HYDRAULICS DIVISION

TECHNICAL NOTE

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TITLE: Annual Loadings of Trace Metals in Urban Runoff in the Great Lakes Basin

REASONS FOR REPORT: In response to a request from the International Joint Commission

CORRESPONDENCE FILE: 1330-J2-2

1.0 INTRODUCTION

Estimates of annual trace metal loadings in urban runoff were calculated from annual runoff volumes, annual discharges of solids, and the corresponding concentrations of metals in stormwater and solids. A description of procedures employed follows.

2.0 ANNUAL RUNOFF VOLUMES

Annual runoff volumes were estimated from the contributing area, the annual precipitation (available from the Atmospheric Environment Service, Ref. 1), and the volumetric runoff coefficients which were established for various land use types.

In this analysis, all urban centres with the population greater than 5,000 persons were considered. The information on urban areas, their population and their total area, was adopted from the Statistics Canada (5).

Recognizing that the runoff coefficient depends on the land use type, it was necessary to subdivide the total urban land into a number of land use categories. The classification system adopted for this purpose included four categories - residential, commercial, industrial, and other land use. The term "other" land use was used here for open, undeveloped land.

To establish the areas for individual land use categories, charts correlating the land use areas with the population were used. Such charts were developed by the Community Planning Branch of the Province of Ontario and are shown in Appendix (4). Comparisons of the land use distributions calculated from these charts with the distributions reported for several Ontario cities (6) indicated a good agreement except for industrial areas. Industrial areas determined from the charts were much too large and, consequently, they were reduced to 25% of the residential land.

Finally, the volumetric runoff coefficients were established for individual land use categories on the basis of literature data (7). Such coefficients are listed in Table 1.

Table 1. Volumetric Runoff Coefficients for Various Land Use Types

Land Use Type	Volumetric Runoff Coefficient
Residential	0.35
Commercial	0.90
Industrial	0.70
Open	0.10

The annual runoff volume, $R(m^3/yr)$, was then calculated from the following equation:

$$R = P \sum_{i=1}^{4} C_i A_i$$

where $P(m)$ is the annual precipitation, C is the runoff coefficient, $A(m^2)$ is the contributing area, and the subscript i ($i=1,2,3,4$) denotes the land use.

The calculations of annual runoff volumes was done for 70 urban centres in the Great Lakes Basin. A list of these centers is provided in the Appendix.

3.0 ANNUAL DISCHARGE OF SOLIDS IN URBAN RUNOFF

Solids have been found to be a very effective medium for transport of trace metals in urban runoff. Consequently, it was of interest to estimate the annual discharge of solids in urban runoff. Towards this end, a simple procedure based on annual unit loadings was used (2,6). In this procedure, the annual discharge of solids in urban runoff is computed as follows:

$$S = \sum_{i=1}^{4} U_i \, A_i$$

where S(kg/yr) is the annual discharge of solids in runoff from an urban area, U (kg/ha/yr) is the annual unit loading of solids, and the subscript, i, denotes the various land use types.

The annual unit loading which were used in the calculations are listed in Table 2.

Table 2. Annual Unit Loadings of Solids for Various Urban Land Use (3)

Land Use Type	Annual Unit Loading of Solids (kg/ha/yr)
Residential	390
Commercial	560
Industrial	672
Open	11.2

4.0 ANNUAL LOADINGS OF TRACE METALS

The annual loadings of trace metals were calculated as follows:

$$L_j = C_{w_j} R + C_{s_j} S$$

where L is the annual loading (kg/yr), C_w is the concentration of metals in water, C_s is the concentration of metals in solids, and the subscript, j, denotes various trace metals.

Concentrations C_w and C_s were adopted from an earlier study of toxic substances in urban runoff in Ontario communities (3). Such concentratins of trace metals are listed in Table 3.

It is obvious from Table 3 that the highest concentrations were observed for zinc and lead. In general, the concentratons of metals in solids exceeded significantly those in water.

Table 3. Concentration of Trace Metals in Stormwater and Solids (3)

Trace Metal	Mean Concentration in Water Samples (ppb)	Mean Concentration in Sediment Samples (ppm)
As	2.0	8.2
Cd	1.2	2.0
Cu	14.9	67.0
Co	2.7	10.6
Cr	6.0	106.2
Pb	63.5	465.9
Hg	3.2	0.2
Ni	14.9	49.8
Se	1.6	0.3
Zn	372.7	400.6

Finally, the annual loadings of trace metals in urban runoff were produced and summarized for individual basins in Table 4.

