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A Landscape Assessment of the Catskill/Delaware Watersheds 1975-1998

New York City's Water Supply Watersheds

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Chapter 5. Landscape Change

The landscape is transformed from one cover type to another by a number of different mechanisms. Human-induced changes (suburbanization, farming, and logging) and natural changes such as fires and flooding are the most common drivers of land cover change over time (Forman, 1995b). This chapter provides an assessment of the land cover and land use changes which have taken place in the CD watersheds across a 25-year time span.

Change in the Watershed

Between the mid-1970s and the late 1990s, a total of 8% of the CD watersheds changed from one cover type to another. The majority of the change is from agriculture to forest (5% of the area) or forest to agriculture (3% of the area). During the past two decades many acres of pasture have been released allowing forest regrowth to occur and resulting in a 2% net increase in secondary forest cover across the watersheds. The decrease in percent agriculture within the CD watershed is reflected in other related metrics, such as the human use index, percent agriculture on erodible soil, and agriculture on slopes greater than 5, 10, and 15% (Table 5.1). The next largest change, following agriculture and forest, is an increase in urban development of less than 1% across the watersheds (Figure 5.1b). The majority of the change in urban development occurred between the mid-1970s and the mid-1980s which corresponds to increases in population.

The rate of change was fairly consistent throughout the two decades, with the exception of a slight increase in change from agriculture to forest during the mid-1980s to the early 1990s (Figures 5.1a and c). The CD watersheds which had the greatest percentage of change from agriculture to forest classification are the Cannonsville, Pepacton, and Schoharie. Vegetation change between the mid-1970s and the late 1990s in these three watersheds resulted in a net increase of forest cover by 5, 3, and 2%, respectively (Table 5.2).

Table 5.1. Change in Agriculture Metrics in the Catskill/Delaware Watersheds (mid-1970s to late 1990s)

	Agriculture k >0.3		Agriculture Slope >5%		Agriculture Slope >10%		Agriculture Slope >15%	
Watershed	km^2	%	km^2	%	km^2	%	km^2	%
Cannonsville	0.24	0.02	46.00	3.92	21.00	1.74	6.00	0.49
Pepacton	0.58	0.06	12.00	1.28	4.00	0.37	0.48	0.05
Ashokan	0.40	0.06	20.00	3.03	9.00	1.34	2.00	0.25
Neversink	0.02	0.01	0.05	0.02	0.05	0.02	0.02	0.01
Schoharie	0.00	0.00	1.00	0.13	0.25	0.03	0.16	0.02
Rondout	0.00	0.00	0.59	0.24	0.42	0.17	0.01	0.00

The only watershed showing a net loss in forest cover is the Ashokan (Table 5.2). With the exception of one subwatershed, which had no change between the mid-1970s and the late 1990s, all of the Ashokan subwatersheds lost forest cover during the past two decades (Figure 5.2). The loss of forest in the Ashokan and its subwatersheds is likely related to increases in urban development (Figure 5.1b).

Barn, hayfield, and row crops in Cannonsville near Hobart.

Outside of the Ashokan, there are only three other subwatersheds which have a net loss in forest cover across time, one each in the Cannonsville, Schoharie, and Rondout (Figure 5.2). The Cannonsville subwatershed forest loss is the result of increases in urban and agriculture land use, while the Schoharie subwatershed lost forest as the result of urban growth and increases in bare ground (ski resort development) (Figure 5.1b, c, and d). Loss of forest cover in the Rondout reservoir subwatershed is also caused by urban growth.

Strip cropping (corn, alfalfa, pasture) in Cannonsville, North of New Delhi.

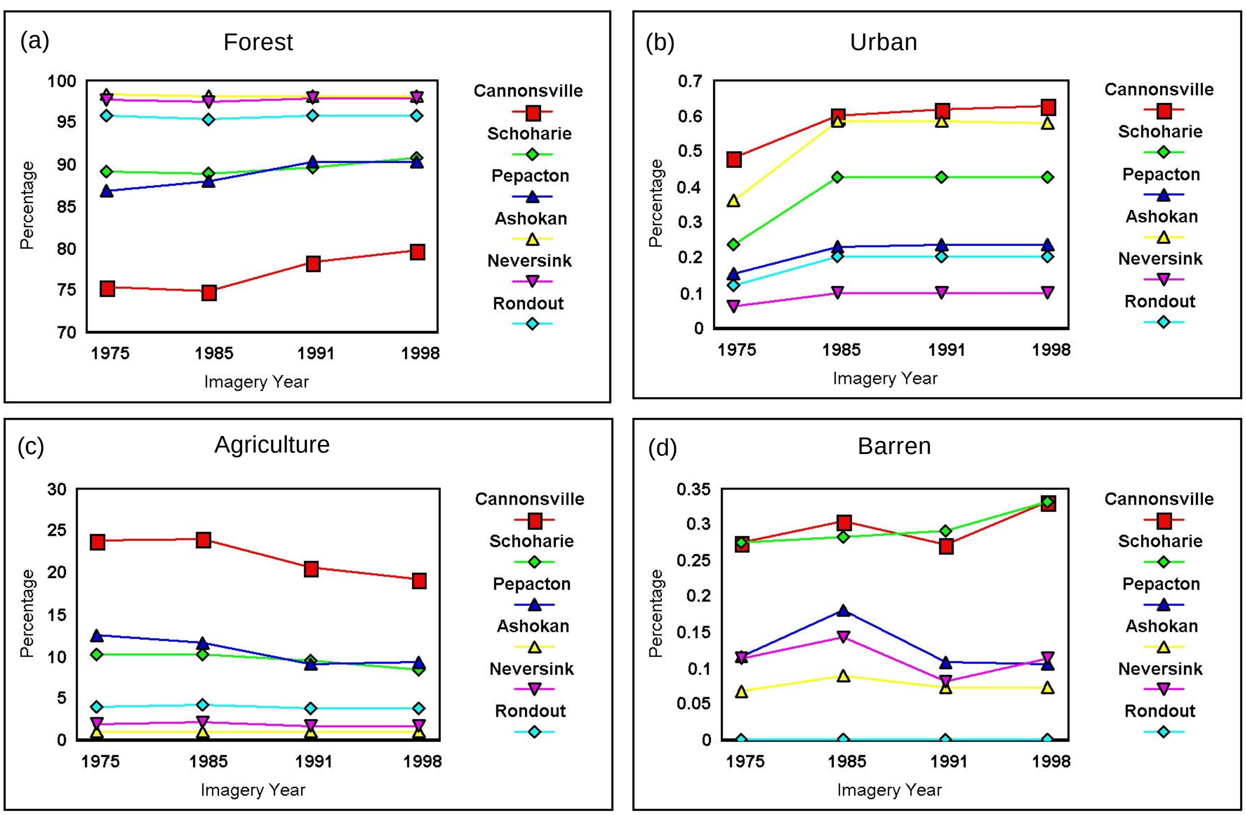

Figure 5.1. *Change in percent* ***(a)*** *forest,* ***(b)*** *urban,* ***(c)*** *agriculture, and* ***(d)*** *barren in the Catskill/Delaware watersheds from mid-1970s to late 1990s.*

Table 5.2. Land Cover/Use Change (mid-1970s to late1990s) in the Catskill/Delaware Watersheds

Watershed	Total Change		Ag to Forest		Forest to Ag		Net Change to Forest	
	km^2	%	km^2	%	km^2	%	km^2	%
Cannonsville	162	14	107	9	55	5	52	5*
Schoharie	53	7	33	4	19	2	14	2
Pepacton	80	9	55	6	24	3	32	3
Ashokan	5	1	2	< 1	3	< 1	-1	<1
Neversink	4	2	2	1	2	1	0	0
Rondout	8	3	4	2	4	2	0	0

* Seeming inaccuracies in net change results are the result of rounding.

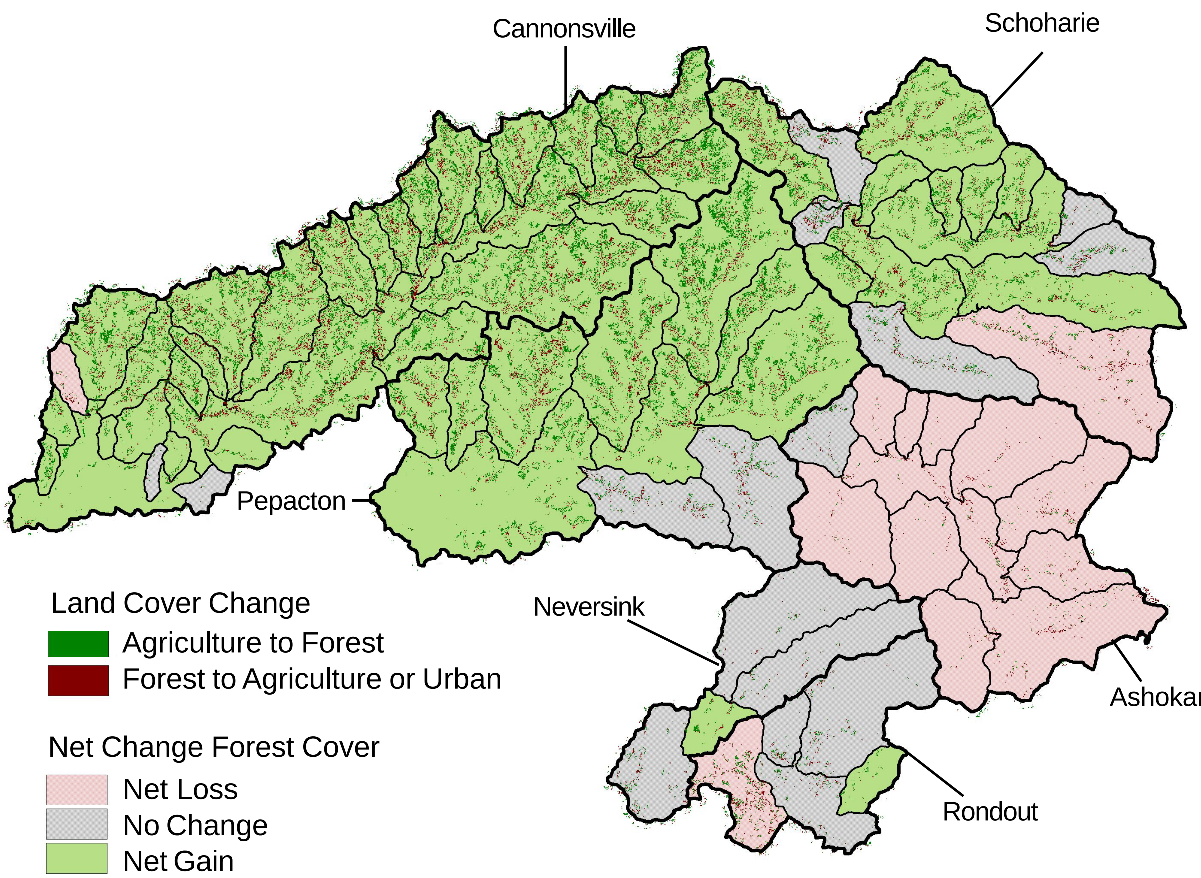

Figure 5.2. *Vegetation change between forest cover and agricultural or urban land use from mid-1970s to late 1990s in the Catskill/Delaware watersheds. The metrics were calculated as total net change divided by subwatershed area.*

Change in the Riparian Buffer

A riparian buffer can carry out the functions of filtering and sequestering nonpoint pollution. However, when riparian vegetation is replaced by agricultural or urban development, the natural buffering capacity is lost and it becomes a potential source of nutrient, bacterial, chemical, and erosional pollution (Lowrance et al., 1984). Riparian buffer make up a large proportion of the CD watersheds. As a result of high stream density, an average of 44% of the land is located within 120 m of a stream. Therefore, a large percentage (68%) of the total vegetation change observed between the mid-1970s and the late 1990s took place within riparian buffers.

