Article 11

Technical Note #69 from Watershed Protection Techniques. 2(2): 348-351

Multiple Indicators Used to Evaluate Stream Conditions in Milwaukee

Masterson and Bannerman recently reported on a long-term monitoring effort to assess the impacts of stormwater runoff on an urban creek. This effort focused on Lincoln Creek, a second order tributary draining through a highly urban portion of Milwaukee County, Wisconsin. The creek drains a watershed of 19 square miles, and is nine miles long. Lincoln Creek was selected for analysis since it had a good mix of different urban land uses draining to it. A tiered monitoring approach was employed, which combined chemical, physical, and biological monitoring efforts to assess existing conditions. The seven monitoring elements were as follows:

- Analysis of water chemistry at selected storm drain outfalls and in-stream stations
- Chemical analyses of bottom sediments at several streambed stations
- Chemical analyses of whole fish and crayfish tissues
- Use of Semipermeable Polymeric Membrane Devices (SPMDs) to estimate potential pollutant accumulation in biological tissue
- Short-term toxicity testing and long-term mortality testing
- Macroinvertebrate and fish bioassessments
- Physical habitat assessments

Data was collected both at Lincoln Creek and at a reference site for comparison purposes. The reference site was located in a non-urbanized watershed in Fond du Lac County, Wisconsin, along the East Branch of the Milwaukee River.

Stormwater samples were collected in the Lincoln Creek watershed at 10 individual storm drainage outfall locations and at one instream stattion (using an automated sampler at a USGS gaging station) for a total of 43 separate storm samples. Forty-four fixed interval grab samples were also collected every two weeks at the USGS station. Bottom sediments were collected at six stations in Lincoln Creek and two stations from the reference site.

Fish and crayfish were collected in both the reference site and Lincoln Creek for analysis of tissue concentrations of various pollutants. *Cyprinus carpio* (common carp) were collected where available, *Carassius auratus* (goldfish) were substituted where carp could not be obtained. *Dacapoda* (crayfish) were collected in all types of stream habitat and often required a stream length of 100 meters to obtain enough material for an adequate sample.

Benthic macroinvertebrates were collected at four individual locations in Lincoln Creek and two locations at the reference site. Fish sampling was done initially at one station in Lincoln Creek in 1992 and 1993; four additional stations were added for 1994 and 1995 monitoring. Fish were also sampled at the reference stream. A qualitative analysis of habitat was conducted at both Lincoln Creek and the reference site. SPMDs, incorporating a synthetic material capable of accumulating contaminants, were also deployed as a surrogate for biological organisms to verify the potential biological accumulation of pollutants in living organisms. On-site, in-situ toxicity testing was performed using a flow-through system of aquaria supplied with creek water. Chronic toxicity tests used fathead minnow *(Pimephales promelas)* exposed to creek water for 30 days. Control conditions were provided for all toxicity testing.

Lincoln Creek has over 200 stormwater outfalls discharging directly into it. Testing at the storm drain outfalls showed suspended solids and BOD_5 levels exceeded Wisconsin Department of Natural Resources (WDNR) effluent criteria. Two trace metals, copper and zinc, also were found to exceed toxicity criteria for warm water sport fisheries. Polycyclic aromatic hydrocarbons (PAHs) and trace metal concentrations also showed consistently high levels in the in-stream stormwater and base-flow samples. Carcinogenic PAHs exceeded water quality standards for human cancer criteria. Total recoverable copper and zinc, again, exceeded the acute toxicity criteria for warm water sport fisheries.

Sediment samples were found to have high average concentrations of petroleum by-products and trace metals. Sediment concentrations of oil and grease exceeded EPA's moderately polluted guidelines and those of the reference site (Master and Bannerman, 1994). Trace metals of surface sediment samples did not exceed EPA's heavily polluted guidelines, but copper, lead, and zinc levels in the silt fraction of the sediment did exceed the guidelines. This is reasonable given the higher absorptive capabilities of fine-grained particles over coarser grained particles. Figure 1 illustrates the comparison of storm event water and sediment concentrations with those of WDNR criteria, U.S. EPA criteria, and reference site conditions.

