SUBURBAN STORMWATER RUNOFF: THE SOPE CREEK CASE STUDY

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Abstract. Stormwater runoff in a suburban basin is compared to stormwater runoff in a forested reference basin of comparable size. Elevated loads of nitrate, nitrite, ammonia, suspended sediment, dissolved solid load, two herbicides and a pesticide are seen in the suburban basin. Management strategies must focus on comprehensive land use controls to mitigate effects of storm runoff on water quality.

INTRODUCTION

Aquatic ecosystems within urban landscapes are severely impacted components of a disturbed system and urban streams in Georgia are among the most degraded aquatic systems in the state (Mikalsen, 1993). Urban and suburban streams face continuous inputs from land use practices such as land clearing, construction, paving, lawn and golf course maintenance, and industrial activity. Stormwater runoff is a major contributor to water quality degradation (USEPA, 1983); elevated peak flows resulting from storms that are intensified by the large percentage of impervious surface in urban areas carry toxics, trace metals, nutrients, and sediment into the water. The high volume of runoff has the potential to markedly increase the export of contaminants from developed areas which may degrade aquatic habitats and resident biota of urban streams.

With respect to management, stormwater is regulated as a point source although pollutants originate from a variety of diffuse sources before being conveyed to a discrete drainage. The 1987 Clean Water Act reauthorization directed the U.S. Environmental Protection Agency (USEPA) to regulate stormwater discharge under the National Pollutant Discharge Elimination System (NPDES) program. In 1990, USEPA promulgated regulations requiring stormwater discharge permits for industrial sites and large municipalities (>250,000; Georgia Environmental Protection Division, 1992).

Toward this goal, the five county (Cobb, DeKalb, Clayton, Fulton, Gwinnett) metropolitan area, through the coordination of the Atlanta Regional Commission (ARC) Stormwater Management Task Force, instigated a regional stormwater characterization plan. The plan is designed to achieve two goals: 1) fulfill NPDES regulations that require the monitoring of outfalls representative of certain land use types for 120 pollutants following three storm events; and 2) establish long term monitoring to evaluate the trend of stormwater quality and the effectiveness of stormwater control methods. Currently, 27 sites in the metropolitan Atlanta area are monitored by local governments to accomplish these goals (Thomas, 1993).

This paper examines some of the environmental problems associated with the Sope Creek basin, a basin characterized by suburban land use. Six of the ARC stormwater monitoring sites are within this basin. Comparison to Snake Creek, a basin representing forested land use, is made to indicate the relative quality of suburban stormwater. Data from the National Water Quality Assessment (NAWQA) program of the U.S. Geological Survey (USGS) is used to assess the effects of suburban land use on water quality during storm and baseflow conditions, and then to suggest approaches for current stormwater management policy.

SITE DESCRIPTION

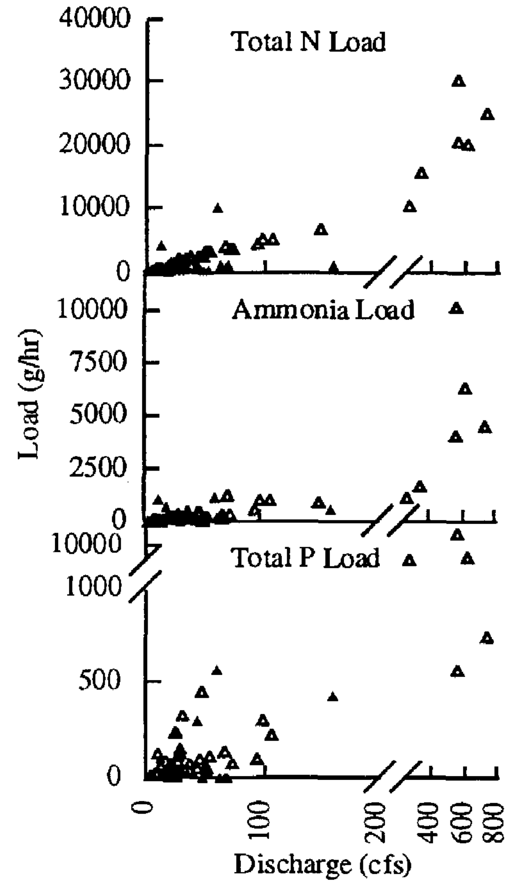
Sope Creek Basin drains a 79.8 km^2 watershed north of Atlanta in Cobb County. The majority of land use in Sope Creek watershed consists of suburban housing (67.6%) followed by small commercial developments (7.15%) (Table 1). This impacted basin also encompasses the city of Marietta (population of approximately 45,000) where the creek drains a more intensely developed area including industrial parks and shopping malls. Thirty percent of the land surface in the basin is impervious surface; this contributes to quick peak flows and a spiked hydrograph during storms.

