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TOXIC SUBSTANCES IN URBAN LAND RUNOFF IN THE NIAGARA RIVER AREA

by

J. Marsalek and B. Greck

Environmental Hydraulics Section
Hydraulics Division
National Water Research Institute
Burlington, Ontario

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ABSTRACT

Frequencies, concentrations, and annual loadings of 51 selected persistent toxic substances in urban runoff have been studied in the Niagara area. Toward this end, samples of urban runoff and sediment have been collected at 15 sites in Fort Erie, Niagara Falls, and Welland. The collected samples have been analyzed for polychlorinated biphenyls, organochlorine pesticides, polyaromatic hydrocarbons, chlorinated benzenes, and trace elements. For each substance studied, frequencies of occurrence and mean event concentrations have been determined. Using such data and the calculated annual runoff volumes and sediment yields, estimates of annual loadings of toxics transported by urban runoff and sediment have been produced for the Niagara area.

SOMMAIRE

Les fréquences, les concentrations et les charges annuelles de 51 substances toxiques persistantes choisies dans le ruissellement urbain ont fait l'objet d'une étude dans le secteur de Niagara. Dans le cadre de celle-ci, on a prélevé des échantillons d'eau de ruissellement urbain et de sédiments en 15 endroits à Fort-Érié, Niagara Falls et Welland. On a analysé des échantillons prélevés à recherche de biphényles polychlorés, de pesticides organochlorés, d'hydrocarbures polyaromatiques, de chlorobenzènes et de métaux à l'état de trace. On a déterminé, pour chaque substance étudiée, la fréquence de présence et les concentrations moyennes. Ces données et le calcul des volumes de ruissellement annuel et de la quantité de sédiments ont permis d'évaluer les charges de produits toxiques transportées annuellement par les eaux de ruissellement urbain et les sédiments dans la région de Niagara.

MANAGEMENT PERSPECTIVE

The Niagara River has been identified by the International Joint Commission (IJC) as one of the "areas of concerns" characterized by severe pollutional problems. Most of these problems are caused by persistent toxic substances originating from various sources which were identified by IJC. To develop an effective strategy for control of sources of toxics, it is necessary to evaluate the strength of various sources. The report that follows quantifies the concentrations, occurrences, and annual loadings of more than 50 selected persistent toxic substances in one of their principal sources - the urban runoff.

The reported data should be viewed in relation to those for other sources, including municipal and industrial discharges, waste disposal sites, combined sewer overflows, agricultural runoff, and in-place pollutants. When writing this report, evaluations of the other sources have not been available and thus the assessment of the significance of urban runoffs as a source of toxics entering the Niagara River will be delayed until all the sources are evaluated.

The results and methodologies presented here can be used in comparative studies of sources of toxics and in general studies of toxics in urban runoff.

T.M. Dick
Chief
Hydraulics Division

PERSPECTIVE-GESTION

Le rivière Niagara a été désignée par la Commission mixte internationale (CMI) comme un "secteur de préoccupations" en raison des graves problèmes de pollution que l'on y retrouve. La majorité de ces problèmes sont attribuables à des substances toxiques persistantes provenant de diverses sources qui ont été définies par la CMI. Si l'on veut établir un plan d'action efficace pour le contrôle de ces substances toxiques, il est nécessaire d'évaluer l'influence de leur diverses origines. Le rapport qui suit décrit les concentrations, les fréquences et les charges annuelles de plus de 50 substances toxiques persistantes dans l'une des principales sources de pollution: les eaux de ruissellement chargées d'effluents urbains.

Les données présentées dans le rapport devraient être considérées parallèlement à celles d'autres sources de pollution, dont le déversement d'eaux usées urbaines et d'eaux résiduelles industrielles, les sites d'enfouissement des déchets, le déversement des égoûts unitaires, l'entraînement par les ruissellement de produits utilisés en agriculture ainsi que les polluants enfouis dans le sol. Au moment de l'établissement de ce rapport, l'évaluation des autres sources de pollution était impossible à obtenir et il faudra donc attendre qu'elles aient toutes été étudiées avant de pouvoir déterminer l'importance relative des eaux de ruissellement chargées d'effluents urbains comme source de produits toxiques déversés dans la rivière Niagara.

Les résultats et les méthodes de recherche exposés dans le rapport peuvent être utilisés dans le cadre d'études comparatives de diverses sources de substances toxiques ou encore d'études plus générales sur les substances toxiques dans les eaux de ruissellement chargées d'effluents urbains.

T.M. Dick
Chef
Division de l'hydraulique

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1.0 INTRODUCTION

Many toxic substances are known to produce adverse environmental and human health effects. Furthermore, some of these substances are bioaccumalative and pass through the food chain in increasing concentrations. The stability and persistence of many toxic substances contributed to their widespread distribution in the environment, generally in fairly low levels. Although the environmental and human health effects of relatively low levels of concentration of toxic substances are not sufficiently well understood, a conservative stance should be adopted.

Since 1974, the Water Quality Board has been reporting on Great Lakes water quality to the International Joint Commission (IJC). IJC noted that many pollutional problems have been repeatedly reported for certain areas which have been then identified by IJC as "areas of concern". One of such areas of concern is the Niagara River on both sides of the border between Canada and the U.S.A. The concerns regarding the Niagara River quality, as reported by IJC (6)*, are summarized below.

Water, sediment and fish from the Tonawanda Channel of the Niagara River are severely contaminated. Extensive contamination was also found in the lower Niagara River. Almost all sediments from the Tonawanda Channel are heavily contaminated with conventional pollutants, heavy metals, and PCB's in excess of acceptable concentrations for open-water disposal of dredged materials. High contamination by other organic substances of industrial origin was also found in many samples.

Sediments from the lower Niagara River were generally contaminated by heavy metals. Many organic substances have been found in sediment and water samples collected in the river near industrial landfills.

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* Reference Number, see Section 9.0

Numerous organic chemicals of both industrial and agricultural origin have been found in fish. High concentrations of some of these substances lead to restrictions on fish comsumption.

The IJC report further states that some Agreement or Ontario objectives have been exceeded in some water samples, from the Tonawanda Channel and the lower Niagara River, for PCB's, aldrin/dieldrin, DDT and its derivatives, endrin, phenolics, heptachlor/heptachlor epoxide, endosulfan, fecal and total coliform, and some heavy metals.

Generally high levels of pollution then led to disruptions of benthic fauna in the Tonawanda Channel and in the lower Niagara River. Toxicity was a limiting factor along the shoreline of the upper Niagara River and also presented problems in the lower Niagara River.

To address the environmental and human health concerns related to the Niagara River, the Canada-U.S. Niagara River Toxics Committee has been established and further charged with responsibility to develop a monitoring and remedial program for the area of concern.

Beside the remedial measures program, the Canadian contribution includes evaluation of various sources of toxics reaching the Niagara River. Such sources fall generally in the following six categories (6):

- Municipal and industrial discharges
- Waste disposal sites
- Combined sewer overflows
- Urban land runoff
- Agricultural land runoff, and
- In-place pollutants.

The report that follows investigates one of these six sources - Urban land runoff.

The terms of reference of the study may be summarized as follows:

(1) Establish frequencies of selected persistent toxic substances in urban runoff in the Niagara area.

(2) Establish the annual loadings of selected persistent toxic substances in urban runoff in the Niagara area.

It should be mentioned that the combined sewer overflows have not been specifically evaluated in this study. The loadings in overflows represent the sum of loadings in urban runoff (discussed here) and loadings in the municipal sewage contained in overflows. The later loading can be evaluated using information on toxics in municipal wastes. Such information was not available during the preparation of this report.

To estimate frequencies, concentrations, and loadings of toxics in urban land runoff, a field program was initiated in the study area. The main objective of this program was to sample representatively urban runoff and sediment and, from analysis of collected samples, to determine typical frequencies and mean concentrations of toxics for individual runoff events. Such mean concentrations can then be used in conjunction with the computed annual runoff volume to produce annual loadings of toxics.

2.0 STUDY AREA

The study area represents the Canadian basin of the Niagara River. Basic characteristics of the area are described in this section. Such characteristics include water resources, demographic data, land use, and climatology.

2.1 **Water Resources**

The Niagara River and its tributaries drain a large part of the Niagara Peninsula in Southern Ontario. Drainage boundaries of the Canadian Niagara River basin are shown in Fig. 1. These boundaries were replotted from a map provided by the Niagara Conservation Authority (13).

The total area of the (Canadian) Niagara River basin was determined as 1,360 km^2. In general, the basin extends about 70 km west of the Niagara River and slopes gently in the easterly direction. The main tributaries, which are also shown in Fig. 1, include the Welland River, with its main tributaries Oswego, Forks and Lyons Creeks, and Baker, Bayers, Black, Frenchman, Miller and Usshers Creeks in the Fort Erie area. The creeks in the Fort Erie area more or less serve as municipal drainage ditches.

The Welland River, the largest tributary, has a drainage area of about 1,150km^2 and is characterized by a shallow gradient. Consequently, its water level is affected by the operation of control devices of the power plants at Niagara Falls and the river flow is partly diverted to the power canal which then discharges into the Niagara River.

The Welland Ship Canal and The Old Welland Canal pass through the study area. In general, these canals do not serve for surface drainage, because most streams pass under their grade levels via pipes and siphons.

For the purpose of this study, the total basin was divided into four sub-basins which are defined according to the location of the runoff discharge point. These sub-basins are listed in Table 1.

2.2 Demographic Data and Land Use

Characteristics of the hydrologic cycle and surface water quality are closely related to the basin population and land use. It

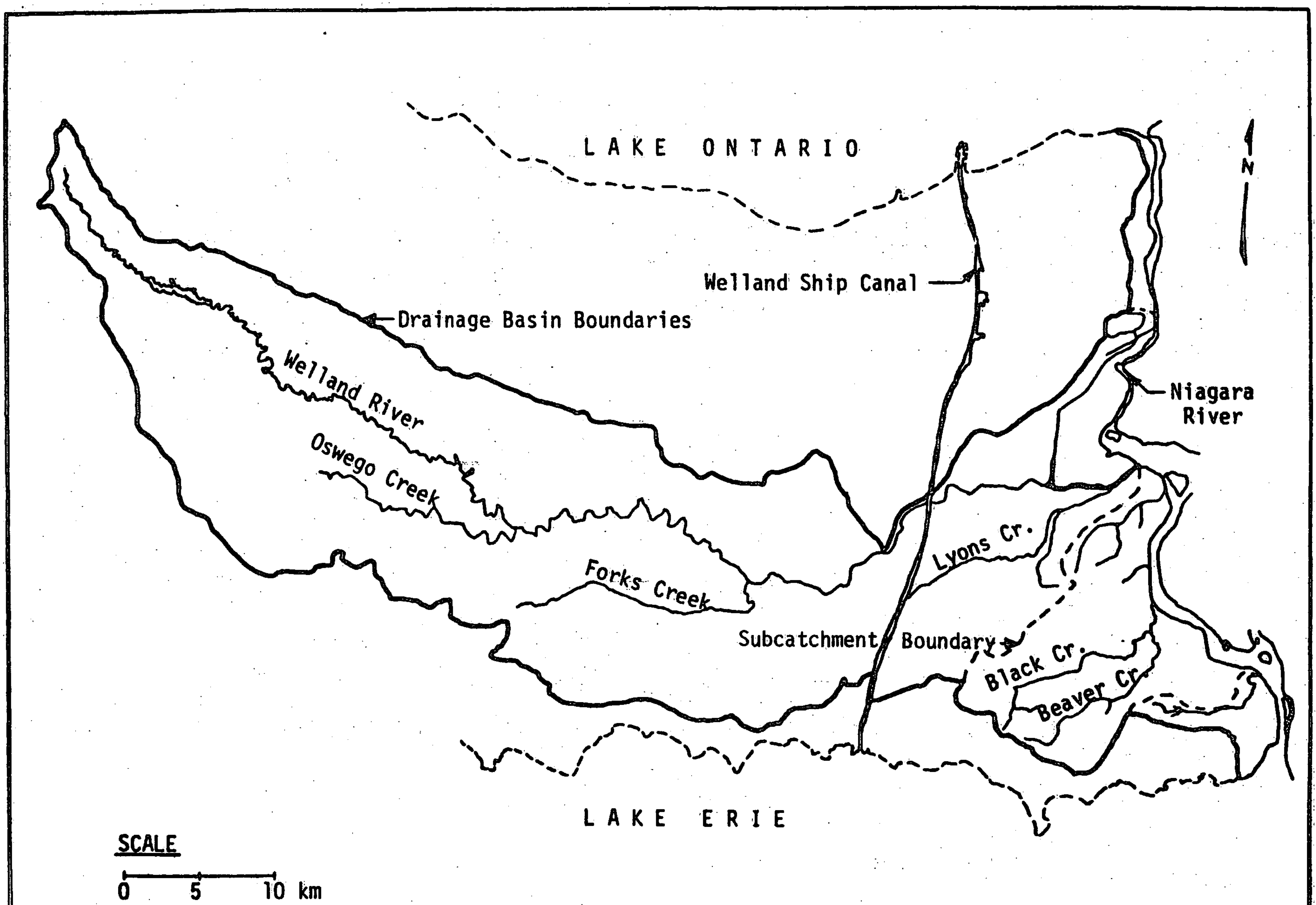


Fig. 1. Niagara River Study Area

TABLE 1. **Study Sub-Areas**

Sub - Basin	Contributing Area (km^2)	Level of Urbanization	Discharge Point
Fort Erie Area	26	High	at Fort Erie
Black Creek	166	Low	Downstream of Fort Erie
Niagara Falls	1,153	Medium	at Niagara Falls
Niagara-on-the-Lake	15	Low	Downstream of Niagara Falls

For further details of water resources in the study area see Ref. 13

was therefore of interest to collect information on population and land use in the study area.

The interest in urban population of a basin stems from the fact that such population and its density determine the imperviousness of populated areas. The larger the urban population and its density, the greater portion of precipitation will be transformed into surface runoff because of high imperviousness of populated areas. Furthermore, the density of population also affects the composition of surface runoff.

Estimates of population of the study area were produced on the basis of the 1981 Population Census (16). Such estimates are only approximate because of the differences in political and drainage boundaries. Demographic data are generally available for counties, or other administrative units. To determine the population in the study area, it was necessary to divide the population of some counties into the parts inside and outside of the study area. Similar problems were encountered in the cities of Niagara Falls and Welland which extend outside of the study area. Furthermore in urban areas, it is necessary to consider not only surface drainage to determine drainage boundaries but also the discharge points of subsurface drainage.

Recognizing the uncertainties involved, the total population of the study area was estimated as 148,000 persons and this population includes 113,550 persons living in urban centres and the remaining 34,450 living in rural areas. Thus about 77% of the total area population live in urban centres. Furthermore, the urban population is concentrated in three major centres- Fort Erie, Niagara Falls and Welland. The definition of urban population was adopted from the Statistics Canada as the population living in centres with population greater than 1,000 persons and the density greater than 400 persons per km^2.

Basic data on urban population in the study area are given in Table 2.

TABLE 2. Population of Urban Centres in the Niagara Area

Urban Centre	Total Urban Population (persons)	Urban Population Within the Study Area (persons)	Urban Area Within the Study Area (km^2)	Population Density (persons/km^2)
Fort Erie	24,096	16,925	16.38	1,033
Niagara Falls	68,845	58,077	64.83	896
Welland	45,448	38,548	27.99	1,377
Reference	16	---	---	---

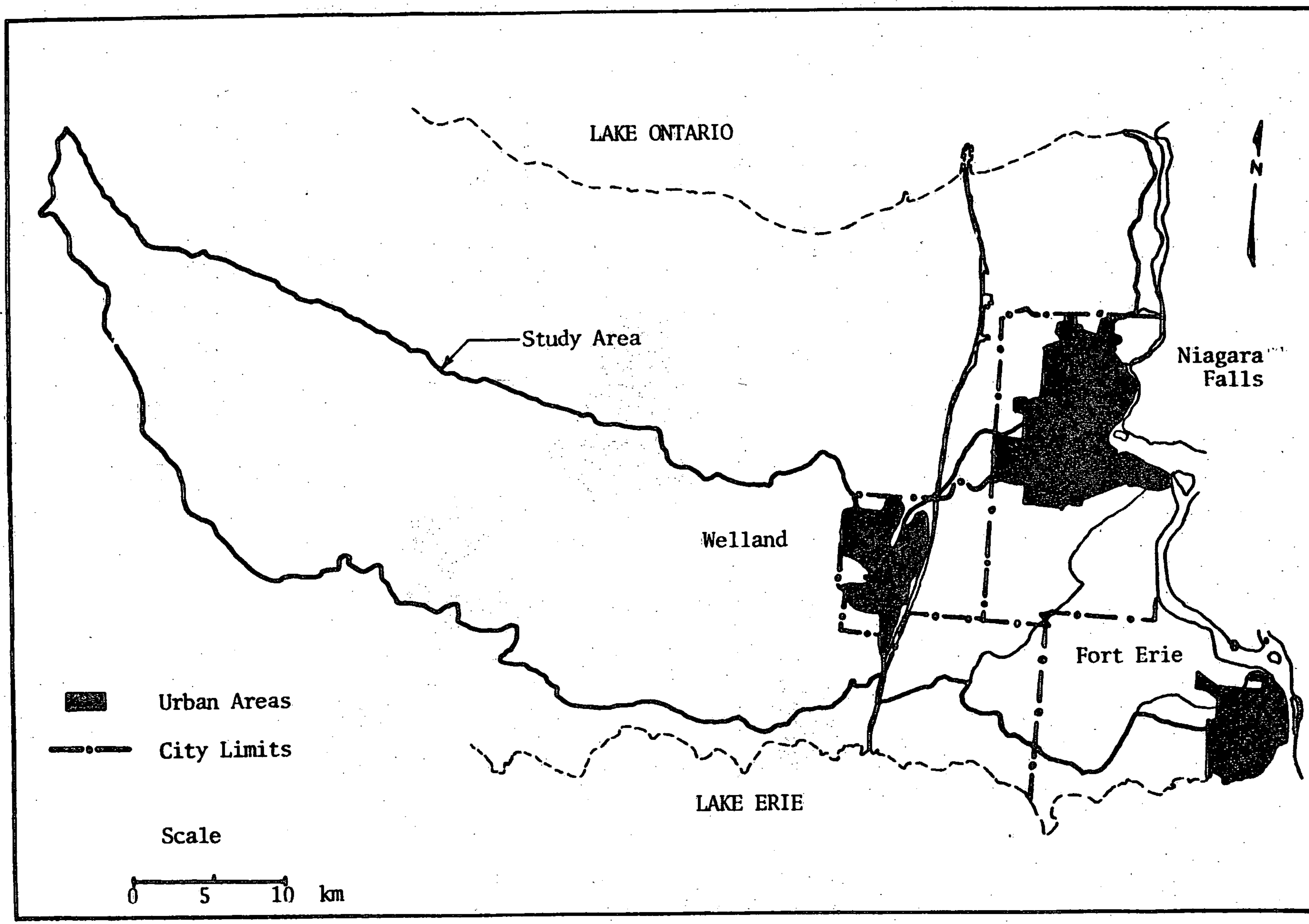


Fig. 2. Location of Urban Centres in the Study Area

The location of the three major urban centres is shown in Fig. 2.

The fact that the urban population in the study area is concentrated in the three centres has important implications for the sampling program which should concentrate on these three areas.

Local surface runoff volumes and runoff composition are also affected by land use. For this reason, the urban areas were classified into several land use categories- residential, commercial, industrial, institutional, and open land. The names of land use categories are selfexplanatory, except for the open land which represents parks, recreational areas, and undeveloped land within the urban political boundaries.

Information on the three major urban centres in the study area was collected and presented in Table 3.