Table 4. Estimates of Annual Trace Metal Loadings in Urban Runoff in the Great Lakes Basin

	Annual Loading (tonnes/yr)									
Lake Basin	As	Cd	Cu	Co	Cr	Pb	Hg	Ni	Se	Zn
L.Ontario	1.9	1.0	14.1	2.5	9.5	68.6	2.3	13.3	1.2	290.9
L.Erie	0.4	0.2	2.9	0.5	1.9	13.9	0.5	2.7	0.2	59.8
L.St. Clair	0.3	0.2	2.3	0.4	1.5	11.1	0.4	2.2	0.2	48.1
L.Huron	0.7	0.4	5.2	0.9	2.9	24.1	1.0	5.1	0.5	119.2
L.Superior	<.1	<.1	0.6	<.1	0.4	2.7	<.1	0.5	<.1	11.8

4.0 REFERENCES

1. Canada Atmospheric Service. Canadian climate normals 1951-1980. Volume 3, Catalogue No. En 56-60/6-1982, Supply and Services Canada, Ottawa.
2. Marsalek, J. Pollution due to urban runoff: unit loads and abatement measures. A PLUARG report, IJC, Windsor, Ontario, October 1978.
3. Marsalek, J., and Greck, B. Toxic Substances in urban land runoff in the Niagara River area. Unpublished Report, National Water Research Institute, Burlington, Ontario, June 1983.
4. Ontario Community Planning Branch. Urban land use in Ontario areas and intensities. Department of Municipal Affairs, Toronto, Ontario 1970.
5. Statistics Canada. 1981 Census of Canada, Population Geographic Distributions, Ontario. Catalogue No. 93-906, Vol. 2, Provincial Series, Ottawa 1981.

6. Sullivan, H.R., Hurst, W.D., Kipp, T.M., Heaney, J.P., Huber, W.C., and Nix, S. Evaluation of the magnitude and significance of pollution from urban storm water runoff in Ontario. Research Report No. 81, Canada-Ontario Agreement, Environment Canada, Ottawa, Ontario, 1978.

7. The Urban Dranage Subcommittee. Manual of practice on urban drainage. Research Report No. 104, Canada-Ontario Agreement, Environment Canada, Ottawa, Ontario, 1980.

