QUALITY OF URBAN FREEWAY STORM WATER

James B. Jodie, Division of Highways, Wisconsin Department of Transportation

This paper discusses the quality of storm-water runoff from urban freeways in Milwaukee, Wisconsin. The storm water from preselected areas was collected and tested to determine the concentrations of study parameters. Freeway runoff was compared with influent and effluent of the Milwaukee Sewage Treatment Plant, adopted intrastate water quality standards for Wisconsin, water from the Menominee River (which is the outfall for the freeway watersheds studied), and other national and international urban storm-water data. The results of this study indicate that the runoff from freeways in an urban area is of poor quality. Further research is needed to provide more specific data about the source of pollution so that the problem of storm-water runoff quality can be solved.

•STORM water draining from urban freeways has been criticized by some environmentalists as contributing to the pollution of adjacent ponds, streams, and lakes. As of this date, there is a lack of tangible data to either contradict or confirm statements that freeway storm water is creating an environmental problem. This project was established to determine the quality of freeway storm-water runoff in an urban area by analyzing it to determine its physical, chemical, and bacterial makeup and by comparing it with established water quality standards, sewage plant influent and effluent, and other urban storm-water runoff. The information obtained from this paper will also lay the foundation for possible future studies.

PROCEDURE FOR TEST

In July 1972, a 1-year sampling and testing program began at two storm-water outfall locations on the urban freeway system in Milwaukee County. The watersheds or drainage basins studied collected only the runoff from the freeway surface and the adjacent cut areas that drain onto the freeway. Questions asked about the watershed requirements were as follows:

1. Is the watershed typical of an urban area?
2. Has a storm sewer system been designed for the freeway segment selected?
3. Does the storm sewer system collect only water draining from the freeway pavement surface and the adjacent slopes?
4. Is there an accessible sampling location (e.g., manhole or sewer outfall)?
5. Is there a predominant land use adjacent to the freeway?

Specific features such as adjacent land developments, topography, and amount and kind of vegetative cover were noted for each watershed. This was done to locate the source of a pollutant and to associate the concentration of a parameter (pollutant indicator) with the location on the freeway. The watersheds selected were as follows:

1. The Stadium Freeway has a 48-in. (122-cm) storm sewer that has an outlet into the Menominee River at State Street. Adjacent land use is 65 percent residential, 5 percent industrial, and 30 percent parkland. The drainage area is 34 acres (13.8 hm^2) (Figure 1).

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2. The East-West Freeway has a 30-in. (76-cm) storm sewer that has an outlet into the Menominee River at the Stadium interchange. Adjacent land use is 50 percent industrial, 45 percent residential, and 5 percent parkland. The drainage area is 8 acres (3.2 hm^2) (Figure 2).

Parameters were selected that would define freeway runoff waters and that could be used as a comparison with other studies. The parameters selected were sodium chloride (NaCl), calcium chloride ($CaCl_2$), total solids, volatile total solids, suspended solids, volatile suspended solids, 5-day biochemical oxygen demand (BOD), total nitrogen (N_2), pH, total phosphorous (P), ammonia (NH_3), fecal coliforms (MFFCC), lead (Pb), dissolved oxygen (O_2), and nitrates (NO_3^-) and nitrites (NO_2^-). Other physical characteristics noted were air temperature, water temperature, form of precipitation, gasoline odor, and indications of an oil slick. The pH and dissolved oxygen concentrations were determined in the field; all other bacterial and chemical testing was conducted by the Wisconsin State Laboratory of Hygiene in Madison.

In all months, except August and October, samples were collected at least once. All samples were collected at the outfall of the freeway storm sewer system.

RESULTS OF TESTS

The results of the samples indicated the following:

1. The parameter concentrations for a sample collected in the first hour of a storm tended to be higher than those collected in the remainder of the storm.
2. The concentration of parameters tended to be very high during a snowstorm.
3. Pollutants released into the atmosphere from adjacent land developments were not detected (by observation) in the storm runoff.
4. No difference in the quality of storm water was observed between the two watersheds sampled.
5. Salt concentrations can be quite high and can have several surges of high concentrations during the winter and spring. Salt concentrations tend to taper off with the onset of summer.

A comparison of freeway runoff with adopted intrastate standards for Wisconsin (6) indicate this water is inadequate to support fish life and is unacceptable for recreational purposes. In comparison to that in the effluent from Jones Island Treatment Plant in Milwaukee (5), the concentration of phosphorous and nitrogen in the runoff is minimal (Table 1). However, the freeway runoff contains a greater concentration of total solids, suspended solids, and BOD than the effluent from the treatment plant. In accordance with a Southeastern Wisconsin Regional Planning Commission study of the Menominee River in April 1973, the runoff from both the river and the freeway is of poor quality. Comparable international studies from local streets show that urban runoff is characterized by a high fecal coliform and phosphate concentration; however, freeway runoff tends to contain high concentrations of total solids and chlorides [Table 2 (1, 9)].