TABLE 3. Urban Land Use Within the Study Area

	LAND USE									
	Residential		Commercial		Industrial		Institutional		Open	
City	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area ($km^2$0	%	Area ($km^2$0	%
Fort Erie	3.57	21.8	0.94	5.7	0.95	5.8	0.75	4.6	10.19	62.2
Niagara Falls	14.13	21.8	2.88	4.4	5.31	8.2	*	-	42.51	65.6
Welland	8.77	31.4	0.70	2.5	2.38	8.5	1.63	5.8	14.51	51.8

* Institutional land included in the residential land

It can be inferred from Table 3 that all three cities have a large portion of open land. For the remainder the predominant land use is residential, followed by industrial and commercial.

The distribution of urban land use has some implications for the composition of runoff and, consequently, for the sampling program as well. Earlier studies(11, 24, 25) of toxics in runoff from Ontario municipalities indicated that the highest frequencies and concentrations of toxics were found in stormwater and sediment samples from industrial areas. Thus it is desirable to ensure good coverage of industrial areas in the sampling program.

The types of industry in the study area were surveyed and classified according to the Standard Industrial Classification (SIC) (14). The results of this survey are presented in Table 4 which includes 19 types of industries in the study area.

It can be inferred from Table 4 that the greatest number of manufacturing firms is in the field of fabricated metal products, followed by food and kindred products, and machinery.

2.3 Climate Characteristics

Whenever the rainfall rate exceeds the rate of water infiltration into the ground, water accumulates on the catchment surface and starts to fill surface depressions. After such depressions have been filled, water starts to flow across the catchment surface as surface runoff which is conveyed by various channels or conduits comprising the catchment drainage system. Thus the surface runoff is formed as a result of interaction of precipitation and of the catchment surface. Consequently, one is interested in some aspects of the climate in the study area. Among these aspects, only precipitation, temperatures and wind direction are discussed here. Other types of information can be found elsewhere(2).

There is a number of precipitation gauges within or near the study area. A screening of their records revealed only minor variations between stations and, consequently, the precipation record from the Niagara Falls station was adopted as characteristic for the

TABLE 4. Classification of Industries in the Study Area

Standard Industrial Classification	Number of Manufacturing Firms*			
	Fort Erie	Niagara Falls	Welland	Whole Study Area
Fabricated Metal Products	12	28	8	48
Food and Kindred Products	2	24	6	32
Machinery (Except Electrical)	5	15	8	28
Printing, Publishing and Allied Products	6	13	3	22
Chemicals and Allied Products	7	13	1	21
Electrical Machinery Equipment and Supplies	5	12	4	21
Stone, Clay and Glass Products	3	14	4	21
Miscellaneous Manufacturing Industries	7	7	1	15
Primary Metals Industries	2	5	8	15
Transportation Equipment	6	7	0	13
Rubber and Plastic Products	4	3	4	11
Lumber and Wood Products (except Furniture)	0	6	4	10
Leather	1	4	0	5
Professional, Scientific and Controlling Instruments	1	3	1	5
Apparel	1	2	1	4
Furniture	1	1	0	2
Paper	1	1	0	2
Textiles	0	1	1	2
Petroleum	0	0	0	0

* Some firms may be classified under two categories

study area. This station is operated on the year-round basis and produced the longest precipitation record.

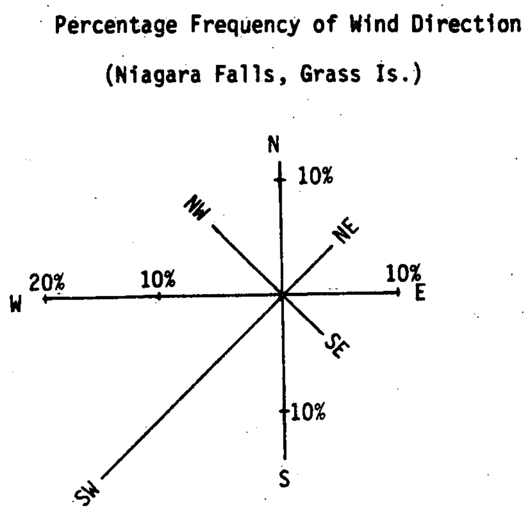
The mean annual precipitation for the Niagara Falls station is 942.3 mm. The monthly precipitation is distributed fairly uniformly throughout the year. In fact, the minimum and maximum monthly precipitation are within 17% of the mean monthly precipation of 78.5 mm. It follows therefore that the annual runoff will be also fairly uniformly distributed with the exception of winter months.

The maximum 24-hour rainfall depths, observed during the past 50 years, reach about 10% of the annual precipitation. The three greatest 24-hour rainfalls were reported in August, February and July. With regard to urban runoff, this indicates that for a 50-year return period, about 10% of the annual runoff can be concentrated in a single 24-hour period. Such an event may occur almost any time during the year.

The annual mean temperature is 8.9°C. During the period from December to February, the monthly temperatures drop below the freezing point. Even during these three months, rainfall occurs fairly frequently (30% - 50% of all precipitation events) and runoff can be expected although in smaller quantities than during the rest of the year.

Precipitation and temperature data from the Niagara Falls Station are summarized in Table 5. Monthly precipitation is plotted in Fig. 3.

Wind direction data were also obtained for the study area, from the Niagara Falls Grass Island Station. Such data were plotted in Fig. 3 and indicated the highest incidence of winds from the west, southwest, and south. The wind direction gives some indication (not very precise) of storm movement and local pollutant transport direction.



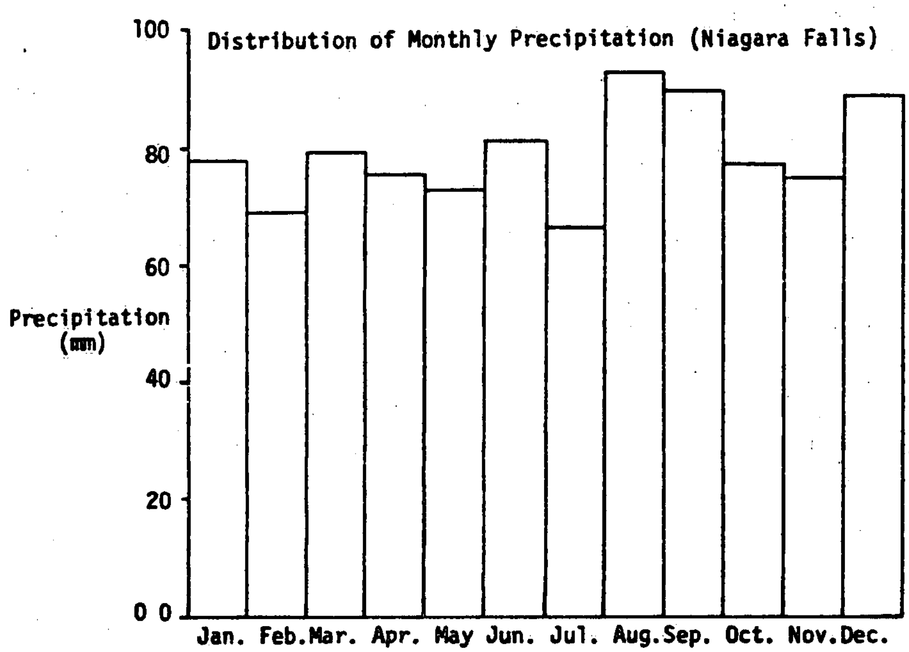


Fig. 3. Precipitation and Wind Direction Data

TABLE 5. Niagara Falls Station Temperature and Precipitation

MONTH	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
Daily temperature(°C)	-4.6	-4.0	0.6	7.2	13.5	19.3	22.0	21.4	17.3	11.1	4.6	-1.2	8.9
Years of Record	← 25 to 39 YEARS →												
Total Precipitation (mm)	78.0	68.4	79.3	75.8	72.4	81.3	66.1	92.1	89.7	77.0	74.1	88.1	942.3
Greatest Rainfall in 24 hrs. (mm)	38.1	82.8	43.9	51.1	47.8	75.2	81.0	95.3	81.5	62.2	43.2	71.9	95.3
Years of Record	44	48	48	46	48	48	50	50	50	48	50	48	

3.0 FIELD PROGRAM

The field program represented a major effort in the study of toxics in the Niagara area. This program was operated from March, 1982 to December, 1982. The main objective of the program was to collect representative samples of urban runoff and sediment from various sources. Such a program was designed on the basis of understanding of pollutant pathways in urban areas as obtained from the earlier studies and the literature.

Various sources and pathways of urban runoff pollutants are described first, followed by details of the field program procedures.

3.1 Sources and Pathways of Urban Runoff Pollutants

In order to design an effective sampling program for investigations of urban land runoff pollution, it is necessary first to examine the sources and pathways of runoff pollutants in urban areas. Although such processes are very complex, considerable simplifications are acceptable for the purpose of this study. Detailed discussion follows.

The sources of toxics in urban runoff are quite numerous and include atmospheric sources and sources related to land use activities. The atmospheric sources may be of local or remote origin and contribute to runoff pollution through both dry and wet precipitation.

Dry precipitation results in accumulation of particle deposits on the catchment surface and these deposits are then washed off during the periods of runoff. To investigate this source and possible source controls, it is of interest to collect samples of street surface deposits, as done in this study. Their composition may vary depending on the local sources of pollutants and the direction and intensity of their transport. Pollutants from remote sources are imported to the catchment and their characteristics do not necessarily correlate well with local land use and other conditions. On the other hand, local air pollution also contributes to pollutant accumulation and such a contribution will be related to the distance from local sources and prevailing wind directions.

Another source of toxics is wet precipation. It has been noted in the literature that many toxics are transported over large distances and reach the ground in the form of wet precipitation. Thus such substances are imported and do not necessary relate well to the local land use. Again, it is of interest to sample this source by collecting rainwater samples. Findings of earlier studies (24) indicated only minor variations in concentrations of toxics in rainwater within an urban area.

Other sources of toxics are those related to land use activities. Such sources include applications of pesticides in urban areas, release of toxics during industrial operations, spills, etc. Such activities determine the composition of runoff in the affected areas and seem to be particularly pronounced in industrial areas. In most cases, toxics accumulate on the catchment surface and are subsequently washed off during wet weather. To sample these source, one needs to collect samples of deposits and stormwater.

During the periods of runoff, the rainwater, which is already contaminated by toxics, reaches the catchment surface and washes off and transports substances accumulated on the catchment surface. Such processes are particularly intense on impervious parts of the catchment where practically all the rainwater runs off and the flow velocities and the resulting transport rates are fairly high. On pervious areas, the rainfall rate is smaller than the rate of losses (i.e. infiltration and surface storage) for long segments of the storm and, consequently, the rate and volume of runoff are rather small. Exceptionally, during rain storms of high intensity, or in the case of poorly drained soils, pervious parts of the catchment may contribute appreciably to the catchment runoff. Thus the monitoring activities should concentrate on impervious areas whose extent is closely related to land use and the population density.

The rate of pollutant transport during individual storms is not generally constant, but varies depending on the runoff rate, the amount of pollutants remaining on the catchment surface, and some other factors.

In some catchments, the so-called first-flush was reported for conventional pollutants. This term is used to describe pollutographs which exhibit the highest concentrations during the early parts (more or less coinciding with the rising hydrograph limb) of the runoff events when the greatest quantities of pollutants are available on the catchment surface. Considering the high costs of toxics analyses, it is infeasible to collect sequential samples and to characterize toxics concentrations variations during storms. If the primary interest is the substance loading, it is preferable to collect composite samples for individual events. Ideally, the sample composition should be flow proportional.

Earlier studies indicated (11, 24) that toxics are associated with urban sediment in concentrations two to three orders of magnitude higher than those found in stormwater. Thus it is desirable to sample both urban sediment and stormwater. Urban sediment samples can be obtained by collecting street deposits samples or by filtering out solids which are transported by stormwater. Stormwater samples may be collected in various transport elements of the drainage system.

Thus it follows from the above discussion that the sampling program should be designed on the basis of the following considerations:

Sediment as well as liquid samples should be collected in areas with various land use (with emphasis on industrial land use).

Sediment samples should be collected during both dry and wet periods.

Liquid samples should be collected as flow-proportional composite samples.

3.2 Selection of Study Sub-Areas

The selection of study sub-areas was governed by the distribution of the urban population in the basin and by the need to determine the toxics loadings for areas related to those used by others in studies of point sources. From the population point of view, it was desirable to cover the three major population centres, Fort Erie, Niagara Falls, and Welland. The runoff discharge from these three centres could be attributed to two points - the discharge at Fort Erie and the combined discharge, from Welland and Niagara Falls, at Niagara Falls. It should be noted that the other two sub-areas, identified in the section on water resources as the Black Creek sub-area and the Niagara-on-the-Lake sub-area, do not contain any urban land and may be eliminated from further considerations.

3.3 Sampling Locations

Eight permanent sampling stations were established and monitored in three urban centres during the study period. These stations were further supplemented by some temporary sites. The characteristics of the sampling stations are listed in Table 6 and the locations of stations are shown in Fig. 4.

Among the eight permanent stations, four were in Niagara Falls, three in Welland and one in Fort Erie. Such a distribution reflects the relative distribution of population in these three cities.

In terms of land use, two residential and six industrial areas were investigated, thus reflecting the primary concern about pollution from industrial areas. The information from the residential areas was further supplemented by data from other Ontario municipalities. Earlier studies showed little variation in toxics in urban residential runoff from different locations as opposed to larger variations in the industrial runoff composition.

TABLE 6. Sampling Locations and Methods

LOCATIONS	SITE NUMBER	LAND USE[1]	NUMBER OF EVENTS SAMPLED	SAMPLE SOURCE			SAMPLING METHOD[2]			
				ROAD RUNOFF	ROAD SEDIMENT	STORM SEWER	CBS	VC	PP	FS
Fort Erie										
Russell St.	FI1	IND.	15	X	X		X	X		X
Welland										
Ontario/Iron St.	WI1	IND.	13	X	X	X	X	X	X	X
Patterson/Cohoe St.	WI3	IND.	11	X	X		X	X		X
Holy Cross Cemetary	WR4	RES.	12		X	X		X	X	X
Hariet/Orchard St.	---	RES.	1		X			X		
Church/Aqueduct St.	---	RES.	1		X			X		
Canal Bank/Ontario St.	---	IND.	1		X			X		
Niagara Falls										
Earl Thomas Ave.	NI1	IND.	10		X	X		X	X	X
Fourth/Hamilton St.	NI2	IND.	11	X	X		X	X		X
Thorald Stone/Stanley	NI3	IND.	13		X	X		X	X	X
Aintree/Lexington St.	NR4	RES.	15	X	X		X	X		X
Rain Samples										
Niagara Ave. Fort Erie	---	OPEN	2	RAIN			GLASS TRAYS			
Thorald Stone/Stanley		IND.	2	"			"			
WPCP Welland>		OPEN	1	"			"			
Cross St. Welland		COMM.	1	"			"			

1. IND. - INDUSTRIAL
   RES. - RESIDENTIAL
   COM. - COMMERCIAL

2. CBS - CATCHBASIN SAMPLER
   VC - VACUUM CLEANER
   PP - AUTOMATIC PERISTALTIC PUMP
   FS - FILTERED SEDIMENT

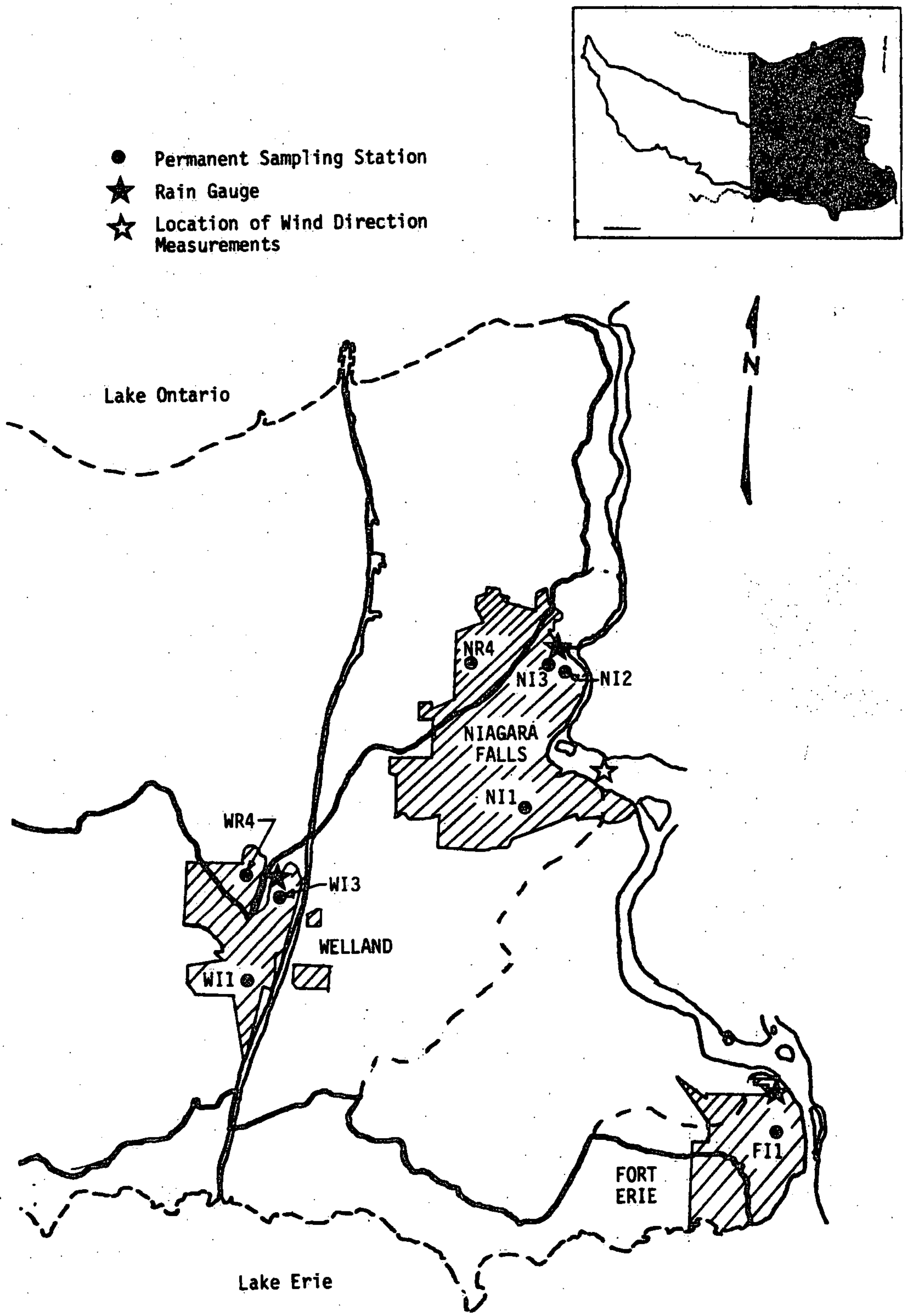


Fig. 4 Location of Monitoring Stations

At each site, from 10 to 15 events were sampled. In this connection, an event represents either a runoff event, or a dry weather period for solids accumulation. The average number of runoff events sampled at each site was 10. Estimating the total number of runoff events per year as 70, approximately one in seven runoff events per year was sampled at each site. The number of runoff events per year was estimated from the total number of days with precipitation greater than 1.25 mm.

Various sources of urban runoff and sediment were sampled. In most cases, the sampling was limited to road runoff and street surface sediment - the major sources in terms of volumes and loadings. At four sites, samples of stormwater in storm sewers were also collected and, by filtration of such samples, samples of suspended solids were obtained. Such samples reflect contributions of various sources. At two sites, a few grab samples of road snow and ice were also collected. Further studies of snowmelt quality were prevented by the study timing.

Besides the eight permanent stations, several temporary sites were used to collect rainwater and stormwater samples.

In total, 110 events were sampled at 15 sites within the study area. The most of these events, 100, were sampled at the eight permanent sites which were described earlier.