Riparian buffer changes are greatest in the Cannonsville, Pepacton, and Schoharie watersheds, resulting in net gains in the amount of forest cover in the 60-m riparian from 2 to 4% (Table 5.3). The largest increases in forest cover occurred between the mid-1980s and the early 1990s (Figure 5.3a). In the Cannonsville watershed the amount of forest gain in the riparian buffer was slightly lower than the watershed as a whole, suggesting that more conversion from agriculture to forest occurred farther than 60 m from streams.

A decreasing trend in riparian agriculture occurred during the same 10 years (mid-1980s to early 1990s) as forest increases, followed by a leveling off (Figure 5.3c). The percentage change in bare ground fluctuated between each of the four time periods with no obvious trend across time (Figure 5.3d). Urban development increases in the riparian buffer of the CD watersheds were greatest between the mid-1970s and the mid-1980s paralleling watershed results (Figure 5.3b).

When assessing riparian buffer changes at the subwatershed scale, the range of gains and losses is considerably larger than suggested by the change in the watershed. Changes in the subwatershed riparian buffer range from forest cover losses of 3% to gains of 14% (Figure 5.4). In five of the CD subwatersheds forest percentages remained the same or decreased in the 120-m buffer over time (Figure 5.4); however, these same subwatersheds were shown to have an increase in percent forest cover across the whole area (Figure 5.2). Four Cannonsville subwatersheds had the highest net gains in riparian forest cover. All of the subwatersheds in the Ashokan had net decreases in riparian forest cover with time, which is most likely related to urbanization along major roads paralleling nearby streams.

Table 5.3. Total Land Cover, Agriculture (Ag), and Forest Change in the Catskill/Delaware Watersheds Riparian Buffer (60-m) from mid-1970s to late 1990s

	Total Change		Ag to Forest		Forest to Ag		Net Change to Forest	
Watersheds	km^2	%	km^2	%	km^2	%	km^2	%
Cannonsville	95	20	59	11	36	8	22	4*
Schoharie	37	10	22	5	15	4	7	2
Pepacton	50	13	34	8	16	4	18	4
Ashokan	4	2	2	1	2	1	0	0
Neversink	2	2	1	1	1	1	0	0
Rondout	5	4	2	2	2	2	0	0

* seeming inaccuracies in net change results are the result of rounding

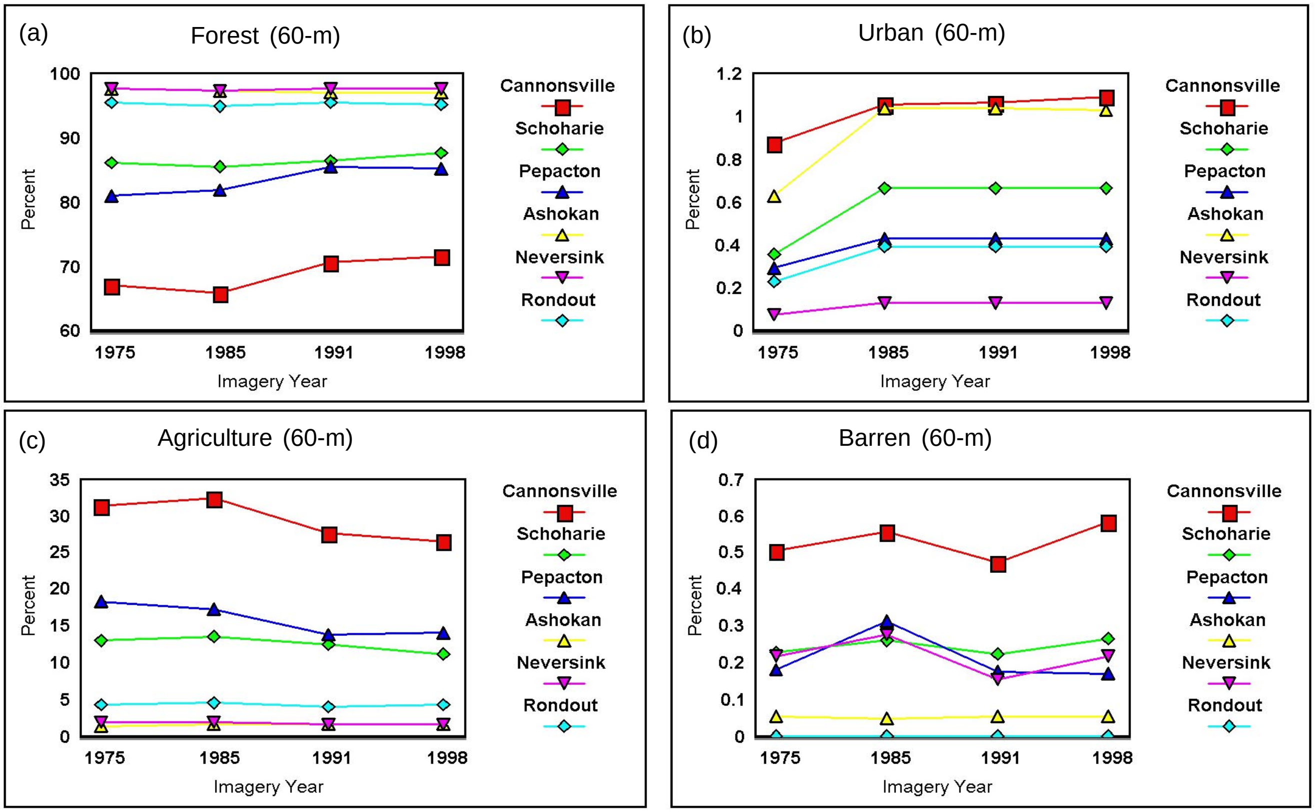

Figure 5.3. *Change in riparian buffer (60 m) percent **(a)** forest, **(b)** urban, **(c)** agriculture, and **(d)** barren in the Catskill/Delaware watersheds from mid-1970s to late 1990s.*

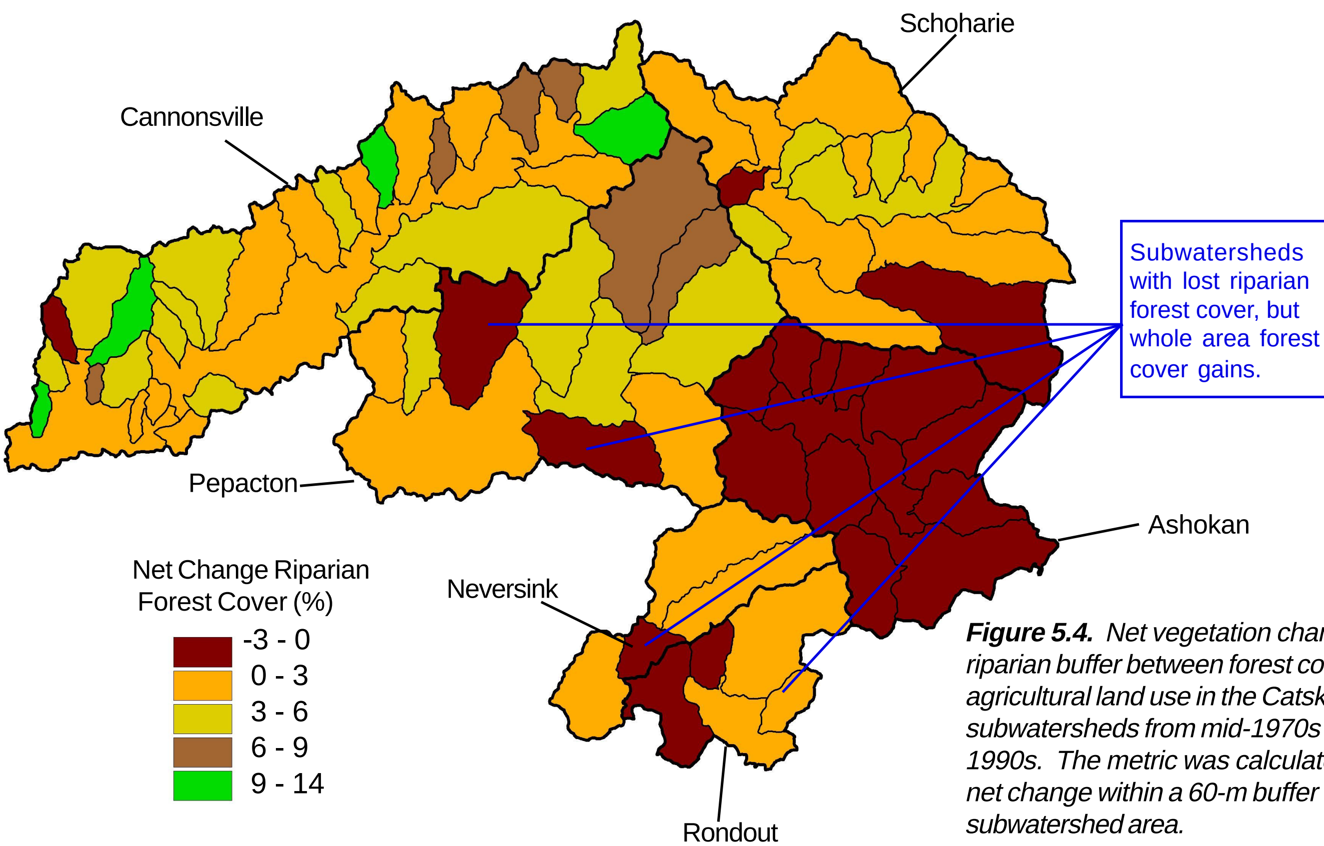

Figure 5.4. *Net vegetation change in the riparian buffer between forest cover and agricultural land use in the Catskill/Delaware subwatersheds from mid-1970s to late 1990s. The metric was calculated as total net change within a 60-m buffer divided by subwatershed area.*

Landscape Change Summary

Across all six watersheds there was a total of 2% gain in forest cover. The majority of the change was between agriculture land use and forest land cover, with only a small portion of forest loss as a result of urbanization. The increases in urban percentages occurred during the period of greatest population increase from the mid-1970s to the mid-1980s. A majority of the forest increases were between the mid-1980s and the early 1990s, with a further small increase between the early 1990s and the late 1990s. The Cannonsville watershed had the greatest number of subwatersheds showing a net gain in forest cover percentages, while the Ashokan was the only watershed to have an overall loss in forest cover with time. All but one of the subwatersheds in the Ashokan lost forest cover during the past two decades. Most of the losses in the Ashokan were the result of increased urban development between the mid-1970s and the mid-1980s and increased agriculture land use between the mid-1980s and the early 1990s. In general, changes occurring in the riparian buffer parallel watershed and subwatershed results. Forest cover gains in the subwatershed riparian buffers ranged between 1 and 14% and are mostly the result of shifts from agriculture to forest. Riparian forest losses ranged between 0 and 3%, with the highest losses occurring in the Ashokan subwatershed buffer.