Snake Creek drains a 91 km^2 forested watershed in Carroll County west of Atlanta and serves as a reference watershed for the NAWQA study. Land use in the Snake Creek watershed is primarily forest (83%) with some crop and pastureland (13%). In contrast to the Sope Creek basin, Snake Creek has a drainage with only 0.26% impervious surface (Table1). Both basins are in the Piedmont physiographic region and are similar in size. Both streams are also fourth order tributaries to the Chattahoochee River.

Table 1 - Land Use in the Sope Creek and Snake Creek Basins
[LDR, low density single-family residential; MDR, medium density single-family residential; CS, commercial and services; ICC, industrial and commercial complexes; GC, golf courses; CP, cropland and pasture; F, forested; ---, negligible]

	Sope BFS	Snake BFS
Stream Order	4	4
Drainage Area (km^2)	79.8	91.9
Impervious Surface (%)	30	0.26
Landuse[1](%)		
LDR	0.69	---
MDR	68.85	0.80
CS	7.15	---
ICC	2.28	---
GC	1.34	---
CP	3.88	15.38
F	12.28	83.31

[1]From Atlanta Regional Commission, 1990.



Figures 1-3. Nutrient loads in Sope (Δ) and Snake (▲) Creek.

METHODS

As basic fixed station (BFS) sites in the NAWQA program, Sope Creek and Snake Creek are intensively sampled by the USGS to establish trends in water quality. Water is analyzed for nutrient chemistry, major ions, and pesticides during baseflow and storm flow. NAWQA's extensive water chemistry data are used to characterize the dynamics of water quality and can be used to infer problems associated with suburban stormwater runoff.

DATA RESULTS

Nutrients

The preliminary data summarized in this paper were collected during the time period from March of 1993 to October of 1994. During this time period, more data from high flow conditions were available for Sope Creek than for Snake Creek, thus limiting comparability. Ongoing collection of water samples continues as part of the NAWQA program. NO_2-N and NO_3-N at Sope ranged from 0.1 - 0.7 mg/L, all values well below the EPA maximum contaminant levels (MCL) for the protection of human health. Ammonia ranged between 0.0 - 0.2 mg/L and phosphorus ranged between 0.01- 0.28 mg/L.

At Snake Creek NO_2-N and NO_3-N concentrations ranged from 0.1 - 0.3 mg/L while NH_4 ranged between 0.01 - 0.1 mg/L. Total phosphorus ranged from 0.01 - 0.08 mg/L.

In a storm, NO_2-N and NO_3-N load (defined as discharge x concentration) rose as high as 30,000 g/h (Figure 1) with a strong correlation (r^2=0.94) between discharge and total N load. In the forested watershed N load reached only 5,000 g/h (Figure 1), however during the time period represented by the data, few storm samples were available for Snake Creek.

NH_4-N in Sope Creek also showed a positive relationship with discharge. Total NH_4 load had values of up to 10,000 g/h at higher discharges. A sixteen fold difference in NH_4 load between the suburban basin and the forested basin can be seen at high discharges (Figure 2).

Phosphorus also showed a positive correlation with discharge although the difference between total P load in Sope and Snake Creek was less than differences in nitrogen load (Figure 3).

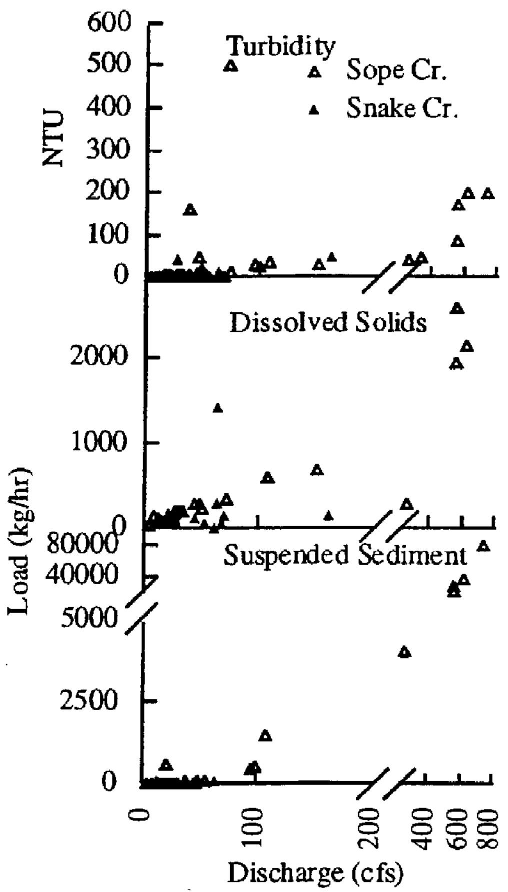
Dissolved Oxygen

Dissolved oxygen (DO) at Sope Creek ranged from 6.3 to 12.4 mg/L while DO levels at Snake Creek ranged from 7.8 mg/L to 13.8 mg/L. DO varied with season and temperature and dipped to its lowest point in the Summer at both sites.

