fork drainage. The Transitional Policy Area, as the name suggests, is intended to provide a transition between suburban eastern Loudoun County and rural western Loudoun County. The planned density is one dwelling per 10 acres. The Transitional Policy Area occupies most of the lower portion of the Sycolin subwatershed and the portion of the subwatershed above the Goose Creek reservoir east of Goose Creek. The Transitional Policy Area also includes a quarry overlay zoning district intended to protect the quarries in the Goose Creek watershed from the encroachment of development.

The General Plan intends that development within the Rural and Transitional Policy Areas should be clustered to preserve open space. In the transitional area development is supposed to be clustered into rural "villages." In the Rural Policy Area, denser development is permitted if land is also set aside for agricultural use. The maximum residential density permitted under the General Plan is one dwelling per three acres. In the Transitional Policy Area the maximum density can be realized only if 70% of the land under development is set aside as open space. In the northern portion of the Rural Policy Area, the maximum density of development is permitted if enough land is set aside for agriculture so that an overall density of one dwelling per ten acres is achieved. In the southern portion, the maximum density of development is permitted if enough land is set aside for agriculture so that the overall density is one dwelling per twenty acres. The General Plan encourages a greater clustering of development than one dwelling per three acres and if greater clustering occurs, more open space will be preserved.

6.2.3.1 Full Build-out Scenario

Table 6.10 summarizes the percent of developable land that could be developed in each policy area under the current General Plan, taking into account the open space requirements. It was assumed that 95% of Towns and JLMAs would be developed. It was also assumed that Fauquier County would remain slightly less developed than Loudoun County.

Table 6.10: Fraction of Developable Land Projected to be Developed Under Full Build-Out

Policy Zone	Fraction of Developable Land Developed Under Full Build-Out
Town	0.95
JLMA	0.95
Suburban	0.95
Transitional	0.30
Rural (1 du/20 ac)	0.30
Rural (1 du/50 ac)	0.15
Fauquier County	0.10

The amount of developable land in the Goose Creek watershed was taken from the Center for Watershed Protection's "Goose Creek Vulnerability Analysis" (2002). In that study, the Goose Creek watershed was divided into forty subwatersheds. In each subwatershed, the amount of developable land was calculated as follows: (1) The undeveloped parcels in each subwatershed were identified; (2) conservation easements were identified and subtracted from the undeveloped parcels; and (3) land in floodplains or on slopes greater than 25% were subtracted from undeveloped parcels. The amount of developed land under a full build-out scenario was then calculated by (1) classifying each of CWP's subwatersheds according to the predominant policy area in the subwatershed (taking into account the areas of towns and JMLAs within each subwatershed) and (2) calculating how much of the developable land would be developed if the open space requirements of the General Plan, as embodied in

Table 6.10, are met. The full build-out in the Transitional Policy Area is probably underestimated by this method because some land in the floodplain or on slopes greater than 25% would be used to satisfy open space requirements. This is less true in Rural Policy Area because the land preserved from development is supposed to be suitable for agriculture. Table 6.11 shows the amount of developed land projected under a full build-out scenario.

Table 6.11: Scenario Land Use Distributions (acres)

Land Use	Simulation Period	Current Conditions	2015	Full Build-out
Forest	99,375.3	99,375.3	99,375.3	99,375.3
Crops	3,728.7	3,594.0	3,258.2	3,017.8
Pasture	136,278.0	131,355.3	120,494.9	112,725.7
Developed	5,458.1	10,395.8	21,592.0	29,601.7
Construction	284.7	284.7	219.9	153.7
% Developed	2%	4%	8%	12%

The projections for the amount of agricultural and forest land under the full build-out scenario were calculated as follows:

- All future development occurred on agricultural land, so the amount of forested land in the Goose Creek watershed remained unchanged;

- 97% of the future developed land was subtracted from pasture and 3% of the future developed land was subtracted from cropland, reflecting the current ratio of cropland to pasture.

The amount of land under construction was estimated using the following assumptions:

- In 2030, it is estimated by the Loudoun County Department of Economic Development that 90% of the full build-out development would be realized (C. Draper, personal communication);

- 24% of the land under development is disturbed by construction, based on information taken from grading permits issued by Loudoun County.

Table 6.11 shows the distribution of land uses under the full build-out scenario.