Tributary of the East Branch Delaware River in the Pepacton.

Chapter 6. Surface Water Quality

A large portion of the water collected in the reservoirs of the CD watersheds is supplied by surface water runoff. The biophysical setting within the watershed influences the quantity and quality of surface water entering the streams and reservoirs (Herlihy et al., 1998). The rate of water runoff depends on properties such as forest, slope, and water-holding capacity (Nash et al., 1992 and 1999). Therefore, amounts of surface water total nitrogen, phosphorus, and fecal coliform bacteria are expected to be strongly affected by topography, soil, and vegetative cover (Slaymaker, 2000). In this chapter, spatial and temporal variation of the three measurements of water quality are examined. An average across the most recent five years of water data (1994 -1998) at all water sample site is used for spatial estimates. Temporal patterns of fecal coliform bacteria, total nitrogen and total phosphorous, discharge, and precipitation are determined using 8 to 10 years of data.

Spatial Variation

Like many of the landscape metrics, water quality measurement averages (1994-1998) of fecal coliform bacteria, total nitrogen, and total phosphorus are highest in the northwest and lowest in the southeast in the CD watersheds (Figures 6.1a, b, and c). The lowest average concentrations of total nitrogen, phosphorus, and fecal coliform bacteria counts are found within the Catskill Park boundary and other areas of low human use (Figure 2.3b). Median fecal coliform bacteria counts ranged from 0 to 200 CFU/100 ml. Maximum fecal coliform bacteria counts are sometimes greater than 10,000 CFU/100 ml at sites in the Ashokan, Cannonsville, Pepacton, and Schoharie watersheds (Table D-3). Sites having the highest average, median, and maximum total nitrogen content are located on the West Branch Delaware river in the Cannonsville watershed. Three sites in the Cannonsville watershed have greater than 1.5 mg/L median total nitrogen concentrations and are located on the upper portion of the West Branch Delaware river (Figure 6.1b). Total phosphorus median concentration values ranged from 3 to 111 *u*g/L across the watersheds. Similar to total nitrogen, the highest phosphorus average, median, and maximum values are found in the Cannonsville and Schoharie watersheds (Table D-1).

In general the average and median total nitrogen, phosphorus, and fecal coliform bacteria did not exceed state and federal surface water standards. However, in watersheds having the most human use (i.e., Cannonsville, Schoharie, and Pepacton), a few water sampling sites have maximum values that approach or slightly exceed established standards. Often these sites are located downstream of point sources, such as sewage treatment facilities, dairy farms, and landfills. The NYCDEP monitors both upstream and downstream of treatment plants to determine general effectiveness of each treatment plant (Figure 6.2). Furthermore under the MOA the NYCDEP is committed to upgrading all wastewater treatment plants in order to meet phosphorus effluent discharge limits and remove the presence of protozoan pathogens.

Over 70% of the monitored point source sites have greater median nutrient concentrations and fecal coliform bacteria counts downstream. Upstream and downstream differences are greatest in the Cannonsville and Schoharie watershed sites for all three water parameters (Table 6.1). Differences in median values for the selected treatment plant sites in each watershed ranged from 0.08 to 0.38 mg/L nitrogen, 6 to 82 *u*g/L phosphorus, and -8 to 20 CFU/100 ml fecal coliform bacteria. These results suggest that until treatment plant upgrades are implemented by the NYCDEP, nutrients and fecal coliform bacteria contributions from effluent will continue to be a problem for a number of streams in the CD watersheds.

Temporal Variation

Climate in the CD watersheds includes mild summers and cold winters. Yearly precipitation (rainfall and snowfall) can average as much as 1650 mm (65 in.), with snowfall accounting for up to 18% of the yearly total (Murdoch and Barnes, 1996). Over time, precipitation rates vary, and in turn influence discharge, surface water runoff, nutrients,

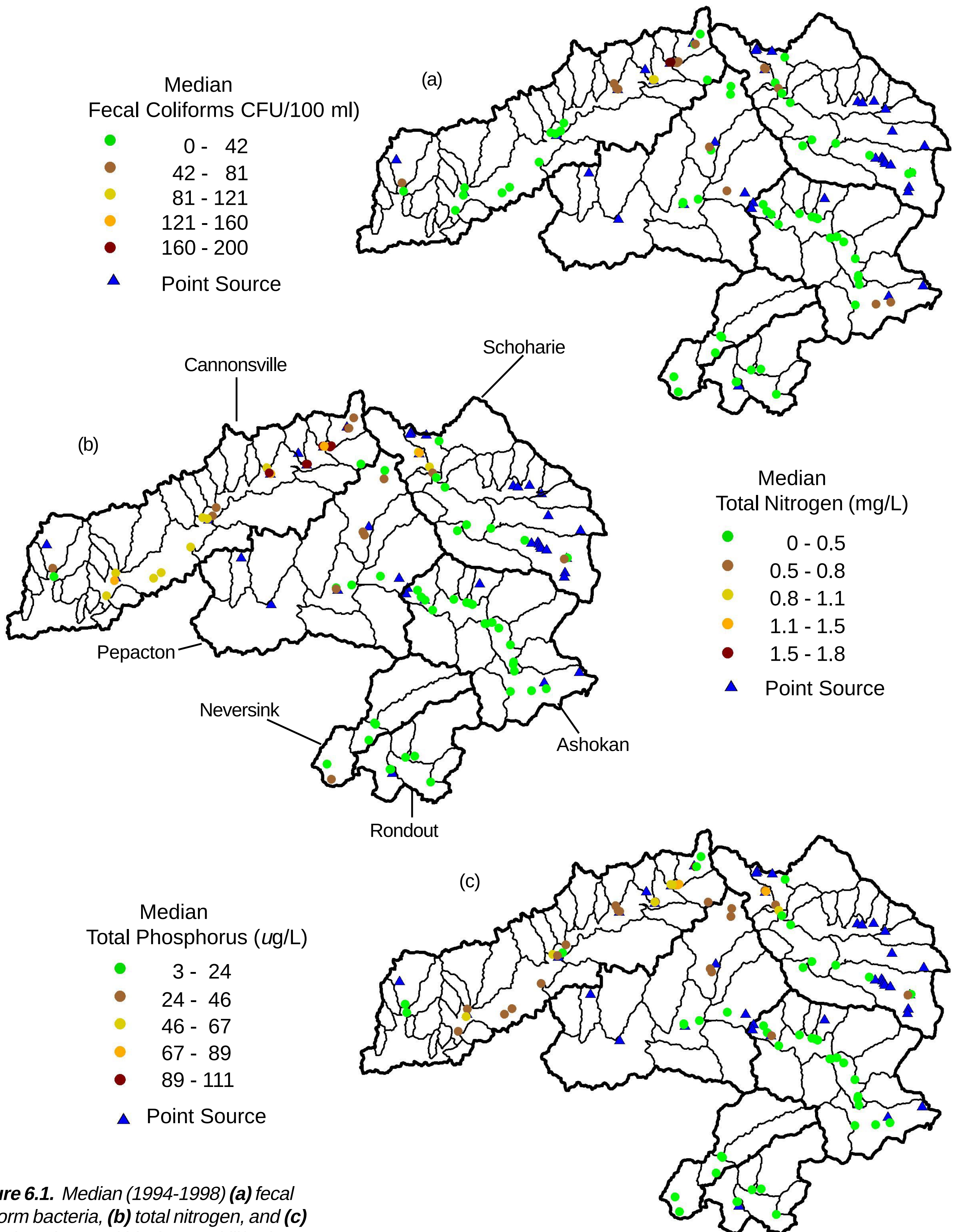

***Figure 6.1.** Median (1994-1998) **(a)** fecal coliform bacteria, **(b)** total nitrogen, and **(c)** total phosphorus within the Catskill/Delaware subwatersheds.*