Storm-water runoff from freeways contains concentrations of contaminants that make this poor-quality water. This runoff is a possible detriment to the environment. Therefore, more attention must be directed to the effect of all freeway runoff on the ecological system of an urban area. This awareness is further emphasized by anticipated increases in population and movements toward urban areas. As a result, the dependency on the automobile for employment, recreation, and industrial purposes will tend to increase. This factor, coupled with the increasing need for available water resources, places great responsibility on planning agencies to manipulate or modify the character of water, such as freeway runoff, so that it can become readily available for many beneficial uses.

Figure 1. Stadium Freeway watershed.

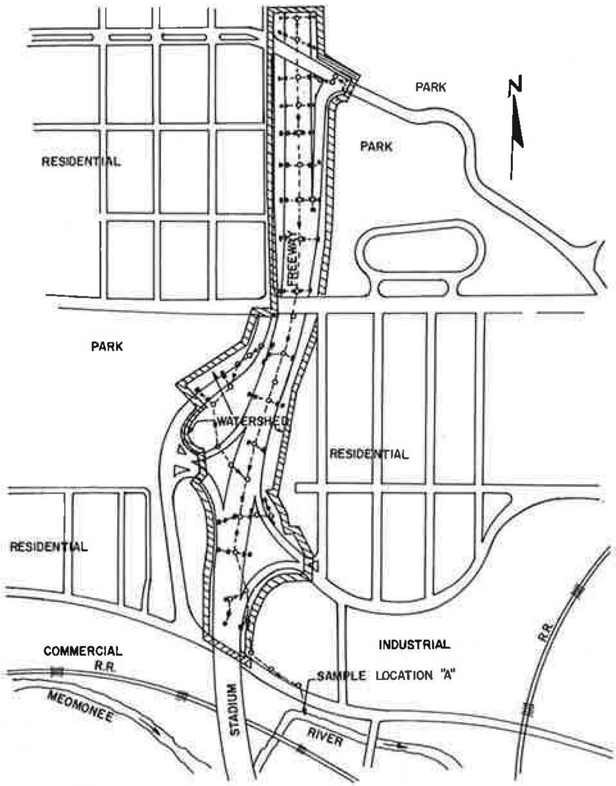

Figure 2. East-West Freeway watershed.

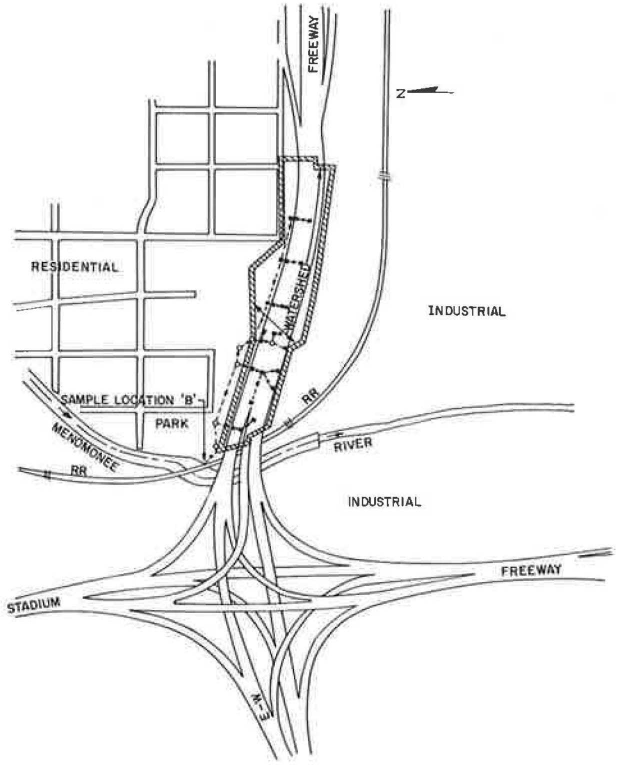

Table 1. Parameter values for Milwaukee urban freeway storm water.

Parameter	Stadium Freeway		East-West Freeway		Milwaukee Sewerage Commission (1970)			Menominee River
					Yearly Avg of Screened Effluent	Plant Effluent		
	Avg	Range	Avg	Range		West	East	
BOD	17	1.80 to 45.0	30	8.60 to 90.0	209	12.5	16.3	3.7
Total solids	5,188	244 to 26,650	7,380	156 to 54,120	939	724	759	–
Volatile total solids	393	55 to 1,050	244	54 to 570	–	–	–	–
Suspended solids	235	0 to 1,230	192	19 to 785	207	18.5	23	–
Volatile suspended solids	47	0 to 185	38	5 to 125	–	–	–	–
Cl^- as NaCl	2,606	30 to 26,000	4,128	8 to 35,000	–	–	–	98
Ca^{++} as $CaCl_2$	142	40 to 250	189	36 to 300	–	–	–	–
Total N_2	1.43	0.29 to 3.40	1.77	0.56 to 3.70	28.30	10.90	8.60	0.75
NH_3	0.49	0.05 to 1.10	0.72	0.05 to 1.40	–	–	–	0.36
Total P	0.20	0.002 to 1.06	0.21	0.02 to 0.64	8.20	1.40	0.70	0.30
Dissolved O_2	11.0	9.2 to 12.2	10.3	7.2 to 11.8	–	–	–	11.1
pH	7.7	6.3 to 9.0	7.9	7.2 to 9.3	–	–	–	8.0
Water temperature, deg C	9.3	1 to 23	9	1 to 21	–	–	–	5.8
NO_3^- and NO_2^-	1.08	0.15 to 2.00	1.51	0.24 to 2.60	–	–	–	1.70
MFFCC[a]	2,750	100 to 6,200	1,600	1,300 to 1,900	–	–	–	1,210
Pb	0.90	0.71 to 1.10	0.84	0.56 to 1.00	–	–	–	–