6.2.3.2 2015 Scenario

The 2015 Scenario represents the projected level of development in 2015. The distribution of land uses was calculated on the basis of housing estimates obtained from the Loudoun County Department of Economic Development. As noted above, it was estimated that 90% of the development under full build-out will occur by 2030. Housing projections exist for 2015 and 2030. It was then assumed that the percent of full build-out realized in 2015 would be proportional to the ratio of the population estimates between 2015 and 2030:

$$\frac{\text{\% Full Build-out in 2015}}{\text{Population Increase 2000-2015}} = \frac{\text{90\% Full Build-out in 2030}}{\text{Population Increase 2000-2030}}$$

Population projections for 2015 and 2030 were available on the level of COG Transportation Zones, which are smaller than CWP subwatersheds. The transportation zones were therefore assigned to the CWP subwatersheds and aggregated to give population projections for the CWP subwatersheds. These population projections were then used to calculate the percent of full development realized by 2015. The distribution of land uses was calculated using the principles described in Section 6.2.4.1. Table 6.11 shows the distribution of land uses in the 2015 Scenario.

6.2.3.3 Future Land Use within MS4 Boundaries

Future land use within the MS4 permit boundaries of the Town of Leesburg and Loudoun County were also calculated. It is expected that Leesburg will reach full build-out prior to 2015. Table 6.12 shows the area available for development (N. Colonna, personal communication). By definition, construction ceases at full build-out. Table 6.12 also shows the projected developed land and land under construction within the Loudoun County MS4 boundary, excluding the portion within the Beaverdam Reservoir drainage, which contributes no loads to Goose Creek. These estimates were obtained using the methods described in Sections 6.2.3.1 and 6.2.3.2.

Table 6.12: Developed Land and Land Under Construction With MS4 Boundaries

Scenario	Land Use	Town of Leesburg		Loudoun County (excluding Beaverdam Reservoir)	
		Area (acres)	Percent of Watershed	Area (acres)	Percent of Watershed
2015 Scenario	Developed	6,334	29%	1,613	7%
	Construction	0	0	15.1	7%
Full Build-out	Developed	6,334	22%	3,069	10%
	Construction	0	0	19.1	12%

6.2.4 Load Reduction Scenario Results

The three load reduction scenarios were run using the land use distributions in Table 6.11 and the wasteload allocation principles discussed in Section 6.2.1. For each scenario, the "a" factor for streambank erosion was adjusted to reflect the percent development as given in Table 6.11. No other adjustment was made to the "a' factor. It is plausible that animal unit density will decrease with increased development, but it is also possible that any decrease in the cattle population will be compensated by an increase in the horse population.

Table 6.13 shows the average annual sediment loads by source for the three load reduction scenarios. As shown in the table, sediment loads increase as development increases, primarily due to the predicted increase in streambank erosion. Sediment loads from streambank erosion are predicted to double from current conditions to full build-out. The loads from developed land nearly triple from current conditions to full build-out, but the percent of the total load due to direct erosion from developed land remains less than 2%. Sediment loads from land under construction declines because the amount of land under construction declines as development increases. Construction loads reflect the 35% reduction called for above in 6.2.2. As a conservative measure, the reduction in load from reservoir trapping was not applied to the loads from developed land within the MS4 boundaries or other wasteload allocations.

Table 6.13: Average Annual Sediment Loads (tons/yr) Load Reduction Scenarios

Source	Current	2015	Full Build-out
Forest	1,072	1,072	1,072
Cropland	1,843	1,666	1,540
Pasture	15,481	14,185	13,257
Developed Land Inside MS4 Boundaries	299	357	435
Developed Land OutsideMS4 Boundaries	178	634	923
Construction	1,002	774	541
Streambank Erosion	55,502	83,842	110,277
Other Permitted Sources	456	456	456
Reservoir Trapping	-7,408	-10,140	-12,707
Total	68,425	92,846	115,794
TMDL Target Load	42,396	42,396	42,396
Required Reduction	38%	54%	63%

6.3 Selection of the TMDL for Goose Creek

A TMDL must take into account future growth. Because the planning horizon for TMDL implementation is about 10 years, it is appropriate to base the TMDL on the estimates of sediment loads in the 2015 Scenario.

The TMDL must determine how to divide the Load Allocation among sources. An equal percent reduction in nonpoint source loads among agriculture, developed land, and streambank erosion would call for a 55% reduction from these sources. The scenarios show, however, that development is responsible for an increase in sediment loads over time, and it is perhaps not equable to call for greater reductions over time from the agricultural sector despite the fact that the sediment load from agricultural sources and its share of the load overall are both decreasing. For that reason, the reduction from agricultural nonpoint sources was set at 30%, the level that would have been necessary had conditions remained as they were during the simulation period 1990-2001.