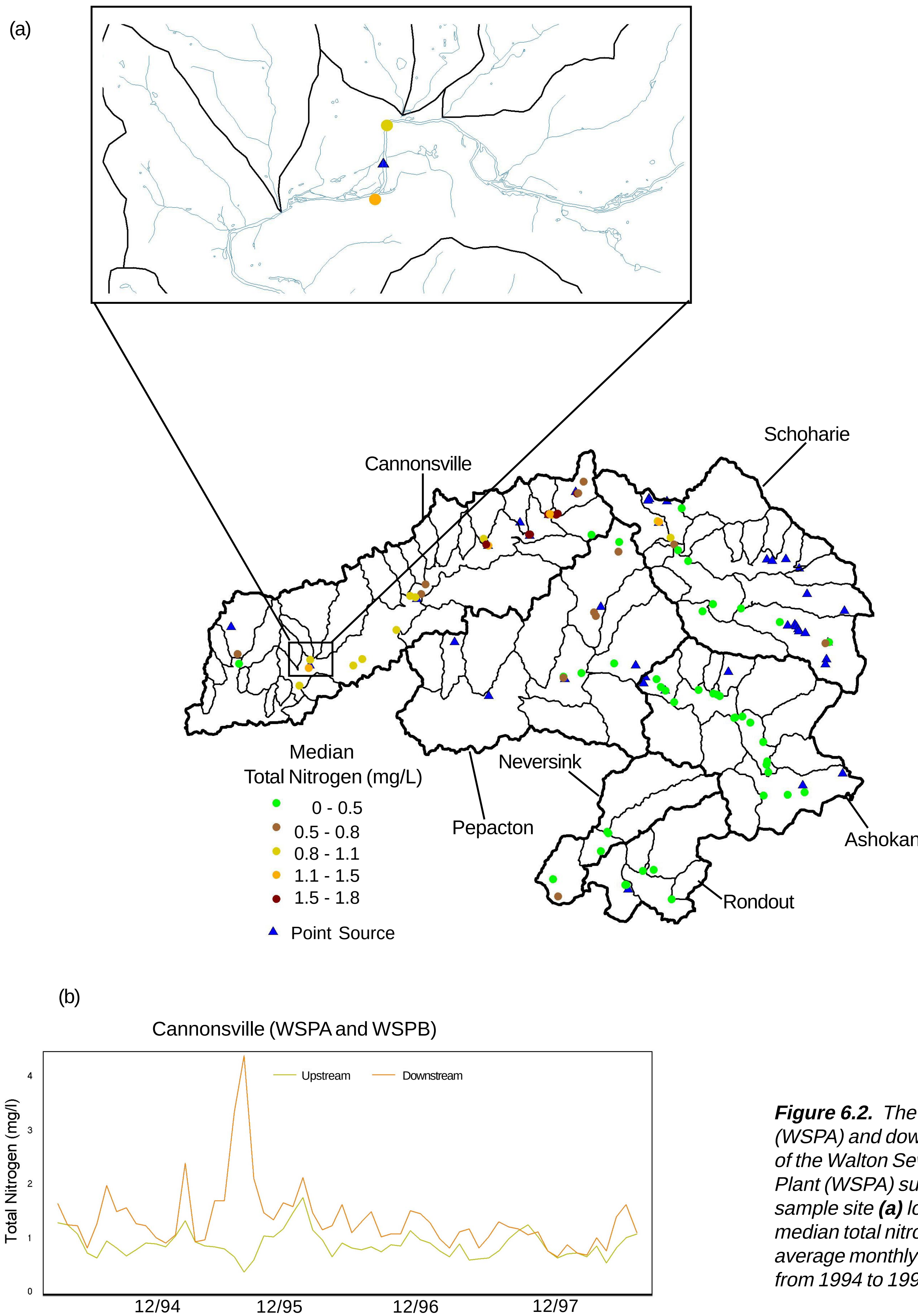

Figure 6.2. *The upstream (WSPA) and downstream (WSPB) of the Walton Sewage Treatment Plant (WSPA) surface water sample site **(a)** location and median total nitrogen and **(b)** average monthly total nitrogen from 1994 to 1998.*

Table 6.1. Mean and Median Total Nitrogen, Total Phosphorous, and Fecal Coliform Bacteria (1994-1998) in Surface Water Sample Sites Upstream and Downstream of Sewage Treatment Plants in the Catskill/Delaware Watersheds

			Total Nitrogen (mg/L)		Total Phosphorus (ug/L)		Fecal Coliform B (CFU/100 ml)	
Watersheds*	Site	Stream Location	Mean	Median	Mean	Median	Mean	Median
Ashokan	E3	Upstream	0.27	0.29	15.95	14.00	14.38	6.00
	E15	Downstream	0.36	0.37	28.57	23.00	19.42	10.00
Cannonsville	WSPA	Upstream	0.94**	0.92	31.17	28.00	94.76	20.00
	WSPB	Downstream	1.39	1.30	102.76	110.00	197.44	40.00
Pepacton	PMSA	Upstream	0.37	0.38	16.85	15.00	93.30	28.00
	PMSB	Downstream	0.50	0.49	27.87	25.00	75.80	20.00
Rondout	RGA	Upstream	0.35	0.36	12.37	11.00	82.00	24.50
	RGB	Downstream	0.44	0.44	17.96	17.00	97.76	22.00
Schoharie	S1	Upstream	0.35	0.36	14.71	11.00	30.19	4.00
	S2	Downstream	0.73	0.60	48.20	37.00	47.23	12.00

* there are no sewage treatment plants with up and downstream monitoring in the Neversink watershed
** red color = close to or exceeding federal and state surface water standards

and fecal coliform bacteria input to streams. Examining long-term precipitation and surface water measurements provides a picture of trends and changes over time.

Rainfall and Discharge

The average monthly rainfall in the CD watersheds from 1987 through 1998 ranges between 79 and 112 mm (3.1 and 4.4 in.) with the highest monthly rainfall average occurring in the Neversink watershed (Table 6.2). Variation in the amount of rainfall is random and does not change with time at any of the six rain gauge sites selected for temporal analysis.

The highest average monthly discharge occurs at the stream gauge in the Ashokan watershed. However, the widest range of discharge occurs at the stream gauge in the Cannonsville watershed. In contrast to rainfall, a significant 12-month cyclical pattern occurs in discharge with time at all six stream gauges selected for temporal analysis (Figures D-1, 3, 5, 7, 9 , and 11). The maximum discharge measurements are generally seen during the months of April and May. Since discharge tends to be skewed by large storm events the median values are lower than the mean.

Peaks and depressions in monthly discharge are synchronized with rainfall (Figures D-1, 3, 5, 7, and 11). Cross correlation between discharge and rainfall indicates that discharge has an immediate response to rainfall. The instantaneous affect of rainfall on discharge suggests that flow and precipitation sample sites are sufficiently close together to insure that distance between sites is not impacting the relationship between rainfall and discharge.

Table 6.2. Descriptive Statistics for Monthly Precipitation(1987-1998), Discharge (1987-1998), Total Nitrogen (1990-1998), Total Phosphorus (1990-1998), and Fecal Coliform Bacteria (1987-1998) at Select Surface Water Sample Sites in the Catskill/Delaware Watersheds

Watershed	Variable	Mean	Median	Minimum	Max
Ashokan	Precipitation (mm)	101.09	101.60	10.41	262.38
	Discharge (ft^3/sec)	735.22	517.00	149.47	2,927.60
	Total Nitrogen (mg/L)	0.17	0.17	0.02	0.60
	Total Phosphorus (*u*g/L)	11.44	10.00	6.00	30.00
	Fecal Coliform (CFU/100ml)	28.22	4.00	2.00	210.00
Cannonsville	Precipitation (mm)	93.22	81.79	9.40	224.03
	Discharge (ft^3/sec)	583.06	326.00	27.58	2,756.60
	Total Nitrogen (mg/L)	0.99	0.92	0.43	1.82
	Total Phosphorus (*u*g/L)	31.49	27.00	11.50	86.50
	Fecal Coliform (CFU/100ml)	86.21	20.00	1.50	853.33
Neversink	Precipitation (mm)	112.78	100.58	12.70	259.33
	Discharge (ft^3/sec)	195.08	117.00	19.26	898.77
	Total Nitrogen (mg/L)	0.31	0.29	0.12	0.86
	Total Phosphorus (*u*g/L)	5.61	4.00	2.00	107.00
	Fecal Coliform (CFU/100ml)	8.52	3.00	1.00	78.33
Pepacton	Precipitation (mm)	85.60	84.07	3.05	213.36
	Discharge (ft^3/sec)	54.67	34.00	2.47	257.73
	Total Nitrogen (mg/L)	0.42	0.36	0.13	0.91
	Total Phosphorus (*u*g/L)	10.34	8.00	2.00	127.67
	Fecal Coliform (CFU/100ml)	27.86	7.00	1.00	302.00
Rondout	Precipitation (mm)	97.79	91.69	5.59	271.53
	Discharge (ft^3/sec)	103.80	64.00	8.86	442.77
	Total Nitrogen (mg/L)	0.32	0.30	0.07	0.88
	Total Phosphorus (*u*g/L)	7.06	5.00	2.00	98.00
	Fecal Coliform (CFU/100ml)	23.13	8.00	1.00	404.00
Schoharie	Precipitation (mm)	79.25	76.20	2.03	261.87
	Discharge (ft^3/sec)	49.02	23.00	1.60	296.57
	Total Nitrogen (mg/L)	0.25	0.24	0.03	0.51
	Total Phosphorus (*u*g/L)	13.21	11.00	5.00	36.00
	Fecal Coliform (CFU/100ml)	80.46	16.00	1.00	2,816.25

Total Nitrogen

The Cannonsville sample site has the highest monthly mean, median, minimum, and maximum nitrogen value for the sampling period (Table 6.2). The Pepacton site had the second highest recorded mean, median, and maximum monthly nitrogen value. The average monthly nitrogen values at the other water chemistry sample sites range between 0.17 and 0.32 mg/L. The median values are similar to the means suggesting a fairly evenly distributed set of data.

Trends analyses for four of the six water chemistry sites indicate an overall decrease in monthly nitrogen values since 1990 (Figures D-2, 8, 10, and 12). However, no significant change in time took place at the Ashokan and Neversink sites. The rate of change in nitrogen at these sample sites is slight and remains near the average throughout time.

A 12-month cyclic pattern in monthly total nitrogen is present at all six water chemistry sample sites, with maximum values generally occurring during the winter and spring months (Appendix D-1, 3, 5, 7, 9, and 11). The Ashokan water chemistry sample site was the only site that didn't show an immediate nitrogen concentration response to greater discharge. Nitrogen concentrations at the other five sites respond quickly to changes in discharge, suggesting that nitrogen contributions from the surrounding landscape are expected to increase during high rainfall and snowmelt events.

Total Phosphorus

The Cannonsville water chemistry sample site has the highest mean and median monthly total phosphorus (31.49 *u*g/L) concentrations, which are more than twice those of the other five sites (Table 6.2). The Ashokan and Schoharie site had the second highest average total phosphorus concentration (11.44 and 13.21 *u*g/L). The lowest average monthly phosphorus concentration values are at the Neversink and Rondout sites. Median total phosphorus values are only slightly lower than mean values and the relative ranking of the water chemistry sites is the same as for the means.

Total phosphorus concentration significantly increases over time at the Ashokan and Schoharie sample sites (Figures D-2 and 12). However, the monthly total phosphorus concentrations at the Cannonsville and Neversink watershed sites decrease (Figures D-2 and 6). The remaining water chemistry sample sites did not show any significant trends in time.

Time series analyses indicated no significant cyclic pattern in monthly total phosphorus at any of the six water chemistry sample sites. There is a slight delay in response (1 to 2 months) of phosphorus concentrations to discharge at the Schoharie and Ashokan sites. At the site in the Cannonsville watershed there is an immediate total phosphorus to discharge response (Figure D-1). The other three sites did not show any significant response to discharge. The lack of a consistent response to discharge suggests that monthly total phosphorus concentrations were less tightly coupled to surface water runoff than total nitrogen.

Fecal Coliform Bacteria

Monthly fecal coliform bacteria counts over the sampling period are highest at the Cannonsville site, with the widest range of values at the Schoharie sample site. The average and maximum monthly counts at the Neversink site are more than two times lower than the other five sites. Like discharge data, the fecal coliform bacteria counts peak a few times a year with the majority of the counts being lower. This type of skewed data results in the lower median values seen in Table 6.2.