Note that the number of events for which analytical data were available when writing this report was less than 110. This was caused mainly by delays in sample analysis.

3.4 Sample Collection Methods

Flow measurement and sampling methods for studies of urban runoff have been established for conventional pollutants (21). In such studies, the pollutant concentrations are fairly high and the sample cross-contamination is limited. The methodology for monitoring of toxics in urban runoff is not well established and many procedures used in this study were developed on the basis of general recommendations of the U.S. Environmental Protection Agency (21) and the Water Quality Branch of Inland Waters Directorate. It should be also emphasized that the study budget and schedule did not allow acquisition of sophisticated equipment. Descriptions of various sample gathering methods follow.

Sewer Inlet Sampler

The sewer inlet sampler is a simple custom made device which serves for collection of road runoff samples. Basically, the sampler consists of a large stainless steel funnel, which fits under the inlet grate, and of a sample container. The funnel diverts a small fraction of the total inflow via a teflon tube into the sample container which is either a glass bottle or a stainless steel vessel. The bottles used for storage had a capacity of 22 litres, the stainless steel vessel had a capacity of 15 litres.

The sewer inlet samplers were used to collect about 75% of all water samples.

Automatic Wastewater Samplers

At three sites in Niagara Falls and Welland, some stormwater samples were collected by means of automatic wastewater samplers which were operated in the sequential mode. Sequential samples were then composed proportionally to the flow rates measured by an electromagnetic flow recorder (Marsh - McBirney Model 265).

The automatic sampler originally employed was the ISCO Model 2100 which has been recommended for toxics monitoring in the U.S.A.. It is a sequential sampler which collects samples by means of a peristaltic pump. To avoid sample contamination, all the internal plumbing is made of stainless steel or teflon, with the exception of a short piece (0.6 m) of tubing in the peristaltic pump. This tubing must be fairly flexible for good pump operation and, consequently, a medical-grade silicone rubber tubing is used for this purpose. The particular brand used in the ISCO sampler is referred to as the Dow Corning medical grade Silastic. The sampler manufacturer states that this brand of tubing will not contribute any organic material to samples (7). In field operation, up to 24 sequential samples of stormwater were collected and used to produce a single flow-proportional composite sample.

In a later phase of the study, another automatic sampler, the Sigmamotor 6201, was also used. A standard Model 6201 was modified for the monitoring of toxics in a similar way as done in the ISCO sampler. Again a medical-grade silicone rubber tubing was used in the sampler peristaltic pump. The sample distribution system which could contaminate samples was bypassed using teflon tubing and samples were composed in a single glass container.

Concerns about the possible contamination of samples by various types of tubing led the Environmental Protection Service, Ontario Region, to initiate tests of three types of tubing (3). The test results were released in June 1983, thus too late to be implemented in this study. These results may be helpful in future studies and thus the EPS findings are briefly summarized below.

Two types of tests were conducted. In the first series, 3-metre sections of silicone, teflon and tygon tubing were immersed in nine litres of deionized water for a period of four days. In the second series, a 0.3 m section of tubing was pretreated and then used in a peristaltic pump to collect 9-litre, 24-hour composite samples. This second series seems to simulate more closely the actual field conditions observed in this study. Under such conditions, up to 24 of 350 ml samples were collected. The collection of these 24 samples would require about 2.8 minutes of the peristaltic pump operation. The average residence time of samples in the tubing was seven seconds.

The EPS study indicates that, for the severe test conditions employed, some sample contamination may be caused by both silicone and tygon tubing. It should be mentioned that the silicone tubing has not been properly identified in the draft report (3) and subsequent enquiries have not clarified the tubing origin. In particular, two substances, ethoxy butoxy ethanol and dichlorobenzoic acid, appeared on the spectrum printout in an area where certain priority pollutant could appear. If such priority pollutants were of low concentration, they would be masked by the leached substances. It was recommended to pretreat the silicone rubber tubing by flushing with deionized water at pH2, for 16 hours prior to the use, to minimize contamination.

Although the possibility of sample contamination in automatic samplers with peristaltic pumps cannot be completely discounted, the danger of such contamination can be reduced by using a proper tubing material and by pretreating the tubing. No evidence has been found that the silicone rubber tubing in the ISCO sampler contaminates samples.

After every event, the sampling equipment was cleaned.

Rainwater Collectors

Rainwater was collected at several temporary sites using a set of glass trays with capacity 2 litres each.

Collection of Sediment Samples

Two collection methods were used to obtain sediment samples. In the first one, suspended solids samples were obtained by filtration of stormwater samples which were typically collected by means of sewer inlet samples. Standard laboratory equipment was used to filter stormwater samples. The filtration process was aided by vacuum, or for large volumes, by compressed gas. The filter used was the MILLIPORE type LS with the pore size of 5.0 μm (0.005 mm). To obtain a sufficent quantity of solids, from 5 to 15 litres of stormwater had to be filtered. Filtered solids were placed in glass jars and submitted for analysis.

Samples of street surface sediment were generally collected by dry vacuuming. A household vacuum cleaner was used for this purpose. Collected solids were place in glass jars and transported to the laboratory for analysis. Some fractions of such samples were further analyzed for particle size distribution.

3.5 Transport and Preservation of Samples

All field samples were removed from sampling devices as soon as possible after the sampled event and placed in transport containers. Glass bottles or jars with their top covered by aluminum foil were used for such a purpose.

In the laboratory, the samples were transferred from transport containers into laboratory bottles, preserved, and submitted for analysis. For organics analyses, two 1-litre samples in glass bottles were submitted. Samples for trace metals analysis were placed in 250 ml plastic bottles and preserved by adding 1 ml of 50% HNO_3. Samples for mercury analysis were submitted in 100-ml brown glass bottles. Such samples were preserved by adding 1 ml of concentrated H_2SO_4 and 1 ml of 5% potassium dichromate solution (dithizone-extracted).

Sediment samples were delivered in glass jars to the analytical laboratory and subsequently were frozen.

3.6 Cleaning Procedures for Sample Containers

For cleaning sample containers, the procedures recommended by the Water Quality Branch, IWD, Ontario Region, were used. According to these procedures, containers were washed with soap and hot water, rinsed several times with hot water and then rinsed several times with distilled water. After draining water from the container, it was rinsed two or three times with analytical grade acetone and petroleum ether, followed by two or three rinses with pesticide residue grade ethyl acetate and, finally, the container was rinsed with pesticide residue grade hexane. The volume of each rinse was 2-3% of the container volume.

Clean bottles were capped with solvent washed aluminum foil.

4.0 SAMPLE ANALYSIS

Field samples were delivered to analytical laboratories for detailed and extensive analyses. A list of substances studied is presented first followed by a summary of analytical procedures.

4.1 Toxic Substances Studied

The selection of toxic substances studied was initially based on the U.S. Environmental Protection Agency list of priority pollutants. This list was further modified and the final selection of 51 substances was more or less given by the availability of anlaytical procedures in the laboratories employed. These substances can be divided into five groups: Polychlorinated biphenyls (PCB's), organochlorine pesticides (OCP's), polyaromatic hydrocarbons (PAH's) chlorinated benzenes (CB's) and trace elements (TE).

PAH's analyses could not be performed on all samples because of coextracted interfering compounds.

A detailed listing of substances in individual groups and the detection limits for analyses employed are presented in Table 7.

Information on the toxic substances studied can be found in Ref. 22.

TABLE 7. Substances Studied and Detection Limits

Substance	Detection Limits Water (ppb) IWD*	MOE**	Sediment (ppm) IWD	MOE
PCB's				
Total polychlorinated biphenyls	0.009	.02	.09	.02
Organochlorine Pesticides				
Hexachlor benzene	.0004	-	.004	-
α - BHC	.0004	.001	.004	.001
Lindane	.0004	.001	.004	.001
Heptachlor	.0004	.001	.004	.001
Aldrin	.0004	.001	.004	.001
Heptachlor epoxide	.0004	.001	.004	.001
γ - chlordane	.0004	.002	.004	.002
α - chlordane	.0004	.002	.004	.002
α - Endosulfan	.0004	.002	.004	.002
p,p' - DDE	.0004	.001	.004	.001
Dieldrin	.0004	.002	.004	.002
Endrin	.0004	.004	.004	.004
o,p' - DDT	.0004	.005	.004	.005
p,p' - TDE	.0004	.005	.004	.005
p,p' - DDT	.0004	.005	.004	.005
β - Endosulfan	.0004	.004	.004	.004
Mirex	.0004	.005	.004	.005,.5
Methoxychlor	.0004	.005	.004	.005
Polyaromatic Hydrocarbons				
Indene	.05	-	.05	-
1,2,3,4 tetrahydronaphthalene	.05	-	.05	-
2, methylnaphthalene	.05	-	.05	-
Quinoline	.05	-	.05	-
1, Methylnaphthalene	.05	-	.05	-
β - chloronaphthalene	.05	-	.05	-
Acenaphthylene	.05	-	.05	-
Acenaphthene	.05	-	.05	-
Flourene	.05	-	.05	-
Phenanthrene	.05	-	.05	-
Flouranthene	.05	-	.05	-
Pyrene	.05	-	.05	-

* IWD Laboratory
** MOE Laboratory

TABLE 7. (continued)

Substance	Detection Limits Water (ppb) IWD	MOE	Sediment (ppm) IWD	MOE
Chlorinated Benzenes				
1,3 dichlorobenzene	0.005	-	0.05	-
1,4 dichlorobenzene	0.005	-	0.05	-
1,2 dichlorobenzene	0.005		0.05	-
1,3,5 trichlorobenzene	0.001	0.01	0.005	-
1,2,4 trichlorobenzene	0.001	0.01	0.005	-
1,2,3 trichlorobenzene	0.001	0.01	0.005	-
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.001	0.01	0.005	-
1,2,3,4 tetrachlorobenzene	0.001	0.01	0.005	-
pentachlorobenzene	0.001	0.01	0.005	-
Hexachlorobenzene	0.0004	0.001	0.004	0.001
Trace Elements				
Arsenic	0.1	30	0.05	0.03
Cadmium	1.0*	0.2,10	10	0.3
Copper	1.0*	10,20	10	1.0
Cobalt	1.0*	20,40	10	2.0
Chromium	1.0*	10	0.5	3.0
Lead	1.0*	60	0.5	3.0
Mercury	0.05	-	0.1	-
Nickel	1.0*	30	10,30	2.0
Selenium	0.1	1,30	0.05	0.03
Zinc	1.0	1.0	0.1	2.0

* For several samples, the detection limit was 10 ppb.

4.2 Laboratory Procedures

Sample analyses were done by two analytical laboratories - The Laboratory of the Water Quality Branch of IWD, Ontario Region and by the Analytical Laboratory of the Ontario Ministry of the Environment. Although the use of two laboratories which may employ different analytical procedures is not generally desirable, such a solution was necessitated by the fact that neither laboratory had a spare capacity to analyze all the samples.

4.2.1 IWD laboratory procedures

Details of analytical methods used by the IWD laboratory can be found elswhere (23). A brief description of general procedures follows.

Trace Elements. Atomic absorption spectroscopy was used for determination of metals in stormwater samples. The main advantages of this technique follow from its ease of operation, sensitivity, and applicability to a large number of metals in a wide variety of waters, including surface water, domestic wastes and industrial wastes. Further details are given in Ref. 23.

Several methods were used to determine total metals and other inorganics in sediments.

Mercury in sediment was detemined by cold vapour atomic absorption. Arsenic and selenium were determined by flameless atomic absorption. The remaining analyses were done by means of the bomb digestion method. In this method, the sample decomposition is carried out in a sealed teflon bomb. Sample solutions are then analyzed by atomic absorption spectroscopy. This method was used for cadmium, chromium, cobalt, copper, lead, nickel, selenium and zinc.

Trace Organics. All water samples were extracted using the methylene chloride water extraction method which was described elsewhere (18). The sediment samples were extracted by ultrasonic extraction. (18). Because of high amounts of coextracted interfering compounds present, an additional clean-up step involving gel permeation chromatography was added. Further information on this procedure, which is not among standard procedures, can be obtained from the IWD laboratory.

The analysis of extracts was performed using gas chromatography. For PCB's and organochlorine pesticides, high resolution gas chromatography with two columns was used. For PAH's and CB's, one column gas chromatography was used. The detectors used were a flame ionization detector for PAH's and an electron capture detector for the remaining substances.

4.2.2 MOE laboratory procedures

A description of laboratory procedures was supplied by the MOE laboratory (9, 12). Such procedures are summarized below.

Trace Elements

Heavy metals in water samples were analyzed by means of either atomic absorption spectrometers or inductively coupled plasma atomic emission spectrometers. Both types of instruments produce equivalent, unbiased data.

For sediment samples, the samples were first digested with aqua regia and then analyzed using the same instruments as for water samples.

Arsenic and selenium in both water and sediment were determined by first digesting appropriate aliquotes with sulphuric, nitric acid mixture in a hot block to fumes. The digestate was then analyzed by automated hydride generation, flameless atomic absorption.

Trace Organics

Water samples were extracted by the methylene chloride extraction method. Sediment samples were extracted by ultrasonic extraction, referred to as the Sonifier method. Extraction was followed by a cleanup procedure using adsorption chromatography on Florisil.

Sample analysis was done by gas chromatography using Hewlett Packard 5700 series gas chromatographs equipped with electron capture detectors.

5.0 ANNUAL VOLUME OF URBAN RUNOFF AND DISCHARGE OF SOLIDS

Field studies of toxic substances in urban runoff indicate that there are two mechanisms for transport of toxics from the catchment surface. The first mechanism is transport by runoff water and the second one is by means of solids suspended in stormwater, or transported as bed load. Thus, the total loading of toxics in urban runoff can be conceptually divided into the loading attributed to the liquid phase and the loading attributed to the solid phase. To estimate such loadings, on an annual basis, it is required to estimate the annual runoff volume and the annual discharge of solids. Such quantities are then multiplied by mean toxics concentrations to obtain annual loadings of toxics.

Computations of annual runoff volume and solids production follow.

5.1 Annual Volume of Runoff From the Study Area

The annual volume of runoff can be calculated from the contributing area and the annual rainfall excess, which equals the fraction of annual precipitation converted into runoff.

For runoff computations, the precipitation record from the Niagara Falls station was used. This was the only station in the study area for which hourly rainfall data were available for at least a part of the year (April to October). Daily precipitation was available for the entire record length of 25 years.

To reduce the volume of computations, runoff was computed for one year only. For this purpose, the 1978 data were used because the annual precipitation for that particular year was within 1% of the long-term mean precipitation. To simplify computations, snowfall was replaced by equivalent rainfall. Such a simplification may distort runoff distribution during the winter months, but it should not affect much the computed runoff volumes.

The runoff computations were done separately for impervious and pervious parts of the catchment, in order to account for different abstractions occurring in each of these parts. Without any calibration data, the magnitude of such abstractions had to be estimated. Whenever practical, the sensitivity of computed runoff depths or volumes to variations in the assumed abstractions was determined.

5.1.1 Runoff from impervious areas

Rainwater falling on the impervious surface fills minute surface depressions and once such depressins have been filled, surface runoff commences. Generally, the depression storage represents a combination of such losses as those due to interception, surface wetting, surface ponding, and evaporation.

The depression storage is averaged over the contributing area and then expressed as the depth of storage. Various estimates of the depression storage depth can be found in the literature, with typical values ranging from 0.5 mm to 1.6 mm.

For a record of N events, among which S events have the total rainfall depth smaller than the depression depth, the total depression storage abstraction, H_{ds}, may be expressed as

$$H_{ds} = \sum_{i=1}^{S} P_i + (N-S)\, h_d \qquad (1)$$

where h_d is the assumed depression storage depth, and P_i is the total rainfall depth for events with $P < h_d$.

Eq. 1 was applied to seven months of hourly rainfall data for several values of h_d and the results were then extrapolated to the full record length of 12 months. The values of h_d ranged from 0.5 mm to 1.5 mm. The results of such calculations are presented in Fig. 5 where the annual depression storage abstraction is plotted versus the depression storage depth.

To estimate the annual depression storage abstraction, three values of the depression storage depths were selected on the basis of the literature data (1). The minimum value was taken as 0.5 mm, the maximum value as 1.5 mm, and the best estimate as 1.18 mm. The best estimate was derived from the default values in the Storm Water Management Model (4). In this model, the impervious depression storage is 1.575 mm for 75% of the total impervious area. The remaining 25% of the area have zero storage. Thus the combined value is 0.75 x 1.575 = 1.18 mm.

The annual depression storage abstractions, derived from the Niagara Falls data, were adopted for all three cities in the study area and used to calculate the annual runoff volume, V, from the following formula:

$$V_{imp} = A_{imp} (P - H_{ds}) \qquad (2)$$

where A_{imp} is the contributing impervious area and P is the annual precipitation. The results of such calculations are summarized in Table 8.

5.1.2 Runoff from pervious areas

Whenever the rainfall rate exceeds the rate of water infiltration into the soil, water starts to accumulate on the surface of a pervious area and fills surface depressions. After such

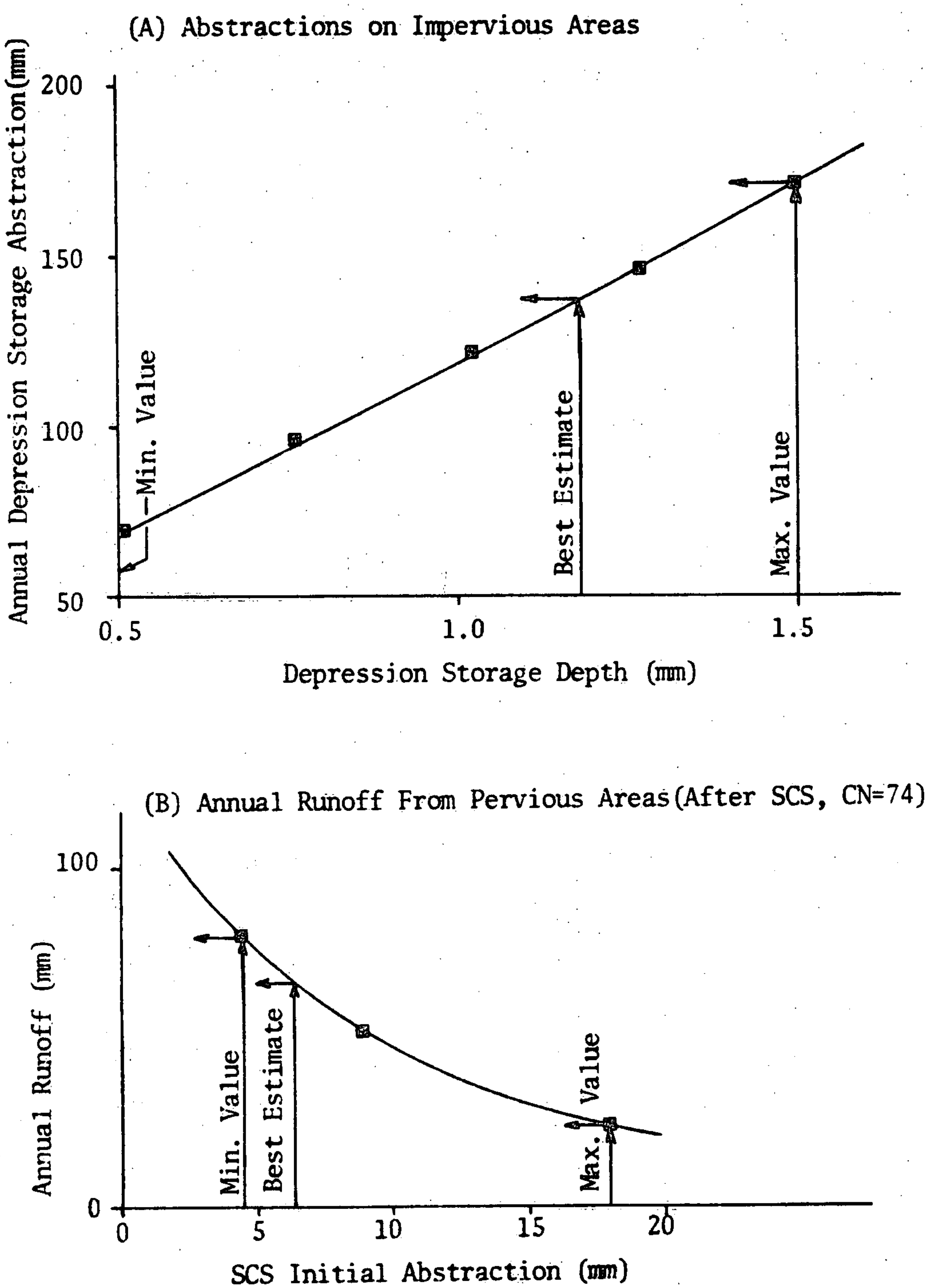


Fig. 5. Supporting Data for Runoff Computations

TABLE 8. Volumes of Annual Runoff from Impervious Areas

City	Impervious Area [km^2]	Annual Precipitation [mm]	Depression Storage Abstractions [mm]			Runoff Volume [$10^6 \times m^3$]		
			Minimum	Best Estimate	Maximum	Minimum	Best Estimate	Maximum
Fort Erie	2.95	995.0	68	137	170	2.43	2.53	2.75
Niagara Falls	10.82	942.3	68	137	170	8.36	8.71	9.46
Welland	5.37	938.0	68	137	170	4.12	4.30	4.67

depressions have been filled, water starts to flow across the catchment surface as surface runoff. Thus two important abstractions occur during this process - soil infiltration and depression storage.