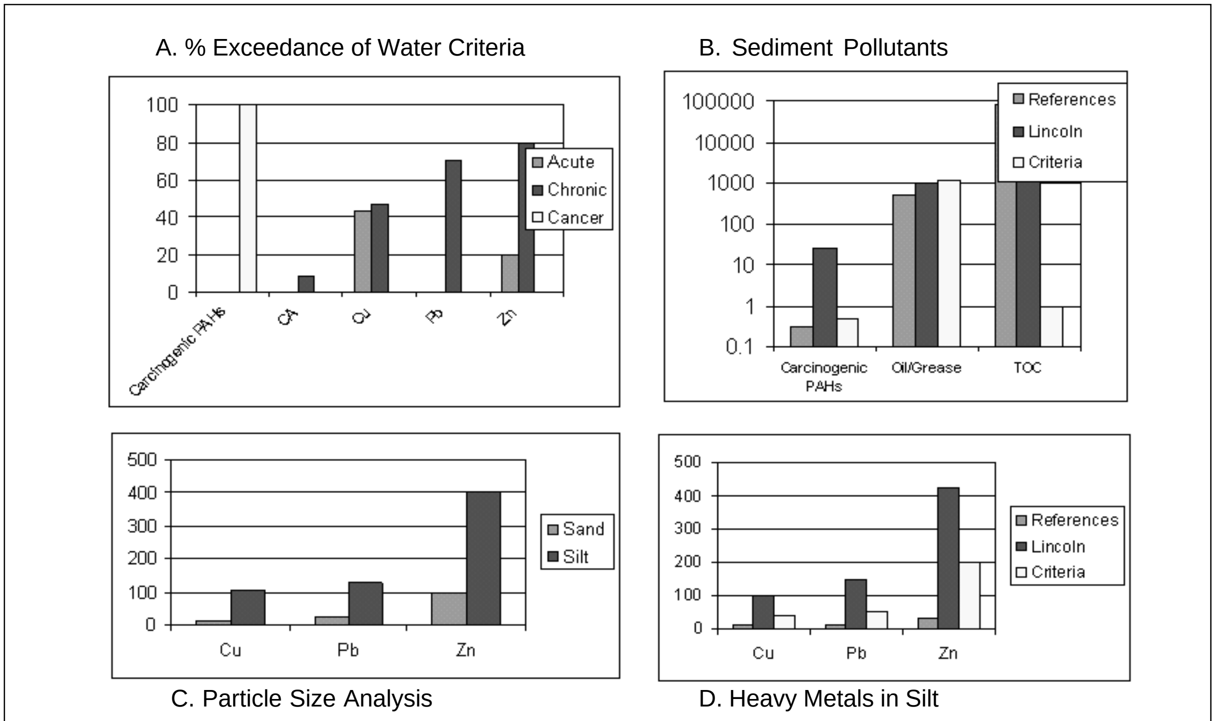

Figure 1: Comparison of Storm Event Concentrations With Wisconsin's DNR Criteria (A), and Bottom Sediment Pollutant Concentrations With U.S. EPA Criteria and Those of the Reference Site (B, C, and D). All Units in mg/kg Dry Weight (Masterson and Bannerman, 1994)

Pollutant tolerant species of fish and macroinvertebrates were prevalent in Lincoln Creek, whereas the reference site supported a wide variety of both intolerant and tolerant species. Fish diversity was significantly lower in Lincoln Creek, as well. Table 1 illustrates the comparison between the reference site and Lincoln Creek for fish diversity and macroinvertebrate bioassessment scores.

Analyses of fish, crayfish, and microorganisms were conducted to determine if pollutants detected in the water and stored in the sediment can bioaccumulate in aquatic organisms. Total DDT and PCBs were found in whole fish tissue samples at higher levels in Lincoln Creek than at the reference site. It was also believed that the organisms which fish feed upon can accumulate toxins. The urban crayfish tissues of Lincoln Creek had high PAH and heavy metal concentrations. Lead, in particular, was found at 40 times the rate of the reference site. Table 2 illustrates the comparison between fish and crayfish tissue pollutant concentrations between Lincoln Creek and the reference site.

SPMDs indicate that lipophilic contaminants, such as PAHs, can bioconcentrate in aquatic organisms. Extremely high levels of PAHs accumulated in SPMDs placed for two weeks in Lincoln Creek, while levels of PAHs in the SPMDs from the reference stream were two orders of magnitude lower.

Short-term toxic tests (less than eight days) appear to underestimate the toxic effects of urban stream water. Frequency of mortality in both short term laboratory or in-situ toxicity test data was insufficient to indicate that stormwater has an effect on the stream biota. However, longer term mortality tests indicated that juvenile and adult fathead minnows *(Pimephales promelas)* exposed on-site to Lincoln Creek water for more than 14 days suffered substantial mortality (see Figure 2). This response to long-term exposure could partially explain the low quality of the aquatic ecosystem.

The qualitative habitat analysis scores reinforced the fish diversity findings and the macroinvertebrate bioassessment scores for Lincoln Creek and the reference site. Scores for Lincoln Creek were poor compared to the reference site, which rated good.

Masterson, Bannerman, and their colleagues concluded that Lincoln Creek was degraded when compared to the reference site and that the likely culprit was urban runoff. High concentrations of metals, suspended solids, bacteria, oil/grease, and PAHs were detected in storm drain outfalls and in-stream samples. Several of the pollutants found in the bottom sediments can resuspend in future storms and contribute to bioaccumulation of pollutants in macroinvertebrates and fish. The SPMD results confirm this finding.