The only site to show any significant decreasing trend in monthly fecal coliform bacteria counts is the one located in the Schoharie watershed (Figure D-12). A slight negative slope can be seen at the other five sites, however the trend is not significant.

Only the Ashokan and Neversink sample sites have a significant 12-month cyclic pattern (Figures D-3 and 5). However, all the watershed sample sites have higher values of surface water fecal coliform bacteria during the summer months (e.g., July and August) and lower values in winter (November and December). Fecal coliform bacteria have a delayed response (1 to 5 months) to discharge in all but the Schoharie sample site, which did not respond to changes in discharge. These results suggest a potential dilution effect in spring followed by higher reproduction rates in the warm summer months when discharge is low.

Water Quality Summary

Average monthly measurements of fecal coliform bacteria, total nitrogen, and total phosphorus appear to be greatest in the northwest watersheds where human use is higher and least in the southeast watersheds where human use is lower. Point source contributions are influencing downstream sample sites by increasing nutrient concentrations and, to a lesser degree, fecal coliform bacteria counts.

There is an overall decreasing trend in monthly total nitrogen concentrations with time at four of the six water chemistry sample sites selected for temporal analysis. There doesn't appear to be any consistent trend in monthly total phosphorus concentrations. The Cannonsville sample site, which has the highest average nutrient concentrations, is the only site where a decreasing trend over time is observed for both total nitrogen and phosphorus. Fecal coliform bacteria counts are highest in the warm summer months for all sample sites and did not change over time at five of the six sample sites. Only the Schoharie watershed sample site has a significant decreasing trend with time in fecal coliform bacteria.

Total nitrogen concentrations have a strong 12-month cyclical pattern and an instant response to the rate of discharge. Maximum values are often seen during the spring and winter months. The relationship between peak total nitrogen levels and discharge suggests that a greater contribution from surrounding landscape occurs as a result of increases in surface runoff during high rainfall and snowmelt. Total phosphorus and fecal coliform bacteria are less influenced by discharge and surface water runoff than total nitrogen. There is, however, a slight seasonal effect on fecal coliform bacteria with higher values occurring during the summer months (July and August).

Chapter 7. Landscape and Water Relationships

An imprint of landscape condition is collected and transported to the streams via surface runoff. The impact of land cover and use can be seen in the measurements of nutrient concentrations and fecal coliform bacteria counts. The previous chapters present an overview of spatial and temporal aspects of landscape and water parameters. This chapter focuses on relationships between landscape and water quality data within the 32 EPA delineated subwatersheds within the CD watersheds (Figure 2.8). The following subsections discuss regression analyses on the mid-1980s, early 1990s, and late 1990s data, as well as trends across the three time periods.

Regression Models

The riparian metrics are highly correlated with whole watershed metrics and were therefore eliminated from the regression. The forest cover metric was also eliminated, since in the CD watersheds the percent of forest is simply the inverse of the percentage of agriculture and other land uses make up only a small percentage of the area. Of the remaining landscape metrics calculated, multiple regression analyses for total nitrogen, total phosphorus, and fecal coliform bacteria indicated seven that are significant to the final models. In general, metrics in the final model which are an estimate of land use are positively related to water quality measurements (Table 7.1). Therefore, the greater the percentage of land use in the watershed, the more total nitrogen, total phosphorus, and fecal coliform bacteria present in the surface water. Two measurements of land use that are positively related to water quality, and consistently present in all three models, are percent agriculture and percent urban development. The combined effect of these two land uses strongly influences water quality measurements, explaining between 25 and 75% of the model variation (Partial R^2).

By examining the magnitude of the coefficients (ß), an indication of how contributions of a particular land use change between time periods can be determined. For example, the contribution of percent agricultural land use to each of the surface water quality measurements decreases with time from the mid-1980s to the late 1990s. Three land use measurements having for the most part a weaker positive relationship to water quality and explaining only 3 to 46% of the variability are percent barren, percent agriculture on steep slopes, and percent agriculture on erodible soils in the subwatersheds. The inclusion of these metrics in the regression models indicates that land uses which affect the rate of erosion, also affect concentrations of total nitrogen and total phosphorus and counts of fecal coliform bacteria in surface water. The only metric consistently having a negative relationship to measurements of surface water total nitrogen, total phosphorus, and fecal coliform bacteria was stream density. The negative value of the stream density metric most likely reflects the affect of water volume flowing through the streams. As stream density increases, the quantity of water reaching a site increases, diluting nutrient concentrations.

Total Nitrogen

Since total nitrogen measurements did not begin until 1990, the regressions were run for only the early 1990s and late 1990s time periods. The landscape measurements in the nitrogen regression model are strongly related (79%) to surface water total nitrogen concentrations (Table 7.1). Stream density, percent agriculture, and percent urban land use are the dominant landscape metrics in the subwatersheds for both time periods. More than half of the nitrogen variability is explained by the percentage of agriculture land use in the subwatersheds. However, the contribution of agriculture and urban land use, as indicated by the magnitude of their coefficients (ß), decreases with time. The relationship between stream density and total nitrogen concentration indicates that subwatersheds having greater stream mileage per hectare would be expected to have a lower average total nitrogen. The other two land uses which are significant, but explain only small amounts of the variability in the average total nitrogen concentration data, are percent agriculture on erodible soils and percent barren within the subwatersheds. In the early 1990s the percentage of

Table 7.1. Regression Model Estimates (ß), Partial R^2 and Model R^2 for Landscape Metrics and Surface Water Total Nitrogen, Total Phosphorus, and Fecal Coliform Bacteria for mid-1980s, early 1990s, and late 1990s

	Mid-1980s		Early 1990s		Late 1990s	
Regression Models	ß	Partial R^2 (%)	ß	Partial R^2 (%)	ß	Partial R^2 (%)
Log Total Nitrogen						
Stream Density	-	-	0.921	9.6	0.840	7.2
Agriculture	-	-	0.046	59.3	0.039	64.9
Urban	-	-	0.312	6.2	0.256	4.0
Ag. on Erodible Soil	-	-	0.182	4.3	-	-
Barren	-	-	-	-	1.018	3.0
Model R^2				79.4		79.1
Log Total Phosphorous						
Stream Density	-	-	0.574	3.0	0.928	7.0
Agriculture	0.052	50.5	0.047	69.5	0.032	43.1
Urban	-	-	0.233	4.3	0.362	5.4
Ag. on Erodible Soil	-	-	-	-	0.426	7.6
Model R^2		50.5		76.8		63.1
Log Fecal Coliform Bacteria						
Erodible Soil	0.271	16.6	0.206	8.5	0.132	3.3
Urban	0.409	15.9	0.428	10.5	0.389	12.2
Agriculture	0.043	31.0	0.048	48.4	0.046	12.7
Ag. on Slopes >15%	-	-	1.099	5.1	1.494	46.1
Model R^2		63.5		72.5		74.3

agriculture on erodible soil has a weak relationship to total nitrogen and by the late 1990s it is not included as part of the model. The percent of barren in the subwatersheds was only important in the late 1990s nitrogen model. Those subwatersheds having the highest amount of barren land cover have a greater amount of total nitrogen in the stream.

Total Phosphorous

As in the case of average total nitrogen, the percentage of agriculture in the subwatersheds has the strongest relationship to total phosphorus concentrations in all three time periods, explaining 43 to 70% of the variability. In the mid-1980s the percentage of agriculture in the subwatersheds is the only variable with a strong relationship to total phosphorous (51%). However, from mid-1980s to late 1990s the influence of percent total agriculture in the model (ß) decreases and other metrics, such as percent agriculture on erodible soils, stream density, and urban development make a more significant contribution. In the early and late 1990s, stream density, percent agriculture, and urban development in the subwatersheds explain more than a half of the variability in total phosphorus concentration. A fourth metric, percentage of the subwatersheds having agriculture on erodible soil, explains an additional 8% of the variability in the late 1990s model.

Fecal Coliform Bacteria

There are four significant measures of land cover and land use included in the fecal coliform bacteria model. These landscape measurements have a strong relationship to fecal coliform bacteria counts explaining 64 and 74% of the variation in the data. Fecal coliform bacteria is positively related to percent erodible soil, urban development and agriculture within the subwatersheds. Unlike total nitrogen and phosphorous, the influence (ß) of percent urban and percent agricultural in the fecal coliform bacteria model remains the same across time periods. However, the total model variability explained by percent agriculture within the subwatersheds ranges from 13 to 48%. In the early 1990s fecal coliform bacteria responded positively to the percentage of agriculture on slopes greater than 15% within the subwatersheds. The amount of variability percent agriculture on very steep slopes explains increases from 5 to 46% between the early and late 1990s. The overall contribution of this metric, as indicated by the larger coefficient, also increases with time.

Model Application

Using the late 1990s regression models, an estimate was made of potential total nitrogen, phosphorus, and fecal coliform bacteria contributions for all 79 subwatersheds based on the late 1990s land cover (Figure 7.1). The spatial distribution of human use is the most important factor affecting the maps of watershed pollution potential. The highest level of estimated nutrients and fecal coliform bacteria are located within Cannonsville subwatersheds. The West Branch Delaware River subwatershed has the greatest fecal coliform bacteria and total phosphorus measures due to the influence of the percentage of urban and agriculture on slopes >15% within the subwatershed. A similar effect of urban land use on fecal coliform bacteria and phosphorus can be seen in the lower ranking of the Ashokan subwatersheds. The subwatersheds around the Cannonsville Reservoir have the highest nitrogen content as a result of the high percentage of transitional land upstream of the lake.

The accuracy of applying stepwise regression models to other subwatersheds was tested by examining water sample data from four sites not used to develop the models. The observed nitrogen, phosphorus, and fecal coliform bacteria means from the new sites are all within the 95% confidence intervals of predicted values from subwatersheds having comparable landscape metrics (Table 7.2; Figure 7.2).