Computations of runoff from pervious areas are fairly complex and usually require field data for calibration of various process parameters. For the purpose of this study, it was desirable to employ a simple, practical, well established procedure which did not require any calibration. Such criteria were met by the Soil Conservation Service (SCS) method (20).

In the SCS method, the soil water storage capacity, S [mm], can be expressed in metric units as

$$S = \frac{25{,}400}{CN} - 254 \qquad (3)$$

where CN is the soil cover complex number listed in handbook for various soils and land use or cover. For the conditions in the study area, which were characterized by the hydrologic soil group C and open spaces with good grass cover, CN was selected as 74 and the soil water storage capacity was then calculated from Eq. (3) as S = 89.2 mm.

The accumulated runoff, R [mm], can then be expressed as

$$R = \frac{(P-I_a)^2}{P-I_a+S} \tag{4}$$

where P is the accumulated rainfall since the beginning of the storm period and I_a is the initial abstraction which equals the sum of abstractions for interception, depression storage, and infiltration prior to the start of runoff.

Although the initial abstraction has been estimated from the SCS data as 0.2S, there is some evidence indicating that lower values may be more appropriate, especially in urban areas (8). Consequently, the initial abstraction was expressed here as $I_a = pS$, where $0.05 \leq p \leq 0.2$. After substitution into Eq. (4), the final expression can be written as:

$$R = \frac{(P-pS)^2}{P+(1-p)S} \tag{5}$$

To estimate the depth of runoff from pervious areas, Eq. (5) was applied to all events in the 7-month hourly rainfall record and to the daily equivalent rainfall for the remaining five months. Eq. (5) was applied with three different values of p and the resulting values of the runoff depth R were plotted in Fig. 5.

For computation of pervious area runoff volume, three values of the parameter p were selected. The minimum value was p = 0.05 (I_a = 4.46 mm), the maximum value was p = 0.2 (I_a = 17.85 mm), and the best estimate was p = 0.071 (I_a = 6.34 mm). For the best estimate, the initial abstractin equals the value recommended in the literature for urban areas.

The volume of runoff from pervious areas, V_{per}, is then expressed as

$$V_{per} = A_{per} R \qquad (6)$$

where A_{per} is the contributing pervious area. Computations of runoff from pervious areas are summarized in Table 9.

Finally, the total runoff volume is taken as the sum of V_{imp} and V_{per}. All the computations are summarized in Table 10.

It can be inferred from Table 10 that the upper and lower limits of the estimated runoff volumes are within 15% of the mean. It will be shown later that uncertainties in calculated runoff volumes are relatively small compared to other uncertainties in the computation of toxics loadings.

5.2 Annual Discharge of Solids in Urban Runoff

In urban areas, solids which are found in urban runoff originate from dust and debris accumulated on the catchment surface and also from soil erosion. Solids are of importance from the viewpoint of water quality in that they directly interfere with sunlight penetration as well as other processes and, indirectly, they serve as transport media for other substances, including toxics. Consequently, it is of interest to establish characteristics and loadings of solids in urban runoff from the study area. The term solids is used here for both suspended solids as well as solids transported as bed load.

5.2.1 Investigations of street sediments

Sediments accumulate on the surface of urban catchments and they are subsequently washed off during the periods of runoff. Thus it is of interest to investigate accumulation rates and characteristics of street sediments. Towards this end, eleven experimental sites were established and used for collection of sediment samples. Sediment samples were collected by vacuuming. The collected samples were weighed and subsamples were submitted for chemical analysis and

TABLE 9. Volumes of Annual Runoff from Pervious Areas

City	Pervious Area [km^2]	Annual Runoff Depth [mm]			Annual Runoff Volume [$10^6 \times m^3$]		
		Minimum	Best Estimate	Maximum	Minimum	Best Estimate	Maximum
Fort Erie	13.43	23	65	79	0.31	0.87	1.06
Niagara Falls	54.01	23	65	79	1.24	3.51	4.27
Welland	22.62	23	65	79	0.52	1.47	1.79

TABLE 10. Volumes of Annual Runoff from the Study Area

	Annual Runoff Volume [$10^6 \times m^3$]		
	Minimum Estimate	Best Estimate	Maximum Estimate
Fort Erie	2.74	3.40	3.79
Niagara Falls	9.60	12.22	13.73
Welland	4.64	5.77	6.46

particle size analysis. Results of these investigations are presented below.

Accumulation Rates

Street sediment accumulation rates were studied at two residential and six industrial sites. The observed rates varied significantly from 1.4 kg/curb-km/day to 30.3 kg/curb-km/day. For each land use studied, mean accumulation rates were established. In residential areas, the accumulation rate was established as 4.6 kg/curb-km/day and the rate for industrial areas was 11.2 kg/curb-km/day. It was recognized that these rates may represent low estimates because of possible sediment removal by street cleaning for which records were not available.

Particle Size Analysis

The interest in particle size distribution is twofold. Firstly, many pollutants are associated with sediment particles of certain sizes. For example, some earlier studies (15) indicated that up to 85% of pesticides, 95% of lead, and 60% of other heavy metals are found in sediment particles smaller than 0.84 mm. Secondly, the interest in particle size distribution stems from the viewpoint of pollution control. In general, smaller particles are more difficult to remove by such processes as settling, or street sweeping.

The results of particle size analysis are sumarized in Table 11 and plotted in Fig. 6.

It can be inferred from Table 11 that there was practically no difference between size distributions in residential and industrial areas. The commercial site samples exhibited higher percentage of fine particles which may be caused by more frequent street cleaning and the associated removal of larger particles. It was noted that up to 82% of sediments from residential and industrial areas and 95% of sediments from commercial areas were finer than 0.84 mm.

TABLE 11. **Street Sediment Samples - Particle Size Distribution**

SIEVE SIZE [mm]	% FINER BY WEIGHT								
	RESIDENTIAL			INDUSTRIAL			COMMERCIAL		
	NO. OF SAMPLES	MEAN	RANGE	NO. OF SAMPLES	MEAN	RANGE	NO. OF SAMPLES	MEAN	RANGE
>5.6	4	100	-	12	100	-	3	100	-
2.0	4	85	66-99	12	86	75-97	-	-	-
1.19	4	71	50-88	12	72	40-94	-	-	-
0.84	1	71	-	4	68	40-82	3	85	77-95
0.70	4	65	36-87	12	62	28-86	-	-	-
0.50	1	59	-	4	56	29-69	3	77	69-90
0.425	4	49	24-68	12	51	16-72	-	-	-
0.350	1	49	-	4	45	21-56	3	66	58-83
0.250	5	36	15-47	16	36	8-61	3	59	37-71
0.125	5	22	9-29	16	20	3-39	3	19	13-23
0.0625	5	13	6-18	16	10	1-22	3	6	4-7
<0.0625	5	4	0-7	16	3	0-13	3	0	0-1

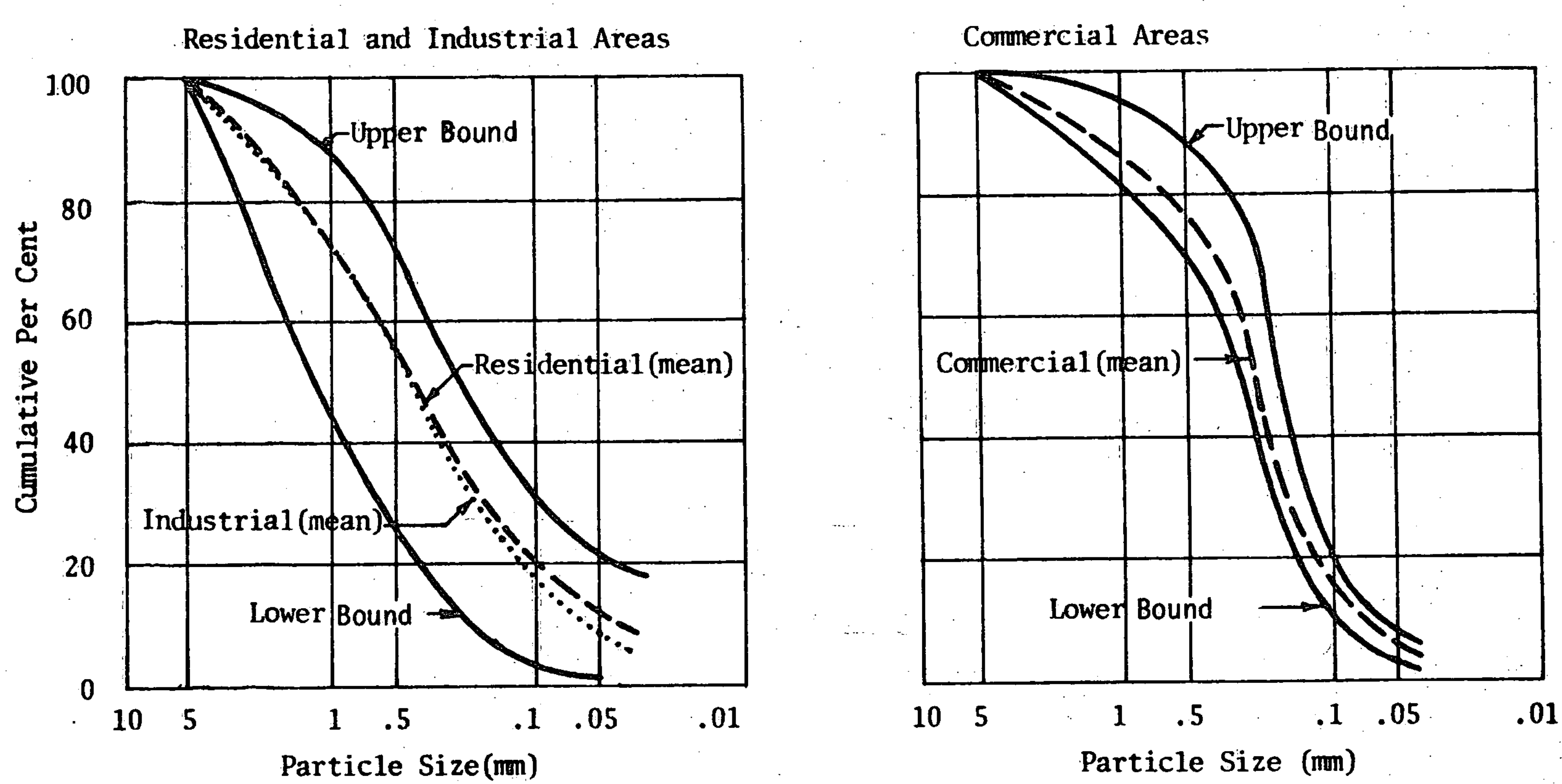


Fig. 6. Street Sediment-Particle Size Distribution

Sediment Composition

Chemical composition of street sediment was also studied and the results are discussed in the next chapter.

5.2.2 Annual loadings of solids

Computations of annual loadings of solids involve large uncertainties and consequently, it is desirable to use several computational approaches to verify the computed loadings. Therefore, three different methods were applied to the study area. The first approach was based on the annual unit loading rates adopted from the literature. The second approach was based on accumulation rates of solids along curbs in urban areas. The third approach was based on mean concentrations of solids in runoff and the annual runoff volumes. As in the previous section, it was of interest to provide the low, high and best estimate. Details of computations follow.

5.2.2.1 Loading estimates from annual unit loadings

The use of annual unit pollutant loadings, for evaluation of urban runoff pollution, has been described in the literature. Such unit loadings are defined as the pollutant weight which is conveyed by urban runoff from a one-hectare area, of a specific land use and sewage system, over the period of one year. Such unit loadings were developed by the American Public Works Association (17) and later modified, for the use in Ontario, by eliminating precipitation as one of the independent variables and by taking into consideration some local data (10).

The annual solids loading, L, can be expressed as

$$L = \sum_{i=1}^{k} UL_K A_K \qquad (7)$$

where UL is the unit solid loading (kg/ha/yr), A is the area with a particular land use, and the subscript K denotes various land use types. All the computations were done for separate storm sewers.

Using Eq. (7), the annual loading of solids were produced for each urban area and presented in Table 12.

TABLE 12. Annual Solids Loadings Derived from Unit Loadings

Urban Area	Annual Loading of Solids (tonnes)
Fort Erie	648
Niagara Falls	3,131
Welland	1,573

5.2.2.2 Loading estimates from daily accumulation rates

Urban runoff quality models, such as the SWMM and STORM models (4,19), use the concept of dust and dirt accumulation for quality modelling. According to this concept, dust and dirt accumulate along curbs at daily rates which depend on land use. This concept was derived from extensive field studies of solids accumulations in urban areas (17). Because of the widespread use and acceptance of both models, it was decided to use the concept of dust and dirt accumulations to produce an estimate of solids loading in the study area.

The annual loading of dust and dirt, L_{DD}, in an urban area can be expressed as

$$L_{DD} = 365 \sum_{i=1}^{K} W_i \, CD_i \, A_i \qquad (8)$$

where W is the daily accumulation of dust and dirt (kg/curb-km/day), CD is the curb density (km/km^2), A is the area, and the subscript i (i= 1,...K) denotes various types of land use.

TABLE 13. **Annual Accumulations of Dust and Dirt**

LAND USE	ACCUMULATION RATES OF DUST AND DIRT [kg/km of curb/day]	CURB DENSITY [km/km^2]	URBAN AREA [km^2]			CURB LENGTH [km]			ANNUAL ACCUMULATION OF DUST AND DIRT [tonnes/yr]		
			FE	NE	W	FE	NF	W	FE	NE	W
Residential	15.9	26.8	4.32	14.13	10.40	116	379	279	673	2,200	1,619
Commercial	49.1	22.5	0.94	2.88	0.70	21	65	16	376	1,165	287
Industrial	68.6	10.2	0.95	5.31	2.38	10	54	24	250	1,352	601
Open	22.3	6.1	10.19	42.51	14.51	62	259	89	505	2,108	724
TOTAL ACCUMULATIONS									1,804	6,825	3,231

The computation of annual loadings of dust and dirt is presented in Table 13. In this computation, the daily accumulation rates and typical curb densities were adopted from the literature (17).

Accumulations of dust and dirt need to be converted to accumulations of various pollutants by specifying the composition of dust and dirt. For this purpose, composition factors are supplied in both the SWMM and STORM models. In the case of the SWMM, the weight of accumulated solids equals 1.1 times the weight of dust and dirt. In the STORM model, solids represent only 0.122 of dust and dirt. The large difference between both composition factors is apparent. It should be stressed, however, that in both models, the composition factors are used as calibration parameters which are adjusted in simulation runs. The larger composition factor in the SWMM model may be acceptable because in the event model, the accumulation period is typically short and the resulting accumulations will not be excessive. On the other hand, STORM is a continuous model in which high accumulation rates could lead to excessive solids accumulations over long periods.

It was of interest to compare the solids loading rates from the study area (Section 5.2.1) to those used in SWMM and STORM. The results of such comparison are shown in Table 14.

TABLE 14. Comparison of Solids Accumulation Rates

	Solids Accumulation Rates (kg/curb-km/day)			
	Observed	Storm	SWMM	Mean of Storm and SWMM
Residential	4.6	1.9	17.5	9.7
Industrial	11.2	8.4	75.5	41.9

It can be inferred from Table 14 that the observed rates which may be possibly underestimated (see Section 5.2.1) fall between the rates for STORM and SWMM. Consequently, it was decided to use the STORM composition factor as the lower limit, the SWMM factor as the upper limit, and the mean of both factors as the recommended value. The computations of annual solids accumulations are presented in Table 15.

5.2.2.3 Loading estimates from mean solids concentrations

The last estimate of solids loading was obtained by considering the computed annual runoff volumes and mean concentrations of solids in stormwater. Because such concentrations vary with land use, it was necessary first to calculate annual runoff volumes for various land use types and then to apply the appropriate solids concentrations to these volumes. The computation of runoff volumes is presented in Table 16 and the computation of solids loadings is given in Table 17. In Table 17, the mean solids concentrations in stormwater, proposed by the American Public Works Association (17) were employed. By considering three estimates of runoff volumes, three estimates of solids loadings were obtained. No variations in solids concentrations were considered because of lack of data on such variations.

It was attempted to verify the APWA solids concentrations against the data collected in the study area. Towards this end, mean solids concentrations were determined for 47 large stormwater samples, which were collected in the study area, and presented in Table 17. The observed concentrations were smaller than the APWA concentrations for residential stormwater, but they were larger than the APWA concentrations for industrial runoff. By considering both the residential and industrial loadings together, a good agreement (5-20%) between the observed and computed values was obtained.

TABLE 15. **Annual Loadings of Solids**

LAND USE	FRACTION OF SOLIDS IN DUST AND DIRT			ANNUAL LOADINGS OF SOLIDS [tonnes/yr]								
				Fort Erie			Niagara Falls			Welland		
	Lower Limit	Recommended Value	Upper Limit	Low	Mean	High	Low	Mean	High	Low	Mean	High
Residential	0.122	0.611	1.100	82	411	740	268	1,344	2,240	198	989	1,781
Commercial				46	230	414	142	712	1,282	35	175	316
Industrial				31	153	275	165	826	1,487	73	367	661
Open				63	309	556	257	1,288	2,319	88	442	796
TOTAL LOADINGS				221	1,103	1,985	832	4,170	7,508	394	1,973	3,554

TABLE 16. **Annual Runoff Volumes for Various Land Use**

LAND USE	ANNUAL RUNOFF VOLUME (10^6 x m^3/yr)								
	Minimum Estimate			Best Estimate			Maximum Estimate		
	FE	NE	W	FE	NF	W	FE	NE	W
Residential	1.14	3.50	2.56	1.32	4.05	2.97	1.44	4.48	3.28
Commercial	0.63	1.80	0.44	0.66	1.92	0.47	0.71	2.07	0.51
Industrial	0.32	1.70	0.76	0.37	1.92	0.85	0.39	2.10	0.94
Open	0.64	2.57	0.88	1.07	4.34	1.48	1.23	5.04	1.72

TABLE 17. Annual Loadings of Solids Computed From Mean Concentrations

LAND USE	MEAN CONCENTRATIONS OF SOLIDS [mg/L]		ANNUAL LOADING OF SOLIDS (tonnes/yr)								
			Minimum Estimate			Best Estimate			Maximum Estimate		
	APWA*	Observed	FE	NE	W	FE	NF	W	FE	NE	W
Residential	286	168	326	1,001	732	378	1,158	849	412	1,281	938
Commercial	174	-	110	313	77	115	334	82	124	360	89
Industrial	244	452	78	415	185	90	468	207	95	512	299
Open	216	-	138	555	190	231	937	320	266	1,089	372
TOTAL LOADINGS			652	2,284	1,184	814	2,897	1,458	897	3,242	1,628

* After Ref. 17. These values were used to compute loadings.

