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Stormwater Pollution Source Areas Isolated in Marquette, Michigan

Much of our knowledge about the source of stormwater pollutants in urban watersheds is confined to broad land use categories, such as residential, commercial, or industrial. Often, engineers need much more detailed information on the individual source areas of pollutants to design more effective stormwater management practices or to craft better pollution prevention plans. For example, residential land use is actually a mosaic of streets, driveways, rooftops and lawns. Each of these individual source areas can contribute vastly different runoff volumes or pollutant concentrations. Consequently, engineers are interested in discovering precisely which source areas in the urban landscape contribute the bulk of the pollutant loads measured at the end of the stormwater pipe, particularly for those pollutants that are potentially toxic.

Urban source area monitoring methods were first pioneered by Roger Bannerman and his colleagues at the Wisconsin DNR (see article 7). They typically involve the installation of very small and specialized sampling devices that collect stormwater runoff from a few thousand square feet of each source area. Several hundred samples are collected, and then geometric mean concentrations are computed. The first major source area monitoring study was conducted in a subwatershed located in Madison, Wisconsin (Bannerman *et al*., 1993).

A second major source area monitoring study was recently completed in Marquette, Michigan by Jeff Steuer and his colleagues (1997). They investigated a 289 acre subwatershed that drains to Lake Superior. The subwatershed is primarily residential with most of the development built 50 to 100 years ago (Table 1). Although the subwatershed had 37% impervious cover, its sandy soils generated relatively little surface runoff (runoff coefficient of 0.14 during the course of the study).

Steuer and his team deployed 34 different source area monitoring devices in the subwatershed and collected more than 550 source samples during 12 storm events. The source area monitoring was performed during the growing season (i.e., snowmelt and winter runoff were not sampled). Eight key source areas were targeted in the sampling effort: commercial parking lots; low, medium and high traffic streets; commercial and residential rooftops; residential driveways and lawns. More than 40 different pollutants were measured in the study, including sediment, nutrients, total and dissolved metals and a wide range of polycyclic aromatic hydrocarbons (PAHs). The study team also sampled pollutant levels at the bottom of the entire subwatershed. This enabled them to calibrate the Source Load and Management Model (SLAMM). The SLAMM model simulates subwatershed hydrology and source area pollutant concentrations to relate the how pollutant loads from individual source areas compared to the subwatershed as a whole (Pitt and Voorhees, 1989).

Table 1: A Profile of the Marquette, a Michigan Subwatershed

Drainage Area	289 acres
Land Use	
Residential	55 %
Open Space	29 %
Commercial	9 %
Institutional	7 %
Pervious Area	63 %
Impervious Area	37 %
Soil Type	Sandy, HSG “A”
Runoff Coefficient	0.14
Age of Development	50 to 100 years
Average Annual Precipitation	31.9 inches
Total Rainfall During Source Sampling	13.2 inches

The SLAMM model did an excellent job of predicting pollutant loads from for the subwatershed. Typically, the pollutant load computed from component source areas was within 90 to 110% of the total subwatershed pollutant load measured over the 12 storm events.

Source Areas: Runoff Production

The load of a stormwater pollutant from any source area is a product of its pollutant concentration and its runoff volume. Thus, it is of considerable interest to

discover how much runoff volume a particular source area actually generates. The team employed the SLAMM model to assess the relative runoff contribution from the eight primary source areas within the Marquette subwatershed (Table 2). The "effective runoff coefficient" was dramatically different for many source areas, ranging from 0.01 to 0.58. As might be expected, the sandy soils of the residential lawns had the lowest runoff coefficient observed during the monitoring study. Despite the fact that lawns comprised more than 60% of subwatershed area, they generated only 6% of subwatershed runoff. The highest runoff coefficient was recorded for commercial parking lots, followed by streets. In contrast, residential rooftops and driveways had relatively low runoff coefficients, suggesting that these source areas were only partially connected to the storm drain system.