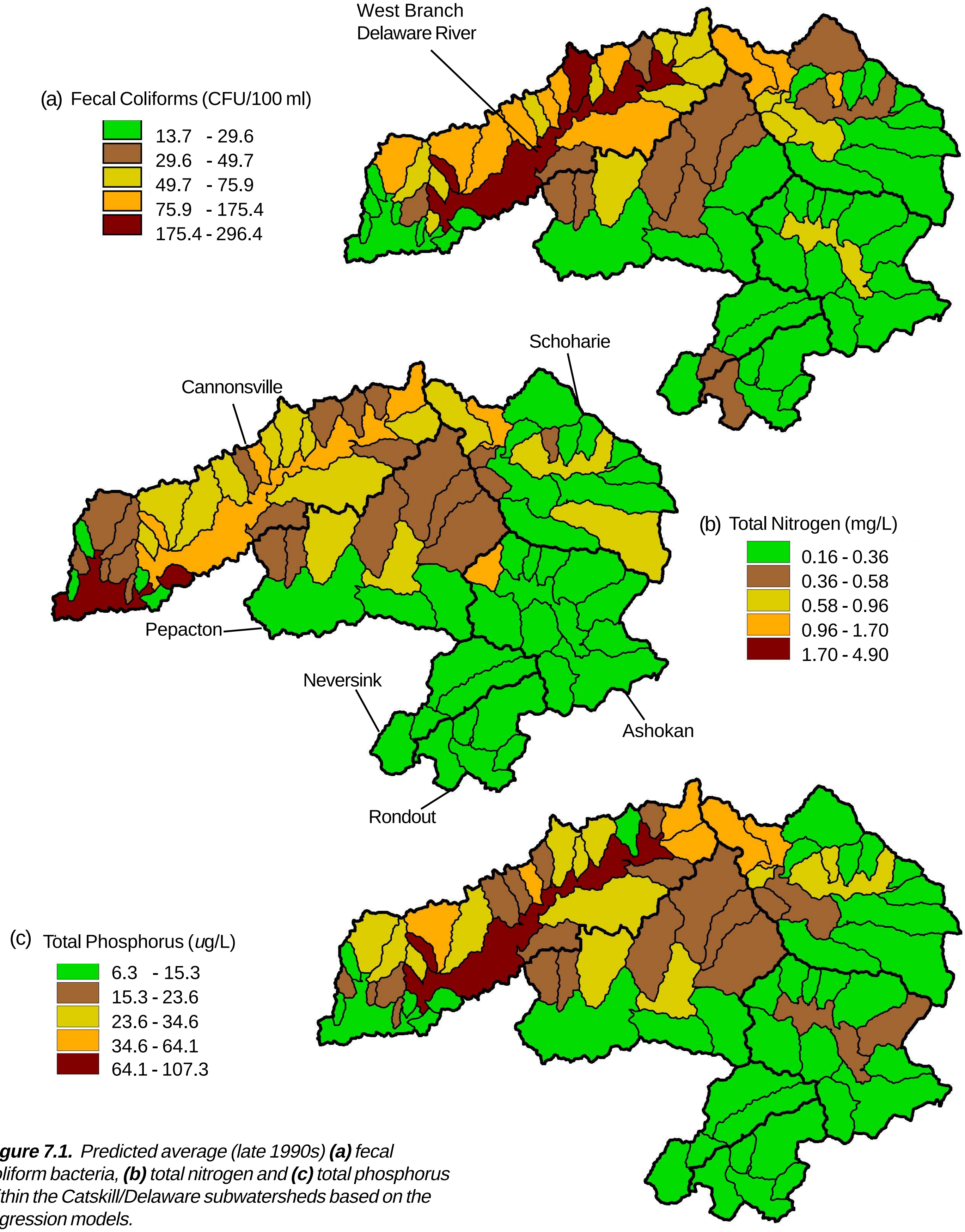

Figure 7.1. *Predicted average (late 1990s)* ***(a)*** *fecal coliform bacteria,* ***(b)*** *total nitrogen and* ***(c)*** *total phosphorus within the Catskill/Delaware subwatersheds based on the regression models.*

Table 7.2. Average Observed Total Nitrogen (TN), Total Phosphorus (TP), and Fecal Coliform Bacteria (FC) from Four Surface Water Sample Sites not used in the Landscape Models Compared with Model Predicted Upper and Lower 95% Confidence Interval (CI) Values from Subwatersheds having Similar Land Cover Percentages

Model Site	Lower 95% CI		Upper 95% CI		New Site	Observed	
	---mg/L---					---mg/L---	
	TN	log(TN)	TN	log(TN)		TN	log(TN)
BRD*	0.13	2.03	0.42	0.87	NWBR**	0.29	1.24
C-38	0.63	0.47	2.23	0.80	CWB	0.92	0.08
E12I	0.16	1.82	0.69	0.37	SCL	0.30	1.20
NK7A	0.13	2.01	0.43	0.85	NEBR	0.25	1.39
	---*u*g/L---					---*u*g/L---	
	TP	log(TP)	TP	log(TP)		TP	log(TP)
BRD	3.82	1.34	22.87	3.13	NWBR	3.91	1.36
C-38	1.27	0.24	104.58	4.65	CWB	34.85	3.55
E12I	6.49	1.87	59.74	4.09	SCL	20.49	3.02
NK7A	1.13	0.12	21.54	3.07	NEBR	3.50	1.25
	---CFU/100 ml---					---CFU/100 ml---	
	FC	log(FC)	FC	log(FC)		FC	log(FC)
BRD	4.10	1.41	47.94	3.87	NWBR	9.48	2.25
C-38	55.70	4.02	796.32	6.68	CWB	347.76	5.85
E12I	4.57	1.52	52.98	3.97	SCL	21.09	3.05
NK7A	4.53	1.51	52.46	3.96	NEBR	8.64	2.16

* The four model sites and their corresponding subwatershed locations can be seen in Figure 3.2.

** The four new sites and their corresponding subwatersheds are NWBR (West Branch Neversink River), CWB(Wright Brook), SCL (Stony Clove Creek), NEBR (East Branch Neversink River); their location within the Catskill/Delaware watersheds can be seen in Figure 2.8.

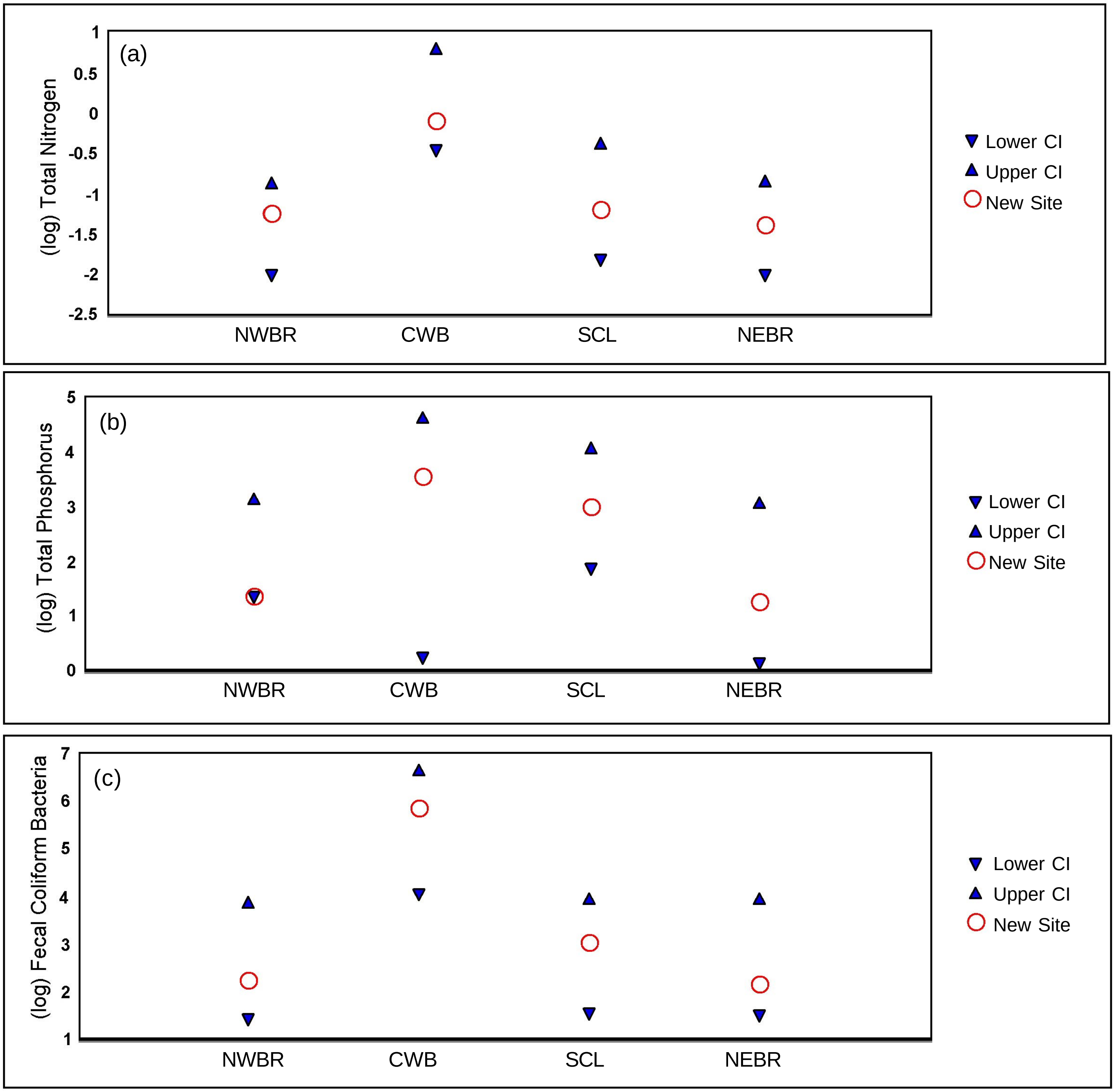

Figure 7.2. *Average observed **(a)** total nitrogen (TN), **(b)** total phosphorus (TP), and **(c)** fecal coliform bacteria (FC) from four surface water sample sites not used in the landscape models. The four new sites and their corresponding subwatersheds are NWBR (West Branch Neversink River), CWB (Wright Brook), SCL (Stony Clove Creek), NEBR (East Branch Neversink River) and their location within the Catskill/Delaware watersheds can be seen in Figure 2.8. The new site values (new site) fall within the 95% confidence intervals (CI) of the predicted model value from subwatersheds having similar land cover percentages.*

Trends in Water and Landscape

The general direction of change in surface water nitrogen, phosphorus, fecal coliform bacteria, and landscape metric percentages with time indicates that those land uses shown to be significant for single-point-in-time comparisons (i.e., the late 1990s image data compared with 1994 -1998 water data) are also important to change through time (mid-1980s to late 1990s) comparisons of water and landscape data.

Decreasing trends through time of percent agriculture land use and increasing trends through time of percent forest cover within the subwatersheds tend to coincide with decreasing total nitrogen concentrations (Table 7.3). In five subwatersheds total nitrogen decreases, while percent agriculture increases and percent forest decreases. However, in three of these subwatersheds, percent agriculture on erodible or sloped soils has decreased, suggesting the possibility of decreased nutrient runoff to streams from these types of farm fields (Table 7.4).

From 1990 to 1998 only four water chemistry sample sites showed a decreasing trend in total phosphorus concentration with time (Table 7.3). In these four subwatersheds there is a decrease in the percentage of total agriculture and an increase in percent forest cover. In all but one of these subwatersheds there was also an increase in riparian forest cover and a decrease in the amount of agriculture on sloped soils. Nine sites had slight increasing trends in total phosphorus which appear to be related to greater percentages of human use, particularly in the riparian buffer.