With a 30% reduction in sediment loads from cropland and pasture, a 61% reduction overall from developed land and streambank erosion is necessary to meet the TMDL. Because over 98% of the remaining load comes from streambank erosion, marginal reductions in sediment loads from developed land do not contribute significantly to the overall load reduction. The load reduction required from developed land was therefore set at 30%, and the load reduction from required from streambank erosion was set at 62%.

Table 6.14 shows the elements of the sediment TMDL for Goose Creek. Table 6.15 shows the wasteload allocation. Table 6.16 shows the load allocation to nonpoint sources.

Table 6.14: Elements of the Benthic TMDL for Goose Creek

Waterbody ID	Parameter	TMDL (tons/yr)	WLA (tons/yr)	LA (tons/yr)	MOS (tons/yr)
Goose Creek	Sediment	47,106	1,587	40,808	4,711

Table 6.15: Sediment Wasteload Allocation for Goose Creek

Permit Number	Facility	Wasteload Allocation (tons/yr)
Wastewater Treatment Plants - Individual Permits		
VA0022802	Purcellville WWTP (Basham Simms)	91.5
VA0024112	Foxcroft School	9.0
VA0024759	US FEMA	16.0
VA0024775	Middleburg WWTP	14.5
VA0026212	Round Hill WTTP	38.0
VA0027197	Notre Dame Academy	3.5
VA0062189	St. Louis Community	19.5
VA0080993	Goose Creek Industrial Park	2.5
VA0089133	Aldie WWTP	3.5
Water Treament Plants—Individual Permits		
VA002666	Goose Creek WTP	57.9
Wastewater Discharge - General Permits		
VAG406015	Residence	0.046
VAG406016	Business	0.046
VAG406018	Residence	0.046
VAG406019	Residence	0.046
VAG406020	Residence	0.046
VAG406047	Residence	0.046
VAG406069	Residence	0.046
VAG406101	Residence	0.046
VAG406113	Residence	0.046
VAG406115	Residence	0.046
VAG406116	Residence	0.046
VAG406121	Residence	0.046
VAG406135	Residence	0.046
VAG406143	Residence	0.046
VAG406146	Residence	0.046
VAG406149	Residence	0.046
VAG406170	Residence	0.046

Permit Number	Facility	Wasteload Allocation (tons/yr)
VAG406172	Business	0.046
VAG406176	Residence	0.046
VAG406193	Residence	0.046
VAG406244	Residence	0.046
Quarries—General Permits		
VAG846011	Luck Stone – Leesburg	56.3
VAG846016	Luck Stone - Goose Creek	90.1
VAG846012	Leesburg Iron and Metal	No longer operating
Industrial Stormwater Outside MS4 Boundaries - General Permits		
VAR051077	Loudoun County Sanitary Landfill	45.3
VAR051115	Waste Management of VA—Leesburg	0.7
VAR051442	Basham Simms Wastewater Faciliity	2.1
Ready-Made Concrete Plants - General Permits		
VAG110123	Crider and Shockey	1.2
VAG110091	Virginia Concrete	3.8
Municipal Separate Storm Sewer Systems (MS4)		
	Town of Leesburg MS4	287.4
VAR051426	Leesburg Municipal Airport	
VAR051427	Leesburg Water Pollution Control	
VAR050980	Leesburg Iron and Metal	
VAR101380	Airport Commerce Park - Phase 1	
VAR102543	Target – Battlefield Marketplace	
VAR101452	Stratford East	
VAR101399	Columbia Gas Transmission Corp. L	
VAR100810	Drymill	
VAR102991	Rokeby Hamlets	
VAR100796	Kincaid Forest	
VAR040062	VDOT—Northern VA MS4	
	Loudoun County MS4	123.6
VAR051013	Superior Paving	
VAR101445	Belmont Glen	
VAR102855	Quail Pond	
VAR101530	Potomac Station - Sections 8B 8G 8I and 10	
VAR100797	Northlake Subdivision	
VAR102006	Riverside Parkway	
VAR100804	Broadlands - Section 22	
VAR100805	Broadlands - Sections 13 and 20	
VAR101478	Cedar Ridge - Parcel 37	
VAR101670	Potomac Station - Section 10 Parcel A and PI	
VAR040062	VDOT—Northern VA MS4	
Erosion and Sediment Control Permits Outside MS4s		719.8
VAR102682	Hamilton Elementary School	
VAR102364	Dominion Virginia Power - Pleasant View	
VAR102736	Barclay Ridge	