TABLE 18. Summary of Annual Solids Loadings

	ANNUAL SOLIDS LOADING [tonnes/yr]		
URBAN AREA	Minimum Estimate	Best Estimate	Maximum Estimate
Fort Erie	221	855	1,985
Niagara Falls	832	3,399	7,508
Welland	394	1,668	3,554

5.2.2.4 Summary of solids loading estimates

All the solids loading estimates are summarized in Table 18 and Figure 7. The least of all estimates was taken as the minimum estimate and the highest value was taken as the maximum estimate. The best estimate was taken as the mean of the recommended estimates produced by each of the three methods.

It can be inferred from Table 18 that the minimum and maximum estimates were obtained in all cases from the computations of solids accumulations using STORM and SWMM default composition factors, respectively. The best estimates represent about 87% of the mean of all three estimates given in Table 18 for each city.

6.0 RESULTS AND DISCUSSION

Results of analysis of the collected samples are presented in this chapter and further described in terms of frequency of occurrence above the detection limits, mean toxics concentrations in water and sediment, and annual loadings of toxics in urban runoff.

6.1 Analytical Results

The collected samples were analyzed for up to 51 substances which were listed in Chapter 4. All the analytical results which were available when writing this report were listed in the Appendix.

It should be reiterated that all the concentrations reported in the Appendix represent mean concentrations for individual sampled events. Instantaneous concentrations will vary about such means. The extent of such variations has not been investigated because of prohibitive costs. To determine time variations in toxics concentrations, sequential samples would have to be collected at relatively short time intervals (say 5 to 10 minutes). Such procedures would increase analytical costs by an order of magnitude.

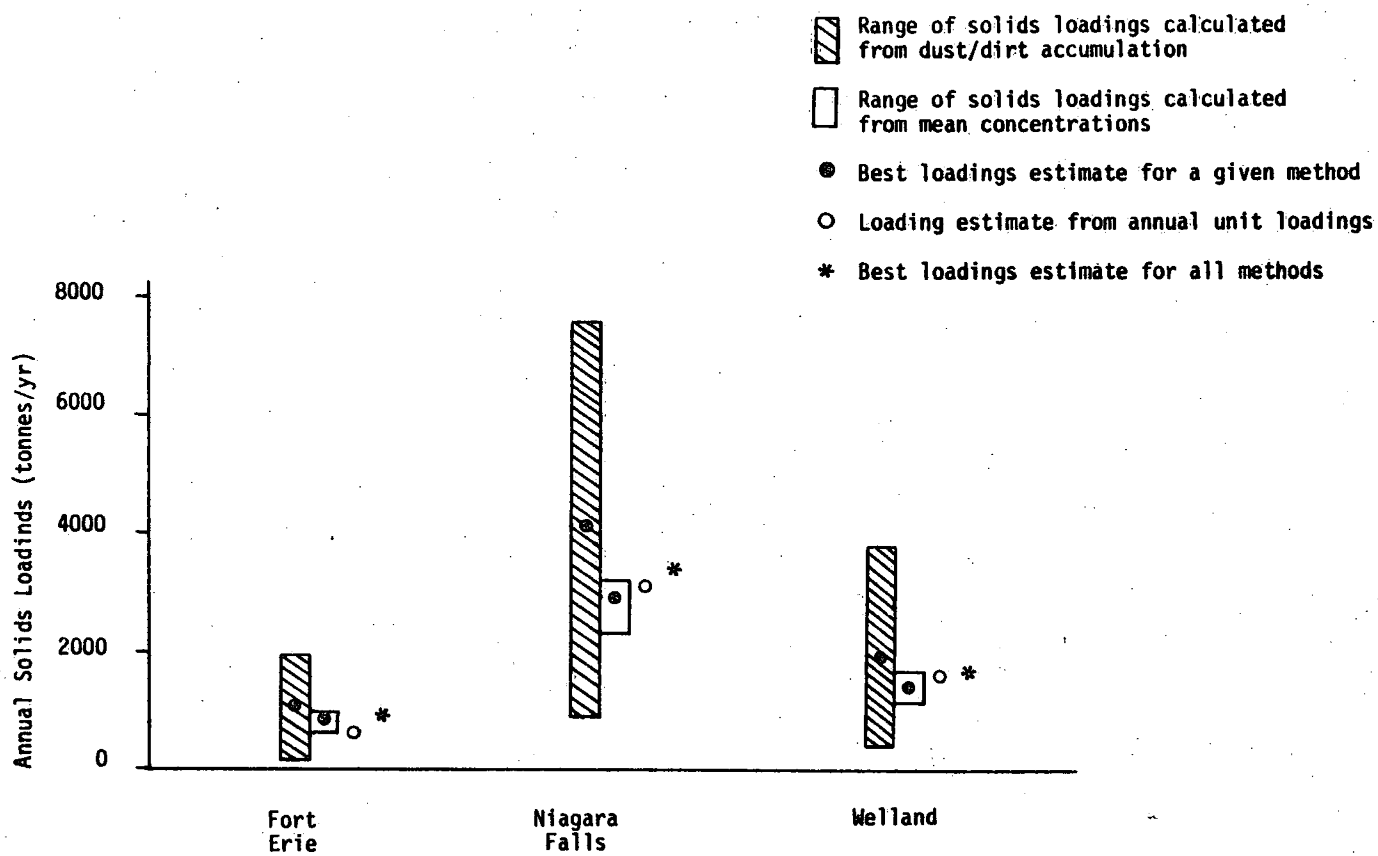


Fig. 7. Estimates of Annual Solids Loadings

Assuming that the time distribution of toxics concentrations during an event is similar to that of conventional parameters, the maximum toxics concentration would occur in the early phase of runoff (the rising limb of the runoff hydrograph) and would exceed the mean concentration by a factor generally varying from 2 to 10. Thus at runoff discharge points, short-duration concentrations, which could be up to an order of magnitude larger than those given in the Appendix, can be expected.

6.2 Frequencies of Occurrence Above the Detection Limit

The analytical results listed in the Appendix were further analyzed for frequencies of occurrence of concentrations above the detection limit. Provided that the runoff events monitored are representative samples of urban runoff in the study area, the frequency statistics can be used to estimate the number of events for which the mean concentration will be above the detection limit. Further inferences about the volume and duration of discharge, associated with such events, can be also made fom the reported frequencies and the annual volume and duration of urban runoff. The annual volume of runoff was described in detail in Chapter 5, the annual total duration of runoff (including snowmelt) is estimated here as 500 hours/year.

The frequency analysis was somewhat complicated by several detection limits reported for some substances. Such variations in detection limits were caused by employing different techniques in the two laboratories supporting this study. To avoid any ambiguities, the frequencies reported here represent the percentage of all samples with the mean event concentration above the highest detection limit used by either laboratory. Whenever a different detection limit was used, it is specified in the discussion.

The highest detection limits and the associated frequencies of exceedance in both water and sediment samples are listed in Table 19 and plotted in Fig. 8. Further discussion follows.

TABLE 19. Frequencies of Occurrence of Toxic Substances Above the Detection Limit

Substance	Water Samples		Sediment Samples	
	Detection* Limit(ppb)	Frequency (%)	Detection* Limit(ppm)	Frequency (%)
PCB's				
Total polychlorinated biphenyls	0.02	11	0.09	74
Organochlorine Pesticides				
Hexachlor benzene	0.001	20	0.004	13
α - BHC	0.001	98	0.004	53
Lindane	0.001	87	0.004	23
Heptachlor	0.001	3	0.004	9
Aldrin	0.001	0	0.004	0
Heptachlor epoxide	0.001	19	0.004	0
γ - chlordane	0.002	3	0.004	40
α - chlordane	0.002	2	0.004	50
α - Endosulfan	0.002	5	0.004	0
p,p' - DDE	0.001	2	0.004	59
Dieldrin	0.002	3	0.004	3
Endrin	0.004	5	0.004	0
o,p' - DDT	0.005	0	0.005	21
p,p' - TDE	0.005	2	0.005	17
p,p' - DDT	0.005	0	0.005	35
β - Endosulfan	0.004	3	0.004	3
Mirex	0.005	0	0.5	0
Methoxychlor	0.005	8	0.005	0
Polyaromatic Hydrocarbons				
Indene	-	-	0.05	0
1,2,3,4 tetrahydro-napthalene	-	-	0.05	0
2, methylnaphthalene	-	-	0.05	0
Quinoline	-	-	0.05	0
1, Methylnaphthalene	-	-	0.05	0
β - chloronaphthalene	-	-	0.05	0
Acenaphthylene	-	-	0.05	0
Acenaphthene	-	-	0.05	0
Flourene	-	-	0.05	0
Phenanthrene	-	-	0.05	14
Flouranthene	-	-	0.05	14
Pyrene	-	-	0.05	14

* The highest value of all detection limits used

TABLE 19. (continued)

Substance	Water Samples		Sediment Samples	
	Detection Limit(ppb)	Frequency (%)	Detection Limit(ppm)	Frequency (%)
Chlorinated Benzenes				
1,3 dichlorobenzene	0.005	29	0.05	7
1,4 dichlorobenzene	0.005	22	0.05	27
1,2 dichlorobenzene	0.005	68	0.05	40
1,3,5 trichlorobenzene	0.01	0	0.005	40
1,2,4 trichlorobenzene	0.01	0	0.005	40
1,2,3 trichlorobenzene	0.01	0	0.005	27
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.01	0	0.005	7
1,2,3,4 tetrachloro-benzene	0.01	0	0.005	7
pentachlorobenzene	0.01	0	0.005	7
Hexachlorobenzene	0.001	8	0.001	7
Trace Elements				
Arsenic	30.0	0	0.05	100
Cadmium	10.0	0	10.0	0
Copper	20.0	13	10.0	100
Cobalt	40.0	0	10.0	44
Chromium	10.0	0	3.0	97
Lead	60.0	4	3.0	100
Mercury	0.05	100	0.1	81
Nickel	30.0	2	30.0	56
Selenium	30.0	0	0.05	100
Zinc	1.0	100	2.0	100

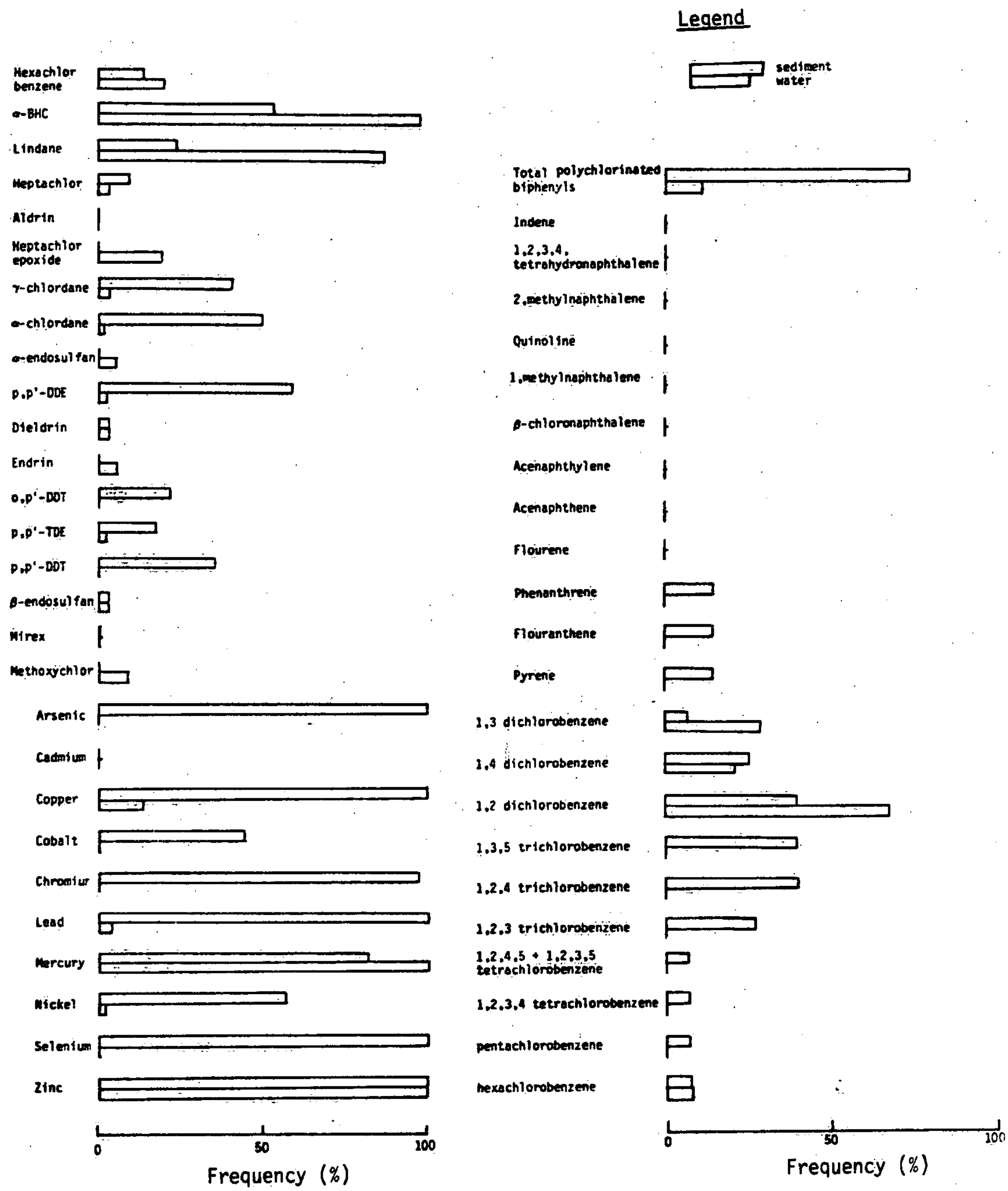


Fig. 8. Frequency of Exceedance of Detection Limits for Toxic Substances Studied

Polychlorinated Biphenyls

PCB's were found in 74% of all sediment samples in concentrations exceeding the detection limits. The frequency in water samples was only 11% and did not seem to be affected by the location, or land use. The frequencies in sediment samples agree with earlier findings in other Ontario cities (24). The frequencies in water samples are somewhat smaller than those reported earlier (11, 24).

Organochlorine Pesticides

Frequencies of organochlorine pesticides in water samples were, on the average, lower than those for sediment samples. The most widespread pesticides in water samples were α-BHC and lindane, which had frequencies of 98% and 87%, respectively. Three pesticides, aldrin, o'p-DDT and p,p'-DDT, and mirex have not been detected in any water samples. The remaining pesticides were detected in water samples with frequencies ranging from 2% to 20%.

In sediment samples, intermediate frequencies were noted for p,p'-DDE (59%). α-BHC (53%), α-chlordane (50%), γ-chlordane (50%), and p,p'-DDT (35%). No detections were reported for aldrin, heptachlor epoxide, α-endosulfan, endrin, mirex, and methoxychlor. The remaining pesticides were detected with frequencies ranging from 3% to 23%.

Polyaromatic Hydrocarbons

PAH's data are available only for seven sediment samples from the study area. Difficulties with sample contamination and the need for extensive sample clean up led to discontinuation of these analyses.

However, fairly extensive data were available from other locations in Ontario (24) and such data are therefore used to make inferences for the study area.

Considering the detection limits for PAH's in water between 1 pbb and 5 ppb, no detections have been made for more than fifty stormwater samples from a number of sites in various cities. Recently, new analytical procedures with a considerably lower detection limit (0.05 ppb) have been introduced. The corresponding frequency would be about 20-25%.

Frequencies of PAH's in sediment samples from the study area were also rather low. In fact, only three hydrocarbons (phenanthrene, flouranthene and pyrene) were found in one sample from a Welland industrial area.

When analyzing samples from other areas, the frequency of PAH's exceedance of detection limits was on the average 12%. The highest frequencies were found in industrial areas in the case of flouranthene, phenanthrene and acenophthylene.

Chlorinated Benzenes

Four chlorinated benzenes were detected in water samples with frequencies from 8% to 68%.

In sediment samples, all chlorinated benzenes were detected. The frequencies of occurrence ranged from 7% to 40%.

Trace Elements

Trace elements, particularly, heavy metals, were by far the most widespread toxics in both water and sediment samples. In general, the frequencies in water samples were lower than those in sediment samples. The most widespread metals in water samples were zinc and mercury which were detected in all samples. Note, however, that the detection limit for mercury was extremely low (0.05 ppb). The frequencies reported for the remaining elements were affected by the magnitude of the detection limits which were used by both laboratories. For example, if one considers the detection limit of 1 ppb (used predominantly by the IWD laboratory), the frequencies for copper and lead are 73% and 98%, respectively. If one considers the higher limits employed by the MOE laboratory (20 ppb for copper and 60 ppb for lead), the corresponding frequencies are reduced to 13% and 4%, respectively.

The average frequency of trace elements in sediments was 78%. Arsenic, copper, lead, selenium and zinc were detected in all samples. The lowest frequency (0% at 10 ppm) was reported for cadmium.

6.3 Mean Concentrations

Estimates of mean concentrations were produced for all the substances studied. Such estimates involve appreciable uncertainties which were caused by the data below the detection limit. There are no established procedures for the treatment of such data. For large sets of samples ($N \geq 50$), with high percentage of data above the detection limit, attempts have been made to fit a particular distribution to the data above the limit and then to extrapolate this distribution below the detection limit. Such an approach could not be adopted here because the data sets are usually small and often contain many values below the detection limit. Consequently, a simplified procedure was used here to estimate the upper and lower limits as outlined below.

Assume a set of n samples, in which r samples have concentrations above the detection limit. Note that the detection frequency is then r/n. The lower concentration limit ($\bar{c}_{min}$) is then obtained by assuming zero concentrations in samples with concentrations below the detection limit:

$$\bar{c}_{min} = \frac{1}{n} \sum_{i=1}^{r} c_i \qquad (9)$$

where c is the concentration and the subscript i (i = 1,2,3,...r) denotes individual samples.

The upper concentration limit, $\bar{c}_{max}$, is obtained by assuming that the concentrations below the detection limit are equal to the detection limit:

$$\bar{c}_{max} = \frac{1}{n} [(n-r)\, c_{dl} + \sum_{i=1}^{r} c_i] \qquad (10)$$

where c_{dl} denotes the detection limit.

The best estimate of mean concentrations was then taken as the mean of the upper and lower limiting values:

$$\bar{c}_{be} = \left[\frac{1}{n} \sum_{i=1}^{r} c_i + \frac{(n-r)}{2n} c_{dl} \right] \qquad (11)$$

Eqs. (9) to (11) were used to estimate mean concentrations for individual substances. Note that the most meaningful results are obtained for $r = n$ (i.e., 100% frequency of detection). In that case, all three estimates of mean concentrations are equal to the mean of the data set. The highest uncertainties in concentrations are encountered when $r = 0$ (i.e., all data below the detection limit). In that case, Eqs. (9) to (11) are simplified to $\bar{c}_{min} = 0$, $\bar{c}_{max} = c_{dl}$, and $\bar{c}_{be} = 0.5\ c_{dl}$. Thus the concentration estimates are controlled by the detection limit.

For some substances, several detection limits were used in the study. In that case, Eqs. (9) to (11) had to be modified by expanding the term $(n-r)c_{dl}$ as follows:

$$(n-r)\, c_{dl} = \sum_{j=1}^{m} t_j\, c_{dlj} \qquad (12)$$

where t_j is the number of concentrations below the detection limit c_{dlj} and the subscript j (j=1...m) denotes the various detection limits.