As seen in the regression analyses, fecal coliform bacteria trends across time appear to be related to changes in human use practices and their location within the subwatersheds. In subwatersheds having significant increases in fecal coliform bacteria levels with time, there are also increasing trends in the percentage of agriculture on erodible soils, slopes >15%, and in the riparian zone within the subwatersheds.

Relationship Summary

Landscape metrics that have a strong positive relationship with concentrations of total nitrogen, total phosphorus, or fecal coliform bacteria are percent urban and total agriculture within the subwatersheds. These two land use measurements also show up as being important in an assessment of trends with time. The smaller contribution of percent agriculture to surface water nutrient concentrations in the late 1990s regression is reflected in the percent forest cover gains and agriculture losses through time. However, in a few subwatersheds changes in land use within the 60- and 120-m riparian buffer zones appear to be more related to trends in water quality.

Stream density was the only landscape measurement included in the regression models with an inverse relationship to all three water quality measurements. As the number of streams per area increases, the amount of water flowing past the sampling point increases resulting in a dilution of surface water nutrients and fecal coliform bacteria. Three other metrics having a slight positive relationship with water quality measurements in the regression models are percent bare ground, percent agriculture on slopes >15%, and percent erodible soils within the subwatersheds. The association between trends in time of landscape percentages and total nutrients concentration data was less obvious then in the regression. However, trends in fecal coliform bacteria and percentage of human use within the watershed show a similar pattern to that seen in the regression models.

Despite decreasing trends at a majority of the water chemistry sample sites in the northwest CD watersheds (Cannonsville, Pepacton, and Schoharie), predicted levels of total nitrogen, total phosphorus, and fecal coliform bacteria within these subwatersheds are higher than those in the southeast as a result of the greater percentage of human use.

Table 7.3. Trends in Total Nitrogen (1990-1998), Total Phosphorus (1990-1998), Fecal Coliform Bacteria (1987-1998), and Landscape Metrics (1987-1998) in 32 Catskill/Delaware Subwatersheds

Watershed	Site	TN	TP	FC	FOR	AGT	ERD	SL5	SL10	SL15	URB	BAR	U_IN
Ashokan	bk	grey	gold	grey	gold	gold	green	green	green	green	grey	grey	gold
Ashokan	bnv	green	gold	green	green	green	gold	green	green	gold	grey	grey	green
Ashokan	brd	green	gold	grey	green	green	gold	green	green	green	gold	grey	green
Ashokan	e1	green	gold	grey	green	green	gold	green	green	gold	gold	grey	green
Ashokan	e10i	green	gold	grey	green	green	gold	gold	gold	green	grey	grey	green
Ashokan	e12i	grey	grey	grey	gold	gold	green	gold	gold	gold	grey	grey	gold
Ashokan	lbk *	grey	gold	grey	green	green	gold	green	green	green	gold	grey	green
Ashokan	wdl	green	gold	grey	gold	gold	green	gold	gold	gold	gold	grey	gold
Cannonsville	c-38	grey	grey	grey	green	green	green	green	green	green	gold	grey	green
Cannonsville	c-7 *	grey	grey	grey	green	green	gold	green	green	green	grey	grey	green
Cannonsville	c-79	green	grey	grey	green	green	gold	green	green	green	grey	gold	green
Cannonsville	c-8	grey	grey	gold	green	green	gold	green	green	green	grey	grey	green
Cannonsville	wdhoa	grey	grey	grey	green	green	gold	green	green	green	gold	gold	green
Neversink	nk6	green	grey	grey	gold	gold	green	green	green	gold	grey	grey	gold
Neversink	nk7a *	grey	green	grey	green	green	green	gold	gold	gold	grey	green	green
Pepacton	p13	green	grey	gold	green	green	gold	green	green	green	gold	green	green
Pepacton	p21	green	green	grey	green	green	gold	green	green	green	gold	gold	green
Pepacton	p50	green	grey	grey	gold	gold	gold	gold	gold	gold	gold	grey	gold
Pepacton	p52	green	grey	grey	green	green	gold	green	green	green	grey	grey	green
Pepacton	p60 *	green	grey	grey	gold	gold	gold	gold	gold	gold	grey	grey	gold
Pepacton	p7	green	grey	grey	green	green	gold	green	green	green	grey	grey	green
Pepacton	p8	green	grey	grey	green	green	gold	green	green	green	grey	grey	green
Rondout	rd1	green	green	grey	green	green	gold	green	green	green	gold	grey	green
Rondout	rd4	grey	green	grey	green	green	gold	green	green	green	gold	grey	green
Rondout	rdoa *	green	grey	grey	green	green	gold	green	green	green	gold	gold	green
Rondout	rga	green	grey	grey	green	green	gold	green	green	green	grey	grey	green
Rondout	rk	green	grey	gold	green	green	gold	green	green	gold	gold	gold	green
Schoharie	fb4	green	grey	grey	green	green	gold	green	green	gold	grey	grey	green
Schoharie	s1	green	gold	green	gold	gold	gold	green	green	green	grey	grey	green
Schoharie	s10	grey	grey	green	green	green	gold	green	green	green	gold	gold	green
Schoharie	s6i	green	gold	green	green	green	gold	green	green	green	gold	gold	green
Schoharie	s7i *	green	grey	green	green	green	gold	green	green	green	grey	grey	green

* = sites also used in time series cross-correlation analysis with discharge and precipitiation; green = positive change (*i.e.*, increasing forest cover, decreasing land use, decreasing nutrient concentrations, and decreasing fecal coliform bacteria counts), gold = negative (*i.e.,* decreasing forest cover, increasing land use, increasing nutrient concentrations, and increasing fecal coliform bacteria counts), grey = no change; TN =Total Nitrogen; TP=Total Phosphorus; FC= Fecal Coliform Bacteria; FOR=Forest; AGT=Agriculture; ERD=Agriculture on Erodible Soils; SL5, SL10, and SL15=Agriculture on 5%, 10%, and 15% slope; URB=Urban; BAR=Barren; U_IN= U-Index.

Table 7.4. Trends in Total Nitrogen (1990-1998), Total Phosphorus (1990-1998), Fecal Coliform Bacteria (1987-1998), and Riparian Landscape Metrics (1987-1998) in 32 Catskill/Delaware Subwatersheds

Watershed	Site	TN	TP	FC	FOR 60m	AGT 60m	URB 60m	BAR 60m	U_IN 60m	FOR 120m	AGT 120m	URB 120m	BAR 120m	U_IN 120m
Ashokan	bk	grey	gold	grey	gold	gold	grey	grey	gold	gold	gold	gold	grey	gold
Ashokan	bnv	green	gold	green	gold	gold	gold	grey	gold	gold	gold	gold	grey	gold
Ashokan	brd	green	gold	grey	green	green	gold	grey	green	gold	gold	gold	grey	gold
Ashokan	e1	green	gold	grey	gold	gold	gold	grey	gold	gold	gold	grey	grey	gold
Ashokan	e10i	green	gold	grey	green	green	gold	grey	green	green	green	gold	grey	green
Ashokan	e12i	grey	grey	grey	green	gold	grey	grey	green	gold	gold	grey	grey	gold
Ashokan	lbk *	grey	gold	grey	green	green	gold	grey	green	green	green	gold	grey	green
Ashokan	wdl	green	gold	grey	gold	gold	gold	grey	gold	gold	gold	gold	grey	gold
Cannonsville	c-38	grey	grey	grey	gold	gold	gold	grey	gold	green	green	gold	grey	green
Cannonsville	c-7 *	grey	grey	grey	green	gold	gold	grey	gold	gold	gold	gold	grey	gold
Cannonsville	c-79	green	grey	grey	gold	gold	grey	green	gold	green	green	grey	gold	green
Cannonsville	c-8	grey	grey	gold	green	green	grey	grey	green	green	green	gold	grey	green
Cannonsville	wdhoa	grey	grey	grey	green	green	gold	grey	green	green	green	gold	grey	green
Neversink	nk6	green	grey	grey	green	green	gold	grey	green	green	green	gold	grey	green
Neversink	nk7a *	grey	green	grey	green	green	grey	gold	green	green	green	gold	gold	green
Pepacton	p13	green	grey	gold	gold	gold	gold	gold	gold	gold	gold	gold	gold	gold
Pepacton	p21	green	green	grey	gold	gold	grey	grey	gold	gold	gold	grey	grey	gold
Pepacton	p50	green	grey	grey	gold	gold	grey	grey	gold	gold	gold	grey	grey	gold
Pepacton	p52	green	grey	grey	gold	gold	gold	grey	gold	gold	gold	gold	grey	gold
Pepacton	p60 *	green	grey	grey	gold	gold	grey	grey	gold	gold	gold	grey	grey	gold
Pepacton	p7	green	grey	grey	gold	gold	gold	grey	gold	gold	gold	gold	grey	gold
Pepacton	p8	green	grey	grey	gold	gold	grey	grey	gold	gold	gold	grey	grey	gold
Rondout	rd1	green	green	grey	gold	gold	grey	grey	gold	green	green	grey	grey	green
Rondout	rd4	grey	green	grey	green	green	gold	grey	green	green	green	gold	grey	green
Rondout	rdoa *	green	grey	grey	gold	gold	grey	grey	gold	gold	gold	grey	grey	gold
Rondout	rga	green	grey	grey	gold	gold	grey	grey	gold	gold	gold	gold	grey	gold
Rondout	rk	green	grey	gold	gold	gold	grey	green	gold	gold	gold	gold	gold	gold
Schoharie	fb4	green	grey	grey	gold	gold	grey	grey	gold	green	green	grey	grey	green
Schoharie	s1	green	gold	green	gold	gold	grey	grey	gold	gold	gold	gold	grey	gold
Schoharie	s10	grey	grey	green	green	green	gold	gold	green	green	green	gold	green	green
Schoharie	s6i	green	gold	green	green	green	grey	gold	green	green	green	grey	green	green
Schoharie	s7i *	green	grey	green	green	green	grey	grey	green	green	green	gold	grey	green

* = sites also used in time series cross-correlation analysis with discharge and precipitiation; green = positive change (*i.e.*, increasing forest cover, decreasing land use, decreasing nutrient concentrations, and decreasing fecal coliform bacteria counts), gold = negative (*i.e.,* decreasing forest cover, increasing land use, increasing nutrient concentrations, and increasing fecal coliform bacteria counts), grey = no change; TN =Total Nitrogen; TP=Total Phosphorus; FC= Fecal Coliform Bacteria; FOR=Forest; AGT=Agriculture; URB=Urban; BAR=Barren; U_IN= U-Index.

Chapter 8. Conclusion

This final chapter provides a synopsis of the landscape and water quality results. A summary of land use metric percentages and trends and how they are related to water quality is presented. The summary section is followed by a set of recommendations that have been developed based on the results from this assessment and with regard to current and proposed future management practices.