Permit Number	Facility	Wasteload Allocation (tons/yr)
VAR101520	Long Meadow Hamlet	
VAR100798	VDOT - 0733 053 P31 C502	
VAR102009	Purcellville Southern Collector	
VAR102008	Village Case The	
VAR102589	Oak Knoll Hamlet	
VAR102686	Dream Homes - William A Kelley Property	
VAR100733	Patrick Henry College	
VAR100734	Patrick Henry College	
VAR102901	Courts of Saint Francis - Ferrell Addition	
VAR100748	Courts of St Francis	
VAR101411	Purcellville Property	
VAR100738	Purcellville WWQMF	
VAR101676	Round Hill - The Villages	
VAR101683	Greenwoods Common	
VAR101677	Hamlets of Blue Ridge	
VAR101615	Round Hill - Lake Point	
VAR101616	Round Hill - Mountain Valley	
VAR101624	Round Hill - West Lake	
VAR102854	Heronwood Farm	
VAR100732	Francis Tract	
VAR102474	Loudoun to Leesburg Tie-Over Gas Pipeline	
VAR101450	VDOT - 0015 053 125 PE101 C501	
Total Wasteload Allocation		1,587.2

Table 6.16: TMDL Load Allocation for Goose Creek

Land Use	Projected Load (tons/yr)	Load Allocation (tons/year)	Percent Reduction
Forest	998	998	0%
Clear-Cut Timber	2	0.2	92%
Select-Cut Timber	72	6	92%
Cropland	1,666	1,166	30%
Pasture	14,185	9,930	30%
Developed Land*	634	444	30%
Streambank Erosion	83,842	31,860	62%
Sediment Trapping	-10,140	-4,440	---
Total	91,259	39,963	56%

* Excludes developed land within MS4s

6.4 Selection of the TMDL for Little River

Little River does not face the same development pressures as the lower portions of the Goose Creek watershed. Much of the watershed lies in Fauquier County, and under the Loudoun County General Plan, the portion of the watershed within the county is expected to remain rural. The base 1990-2001 simulation, therefore, can be expected to reflect sediment loading rates and the distribution of sediment sources for some time to come. Under those conditions, it is necessary to reduce sediment loads from nonpoint sources by 37% to meet the TMDL load. The load reduction was made equally from cropland, pasture, developed land, and streambank erosion.

Table 6.17 shows the elements of the sediment TMDL for Goose Creek. Table 6.18 shows the wasteload allocation. There are only two permitted sources in the watershed. Table 6.19 shows the load allocation to nonpoint sources.

Table 6.17: Elements of the Benthic TMDL for Little River

Waterbody ID	Parameter	TMDL (tons/yr)	WLA (tons/yr)	LA (tons/yr)	MOS (tons/yr)
Little River	Sediment	5,470	105	4,818	547

Table 6.18: Sediment Wasteload Allocation for Little River

Permit Number	Facility	Wasteload Allocation (tons/yr)
VA0089133	Aldie WWTP	3.5
VAG406019	Residence	0.05
VAR102736	Barclay Ridge	97
VAR102474	Loudoun to Leesburg Tie-Over Gas Pipeline	4
Total Wasteload Allocation		102

Table 6.19: TMDL Load Allocation for Little River

Land Use	Current Load (tons/yr)	Load Allocation (tons/year)	Percent Reduction
Forest	266	266	0%
Clear-Cut Timber	0.4	0.03	92%
Select-Cut Timber	2	0.16	92%
Cropland	457	288	37%
Pasture	4,444	2,800	37%
Developed Land	25	16	37%
Streambank Erosion	2,243	1,414	37%
Total	7,438	4,783	36%

CHAPTER SEVEN: TMDL IMPLEMENTATION

The goal of the TMDL program in Virginia is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the benthic impairments on Little River and Goose Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor in-stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual," published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

7.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement. The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