Table 2: Relative Runoff Contribution From Different Source Areas During 12 Storm Events

Source area sampled	Percent of total area	Percent of runoff	Effective runoff* coefficient
Commercial Parking Lot	4.6	19.1	0.58
High Traffic Street	1.4	4.5	0.45
Med. Traffic Street	1.8	5.5	0.43
Low Traffic Street	8.9	26.9	0.42
Commercial Rooftop	3.5	10.2	0.41
Residential Driveway	4.2	9.8	0.32
Residential Rooftops	9.8	12.8	0.18
Residential Lawns	62.4	5.8	0.01
Sidewalks	3.0	ns	ns
Basin Outlet	100.0	95.0	0.14

* Effective runoff is defined as the relative contribution of the source area to the total runoff volume produced in the basin over the 12 storm events.
ns = not sampled

Nutrients and Oxygen Demand

One of the clear trends in the Marquette source area monitoring was that pervious areas had higher nutrient concentrations than impervious ones (Table 3). In particular, nitrogen and phosphorus concentrations in residential lawn runoff were five to 10 times higher than any other source area. Rooftop runoff, on the other hand, had the lowest nutrient concentration of any source area, which is not surprising given that atmospheric deposition is probably the only pollutant pathway. The study also confirmed the strong relationship between greater street traffic and higher nutrient and organic matter concentrations first observed by Bannerman *et al.* (1983). The Marquette team found that nutrient and organic matter concentrations in runoff from high traffic streets were two to three times higher than runoff from low traffic streets.

Hydrocarbons and Metals

The Marquette study also provided our first glimpse about hydrocarbon source areas in the urban landscape (Table 4). One might suspect that source areas dominated by vehicles would have the highest hydrocarbon levels, and this indeed was found to be the case. The highest PAH levels were recorded at the commercial parking lots (75 µg/l) and the high traffic streets (15 µg/l). In contrast, PAH levels at rooftops, driveways and low traffic streets were generally less than 2 µg/l. The team also monitored individual hydrocarbon compounds that comprise PAHs, some of which are known or suspected carcinogens, such as Pyrene. In general, the

Table 3: Geometric Means of Conventional Pollutants at Marquette Source Areas (mg/l)

Source area sampled	Total phosphorus	Total nitrogen	Total Kjeldahl nitrogen	BOD_5
Commercial Parking Lot	0.20	1.94	1.6	10.5
High Traffic Street	0.31	2.95	2.5	14.9
Med. Traffic Street	0.23	1.62	1.3	11.6
Low Traffic Street	0.14	1.17	0.9	5.8
Commercial Rooftop	0.09	2.09	1.6	17.5
Residential Rooftop	0.06	1.46	1.0	9.0
Residential Driveway	0.35	2.10	1.8	13.0
Residential Lawns	2.33	9.70	9.3	22.6
Basin Outlet	0.29	1.87	1.5	15.4

Table 4: Source Area Concentrations of Hydrocarbons and Soluble Metals (µg/l)

Source area sampled	Polycyclic aromatic hydrocarbons	Pyrene	Soluble zinc	Soluble Copper
Commercial Parking Lot	75.6	12.2	64	10.7
High Traffic Street	15.2	2.37	73	11.2
Med. Traffic Street	11.4	1.75	44	7.3
Low Traffic Street	1.72	0.27	24	7.5
Commercial Rooftop	2.1	0.33	263	17.8
Residential Rooftop	0.6	0.10	188	6.6
Residential Driveway	1.8	0.34	27	11.8
Residential Lawns	na	na	na	na
Basin Outlet	21.0	3.36	23	7.0

Notes: Pyrene is one component of PAH's./ All measured in units of micrograms/liter (= ppb)
na = not analyzed at the source area

greatest concentrations of these compounds were also detected at commercial parking lots and high traffic roads.

The team also investigated source area concentrations of total and soluble metals. While no clear trends were observed in total metal levels among most source areas, sharp differences were frequently noted for soluble metals. This is significant as soluble metals are much more likely to exert a toxic effect on aquatic life. Interestingly, the key source areas for soluble zinc were rooftops. Commercial and residential rooftops typically had soluble zinc concentrations that were three to four times higher than other source areas, which is consistent with other research on rooftop runoff.

Moderate levels of soluble zinc were also associated with commercial parking lots and high traffic street. Source areas for soluble copper, on the other hand, were distributed rather evenly across the subwatershed, with the highest concentrations recorded at commercial roofs and parking lots, high traffic streets, and residential driveways. A strong relationship between greater street traffic and higher hydrocarbon and metal concentrations was also found.