Summary

Region 2 hydrologic units surrounding the CD watersheds are in excellent environmental condition. The forest cover in these HUCs is high and land use is minimal (30% total agriculture, 15% urban; Figures 4.2 and 4.8). In the smaller CD subwatersheds agriculture land use percentages range from 0 to 35% (Figure 4.3). However, due to low population growth rates, percentages of urban development in the CD subwatersheds only reach 3.7%. Percentages of riparian land use at the regional scale are slightly lower than in the CD watersheds and have a smaller range than the subwatersheds. Agriculture and urban land use make up from about 0 to 47% of the 60-m riparian buffer in the CD subwatersheds (Table 4.2).

Water quality in the streams of the CD watersheds remains high with only a few cases of exceedance of federal surface water requirements. However, despite the continued high quality of water in the streams of CD watersheds, point source (i.e., treatment plants) and nonpoint source (near-stream land use) impacts to stream condition remain a concern for New York City. A recent mid-course report by the EPA recommended that the city upgrade 34 sewage treatment plants and acquire more "crucial" land during the years remaining under the FAD (EPA, 2000).

In addition to inputs from waste treatment plant facilities and land use, impacts to the CD water supply watershed streams are also related to terrain influences on runoff. The steep slopes result in very rapid water flow across the landscape and into the streams. Therefore, nitrogen in the surrounding landscape will be carried quickly in runoff to streams either in solution or transported in the sediment. Stream total phosphorus concentrations do not appear to respond to rainfall-induced increases in discharge as rapidly as nitrogen. This delay in response to rainfall events suggests that base flow and ground water play an important role in total phosphorus contributions to the streams. Fecal coliform bacteria levels in the streams do not respond to increases in discharge from rainfall, but instead peak during the warm summer months when water temperature is high, flow is low, and recreational and animal usage is the greatest.

Much of the past research has investigated the relationships between landscape and water quality by examining water quality response to a degradation in ecological condition. In this study we have demonstrated that the same linkage between landscape and water quality holds true under improving ecological conditions. In the CD watersheds, releasing agricultural fields from farming has returned a small percentage (2%) of land to secondary growth forest. With the exception of a few subwatersheds the increase in forest cover took place in the northwest. Since the majority of the agriculture in the study area is located within 240 m of a stream, much of the 2% change is located within the riparian buffer.

Pepacton Reservoir, Pepacton watershed.

Agriculture land use is the major contributor to concentrations of total nitrogen and total phosphorus in the streams, but its influence is reduced as percentages within the watershed decrease. The effect of decreasing agriculture and increasing forest cover percentages is evident in the lower agriculture contribution to surface water nutrient concentration seen in the late 1990s regression analyses and in the decreasing trends in total nitrogen across time at many of the water chemistry sample sites. In subwatersheds where there are no trends in agricultural land use or forest cover, surface water nutrient concentrations remain unchanged across time.

Changes in total agriculture land use and forest cover appear to have less influence on fecal coliform bacteria trends. Fecal coliform bacteria are more affected by percentage of agriculture land use on slopes greater than 15% in the watershed. The influence of this type of land use on fecal coliform bacteria increases as total agriculture percentages decrease in the watershed. These results suggest that nitrogen and phosphorus concentrations are strongly related to land use proportions, while fecal coliform bacteria counts are related more to land use location within the watershed.

In general, application of the late 1990s regression models demonstrated that the western watersheds, which have the greatest percentage of human use, would be expected to have higher stream total nitrogen, total phosphorus, and fecal coliform bacteria counts. A number of subwatersheds stand out as being at risk from single or multiple land uses (Figure 8.1). The landscape conditions in these subwatersheds have a high potential for impacts to water quality.

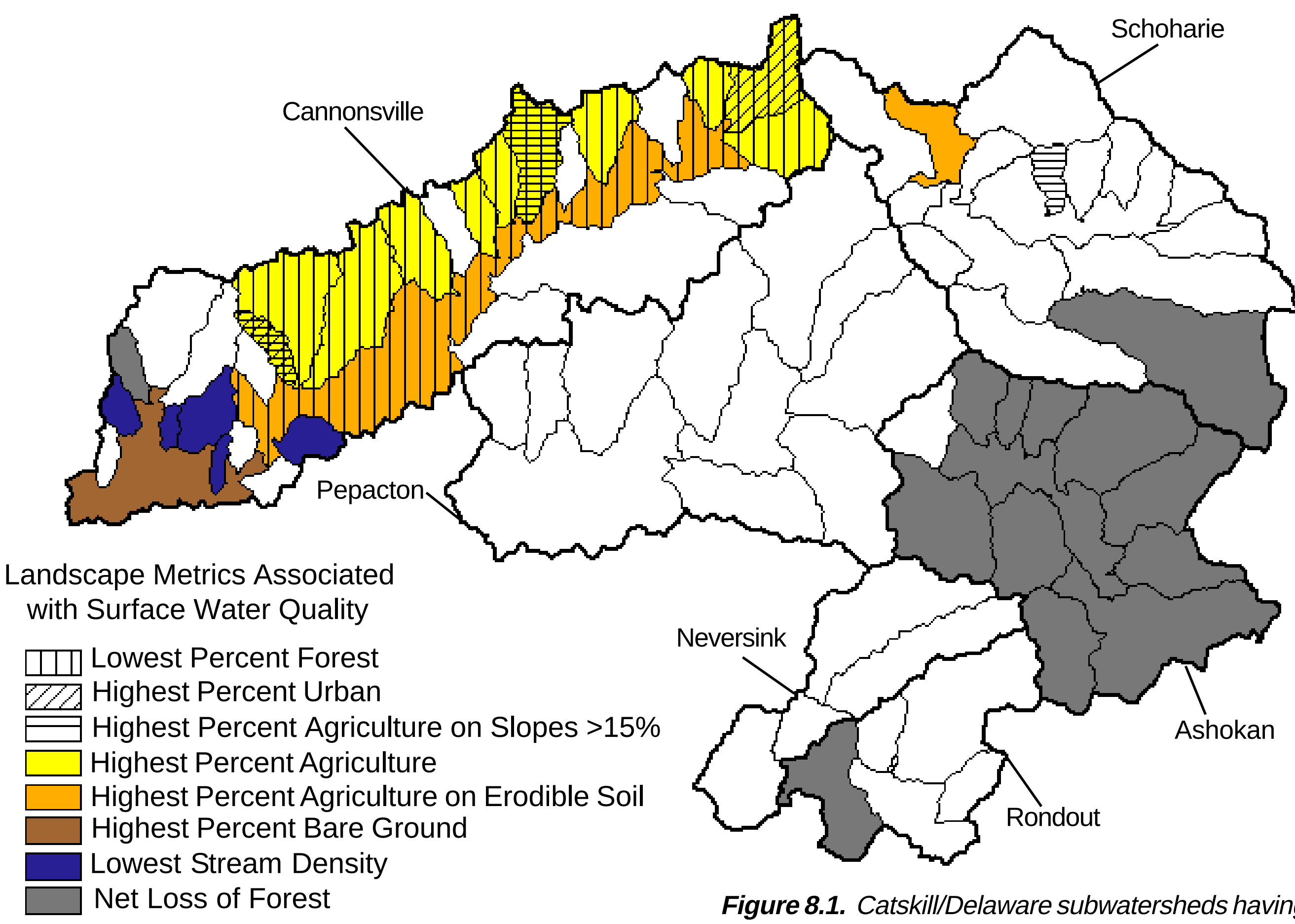

Figure 8.1. *Catskill/Delaware subwatersheds having landscape metrics associated with water quality degredation.*

Recommendations

Agriculture is the greatest human use of the land occurring in the CD watersheds and one of the most likely factors affecting water quality. Agricultural land use can result in nonpoint pollution via runoff from barnyards, pastures, and crop fields. Agricultural practices can also lead to stream sedimentation by increasing erosion rates. In response to potential risks to the water supply, the Watershed Agriculture Council began promoting whole farm planning. The planning process is voluntary and implements farm-specific best management practices (BMPs). Since farming is important to the economic viability of the area, continued education and enrollment of the land owners in these types of programs offers an attractive way of reducing nonpoint source pollution to surface waters (Addiscott, 1997). However, results from this study suggest that in addition to farm-specific criteria, the Watershed Agriculture Council may also want to consider gearing its programs toward subwatershed specific needs.

Targeting the farms in an at risk subwatershed, may achieve greater overall pollution reduction to the water supply than random areawide enrollment. For example, the subwatersheds of Third Brook and Elk Creek have a high potential for pollution by nitrogen, phosphorus, and fecal coliform bacteria (Figure 7.1). Outreach in these subwatersheds might want to focus on farms with cropping or pasture taking place on steep slopes or erodible soils. Subwatersheds having a low stream density and in close proximity to a reservoir are more likely to contribute nutrients to the reservoirs. Encouraging farmers within this type of subwatershed to preserve wetland and riparian areas through enrollment in wetland reserve and forest easement programs would help buffer streams and reservoirs from nutrient runoff impacts.

While comprising a much smaller percentage of the CD watersheds than agriculture, urban land use remains one of the key components in determining water quality. The current regulations proposed in the MOA for improving exiting treatment plant performance and restricting new waste treatment plants should help reduce point source inputs in the CD watersheds. However, in addition to waste treatment plant inputs, high percentages of impervious surfaces and agriculture have increased discharge rates, sedimentation, and pollutant runoff in a number of the subwatersheds. Only after the current impacts are alleviated in the at-risk subwatersheds can planning for future offset needs be implemented.

An urban planning program that helps landowners develop BMPs for golf courses, parks, backyard gardens, and lawns could help address some of the current impacts. Offsetting future land uses will most likely require increasing the percentage of forest cover, particularly in the riparian buffer. One way to help promote more riparian forest is by increasing the setback requirements for human use from 30 to 60 or 120 m. Another recommendation would be for the Watershed Agriculture Council's Forestry Program to set up a model forest in the riparian buffer of one of the more urbanized areas. The study area would provide an excellent opportunity for education outreach and green space for the nearby community.

Balancing water quality protection and economic growth requires a great deal of thought, coordination, and cooperation. Targeting watersheds and farms for possible BMP implementation depends on which pollutant is of highest priority to the community. Numerous groups depend on the water from the CD watersheds for drinking, irrigation, recreational use, and livestock production. As demonstrated by the results of this study, human use of the landscape has direct consequences on water quality resources. Even changes as small as 2% can have an effect. Whether or not the change is beneficial to the quality of water in the CD water supply rests on the choices made by those living in the area. Economic and social incentives which encourage forestry management, and agriculture and urban planning for specific subwatershed needs within the CD watersheds can help facilitate the continued success of long-term watershed management plans set forth in the MOA.