DO is temperature dependent and the values found in Sope and Snake Creek corresponded to seasonal rather than stormwater related discharge influences.

Sediment

In Georgia, stream sediment load is currently measured by nephlemetric turbidity units (NTU) although there is debate concerning the accuracy of this measure. Total suspended solids is also used. In Sope Creek turbidity measurements ranged from 1.5 - 200.0 NTU and increased as a function of discharge, although not strongly. Snake Creek followed a similar pattern and was slightly less turbid than Sope Creek (Figure 4). Total dissolved solids correlated strongly with discharge (r^2=0.91) in Sope Creek while dissolved solid load in Snake Creek was not affected by storm discharge (Figure 5). Suspended sediment during storms in Sope Creek were higher than in Snake Creek and was well correlated with increased discharge (r^2=0.83) (Figure 6).



Figures 4-6. Sediment in Sope (Δ) and Snake (▲) Creek.

Pesticides

The herbicides atrazine and simazine and the insecticide diazinon were detected throughout the year in water samples from Sope Creek. Highest concentrations of atrazine were found in the winter associated with winter annual weed control (Figure 7). Median concentrations for simazine exceeded the MCL on one occasion, but the average median concentration was less than three percent of the MCL. Atrazine and diazinon were found at average median concentrations of one percent of the MCL (Hippe et al., 1994). Herbicide and insecticide values were high compared to the reference site where these toxic substances rarely detected (Figures 8-10). Storm events increased pesticide and insecticide loading in Sope Creek.

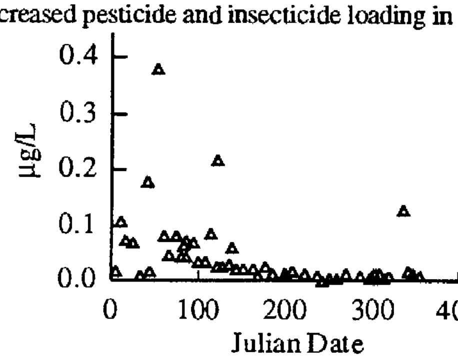
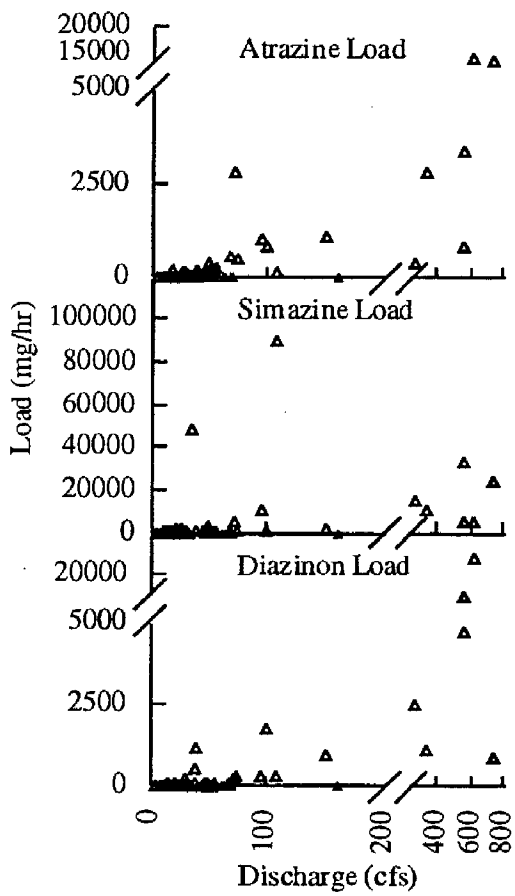


Figure 7. Atrazine concentration in Sope Creek.



Figures 8-10. Pesticide loads in Sope (Δ) and Snake(▲) Creek.

DATA ANALYSIS

High nitrogen loads seen in Sope Creek are probably an indicator of fertilizer use on extensively manicured lawns within the basin. Nitrate is easily carried to streams with storm runoff resulting in the high loading associated with storms. Ammonia loads are lower than nitrate and nitrite loads and this is typical due to nitrification in oxygenated streams. Nonetheless, ammonia values are extremely high compared to the reference stream. Total phosphorus loading is influenced by storm events and likely originates from fertilizers as the sale of phosphorus containing detergents has been banned in Georgia. Phosphorus levels in the developed basin are only slightly higher than the forested basin.