It was noted that in the case of multiple detection limits, some unusually high limits (sometimes two orders of magnitude greater than the lowest limit) strongly affected the calculated mean concentrations. Consequently, the mean of all detected concentrations was compared to all detection limits. Whenever a particular detection limit exceeded the mean, the corresponding concentrations below this detection limit were omitted from final computations.

Finally, the estimates of mean concentrations for all substances studied are given in Table 20. In the case of PAH's, the limited data from the study area were supplemented by data from other Ontario municipalities.

6.4 Annual Loadings

Calculations of toxics loadings were undertaken for stormwater, sediment, and the sum of both components. Detailed loadings for water and sediment in individual cities are given in the Appendix. For brevity, only the total loadings are presented here for Fort Erie, Niagara Falls, Welland and for the whole urban area (see Tables 21, 22, 23, and 24). Further discussion follows.

TABLE 20. Estimates of Mean Concentrations of Toxics in Water and Sediment Samples

Substance	Mean Concentrations in Water Samples (ppb)		
	Lower Estimate*	Upper Estimate*	Best Estimate**
PCB's			
Total polychlorinated biphenyls	.007000	.017813	.012406
Organochlorine Pesticides			
Hexachlor benzene	.000410	.000732	.000571
α - BHC	.013876	.013892	.013884
Lindane	.005063	.005171	.005117
Heptachlor	.000084	.000653	.000369
Aldrin	.000012	.000402	.000207
Heptachlor epoxide	.000619	.001143	.000881
γ - chlordane	.000278	.001192	.000735
α - chlordane	.000108	.001054	.000581
α - Endosulfan	.000356	.001225	.000790
p,p' - DDE	.000044	.000647	.000345
Dieldrin	.000165	.001098	.000632
Endrin	.000571	.002222	.001397
o,p' - DDT	.000015	.000405	.000210
p,p' - TDE	.000563	.000813	.000688
p,p' - DDT	.000059	.000439	.000249
β - Endosulfan	.000978	.001208	.001093
Mirex	.000024	.000415	.000220
Methoxychlor	.000960	.002970	.001965
Polyaromatic Hydrocarbons			
Indene	.000182	.049273	.024728
1,2,3,4 tetrahydro-napthalene	.000182	.049273	.024728
2, methylnaphthalene	.007455	.047455	.027455
Quinoline	.000909	.049091	.025000
1, Methylnaphthalene	.003273	.048727	.026000
β - chloronaphthalene	.006545	.048364	.027455
Acenaphthylene	.013636	.054545	.034091
Acenaphthene	.003091	.045818	.024455
Flourene	.000364	.048545	.024455
Phenanthrene	.004909	.051273	.028091
Flouranthene	.013818	.056545	.035182
Pyrene	.013091	.054000	.033546

* Lower and upper estimates are produced only for data sets with some concentrations below the detection limit

** The best estimate equals the mean of the lower and upper estimates

TABLE 20. Estimates of Mean Concentrations of Toxics in Water and Sediment Samples

Substance	Mean Concentrations in Water Samples (ppb)		
	Lower Estimate*	Upper Estimate*	Best Estimate**
Chlorinated Benzenes			
1,3 dichlorobenzene	.002985	.006522	.004754
1,4 dichlorobenzene	.002722	.006624	.004673
1,2 dichlorobenzene	.038585	.040171	.039378
1,3,5 trichlorobenzene	.000402	.001134	.000768
1,2,4 trichlorobenzene	.001122	.001878	.001500
1,2,3 trichlorobenzene	.000127	.001029	.000578
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	.000190	.001024	.000607
1,2,3,4 tetrachloro-benzene	.000024	.001000	.000512
pentachlorobenzene	.000024	.001000	.000512
Hexachlorobenzene	.000323	.000873	.000598
Trace Elements			
Arsenic	-	-	.800
Cadmium	-	-	.300
Copper	11.052	11.943	11.498
Cobalt	.875	1.656	1.266
Chromium	.327	1.093	.710
Lead	7.191	8.577	7.884
Mercury	-	-	6.100
Nickel	-	-	7.200
Selenium	1.120	1.195	1.158
Zinc	-	-	57.400

* Lower and upper estimates are produced only for data sets with some concentrations below the detection limit

** The best estimate equals the mean of the lower and upper estimates

TABLE 20. Estimates of Mean Concentrations of Toxics in Water and Sediment Samples

Substance	Mean Concentrations in Sediment Samples (ppm)		
	Lower Estimate*	Upper Estimate*	Best Estimate**
PCB's			
Total polychlorinated biphenyls	-	-	.308000
Organochlorine Pesticides			
Hexachlor benzene	.001620	.003220	.002420
α - BHC	.006460	.007993	.007227
Lindane	.005120	.006820	.005970
Heptachlor	.000565	.002418	.001491
Aldrin	.000000	.002324	.001162
Heptachlor epoxide	.000000	.002100	.001050
γ - chlordane	.031250	.032983	.032117
α - chlordane	.046650	.048383	.047517
α - Endosulfan	.000000	.002733	.001367
p,p' - DDE	.010735	.011265	.011000
Dieldrin	.000267	.002933	.001600
Endrin	.000000	.004000	.002000
o,p' - DDT	.003429	.006576	.005003
p,p' - TDE	.001333	.005133	.003233
p,p' - DDT	.011241	.014035	.012638
β - Endosulfan	.000200	.004067	.002133
Mirex	.000590	.004310	.002450
Methoxychlor	.000000	.004633	.002317
Polyaromatic Hydrocarbons			
Indene	.000000	.050000	.025000
1,2,3,4 tetrahydro-napthalene	.000000	.050000	.025000
2, methylnaphthalene	.000000	.050000	.025000
Quinoline	.000000	.050000	.025000
1, Methylnaphthalene	.000000	.050000	.025000
β - chloronaphthalene	.000000	.050000	.025000
Acenaphthylene	.000000	.050000	.025000
Acenaphthene	.000000	.050000	.025000
Flourene	.000000	.050000	.025000
Phenanthrene	.418571	.461429	.440000
Flouranthene	.571429	.614286	.592857
Pyrene	2.428571	2.471429	2.450000

* Lower and upper estimates are produced only for data sets with some concentrations below the detection limit

** The best estimate equals the mean of the lower and upper estimates

TABLE 20. Estimates of Mean Concentrations of Toxics in Water and Sediment Samples

Substance	Mean Concentrations in Sediment Samples (ppm)		
	Lower Estimate*	Upper Estimate*	Best Estimate**
Chlorinated Benzenes			
1,3 dichlorobenzene	.004000	.050667	.027333
1,4 dichlorobenzene	.044000	.080667	.062333
1,2 dichlorobenzene	.246000	.276000	.261000
1,3,5 trichlorobenzene	1.038520	1.041520	1.040020
1,2,4 trichlorobenzene	.011947	.014280	.013113
1,2,3 trichlorobenzene	.033467	.037133	.035300
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	.002400	.007067	.004733
1,2,3,4 tetrachlorobenzene	.000867	.005200	.003033
pentachlorobenzene	.000333	.005000	.002667
Hexachlorobenzene	.000629	.002629	.001629
Trace Elements			
Arsenic	-	-	9.90
Cadmium	-	-	2.00
Copper	-	-	139.60
Cobalt	10.08	13.31	11.70
Chromium	-	-	305.20
Lead	-	0	971.40
Mercury	.162	.181	.171
Nickel	139.38	141.60	140.49
Selenium	-	-	.400
Zinc	-	-	834.8

* Lower and upper estimates are produced only for data sets with some concentrations below the detection limit

** The best estimate equals the mean of the lower and upper estimates

TABLE 21. Annual Total Toxics Loadings in Urban Runoff from Fort Erie

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.0873	0.6789	0.3055
Organochlorine Pesticides			
Hexachlor benzene	0.0015	0.0092	0.0040
α - BHC	0.0394	0.0685	0.0534
Lindane	0.0150	0.0331	0.0225
Heptachlor	0.0004	0.0073	0.0025
Aldrin	0.0000	0.0061	0.0017
Heptachlor epoxide	0.0017	0.0085	0.0039
γ - chlordane	0.0077	0.0700	0.0300
α - chlordane	0.0106	0.1000	0.426
α - Endosulfan	0.0010	0.0101	0.0039
p,p' - DDE	0.0025	0.0248	0.0106
Dieldrin	0.0005	0.0100	0.0035
Endrin	0.0016	0.0164	0.0065
o,p' - DDT	0.0008	0.0146	0.0050
p,p' - TDE	0.0018	0.0133	0.0051
p,p' - DDT	0.0026	0.0295	0.0117
β - Endosulfan	0.0027	0.0127	0.0055
Mirex	0.0002	0.0101	0.0028
Methoxychlor	0.0026	0.0205	0.0087
Polyaromatic Hydrocarbons			
Indene	0.0005	0.2860	0.1055
1,2,3,4 tetrahydro-napthalene	0.0005	0.2860	0.1055
2, methylnaphthalene	0.0204	0.2791	0.1147
Quinoline	0.0025	0.2853	0.1064
1, Methylnaphthalene	0.0090	0.2839	0.1098
β - chloronaphthalene	0.0179	0.2825	0.1147
Acenaphthylene	0.0374	0.3060	0.1373
Acenaphthene	0.0085	0.2729	0.1045
Flourene	0.0010	0.2832	0.1045
Phenanthrene	0.1060	0.1103	0.4717
Flouranthene	0.1641	1.4337	0.6265
Pyrene	0.5726	5.1104	2.2088

TABLE 21. Annual Total Toxics Loadings in Urban Runoff from Fort Erie

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0091	0.1253	0.0395
1,4 dichlorobenzene	0.0172	0.1852	0.0692
1,2 dichlorobenzene	0.1601	0.7001	0.3570
1,3,5 trichlorobenzene	0.2306	2.0717	0.8918
1,2,4 trichlorobenzene	0.0057	0.355	0.0163
1,2,3 trichlorobenzene	0.0077	0.076	0.0321
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.011	0.0179	0.0061
1,2,3,4 tetrachloro-benzene	0.0003	0.0141	0.0043
pentachlorobenzene	0.0001	0.0137	0.0040
Hexachlorobenzene	0.0010	0.0085	0.0034
Trace Elements			
Arsenic	4.4	22.7	11.2
Cadmium	1.2	5.1	2.7
Copper	61.2	322.4	158.5
Cobalt	4.6	32.7	14.3
Chromium	68.4	609.9	263.4
Lead	234.4	1960.7	857.4
Mercury	16.7	23.5	20.9
Nickel	50.5	308.4	144.6
Selenium	3.2	5.3	4.2
Zinc	341.8	1874.6	909.0

TABLE 22. Annual Total Toxics Loadings in Urban Runoff from Niagara Falls

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.3235	2.3370	1.1985
Organochlorine Pesticides			
Hexachlor benzene	0.0053	0.0342	0.0152
α - BHC	0.1386	0.2507	0.1942
Lindane	0.0529	0.1222	0.0828
Heptachlor	0.0013	0.0271	0.0096
Aldrin	0.0001	0.0230	0.0065
Heptachlor epoxide	0.0059	0.0315	0.0143
γ - chlordane	0.9287	0.2640	0.1181
α - chlordane	0.0399	0.3777	0.1686
α - Endosulfan	0.0034	0.0373	0.0143
p,p' - DDE	0.0094	0.0935	0.0416
Dieldrin	0.0018	0.0370	0.0132
Endrin	0.0055	0.0605	0.0239
o,p' - DDT	0.0030	0.0549	0.0196
p,p' - TDE	0.0065	0.0497	0.0197
p,p' - DDT	0.0099	0.1114	0.0460
β - Endosulfan	0.0096	0.0471	0.0206
Mirex	0.0007	0.0381	0.0110
Methoxychlor	0.0092	0.0756	0.0319
Polyaromatic Hydrocarbons			
Indene	0.0017	1.059	0.3872
1,2,3,4 tetrahydro-napthalene	0.0017	1.0519	0.3872
2, methylnaphthalene	0.0716	1.0270	0.4205
Quinoline	0.0087	1.0494	0.3905
1, Methylnaphthalene	0.0314	1.0444	0.4027
β - chloronaphthalene	0.0628	1.0394	0.4205
Acenaphthylene	0.1309	1.1243	0.5016
Acenaphthene	0.0297	1.0045	0.3838
Flourene	0.0035	1.0419	0.3838
Phenanthrene	0.3954	4.1684	1.8388
Flouranthene	0.6081	5.3884	2.4450
Pyrene	2.1462	19.2969	8.7375

TABLE 22. Annual Total Toxics Loadings in Urban Runoff from Niagara Falls

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0320	0.4700	0.1510
1,4 dichlorobenzene	0.0627	0.6966	0.2690
1,2 dichlorobenzene	0.5751	2.6238	1.3683
1,3,5 trichlorobenzene	0.8679	7.8353	3.5444
1,2,4 trichlorobenzene	0.0207	0.1330	0.0629
1,2,3 trichlorobenzene	0.0291	0.2929	0.1270
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0038	0.0671	0.0235
1,2,3,4 tetrachloro-benzene	0.0010	0.0528	0.0166
pentachlorobenzene	0.0005	0.0513	0.0153
Hexachlorobenzene	0.0036	0.0317	0.0128
Trace Elements			
Arsenic	15.9	85.3	43.5
Cadmium	4.6	19.1	10.5
Copper	222.3	1212.1	615.0
Cobalt	16.8	122.6	55.3
Chromium	257.0	2306.4	1046.1
Lead	877.2	7411.1	3398.1
Mercury	58.7	85.2	75.1
Nickel	185.0	1162.0	565.5
Selenium	11.1	19.4	15.6
Zinc	1245.5	7055.9	3538.9

TABLE 23. Annual Total Toxics Loadings in Urban Runoff from Welland

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.1539	1.2097	0.5853
Organochlorine Pesticides			
Hexachlor benzene	0.0025	0.0162	0.0075
α - BHC	0.0669	0.1181	0.0922
Lindane	0.0255	0.0576	0.0395
Heptachlor	0.0006	0.0128	0.0046
Aldrin	0.0001	0.0109	0.0031
Heptachlor epoxide	0.0029	0.0148	0.0068
γ - chlordane	0.0136	0.1249	0.0578
α - chlordane	0.0189	0.1788	0.0826
α - Endosulfan	0.0017	0.0176	0.0068
p,p' - DDE	0.0044	0.0442	0.0203
Dieldrin	0.0009	0.0175	0.0063
Endrin	0.0026	0.0286	0.0114
o,p' - DDT	0.0014	0.0260	0.0096
p,p' - TDE	0.0031	0.0235	0.0994
p,p' - DDT	0.0047	0.0527	0.0225
β - Endosulfan	0.0046	0.0223	0.0099
Mirex	0.0003	0.0180	0.0054
Methoxychlor	0.0045	0.0356	0.0152
Polyaromatic Hydrocarbons			
Indene	0.0008	0.4960	0.1844
1,2,3,4 tetrahydro-napthalene	0.0008	0.4960	0.1844
2, methylnaphthalene			
Quinoline	0.0346	0.4843	0.2001
1, Methylnaphthalene	0.0042	0.4948	0.1860
β - chloronaphthalene	0.0304	0.4901	0.2001
Acenaphthylene	0.0633	0.5301	0.2384
Acenaphthene	0.0143	0.4737	0.1828
Flourene	0.0017	0.4913	0.1828
Phenanthrene	0.1877	1.9711	0.8960
Flouranthene	0.2893	2.5485	1.1919
Pyrene	1.0176	9.1323	4.2802

TABLE 23. Annual Total Toxics Loadings in Urban Runoff from Welland

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0154	0.2222	0.0737
1,4 dichlorobenzene	0.0300	0.3295	0.1309
1,2 dichlorobenzene	0.2760	1.2404	0.6626
1,3,5 trichlorobenzene	0.4110	3.7089	1.7392
1,2,4 trichlorobenzene	0.0099	0.0629	0.0305
1,2,3 trichlorobenzene			
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0018	0.0317	0.0114
1,2,3,4 tetrachloro-benzene	0.0005	0.0249	0.0080
pentachlorobenzene	0.0002	0.0242	0.0074
Hexachlorobenzene	0.0017	0.0150	0.0062
Trace Elements			
Arsenic	7.6	40.4	21.1
Cadmium	2.2	9.0	5.0
Copper	106.3	573.3	299.2
Cobalt	8.1	58.0	26.8
Chromium	121.8	1091.8	513.2
Lead	416.1	3507.8	1665.8
Mercury	28.4	40.0	35.5
Nickel	88.3	549.8	275.8
Selenium	5.4	9.1	7.4
Zinc	595.2	3337.7	1723.7

TABLE 24. Annual Total Toxics Loadings in Urban Runoff from The Study Area

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.5647	4.2256	2.0893
Organochlorine Pesticides			
Hexachlor benzene	0.0093	0.0596	0.0265
α - BHC	0.2450	0.4374	0.3398
Lindane	0.0934	0.2130	0.1448
Heptachlor	0.0022	0.0472	0.0167
Aldrin	0.0002	0.0400	0.0113
Heptachlor epoxide	0.0105	0.0548	0.0251
γ - chlordane	0.0499	0.4589	0.2059
α - chlordane	0.0693	0.6565	0.2938
α - Endosulfan	0.0060	0.0650	0.0250
p,p' - DDE	0.0163	0.1625	0.0725
Dieldrin	0.0032	0.0644	0.0230
Endrin	0.0097	0.1055	0.0417
o,p' - DDT	0.0052	0.0955	0.0341
p,p' - TDE	0.0115	0.0865	0.0339
p,p' - DDT	0.0173	0.1936	0.0802
β - Endosulfan	0.0169	0.0820	0.0360
Mirex	0.0013	0.0662	0.0192
Methoxychlor	0.0163	0.1317	0.0558
Polyaromatic Hydrocarbons			
Indene	0.0031	1.8339	0.6770
1,2,3,4 tetrahydro-napthalene	0.0031	1.8339	0.6770
2, methylnaphthalene			
Quinoline	0.1266	1.7903	0.7353
1, Methylnaphthalene	0.0154	1.8296	0.6828
β - chloronaphthalene	0.0556	1.8208	0.7042
Acenaphthylene	0.1111	1.8121	0.7353
Acenaphthene	0.2315	1.9603	0.8773
Flourene	0.0062	1.8165	0.6711
Phenanthrene	0.6890	7.2498	3.2065
Flouranthene	1.0615	9.3705	4.2634
Pyrene	3.7364	33.5397	15.2264

TABLE 24. Annual Total Toxics Loadings in Urban Runoff from the Study Area

Substance	Annual Total Loadings in Water and Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0565	0.8174	0.2636
1,4 dichlorobenzene	0.1099	1.2113	0.4691
1,2 dichlorobenzene	1.0111	4.5643	2.3879
1,3,5 trichlorobenzene	1.5096	13.6159	6.1754
1,2,4 trichlorobenzene	0.0363	0.2313	0.1097
1,2,3 trichlorobenzene	0.0506	0.0506	0.2214
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0067	0.1168	0.0410
1,2,3,4 tetrachloro-benzene	0.0017	0.0918	0.0289
pentachlorobenzene	0.0009	0.0892	0.0267
Hexachlorobenzene	0.0064	0.0552	0.0224
Trace Elements			
Arsenic	27.9	148.4	75.7
Cadmium	8.0	33.3	18.2
Copper	389.7	2107.8	1072.6
Cobalt	29.5	213.4	96.4
Chromium	447.2	4008.1	1822.6
Lead	1527.7	12879.6	5921.2
Mercury	103.8	148.7	131.5
Nickel	324.0	2020.2	986.0
Selenium	19.6	30.8	27.1
Zinc	2182.7	12268.1	6171.5

In general, the toxics loadings transported by solids exceeded those transported by stormwater. This was particularly pronounced for trace elements (mostly metals). For other substances, both loading components were generally of the same order of magnitude and in some cases, the loadings in stormwater exceeded those in sediment.