Note: With the exception of pH, water temperature, and MFFCC, all concentrations are expressed as mg/liter. MFFCC values are expressed as membrane filter fecal coliform count/100 ml.

[a]Total coliforms = 5 x MFFCC = 25,000 (3).

Table 2. Storm-water quality from urban drainage basin in Milwaukee.

Location	Type of Runoff	Measurement	BOD (mg/liter)	COD[a] (mg/liter)	Total Solids (mg/liter)	Volatile Solids (mg/liter)	Suspended Solids (mg/liter)	Total Phosphate (mg/liter)	Fecal Coliforms/ 100 ml[b]	Cl^- as NaCl (mg/liter)
Durham, N.C.	Urban storm water	Mean	14.5	179	2,730	298	–	0.58	30,000	12.6
		Range	2 to 232	40 to 600	274 to 13,800	20 to 1,110	–	0.15 to 2.50	7,000 to 86,000[c]	3.0 to 390
Cincinnati, Ohio	Urban storm water	Mean	17	111	–	–	227	1.1	–	19.8
		Range	1 to 173	20 to 610	–	–	5 to 1,200	0.02 to 7.3	500 to 76,000	5.0 to 705
Cincinnati, Ohio	Rainfall	Mean	–	16	–	–	12	0.24	–	–
Coshocton, Ohio	Rural storm water	Mean	7	79	–	–	313	1.7	–	–
		Range	0.5 to 23	30 to 159	–	–	5 to 2,074	0.25 to 3.3	2 to 56,000	–
Coshocton, Ohio	Rainfall	Mean	–	9.0	–	–	11.7	0.08	–	–
Detroit, Mich. (1949)	Urban storm water	Range	96 to 234	–	310 to 914	–	–	–	–	–
Seattle, Wash.	Freeway storm water	Range	9 to 198	103 to 1,617	–	–	11 to 1,494	0.14 to 0.51	–	–
Stockholm, Sweden	Urban storm water	Median	17	188	300	90	–	–	4,000	–
		Maximum	80	3,100	3,000	580	–	–	200,000	–
Pretoria, South Africa										
Residential, park, and school			30	29	–	–	–	–	240,000	–
Business and flat area			34	28	–	–	–	–	230,000	–
Oxney, England		Maximum	100	–	–	–	2,045	–	–	–
Leningrad, USSR			36	–	–	–	14,541	–	–	–
Moscow, USSR		Range	18 to 285	–	–	–	100 to 3,500	–	–	–
Milwaukee, Wisc.	Urban freeway storm water	Avg	24	–	6,202	324	215	0.20[d]	2,367	3,298
		Range	1.8 to 90.0	–	156 to 54,120	54 to 1,050	0 to 1,230	0.002 to 1.06	100 to 6,200	8 to 35,000

[a]Chemical oxygen demand. [b]Total coliforms (MPN/100 ml) = 25,000 to 930,000. [c]Range of means for 17 storm series. [d]Total phosphorus.

SUGGESTION FOR FUTURE RESEARCH

Except for the study made in Seattle, Washington (2), the runoff data pertinent to urban freeways is nonexistent. Therefore, the information obtained from this report would, in effect, lay the foundation for future studies of a similar nature.

In general, the methods used in this project provided valid information for a determination of the quality of freeway storm-water runoff. However, a program of continued research is vital to further define this storm water, to locate the sources of pollution, and to determine the full impact of this water on the environment. The objectives of future research should be to answer the following:

1. Is it necessary that this water be treated, or should its environmental impact be diminished by some other means?
2. Is the volume of storm water insignificant (compared with the volume of urban storm-water runoff from all of Milwaukee)?
3. Under what conditions (volume, concentration, and type of pollutant) would treatment of this runoff be necessary?
4. What are the economics of alternate measures of dealing with this water?

If additional research indicates that pollution by freeway runoff is significant, then this research should include solutions to the problem, such as treatment at the outfall, impounding reservoirs, or cross connections to combined sewers. To satisfy public demands and federal requirements, the information should then be placed in environmental impact statements listing the existing and projected water quality conditions. Then, either the insignificance of storm water can be verified, or solutions to the problem of storm-water disposal can be included as part of a project cost. However, the solution of freeway runoff problems will only be made possible by continued research.

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