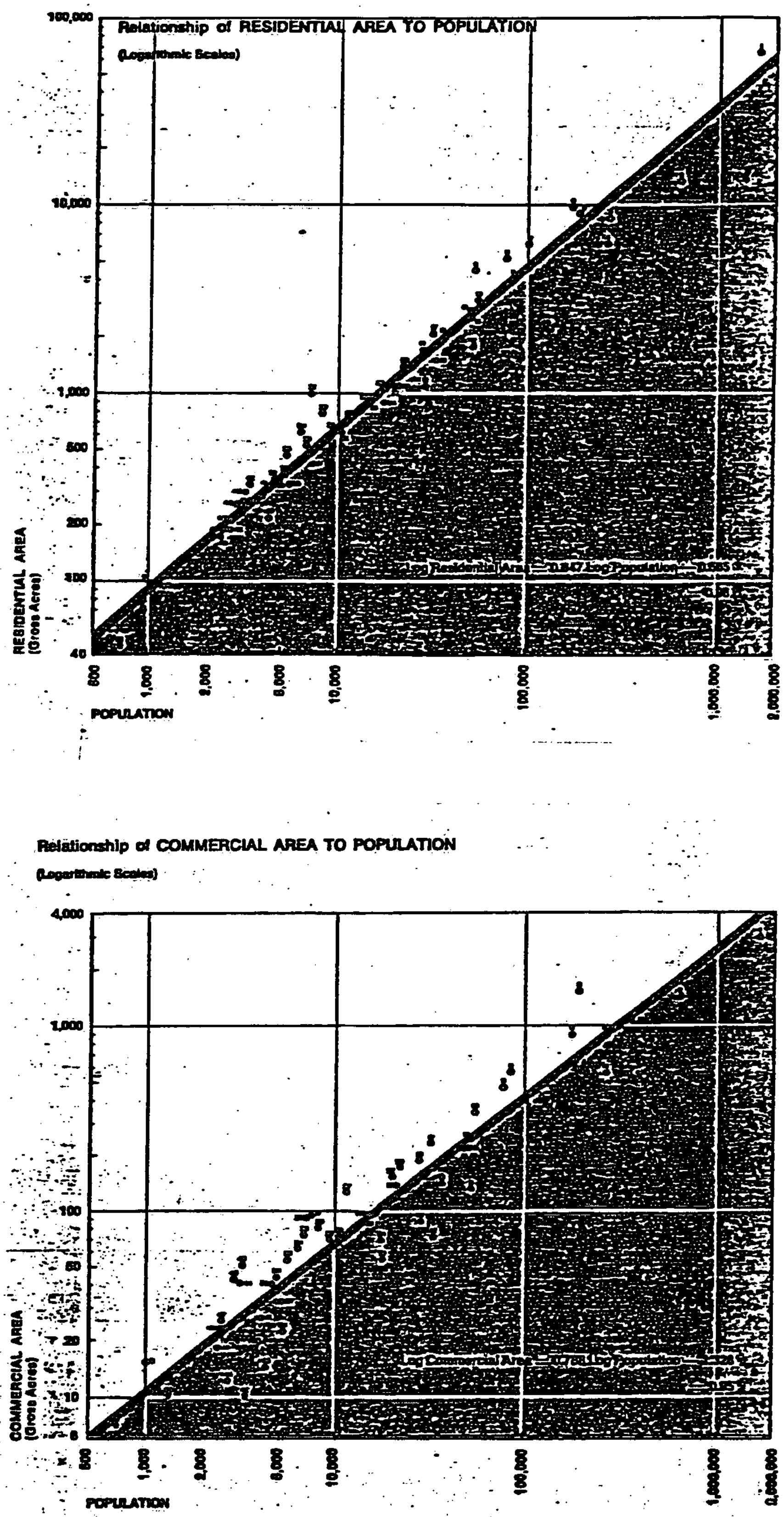

Fig.1. Relationships of Residential and Commercial Areas to Population (After Ref. 4)

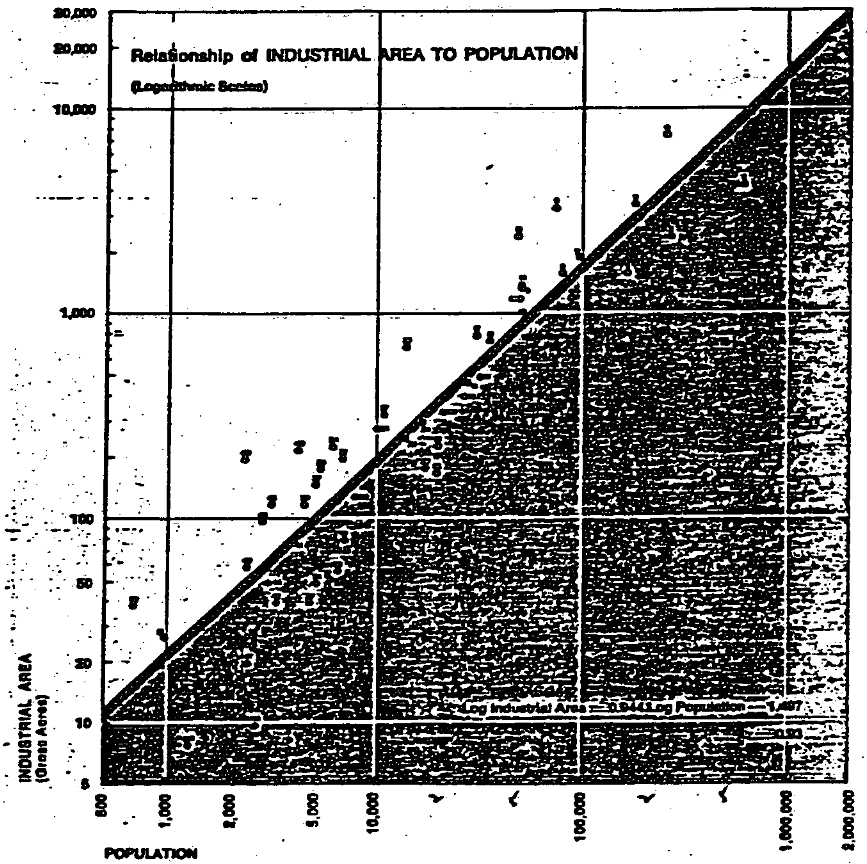

Fig.2. Relationship of Industrial Area to Population
(After Ref. 4)

APPENDIX

LIST OF URBAN CENTRES CONSIDERED IN THE ANALYSIS

<u>Lake Ontario Region</u>

Ajax
Ancaster
Belleville
Brampton
Burlington
Caledon
Cobourg
Dundas
Erneston
Etobicoke
Grimsby
Hamilton
Kingston
Kinston Township
Lindsay
Markham
Mississauga
Niagara Falls
Oakville
Oshawa
Pelham
Peterborough
Pickering
Richmond Hiull
Sidney Township
St. Catharines
Stoney Creek
Thorold
Toronto-Metro

Lake Ontario Basin (continued

Trenton
Vaughan
Welland
Whitby
W.C. Stouffvile

Lake Erie Basin

Brantford
Cambridge
Fergus
Guelph
Kitchener
Leamington
Paris
Port Colborne
Sandwich W.
Waterloo
Windsor
Woolwich

Lake St. Clair Basin

Chatham
Essex
London
Moore
Sarnia
Sarnia Township
Stratford
Tecumseh

23750

Lake Huron Basin

Aurora
Barrie
Innisfil
Midland
New Market
Nickle Centre
North Bay
Orillia
Owen Sound
Penetanguishene
R.S. Balfour
Sault Ste. Marie
Sudbury
Valley East
Walden

Lake Superior Basin

Thunder Bay