7.2 Stage 1 Scenarios

The Goose Creek benthic TMDL was developed to take into account future conditions that are anticipated to be realized in 2015 at the end of the planning horizon for implementation. Rapid development is expected to lead to an increase in streambank erosion. Under current levels of development, however, the average annual sediment loads from streambank erosion are expected to be considerably less than those predicted for 2015. A Stage 1 Scenario, based on current conditions, would therefore provide a useful interim goal for TMDL implementation. Under current conditions, if the same level of reduction was required of nonpoint source loads from crops, pasture, and developed land, only a 45% reduction in sediment from streambank erosion would be required to meet the TMDL. The same wasteload allocation given under the TMDL would be given in Phase I Scenario, except that the MS4 wasteload allocations would reflect current loading rates. Table 7.1 shows the elements of the Stage 1 Scenario for Goose Creek, Table 7.2 shows the wasteload allocation, and Table 7.3 shows the load allocation to nonpoint sources.

Table 7.1: Elements of the Stage 1 for Goose Creek

Waterbody ID	Parameter	TMDL (tons/yr)	WLA (tons/yr)	LA (tons/yr)	MOS (tons/yr)
Goose Creek	Sediment	47,106	1,587	40,808	4,711

Table 7.2: Stage 1 Sediment Wasteload Allocation For Goose Creek

Permit Number	Facility	Wasteload Allocation (tons/yr)
Wastewater Treatment Plants - Individual Permits		
VA0022802	Purcellville WWTP (Basham Simms)	91.5
VA0024112	Foxcroft School	9.0
VA0024759	US FEMA	16.0
VA0024775	Middleburg WWTP	14.5
VA0026212	Round Hill WTTP	38.0
VA0027197	Notre Dame Academy	3.5
VA0062189	St. Louis Community	19.5
VA0080993	Goose Creek Industrial Park	2.5
VA0089133	Aldie WWTP	3.5
Water Treament Plants—Individual Permits		
VA002666	Goose Creek WTP	57.9
Wastewater Discharge - General Permits		
VAG406015	Residence	0.046
VAG406016	Business	0.046
VAG406018	Residence	0.046
VAG406019	Residence	0.046
VAG406020	Residence	0.046
VAG406047	Residence	0.046
VAG406069	Residence	0.046

Permit Number	Facility	Wasteload Allocation (tons/yr)
VAG406101	Residence	0.046
VAG406113	Residence	0.046
VAG406115	Residence	0.046
VAG406116	Residence	0.046
VAG406121	Residence	0.046
VAG406135	Residence	0.046
VAG406143	Residence	0.046
VAG406146	Residence	0.046
VAG406149	Residence	0.046
VAG406170	Residence	0.046
VAG406172	Business	0.046
VAG406176	Residence	0.046
VAG406193	Residence	0.046
VAG406244	Residence	0.046
Quarries—General Permits		
VAG846011	Luck Stone – Leesburg	56.3
VAG846016	Luck Stone - Goose Creek	90.1
VAG846012	Leesburg Iron and Metal	No longer operating
Industrial Stormwater Outside MS4 Boundaries - General Permits		
VAR051077	Loudoun County Sanitary Landfill	45.3
VAR051115	Waste Management of VA—Leesburg	0.7
VAR051442	Basham Simms Wastewater Faciliity	2.1
Ready-Made Concrete Plants - General Permits		
VAG110123	Crider and Shockey	1.2
VAG110091	Virginia Concrete	3.8
Municipal Separate Storm Sewer Systems (MS4)		
	Town of Leesburg MS4	287.4
VAR051426	Leesburg Municipal Airport	
VAR051427	Leesburg Water Pollution Control	
VAR050980	Leesburg Iron and Metal	
VAR101380	Airport Commerce Park - Phase 1	
VAR102543	Target – Battlefield Marketplace	
VAR101452	Stratford East	
VAR101399	Columbia Gas Transmission Corp. L	
VAR100810	Drymill	
VAR102991	Rokeby Hamlets	
VAR100796	Kincaid Forest	
VAR040062	VDOT—Northern VA MS4	
	Loudoun County MS4	123.6
VAR051013	Superior Paving	
VAR101445	Belmont Glen	
VAR102855	Quail Pond	
VAR101530	Potomac Station - Sections 8B 8G 8I and 10	
VAR100797	Northlake Subdivision	