The biological and physical habitat assessments confirmed the chemical constituent monitoring results and support a definitive relationship between degraded stream ecology and impacts from urban runoff. Toxicity testing revealed that longer term, in-situ studies are required to adequately assess the mortality of living organisms in urban streams.

While the study paints a somewhat gloomy picture of the measured impacts of urban runoff in Lincoln Creek, it illustrates the value of a comprehensive monitoring effort to quantify these influences. An obvious conclusion of the Lincoln Creek monitoring is that various method results confirm and support each other. This comprehensive approach helped establish definitive relationships between land use, instream habitat impacts, toxicity to the resident aquatic community, and instream pollutant concentrations.

The value is that other municipalities can begin to answer the questions: what is causing the toxicity, how much is too much urbanization, and can stormwater practices alleviate the conditions? Future monitoring efforts will be able to set aside the more expensive techniques, and rely on less expensive, scientifically tested, techniques to answer these questions. For example, given the cost and complexity of in-situ toxicity testing and whole fish tissue bioaccumulation testing, techniques such as SPMDs can be substituted and relied upon to establish limits of toxicity. Biological assessments using resident fish and macro-invertebrate communities can replace costly instream water chemistry monitoring. Clearly more of these comprehensive studies are needed for different size watersheds, under varied levels of urbanization to continue to define and establish these correlations. The data gained from Lincoln Creek provide a firm foundation in our quest for cost effective methods to answer difficult questions.

— RAC

References

Masterson, J.P., and R.T Bannerman. 1994. "Impacts of Stormwater Runoff on Urban Streams in Milwaukee County, Wisconsin." In *National Symposium on Water Quality*, American Water Resources Association.

Ramcheck, J.M., and R. L. Crunkilton. 1995. *Toxicity Evaluation of Urban Stormwater Runoff in Lincoln Creek, Milwaukee, Wisconsin.* College of Natural Resources, Univ. of Wisconsin. Stevens Point, WI

Wang, L., J. Lyons, and P. Kanehl. 1995. *Evaluation of the Wisconsin Priority Watershed Program for Improving Steam Habitat and Fish Communities, Progress Report for 1995.* Wisconsin Dept. of Natural Resources, Monona.

Table 1: Comparison of Fish Species Diversity and Macroinvertebrate Bioassessment Scores Between Lincoln Creek and Reference Site (Masterson and Bannerman, 1994)

Biological Indicator	Parameter	Lincoln Creek	Reference Site
Fish Species Diversity	Total Fish	2	20
Macroinvertebrate Bioassessment	Total Bioassessment Score	6	24
	Condition Rating	Severely Impaired	Non-impaired

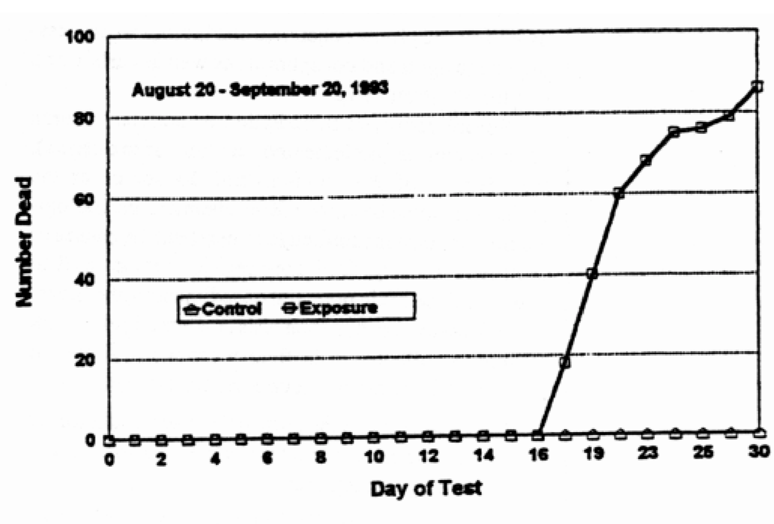

Figure 2: Fathead Minnow Mortality in 30-day, On-site Exposure to Lincoln Creek Water

Table 2: Comparison of Fish Tissue and Crayfish Tissue Between Lincoln Creek and Reference Site (mg/kg), Except PAHs in (µg/kg) (Masterson and Bannerman, 1994)

Biological Community	Stream	%Fat	Cd [0.03]	Cr [0.2]	Cu [0.06]	Hg [0.03]	Zn [0.5]	Total DDT [0.05]	Total PCBs [0.2]	Total PAHs [25.0]
Fish	Lincoln Creek		0.039	0.2	1.24	0.06	10.7	0.2	5.75	—
	Reference	8.3	ND	ND	1.3	0.14	51	ND	ND	—
Crayfish	Lincoln Creek	0.93	0.077	1.223	40.3	0.012	24	—	—	360
	Reference	0.8	0.02	ND	17.9	0.018	17	—	—	ND