Dissolved oxygen in the Sope Creek basin is within the normal range and is comparable to the values found in Snake Creek. This could be due to low biochemical oxygen demand (BOD) in Sope Creek. Organic load is likely to be low as there are no combined sewer overflows (CSOs) or wastewater treatment plants in the basin. Dissolved oxygen levels may also be maintained by riffles which facilitate oxygenation.

Preliminary data indicate that turbidity, dissolved solids, and suspended sediment load in Sope Creek all increased with discharge and extremely high values were seen at discharges of 500 - 700 cubic feet per second (CFS). Dissolved solids and suspended sediment in Sope Creek were significantly higher than values in Snake Creek during storms while turbidity differences were minor. This data will be supplemented by sampling of future storms in Snake Creek.

Evidence of sedimentation is obvious in depositional areas in Sope Creek. Road building, construction, and streambank erosion are the principal causes of erosion in urban areas. In addition to the sediment delivery itself, nutrients such as phosphorus and some metals adsorb to particles and are thus transported to the stream (Paterson et al., 1993).

Herbicide and insecticide levels were not found at levels determined harmful for human health, however the median concentration of diazinon was determined to exceed the established guidelines for aquatic life (Hippe et al., 1994). Simazine was found to exceed the human MCL on one occasion. Both simazine and atrazine are triazine herbicides which have been shown to alter algal photosynthesis (e.g. Millie et al., 1994). The consistent presence of herbicides in the basin could potentially alter stream ecosystem structure and function by changing patterns of algal community structure, biomass, and primary productivity.

DISCUSSION

Stormwater management is a complex problem in developed areas. In less disturbed catchments water can infiltrate through the soil or filter through wetlands or riparian vegetation. Storm runoff through drainage systems in developed areas effectively bypass the natural pollutant filtration capacity of the landscape. Although stormwater in developed areas has become a point source problem and must be regulated as such, stormwater pollutants originate from a multitude of sources (i.e. herbicide runoff and sediment loading from innumerable individual sites).

Understanding the ultimate effect of these different high impact land use practices must be an integral part of any stormwater quality improvement effort. Towards this goal, further sampling should also focus on biological indicators such as fish, macroinvertebrates and algae, as well as ecosystem function measures such as productivity and nutrient cycling all of which integrate pollutant effects over time and space to reflect the cumulative impacts of urbanization. Biomonitors are already used successfully by volunteer groups (i.e. Adopt-a-Stream) and increasingly in rapid bioassessment protocols (e.g. Plafkin et al., 1989).

During discussion of the 1987 Water Quality Act (amendments to the Clean Water Act), Congress recognized the need for municipalities to focus on land use controls as part of comprehensive stormwater quality management. "[G]iven the materials management problems associated with end-of-the pipe controls, management programs that are directed at pollutant sources are often more practical than relying solely on end-of-the-pipe controls." New regulations directed municipalities to reduce pollutants through management strategies to the "maximum extent possible" (Federal Register, 1990).

It is clear from the existing data that certain pollutants are present in unnaturally high levels in the suburban, Sope Creek basin, and that some of these pollutants are carried directly to the stream during storms. While analysis of the source of these pollutants is necessary, comprehensive management must work to reduce storm runoff by mitigating land use practices that contribute both to water quality degradation and to sudden and extreme increases in water quantity. Control options for stormwater runoff include detention, retention, infiltration, vegetated drainages, and the maintenance of natural features such as wetlands and flood plains, all designed to reduce or eliminate peak storm flows that flush pollutants into receiving water bodies (Schueler, 1987). Limiting the amount of runoff can be achieved by minimizing the amount of impervious surfaces laid down during development or by using porous pavement (Ferguson, 1994). Reducing impervious surfaces can be achieved through property tax/zoning incentives, cluster development, and impervious surface ordinances (ARC, 1993).

Integration of regulations relating to stormwater could also facilitate a comprehensive approach to stormwater management. While stormwater is specifically regulated through the NPDES program, stormwater quality in Georgia is also regulated simultaneously through the Water Quality Control Act, the Erosion and Sedimentation Control Act, and the Metropolitan River Protection Act. Sediment delivery, for example, is a major storm associated contaminant and should be addressed in stormwater regulation. The obvious overlap and gaps between these policies reflects a lack of integrated planning that is indicative of water resources management throughout the country (Kundell and Hatcher, 1985).

Given this initial data on the high stormwater nutrient, sediment, and pesticide loads in Sope Creek, we can begin to target the solutions to these problems. The challenge lies in developing policies which minimize our impact on the natural environment and strive to protect biological integrity - the processes and native elements of an ecosystem that allow it to function as a whole (Angermeier and Karr, 1994).

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