Permit Number	Facility	Wasteload Allocation (tons/yr)
VAR102006	Riverside Parkway	
VAR100804	Broadlands - Section 22	
VAR100805	Broadlands - Sections 13 and 20	
VAR101478	Cedar Ridge - Parcel 37	
VAR101670	Potomac Station - Section 10 Parcel A and PI	
VAR040062	VDOT—Northern VA MS4	
Erosion and Sediment Control Permits Outside MS4s		719.8
VAR102682	Hamilton Elementary School	
VAR102364	Dominion Virginia Power - Pleasant View	
VAR102736	Barclay Ridge	
VAR101520	Long Meadow Hamlet	
VAR100798	VDOT - 0733 053 P31 C502	
VAR102009	Purcellville Southern Collector	
VAR102008	Village Case The	
VAR102589	Oak Knoll Hamlet	
VAR102686	Dream Homes - William A Kelley Property	
VAR100733	Patrick Henry College	
VAR100734	Patrick Henry College	
VAR102901	Courts of Saint Francis - Ferrell Addition	
VAR100748	Courts of St Francis	
VAR101411	Purcellville Property	
VAR100738	Purcellville WWQMF	
VAR101676	Round Hill - The Villages	
VAR101683	Greenwoods Common	
VAR101677	Hamlets of Blue Ridge	
VAR101615	Round Hill - Lake Point	
VAR101616	Round Hill - Mountain Valley	
VAR101624	Round Hill - West Lake	
VAR102854	Heronwood Farm	
VAR100732	Francis Tract	
VAR102474	Loudoun to Leesburg Tie-Over Gas Pipeline	
VAR101450	VDOT - 0015 053 125 PE101 C501	
Total Wasteload Allocation		1,587.2

Table 7.3: Stage 1 Load Allocation For Goose Creek

Land Use	Current Load (tons/yr)	Load Allocation (tons/year)	Percent Reduction
Forest	998	998	0%
Clear-Cut Timber	2	0.2	92%
Select-Cut Timber	72	2	92%
Cropland	1,843	1,290	30%
Pasture	15,481	10,837	30%
Developed Land*	178	125	30%
Streambank Erosion	55,502	30,526	45%
Sediment Trapping	-7,408	-4,378	---
Total	66,668	39,400	41%

* Excludes developed land within MS4s, which are included in the wasteload allocation

7.3 Links to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. The BMPs required for the implementation of the sediment allocations in the watersheds contribute directly to the sediment reduction goals set as part of the Chesapeake Bay restoration effort. A new tributary strategy is currently being developed for the Shenandoah-Potomac River Basin to address the nutrient and sediment reductions required to restore the health of the Chesapeake Bay. Up-to-date information on tributary strategy development can be found at http://www.snr.state.va.us/Initiatives/TributaryStrategies/shenandoah.cfm.

The Goose Creek bacteria TMDLs call for, among other things, a 100% reduction in bacteria loads directly deposited by cattle in stream and a 98-99% reduction in bacteria loads in pasture runoff. It is expected that the BMPs and other measures taken to reduce bacteria from livestock and pasture will help reduce sediment loads. Streambank fencing and riparian buffers, for example, will promote bank stability and reduce the amount of sediment entering surface water from adjacent fields. The implementation plans for both the bacteria TMDLs and the benthic TMDLs in the Goose Creek watershed will be developed jointly to take advantage of multiple benefits of many environmental controls.

7.4 Reasonable Assurance for Implementation

7.4.1 Follow-Up Monitoring

VADEQ will continue monitoring its stations on Goose Creek (GOO002.38) and Little River (LIV004.78) in accordance with its biological monitoring program. VADEQ will continue to use data from these monitoring stations and related ambient monitoring stations to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

7.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (§ 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlined the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

7.4.3 Stormwater Permits

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is the Virginia Pollutant Discharge Elimination System (VPDES) Permit Regulation (9 VAC 25-31-10 et seq.). Section 9 VAC 25-31-120 describes the requirements for storm water discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when:…(2) Numeric effluent limitations are infeasible,…".

Part of the Goose Creek watershed is covered by Phase II VPDES permits VAR040067, VAR040059, and VAR040062 for the small municipal separate storm sewer systems (MS-4s) owned by the Loudoun County, the Town of Leesburg, and the Virginia Department of Transportation, respectively. These permits were issued on July 8, 2003. The effective date of coverage is December 9, 2002. The permits state, under Part II.A., that the "permittee must develop, implement, and enforce a storm water management program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP), to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act and the State Water Control Law."

The permit also contains a TMDL clause that states: "If a TMDL is approved for any waterbody into which the small MS4 discharges, the Board will review the TMDL to determine whether the TMDL includes requirements for control of storm water discharges. If discharges from the MS4 are not meeting the TMDL allocations, the Board will notify the permittee of that finding and may require that the Storm Water Management Program required in Part II be modified to implement the TMDL within a timeframe consistent with the TMDL."