Contributions of Individual Source Areas to Subwatershed Pollutant Loads

Using the SLAMM model, the team was able to analyze which source areas contributed most of the stormwater pollutant loads for the subwatershed (Table 5). The team discovered that some source areas delivered a disproportionate share of the total load. Most notable were commercial parking lots, which produced 64% of the PAH load, 30% of the total zinc load and 22% of the total copper load, despite the fact they comprised less than 5% of subwatershed area. Similarly, medium and high traffic streets each generated about six to 10% of the subwatershed PAH, zinc and copper load even though each source area comprised less than 2% of subwatershed area. Surprisingly, residential driveways produced from 14 to 18% of the total phosphorus, copper and zinc load, despite the fact that driveways comprised less than 5% of subwatershed area.

Although residential lawns comprised 62% of subwatershed area, they were not believed to contribute to total load of many pollutants, such as PAH and metals. Lawns were the greatest source of phosphorus in the subwatershed (26%), which reflected the fact that while the sandy soils produced very little runoff, lawn runoff still had a very high phosphorus concentration. It is worth noting that if the study site had less permeable soils, lawns probably would have emerged as an even more important source area for nutrients and organic matter.

Summary

The Marquette source area monitoring study generally reinforced the findings of an earlier source monitoring study conducted in Madison, Wisconsin (Bannerman *et al.,* 1993). While the pollutant concentrations for each source area were not always the same, the relative rank among the source areas was basically the same in each study. This finding supports the notion that stormwater managers should seriously consider pollutant source areas when designing stormwater management practices or devising pollution prevention plans.

Table 5: Comparisons of Source Area Loadings for Selected Pollutants, as Computed by the SLAMM Model

Source area sampled	% Watershed area	Percent of Total Subwatershed Load: Copper	PAH	Zinc	Total phosphorus
Commercial Parking Lot	4.6	22	64	30	8
High Traffic Street	1.4	6	7	10	2
Med. Traffic Street	1.8	8	6	8	5
Low Traffic Street	8.9	17	5	19	15
Commercial Rooftop	3.5	11	3	16	5
Residential Rooftop	9.8	5	1	15	3
Residential Driveway	4.2	18	3	18	14
Residential Lawns	62.4	ns	ns	ns	26
Basin Outlet	97%	87%	89%	116%	77%

ns = not sampled, as early monitoring indicated non-detection

Of particular concern are parking lots, which emerged as the dominant pollutant source for commercial areas in both studies. Parking lots produced a disproportionately high load of hydrocarbons and metals compared to all other source areas. As such, watershed managers can justifiably classify many parking lots as stormwater "hotspots." It may make sense to treat the quality of parking lot runoff directly at the source, using filtering practices such as sand, compost and bioretention filters. In any event, designers should probably avoid infiltrating stormwater runoff from parking lots.

Watershed managers should also take note of the strong relationship between pollutant concentrations and higher traffic streets. Runoff from more heavily traveled roads may require greater treatment volumes to control this important source area. Infiltration of roadway runoff should also be avoided, unless effective and reliable pretreatment can be assured.

The Marquette study also provides strong support for focusing the message of residential pollution prevention programs. Lawns and driveways were both implicated as key source areas for nutrients, organic matter and bacteria. Clearly, homeowners have an important role to play in residential source control. Less lawn fertilizer, more pet cleanups, safer car washing and more frequent driveway sweeping could collectively reduce the importance of residential areas as a source of stormwater pollution. ***—TRS***

References

Bannerman, R., D. Owens, R. Dodd and N. Hornewer. 1993. "Sources of Pollutants in Wisconsin Stormwater." *Water Science Technology*. 28(3-5): 241-259.

Pitt, R. and J. Voorhees. 1989. *Source Load and Management model (SLAMM)—An Urban Nonpoint Source Water Quality Management Model*. Wisconsin Dept. of Natural Resources. PUBL-WR-218-89.

Steuer, J., W. Selbig, N. Hornewer and J. Prey. 1997. *Sources of Contamination in an Urban Basin in Marquette, Michigan and an Analysis of Concentrations, Loads, and Data Quality*. U.S.G.S. Water Resources Investigations Report 97-4242. Wisconsin DNR and EPA. 25 pp.