The highest loadings (more than 16.3 tonnes/yr) were found for heavy metals, particularly in the case of lead (5.9 t/yr), zinc (6.2 t/yr), chromium (1.8 t/yr), nickel (1.0 t/yr) and copper (1.1 t/yr). The two highest loadings, zinc and lead, accounted for 75% of the total metal loading. The widespread occurrence of lead and zinc in urban runoff is generally recognized and it is linked to the operation of motor vehicles.

The next highest loadings were observed for polyaromatic hydrocarbons (29 kg). Because of the limited number of samples, these loadings contain probably the highest uncertainties in the whole group. Among PAH's the highest loadings were found for pyrene (15.2 kg), flouranthene (4.3 kg), and phenanthrene (3.2 kg). These three substances accounted for almost 80% of the total PAH loading.

The loading of chlorinated benzenes was estimated at about 10 kg/yr. Two substances, 1,3,5 trichlorobenzene (6.2 kg/yr) and 1,2 dichlorobenzene (2.4 kg/yr) accounted for almost 90% of the total loading.

The total PCB's loading was estimated at 2 kg/yr.

The loading of organochlorine pesticides was estimated at 1.5 kg/yr. More than half of this amount was contributed by α-BHC (0.34 kg/yr), α-chlordane (0.29 kg/yr) and γ-chlordane (0.21 kg/yr).

7.0 SUMMARY

Urban runoff contribution of toxics to the Niagara River has been evaluated in a selected study area. The study area which represents the (Canadian) drainage basin of the Niagara River contains three major urban centres - Fort Erie, Niagara Falls, and Welland. The total population of these centres has been estimated as 140,000 persons.

Although the general list of priority pollutants established by the U.S. EPA includes 129 substances, only some of these could be studied using the available analytical laboratories. In total, 51 substances representing polychlorinated biphenyls, organochlorine pesticides, polyaromatic hydrocarbons, chlorinated benzenes, and trace elements have been studied.

To determine the levels and frequencies of the substances studied, field investigations of urban runoff were undertaken at a number of sites in all three urban centres. Using mostly custom made sampling equipment, samples of stormwater and urban sediments were collected, documented, and submitted to the IWD and MOE laboratories for analysis. The stormwater samples represented flow-proportional composite samples for entire storm events.

For estimates of annual toxics loadings, it was necessary to calculate the annual volume of runoff and the annual discharge of solids transported by runoff. Runoff volume computations were based on local precipitation data and estimates of rainfall abstractions from the literature data. The soil infiltration was computed by the Soil Conservation Service Method. Using such procedures, the annual runoff from the study area was determined as $21 \times 10^6\ m^3/yr$.

To determine the solids loading, three different approaches were used and the mean value was then used in further computations. The loading of solids in urban runoff from the study area was estimated as 6,000 tonnes/yr.

Analytical results were further processed and analyzed with regard to the frequencies of exceedance of detection limits, estimates of mean concentrations, and annual toxics loadings.

Frequencies of studied toxics were affected by the detection limits. In general, the frequencies for sediment samples were higher than those for stormwater samples.

In sediment samples, the most widespread substances were trace elements (100% frequencies observed for As, Cu, Pb, Se, and Zn), PCB's, some organochlorines pesticides (p,p'-DDE - 59%, α-BHC - 53%, α-chlordane - 50%, γ-chlordane - 40%, and p,p'-DDT - 35%), and several chlorinated benzenes (1,2 dichlorobenzene - 40%, 1,3,5 trichlorobenzene - 40%, and 1,2,4 trichlorobenzene - 40%). Polyaromatic hydrocarbons were rarely detected.

In stormwater samples, the highest frequencies were found for some trace metals (Hg - 100%, Zn - 100%), two pesticides (α-BHC - 98%, lindane 87%), and 1,2 dichlorobenzene (68%). The remaining substances and elements were observed with very low frequencies. It should be emphasized that some frequencies were related to relatively high detection limits and this affected the results. Very low frequencies of PAH's were observed in water samples for other cities.

The next step was to determine mean concentrations for the entire data set. Such concentrations were determined by considering all the data above detection limits and the frequencies of exceedance. To account for concentrations below the detection limit, the lower and upper estimates were produced. For the lower limit, the concentrations below the detection limit were set equal to zero and for the upper limit, they were set equal to the detection limit. Where all data exceeded the detection limit, only the mean concentration was produced.

In general, the mean concentrations of toxics in water samples were several orders of magnitude lower than those in sediment. In water samples, the highest concentrations were observed for trace metals (Zn, Cu, Pb, Ni, and Hg), followed by 1,2 dichlorobenzene, polyaromatic hydrocarbons, α-BHC, and PCB's. It was noted that none of the trace metal or pesticide concentrations exceeded the (1977) IJC Water Quality Objectives (5). The data presented here are means of mean event concentrations and their exceedance for individual events, or during individual events, will occur.

In sediment samples, the highest concentrations were observed for trace metals (Pb, Zn, Cr, Cu, and Ni), followed by some polyaromatic hydrocarbons (pyrene, flouranthene, and phenanthrene), some chlorinated benzenes, and PCB's.

The highests annual loadings were computed for trace elements, more than 16.3 tonnes/yr (Pb - 5.9 ty/yr, Zn - 6.2 t/yr, Cr - 1.8 t/yr, Ni - 1.0 t/yr, and Cu - 1.1 t/yr). Other loadings were 22 kg/yr of polyaromatic hydrocarbons, 10 kg/yr of chlorinated benzenes, 2 kg/yr of PCB's and 1.5 kg/yr of organochlorine pesticides.

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9.0 REFERENCES

1. American Society of Civil Engineers, Design and Construction of Sanitary and Storm Sewers, Manual of Practice No. 9, Water Pollution Control Federation, Washington, D.C., 1970.
2. Environment Canada, Canadian Climatic Normals, Temperature and Precipitation, Ontario, 1951-1980. Available from the Canadian Climate Centre, Downsview, Ontario.
3. Environmental Protection Service, Organic Substances Sampling - Equipment and Materials Evaluation, Draft report by the NCA Operations Office, EPS Ontario Region, Ottawa, Ontario, June 1983.
4. Huber, W.C., Heaney, J.P., Dickinson, R.E., and Polman, D.J., Storm Water Management Model, User's Manual, Version III, Municipal Environmental Research Center, U.S. Environmental Protection Agency, Cincinnatti, Ohio, May, 1982.
5. International Joint Commission, New and Revised Great Lakes Water Quality Objectives, IJC Report, Windsor, Ontario, May, 1977.
6. International Joint Commission, 1982 Report on Great Lakes Water Quality, Windsor, Ontario, November, 1982.
7. ISCO Ltd., Instruction Manual Model 2100 Wastewater Sampler, ISCO, Lincoln, Nebraska, January, 1980.
8. Kibler, D.F. (Editor), Urban Stormwater Hydrology, Water Resources Monograph 7, American Geophysical Union, Washington, D.C., 1982.
9. Loescher, B., Personal Communication, Ministry of the Environment, Laboratory Services and Applied Research Branch, Rexdale, Ontario, June, 1983.
10. Marsalek, J., Pollution due to Urban Runoff: Unit Loads and Abatement Measures, a PLUARG Report, IJC, Windsor, Ontario, 1978.
11. Marsalek, J., Polychlorinated Biphenyls and Organochlorine Pesticides in Surface Runoff from Two Urban Test Catchments, Unpublished Report, National Water Research Institute, Burlington, Ontario, 1978.

12. Ministry of the Environment, Analytical Procedures for Biocides and Industrial Organics, MOE, Toronto, September, 1982.
13. Patrick, N.D., Niagara Peninsula Conservation Report, Volume I, Department of the Environment, Conservation Authority Branch, 1972.
14. Regional Municipality of Niagara, 1982 Niagara Region Industrial Directory, St. Catharines, Ontrio, 1982.
15. Sartor, J.D., and Boyd, G.B., Water Pollution Aspects of Street Surface Contaminants, Report EPA-R2-72-081, U.S. EPA, Washington, D.C., 1972.
16. Statistics Canada, Population - Geographic Distributions, Ontario, 1982 Census of Canada, Catalogue No. 93-906, Volume 2, Statistics Canada, Ottawa, June, 1982.
17. Sullivan, R.H., Hurst, W.D., and Kipp, T.M., Evaluation of the Magnitude and Significance of Pollution from Urban Storm Water Runoff in Ontario, Research Report No. 81, Canada-Ontario Agreement on Great Lakes Water Quality, Ottawa, 1978.
18. Thomson, R., Personal Communication, Water Quality Branch, IWD, Burlington, Ontario, July, 1982.
19. U.S. Army, Corps of Engineers, Storage, Treatment, Overflow, Runoff Model, STORM, Hydrologic Engineering Center, Davis, California, 1976.
20. U.S. Department of Agriculture, Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release 55, Washington, D.C., 1973.
21. Versar, Inc., Monitoring of Toxic Pollutants in Urban Runoff. A draft report prepared for the U.S. EPA, Washington, D.C., 1980.
22. Versar, Inc., Water-Related Environmental Fate of 129 Priority Pollutants, Volume II, Report EPA-440/4-79-029b, U.S. EPA, Washington, D.C., December, 1979.
23. Water Quality Branch, IWD, Analytical Methods Manual, Water Quality Branch, Ottawa, Ontario, 1979.

24. Wong. J., Persistent Toxic Substances in Surface Runoff from the City of Cornwall, Unpublished Report, National Water Research Institute, Burlington, Ontario, October, 1981.

25. Wong, J. and Marsalek, J., Persistent Toxic Substances in Urban Runoff, Proceedings, Stormwater and Water Quality Management Modelling and SWMM Users Group Meeting, Sept. 28-29, 1981, Niagara Falls, Ontario, pp. 455-468, 1981.

APPENDIX

TABLE AA. Codes Used for Parameter Names

Substance	Code	Substance	Code
<u>PCB's</u>		<u>Chloriated Benzenes</u>	
Total polychlorinated biphenyls	TPCB	1,3 dichlorobenzene	M-DCB
<u>Organochlorine Pesticides</u>		1,4 dichlorobenzene	P-DCB
Hexachlor benzene	HXB	1,2 dichlorobenzene	O-DCB
α - BHC	BDH	1,3,5 trichlorobenzene	TCB135
Lindane	LIN	1,2,4 trichlorobenzene	TCB124
Heptachlor	HEP	1,2,3 trichlorobenzene	TCB123
Aldrin	ALD	1,2,4,5 + 1,2,3,5 tetrachlorobenzene	124/35
Heptachlor epoxide	HEX	1,2,3,4 tetrachloro- benzene	1234
γ - chlordane	CHC	pentachlorobenzene	P5CB
α - chlordane	CHA	Hexachlorobenzene	HEXB
α - Endosulfan	EMX	<u>Trace Elements</u>	
p,p' - DDE	DDE	Arsenic	AS
Dieldrin	HEO	Cadmium	CD
Endrin	END	Copper	CU
o,p' - DDT	DDO	Cobalt	CO
p,p' - TDE	TDP	Chromium	CR
p,p' - DDT	DDP	Lead	PB
β - Endosulfan	EMY	Mercury	HG
Mirex	MIR	Nickel	NI
Methoxychlor	MEY	Selenium	SE
<u>Polyaromatic Hydrocarbons</u>			ZN
Indene	IND		
1,2,3,4 tetrahydro- napthalene	THN		
2, methylnaphthalene	2MN		
Quinoline	QUIN		
1, Methylnaphthalene	1MN		
β - chloronaphthalene	CHN		
Acenaphthylene	ANY		
Acenaphthene	AN		
Flourene	FLE		
Phenanthrene	PHN		
Flouranthene	FLN		
Pyrene	PYR		

ORGANOCHLORINE PESTICIDES SEDIMENT (MG/KG)

	HXB	BDH	LIN	HEP	ALD	HEX	CHC	CHA	EMX	DDE
FI1A	.0040	C0.0000	C0.0000	L .0040	L .0040	C0.0000	C0.0000	C0.0000	C0.0000	.0390
FI1B	L .0040	C0.0000	C0.0000	L .0040	L .0040	C0.0000	C0.0000	C0.0000	C0.0000	.0090
WI1A	.0020	C0.0000	C0.0000	.0080	L .0040	C0.0000	C0.0000	C0.0000	C0.0000	.0190
WI3A	.0030	C0.0000	C0.0000	L .0040	L .0040	C0.0000	C0.0000	C0.0000	C0.0000	.0150
WRA	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0030
WRB	.0020	L .0040	L .0040	.0030	L .0040	L .0040	L .0040	L .0040	L .0040	.0080
WIA	.0020	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0030
FI1D	C0.0000	.0200	.0170	L .0010	L .0010	L .0010	.0390	.0420	L .0020	L .0010
WI3C	C0.0000	.0080	.0160	L .0010	L .0010	L .0010	.0020	.0060	L .0020	.0030
WI3D	C0.0000	.0090	L .0010	L .0010	L .0010	L .0010	.0220	.0260	L .0020	.0080
NI2C	C0.0000	.0090	.0410	L .0010	L .0010	L .0010	.0100	.0130	L .0020	.0100
NI2D	C0.0000	.0030	.0310	L .0010	L .0010	L .0010	.0070	.0100	L .0020	.0230
WI1C	C0.0000	L .0010	.0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	.0030
WI1D	C0.0000	L .0010	.0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	.0040
WR4C	C0.0000	.0120	.0190	L .0010	L .0010	L .0010	.0440	.0540	L .0020	L .0010
NI1C	C0.0000	.0060	.0140	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	.0070
NI1G	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
NI2A	.0010	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0170
NI2B	.0030	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0630
WR4A	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
WI1B	.0030	L .0040	L .0040	.0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0300
WI3B	.0040	L .0040	L .0040	.0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0300
NI1A	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0190
NI1B	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
NI2F	C0.0000	.0100	L .0010	L .0010	L .0010	L .0010	.0100	.0050	L .0020	L .0010
WI1F	C0.0000	.0210	L .0010	L .0010	L .0010	L .0010	.0060	.0040	L .0020	L .0010
WI3F	C0.0000	.0160	L .0010	L .0010	L .0010	L .0010	.0270	.0200	L .0020	L .0010
NI3D	C0.0000	.0070	.0060	L .0010	L .0010	L .0010	.0370	.0520	L .0020	.0080
NR4D	C0.0000	.0340	L .0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	.0040
NI3C	C0.0000	.0060	.0030	L .0010	L .0010	L .0010	.0250	.0340	L .0020	.0020
WI3G	C0.0000	.0110	.0020	L .0010	L .0010	L .0010	.0140	.0220	L .0020	.0120
WR4D	C0.0000	.0070	.0020	L .0010	L .0010	L .0010	.6900	1.1000	L .0020	L .0010
NI1D	C0.0000	.0050	L .0010	L .0010	L .0010	L .0010	.0020	.0050	L .0020	.0030
NI1F	C0.0000	.0100	L .0010	L .0010	L .0010	L .0010	.0030	.0060	L .0020	.0240

ORGANOCHLORINE PESTICIDES SEDIMENT (MG/KG) CONTINUED

	HEO	END	DDO	TDP	DDP	EMY	MIR	MEY
FI1A	C0.0000	C0.0000	.0150	C0.0000	.0090	C0.0000	L .0040	C0.0000
FI1B	C0.0000	C0.0000	.0030	C0.0000	.0110	C0.0000	L .0040	C0.0000
WI1A	C0.0000	C0.0000	.0140	C0.0000	.0200	C0.0000	L .0040	C0.0000
WI3A	C0.0000	C0.0000	L .0040	C0.0000	L .0040	C0.0000	L .0040	C0.0000
WRA	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
WRB	L .0040	L .0040	.0020	L .0040	L .0040	L .0040	.0070	L .0040
WIA	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	.0010	L .0040
FI1D	.0080	L .0040	.0300	.0150	.0450	.0060	L .5000	L .0050
WI3C	L .0020	L .0040	L .0050	L .0050	.0050	L .0040	L .5000	L .0050
WI3D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .5000	L .0050
NI2C	L .0020	L .0040	.0100	.0050	.0020	L .0040	L .5000	L .0050
NI2D	L .0020	L .0040	.0100	.0050	.0300	L .0040	L .5000	L .0050
WI1C	L .0020	L .0040	L .0050	L .0050	.0100	L .0040	L .5000	L .0050
WI1D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .5000	L .0050
WR4C	L .0020	L .0040	L .0050	L .0050	.0100	L .0040	L .5000	L .0050
NI1C	L .0020	L .0040	L .0050	.0100	L .0050	L .0040	L .5000	L .0050
NI1G	L .0040	L .0040	.0030	L .0040	L .0040	L .0040	L .0040	L .0040
NI2A	L .0040	L .0040	.0040	L .0040	L .0040	L .0040	L .0040	L .0040
NI2B	L .0040	L .0040	.0200	L .0040	.1150	L .0040	L .0040	L .0040
WR4A	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
WI1B	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
WI3B	L .0040	L .0040	L .0040	L .0040	.0050	L .0040	L .0040	L .0040
NI1A	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
NI1B	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040	L .0040
NI2F	L .0020	L .0040	L .0050	.0050	.0100	L .0040	L .5000	L .0050
WI1F	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .5000	L .0050
WI3F	L .0020	L .0040	L .0050	L .0050	.0300	L .0040	L .5000	L .0050
NI3D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NR4D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI3C	L .0020	L .0040	.0060	L .0050	L .0050	L .0040	L .0050	L .0050
WI3G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	.0050	L .0050
WR4D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI1D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI1F	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050

ORGANOCHLORINE PESTICIDES WATER (UG/L)