For MS4/VPDES general permits, DEQ expects revisions to the permittee's Stormwater Pollution Prevention Plans to specifically address the TMDL pollutants of concern. DEQ anticipates that BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its BMPs to achieve the TMDL reductions. However, only failing to implement the required BMPs would be considered a violation of the permit. Any changes to the TMDL resulting from water quality standards changes on Goose Creek would be reflected in the permittee's Stormwater Pollution Prevention Plan required by the MS4/VPDES permit.

Additional information on Virginia's Storm Water Phase 2 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.deq.state.va.us/water/bmps.html.

7.4.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

CHAPTER EIGHT: PUBLIC PARTICIPATION

The development of the Goose Creek Benthic TMDLs relied on participation from the general public and various stakeholder groups. A series of public meetings were held to present the results of the TMDLs and to solicit comments and suggestions.

Originally, the benthic TMDLs were to be developed in tandem with the bacteria TMDLs for the Goose Creek watershed. The possibility of delisting the benthic impairments in the Goose Creek watershed was discussed at a public meeting held in Leesburg on October 17, 2001. The development of the benthic TMDLs was placed on hold while VADEQ and EPA Region III discussed the possibility of removing the benthic impairments in the Goose Creek watershed from Virginia's 303(d) List. The decision in September 2002 not to delist the benthic impairments and to proceed with the TMDL development was mentioned at the two public meetings held to present the results of the bacteria TMDLs, one in Leesburg on November 14, 2002, and the second in Marshall on November 20, 2002.

Two public meetings were held to explicitly discuss the benthic TMDLs. The first was held in Leesburg on April 10, 2003. At that meeting, the need for the benthic TMDLs was explained and the steps in their development were outlined. The second meeting on December 11, 2003, also held in Leesburg, explained the TMDL allocations developed to address the benthic impairments in the Goose Creek watershed. Copies of the presentation were available at both meetings for public distribution. The meetings were public noticed in the Virginia Register and advertised in the Fauquier Times Democrat, Loudoun Times Mirror and Fairfax Connection newspapers. For each meeting there was a 30-day public comment period. No written comments were received on the first meeting and 3 comments were received on the second. VADEQ has responded to all received comments in a separate document. Table 8.1 presents the specifics of the two public meetings held in support of the development of the benthic TMDLs.

Table 8.1: Public Participation in Development of the Goose Creek Benthic TMDLs

Date	Location	Address	City	Attendance
4/10/03	First Floor Board Room Loudoun Co. Gov't Center	1 Harrison Street, SE	Leesburg, VA	18
12/11/03	First Floor Board Room Loudoun Co. Gov't Center	1 Harrison Street, SE	Leesburg, VA	13

In addition to keeping the public apprised of progress in the development of the Goose Creek TMDLs, a Technical Advisory Committee (TAC) was also established to help advise the TMDL developers. TAC meetings began during the development of the bacteria TMDLs and continued through to the completion of the benthic TMDLs. The TAC membership included representatives from the following agencies and organizations:

- Virginia Department of Environmental Quality
- Virginia Department of Conservation and Recreation
- Virginia Department of Game and Inland Fisheries

- Loudoun County
- Fauquier County
- Town of Leesburg
- Town of Purcellville
- Town of Round Hill
- Town of Middleburg
- City of Fairfax
- Loudoun County Sanitation Authority
- Loudoun Soil and Water Conservation District
- John Marshall Soil and Water Conservation District
- Goose Creek Scenic River Advisory Board
- Piedmont Environmental Council

The Goose Creek TAC met on March 17, 2003 and November 20, 2003, to explicitly discuss the benthic TMDLs. TAC meetings were used as a forum to review data and assumptions used in the modeling, and to provide local city and county government agencies an opportunity to raise concerns about the implications of the TMDL for their jurisdictions. In addition to the meetings, a draft of chapter 3, the stressor identification, was circulated to TAC members for comment in September 2003.

Additional meetings were held with the Soil and Water Conservation Districts, the Loudoun and Fauquier County soil scientists, and staff of a variety of agencies in Loudoun County and the Town of Leesburg to collect data and review the assumptions incorporated into the TMDLs. The generous assistance of the staff of these agencies is gratefully acknowledged.

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