	HXB	BDH	LIN	HEP	ALD	HEX	CHC	CHA	EMX	DDE
NI3H	C0.0000	.0060	.0020	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WR4H	C0.0000	.0110	.0020	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NI3G	C0.0000	.0100	.0030	.0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
FI1D	C0.0000	.0100	.0040	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WI3D	C0.0000	.0140	.0040	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NI2D	C0.0000	L .0010	L .0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NI1G	C0.0000	.0230	.0060	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WI1D	C0.0000	.0160	.0020	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NR4H	C0.0000	.0320	.0050	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WI1G	C0.0000	.0190	.0050	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WI1H	C0.0000	.0140	L .0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WI3G	C0.0000	.0180	L .0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WI3H	C0.0000	.0160	L .0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WR4D	C0.0000	.0090	.0040	L .0010	L .0010	L .0010	.0070	.0060	.0020	L .0010
NI1D	C0.0000	.0200	L .0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
FI1H	C0.0000	.0250	L .0010	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NI1H	C0.0000	.0130	.0030	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NI2G	C0.0000	.0160	.0030	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NI2H	C0.0000	.0240	.0020	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NI3D	C0.0000	.0190	.0020	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
NR4D	C0.0000	.0200	.0090	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WR4G	C0.0000	.0180	.0040	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
FI1G	C0.0000	.0270	.0030	L .0010	L .0010	L .0010	L .0020	L .0020	L .0020	L .0010
WR4A	L .0004	.0067	.0043	L .0004	L .0004	L .0004	L .0004	L .0004	.0007	L .0004
WR4B	L .0004	.0118	.0044	L .0004	L .0004	L .0004	.0004	L .0004	L .0006	L .0004
NI2A	.0004	.0074	.0026	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI2B	.0005	.0127	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	.0027	.0024
WI1B	L .0004	.0102	.0055	L .0004	L .0004	L .0004	L .0004	L .0004	.0014	L .0004
NI1A	.0031	.0109	.0045	L .0004	L .0004	L .0004	L .0004	L .0004	.0019	L .0004
NI1B	.0061	.0134	.0045	L .0004	L .0004	L .0004	L .0004	L .0004	.0017	L .0004
WI1J	.0023	.0174	.0035	L .0004	L .0004	L .0004	L .0004	L .0004	.0025	L .0004
WI3C	.0009	.0228	.0062	.0016	L .0004	L .0004	L .0004	L .0004	L .0004	.0004
NI2C	L .0004	.0189	.0046	L .0004	L .0004	.0045	L .0004	L .0004	.0007	L .0004
WI1C	.0007	.0018	L .0004	.0006	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WR4C	.0030	.0406	.0054	L .0004	L .0004	.0063	.0046	.0008	.0019	L .0004
FI1C	L .0004	.0170	.0032	.0005	.0005	.0005	L .0004	L .0004	L .0004	L .0004
NI1C	L .0004	.0204	.0026	.0006	L .0004	.0048	L .0004	L .0004	.0017	L .0004
NI3C	L .0004	.0378	.0032	L .0004	L .0004	L .0004	.0017	L .0004	L .0004	L .0004
NR4C	L .0004	C0.0000	C0.0000	L .0004	L .0004	C0.0000	C0.0000	C0.0000	C0.0000	L .0004
FI1A	L .0004	.0086	.0093	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
FI1B	L .0004	.0061	.0116	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI1A	L .0004	.0012	.0013	L .0004	L .0004	.0012	L .0004	L .0004	L .0004	L .0004
WI3A	L .0004	.0092	.0057	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
FI1E	L .0004	.0072	.0022	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI1E	L .0004	.0007	.0004	L .0004	L .0004	.0033	L .0004	L .0004	L .0004	L .0004
WI1F	L .0004	.0072	.0039	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI3E	L .0004	.0037	.0027	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI1E	L .0004	.0010	.0005	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI1F	L .0004	.0031	.0026	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI1J	L .0004	.0209	.0048	L .0004	L .0004	.0008	L .0004	L .0004	L .0004	L .0004
NI2E	L .0004	.0053	.0028	L .0004	L .0004	.0059	.0011	L .0004	L .0004	L .0004
NI3A	L .0004	.0191	.0041	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NR4J	L .0004	.0103	.0149	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NR4A	L .0004	.0109	.0074	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI2F	L .0004	.0064	.0025	L .0004	L .0004	.0008	L .0004	L .0004	L .0004	L .0004
NI3B	L .0004	.0099	.0050	L .0004	L .0004	.0032	.0007	L .0004	L .0004	L .0004
NR4B	L .0004	.0216	.0082	L .0004	L .0004	.0012	L .0004	L .0004	L .0004	L .0004
FI1F	L .0004	.0163	.0047	L .0004	L .0004	.0013	L .0004	L .0004	L .0004	L .0004
WI3B	L .0004	.0081	.0027	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI3F	L .0004	.0091	.0043	L .0004	L .0004	.0012	L .0004	L .0004	.0017	L .0004
WR4E	L .0004	.0055	.0014	.0009	L .0004	L .0004	.0018	L .0004	.0026	L .0004
NI2J	L .0004	.0135	.0035	L .0004	L .0004	.0014	L .0004	L .0004	.0006	L .0004
FI1J	L .0004	.0174	.0077	L .0004	L .0004	.0029	L .0004	L .0004	.0009	L .0004
WI3J	L .0004	.0239	.0054	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004

ORGANOCHLORINE PESTICIDES WATER (UG/L)   CONTINUED

	HEO	END	DDO	TDP	DDP	EMY	MIR	MEY
NI3H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WR4H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI3G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
FI1D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WI3D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI2D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI1G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WI1D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NR4H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WI1G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WI1H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WI3G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WI3H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WR4D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI1D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
FI1H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI1H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI2G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI2H	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NI3D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
NR4D	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WR4G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
FI1G	L .0020	L .0040	L .0050	L .0050	L .0050	L .0040	L .0050	L .0050
WR4A	L .0004	L .0004	L .0004	.0010	L .0004	.0011	L .0004	.0162
WR4B	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	.0064
NI2A	L .0004	.0010	L .0004	.0008	L .0004	.0039	L .0004	L .0004
NI2B	L .0004	.0045	.0006	L .0004	L .0004	.0090	L .0004	.0029
WI1B	L .0004	.0006	L .0004	.0007	L .0004	.0007	L .0004	.0018
NI1A	.0013	L .0004	L .0004	.0023	.0010	.0016	L .0004	.0072
NI1B	L .0004	.0004	L .0004	.0006	.0014	.0016	L .0004	.0030
WI1J	L .0004	.0008	L .0004	.0011	L .0004	.0012	L .0004	.0023
WI3C	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	.0007
NI2C	.0020	.0131	L .0004	L .0004	L .0004	.0011	L .0004	L .0004
WI1C	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WR4C	.0014	L .0004	L .0004	.0010	L .0004	.0021	L .0004	.0084
FI1C	L .0004	L .0004	L .0004	.0012	L .0004	.0011	L .0004	L .0004
NI1C	L .0004	L .0004	L .0004	.0015	L .0004	.0027	L .0004	L .0004
NI3C	.0007	.0127	L .0004	.0016	L .0004	.0007	.0010	L .0004
NR4C	C0.0000	C0.0000	L .0004	C0.0000	L .0004	C0.0000	L .0004	C0.0000
FI1A	L .0004	L .0004	L .0004	.0012	L .0004	.0032	L .0004	L .0004
FI1B	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI1A	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI3A	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
FI1E	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI1E	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	.0102
WI1F	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI3E	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI1E	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI1F	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI1J	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI2E	.0022	.0006	L .0004	.0012	L .0004	L .0004	L .0004	L .0004
NI3A	L .0004	.0005	L .0004	L .0004	L .0004	.0021	L .0004	L .0004
NR4J	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NR4A	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI2F	.0007	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI3B	.0006	.0017	L .0004	.0063	L .0004	.0053	L .0004	L .0004
NR4B	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
FI1F	L .0004	L .0004	L .0004	.0009	L .0004	L .0004	L .0004	L .0004
WI3B	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI3F	L .0004	L .0004	L .0004	L .0004	L .0004	.0004	L .0004	L .0004
WR4E	.0013	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
NI2J	L .0004	L .0004	L .0004	.0005	L .0004	.0013	L .0004	.0011
FI1J	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004
WI3J	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004	L .0004

PCB'S AND PAH'S SEDIMENT (MG/KG)

	TPCB	IND	THN	2MN	QUIN	1MN	CHN	ANY	AN	FLE
WRA	.020	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050
WRB	.060	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050
WIA	.530	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050
FI1A	.740	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050
FI1B	.020	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050
WI1A	.760	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050
WI3A	.100	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050	L .050
FI1D	.290	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3C	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3D	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2C	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2D	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1C	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1D	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4C	.740	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1C	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1G	1.140	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2A	.120	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2B	.130	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4A	.090	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1B	.360	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3B	.100	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1A	1.400	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1B	.340	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2F	.035	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1F	.265	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3F	.150	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI3D	.200	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NR4D	.171	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI3C	.167	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3G	.177	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4D	.063	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1D	.077	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1F	.083	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000

PCB'S AND PAH'S SEDIMENT (MG/KG) CONTINUED

	PHN	FLN	PYR
WRA	L .050	L .050	L .050
WRB	L .050	L .050	L .050
WIA	2.930	4.000	17.000
FI1A	L .050	L .050	L .050
FI1B	L .050	L .050	L .050
WI1A	L .050	L .050	L .050
WI3A	L .050	L .050	L .050
FI1D	C 0.000	C 0.000	C 0.000
WI3C	C 0.000	C 0.000	C 0.000
WI3D	C 0.000	C 0.000	C 0.000
NI2C	C 0.000	C 0.000	C 0.000
NI2D	C 0.000	C 0.000	C 0.000
WI1C	C 0.000	C 0.000	C 0.000
WI1D	C 0.000	C 0.000	C 0.000
WR4C	C 0.000	C 0.000	C 0.000
NI1C	C 0.000	C 0.000	C 0.000
NI1G	C 0.000	C 0.000	C 0.000
NI2A	C 0.000	C 0.000	C 0.000
NI2B	C 0.000	C 0.000	C 0.000
WR4A	C 0.000	C 0.000	C 0.000
WI1B	C 0.000	C 0.000	C 0.000
WI3B	C 0.000	C 0.000	C 0.000
NI1A	C 0.000	C 0.000	C 0.000
NI1B	C 0.000	C 0.000	C 0.000
NI2F	C 0.000	C 0.000	C 0.000
WI1F	C 0.000	C 0.000	C 0.000
WI3F	C 0.000	C 0.000	C 0.000
NI3D	C 0.000	C 0.000	C 0.000
NR4D	C 0.000	C 0.000	C 0.000
NI3C	C 0.000	C 0.000	C 0.000
WI3G	C 0.000	C 0.000	C 0.000
WR4D	C 0.000	C 0.000	C 0.000
NI1D	C 0.000	C 0.000	C 0.000
NI1F	C 0.000	C 0.000	C 0.000

PCB'S AND PAH'S WATER (UG/L)

		TPCB	IND	THN	2MN	QUIN	1MN	CHN	ANY	AN	FLE
NI3H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI3G	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1D	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3D	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2D	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1G	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1D	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NR4H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1G	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3G	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4D		.045	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1D	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2G	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2H	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI3D	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NR4D	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4G	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1G	L	.020	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4A	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4B	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2A	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2B	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1B	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1A		.036	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1B		.019	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1J		.027	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3C	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2C	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1C		.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4C		.016	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1C	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1C		.153	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI3C		.021	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NR4C		.046	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1A	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1B	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1A		.026	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3A		.016	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1E	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1E	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI1F		.001	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3E	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1E	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1F	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI1J	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2E	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI3A	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NR4J	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NR4A	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2F	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI3B	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NR4B		.014	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1F	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3B	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3F	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WR4E		.015	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
NI2J	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
FI1J	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000
WI3J	L	.009	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000	C 0.000

PCB'S AND PAH'S WATER (UG/L) CONTINUED

	PHN	FLN	PYR
NI3H	C 0.000	C 0.000	C 0.000
WR4H	C 0.000	C 0.000	C 0.000
NI3G	C 0.000	C 0.000	C 0.000
FI1D	C 0.000	C 0.000	C 0.000
WI3D	C 0.000	C 0.000	C 0.000
NI2D	C 0.000	C 0.000	C 0.000
NI1G	C 0.000	C 0.000	C 0.000
WI1D	C 0.000	C 0.000	C 0.000
NR4H	C 0.000	C 0.000	C 0.000
WI1G	C 0.000	C 0.000	C 0.000
WI1H	C 0.000	C 0.000	C 0.000
WI3G	C 0.000	C 0.000	C 0.000
WI3H	C 0.000	C 0.000	C 0.000
WR4D	C 0.000	C 0.000	C 0.000
NI1D	C 0.000	C 0.000	C 0.000
FI1H	C 0.000	C 0.000	C 0.000
NI1H	C 0.000	C 0.000	C 0.000
NI2G	C 0.000	C 0.000	C 0.000
NI2H	C 0.000	C 0.000	C 0.000
NI3D	C 0.000	C 0.000	C 0.000
NR4D	C 0.000	C 0.000	C 0.000
WR4G	C 0.000	C 0.000	C 0.000
FI1G	C 0.000	C 0.000	C 0.000
WR4A	C 0.000	C 0.000	C 0.000
WR4B	C 0.000	C 0.000	C 0.000
NI2A	C 0.000	C 0.000	C 0.000
NI2B	C 0.000	C 0.000	C 0.000
WI1B	C 0.000	C 0.000	C 0.000
NI1A	C 0.000	C 0.000	C 0.000
NI1B	C 0.000	C 0.000	C 0.000
WI1J	C 0.000	C 0.000	C 0.000
WI3C	C 0.000	C 0.000	C 0.000
NI2C	C 0.000	C 0.000	C 0.000
WI1C	C 0.000	C 0.000	C 0.000
WR4C	C 0.000	C 0.000	C 0.000
FI1C	C 0.000	C 0.000	C 0.000
NI1C	C 0.000	C 0.000	C 0.000
NI3C	C 0.000	C 0.000	C 0.000
NR4C	C 0.000	C 0.000	C 0.000
FI1A	C 0.000	C 0.000	C 0.000
FI1B	C 0.000	C 0.000	C 0.000
WI1A	C 0.000	C 0.000	C 0.000
WI3A	C 0.000	C 0.000	C 0.000
FI1E	C 0.000	C 0.000	C 0.000
WI1E	C 0.000	C 0.000	C 0.000
WI1F	C 0.000	C 0.000	C 0.000
WI3E	C 0.000	C 0.000	C 0.000
NI1E	C 0.000	C 0.000	C 0.000
NI1F	C 0.000	C 0.000	C 0.000
NI1J	C 0.000	C 0.000	C 0.000
NI2E	C 0.000	C 0.000	C 0.000
NI3A	C 0.000	C 0.000	C 0.000
NR4J	C 0.000	C 0.000	C 0.000
NR4A	C 0.000	C 0.000	C 0.000
NI2F	C 0.000	C 0.000	C 0.000
NI3B	C 0.000	C 0.000	C 0.000
NR4B	C 0.000	C 0.000	C 0.000
FI1F	C 0.000	C 0.000	C 0.000
WI3B	C 0.000	C 0.000	C 0.000
WI3F	C 0.000	C 0.000	C 0.000
WR4E	C 0.000	C 0.000	C 0.000
NI2J	C 0.000	C 0.000	C 0.000
FI1J	C 0.000	C 0.000	C 0.000
WI3J	C 0.000	C 0.000	C 0.000

CHLORINATED BENZENES SEDIMENT (MG/KG)

	M-DCB	P-DCB	O-DCB	TCB135	TCB124	TCB123	124/35	1234	P5CB	HEXB
WRA	L .0500	L .0500	L .0500	L .0050	L .0050	L .0050	L .0050	L .0050	L .0050	L .0040
WRB	L .0500	L .0500	L .0500	L .0050	.0230	.0060	L .0050	L .0050	L .0050	L .0040
WIA	L .0500	L .0500	L .0500	L .0050	.0040	L .0050	L .0050	.0010	L .0050	L .0040
FI1A	L .0500	L .0500	L .0500	L .0050	L .0050	L .0050	L .0050	L .0050	L .0050	.0040
FI1B	L .0500	L .0500	L .0500	L .0050	L .0050	L .0050	L .0050	L .0050	L .0050	L .0040
WI1A	L .0500	L .0500	L .0500	L .0050	L .0050	L .0050	L .0050	L .0050	L .0050	L .0040
WI3A	L .0500	L .0500	L .0500	L .0050	L .0050	L .0050	L .0050	L .0050	L .0050	L .0040
FI1D	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010
WI3C	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010
WI3D	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010
NI2C	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010
NI2D	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0020
WI1C	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	L .0010
WI1D	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	L .0010
WR4C	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	L .0010
NI1C	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	L .0010
NI1G	L .0500	L .0500	.2600	9.9999	.0040	.3320	.0360	.0120	L .0050	L .0040
NI2A	L .0500	L .0500	.1800	.0180	.0270	L .0050	L .0050	L .0050	L .0050	L .0040
NI2B	L .0500	L .0500	.0800	.0090	.0060	L .0050	L .0050	L .0050	L .0050	L .0040
WR4A	.0600	.4000	2.6900	L .0050	.0850	L .0050	L .0050	L .0050	L .0050	L .0040
WI1B	L .0500	.0700	.1700	.0110	.0080	L .0050	L .0050	L .0050	L .0050	L .0040
WI3B	L .0500	.0600	.3100	.0120	L .0050	L .0050	L .0050	L .0050	.0050	.0040
NI1A	L .0500	L .0500	L .0500	L .0050	.0220	.1070	L .0050	L .0050	L .0050	L .0040
NI1B	L .0500	.1300	L .0500	.8880	L .0050	.0570	L .0050	L .0050	L .0050	L .0040
NI2F	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010
WI1F	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010
WI3F	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010
WR4D	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	.0010

CHLORINATED BENZENES WATER (UG/L)

	M-DCB	P-DCB	O-DCB	TCB135	TCB124	TCB123	124/35	1234	P5CB	HEXB
NI3H	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WR4H	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	.0040
NI3G	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
FI1D	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WI3D	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NI2D	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NI1G	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WI1A	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	L .0010
NR4H	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	L .0010
WI1G	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WI1H	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WI3G	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WI3H	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WR4D	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NI1D	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
FI1H	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NI1H	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NI2G	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NI2H	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NI3D	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
NR4D	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
WR4G	C0.0000	C0.0000	C0.0000	L .0100	L .0100	L .0100	L .0100	L .0100	L .0100	L .0010
FI1G	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	C0.0000	L .0010
WR4A	.0070	L .0050	.0720	.0020	.0020	.0010	.0010	L .0010	L .0010	L .0004
WR4B	L .0050	L .0050	.0560	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI2A	L .0050	L .0050	.0850	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	.0004
NI2B	.0150	L .0050	.1220	.0040	L .0010	.0020	.0020	.0010	L .0010	.0005
WI1B	L .0050	L .0050	.0590	L .0010	L .0010	L .0010	.0010	L .0010	L .0010	L .0004
NI1A	.0120	L .0050	.0750	.0010	.0230	.0010	.0020	L .0010	L .0010	.0031
NI1B	.0080	L .0050	.0860	L .0010	.0040	L .0010	.0010	L .0010	L .0010	.0061
WI1J	L .0050	L .0050	L .0050	.0010	.0010	.0010	.0010	L .0010	L .0010	.0023
WI3C	L .0050	L .0050	.0150	L .0010	.0010	L .0010	L .0010	L .0010	L .0010	.0009
NI2C	.0060	L .0050	.0240	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI1C	.0050	L .0050	.0150	L .0010	.0010	L .0010	L .0010	L .0010	L .0010	.0007
WR4C	L .0050	L .0050	.0120	L .0010	.0010	L .0010	L .0010	L .0010	L .0010	.0030
FI1C	.0050	L .0050	.0060	.0010	.0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI1C	.0060	L .0050	.0070	.0010	.0080	L .0010	L .0010	L .0010	L .0010	L .0004
NI3C	.0130	L .0050	.0210	.0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NR4C	L .0050	L .0050	L .0050	.0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
FI1A	.0160	.0150	.1140	.0030	L .0010	L .0010	L .0010	L .0010	.0010	L .0004
FI1B	L .0050	.0060	.1170	.0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI1A	L .0050	.0070	.1220	.0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI3A	L .0050	L .0050	.0650	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
FI1E	L .0050	L .0050	.0480	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI1E	L .0050	L .0050	.0170	L .0010	.0040	L .0010	L .0010	L .0010	L .0010	L .0004
WI1F	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI3E	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI1E	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI1F	L .0050	L .0050	.0300	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI1J	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI2E	.0110	.0070	.0620	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI3A	L .0050	L .0050	.0590	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NR4J	L .0050	L .0050	.0540	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NR4A	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI2F	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI3B	L .0050	.0080	.0570	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NR4B	L .0050	.0230	.0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
FI1F	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI3B	L .0050	.0250	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI3F	L .0050	L .0050	.0390	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WR4E	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
NI2J	L .0050	L .0050	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
FI1J	L .0050	.0080	L .0050	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004
WI3J	.0180	.0130	.1370	L .0010	L .0010	L .0010	L .0010	L .0010	L .0010	L .0004

HEAVY METALS SEDIMENT (MG/KG)

	AS	CD	CU	CO	CR	PB	HG	NI	SE	ZN
WRA	C 0.0	.4	11.0	C 0.0	1.7	805.0	.1	6.6	C 0.0	208.0
WRB	C 0.0	.5	20.0	C 0.0	4.6	248.0	C 0.0	13.0	C 0.0	209.0
WIA	C 0.0	.3	6.5	C 0.0	7.1	39.0	.1	12.0	C 0.0	82.0
FI1A	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	.5	C 0.0	C 0.0	C 0.0
FI1B	7.8	L 10.0	52.3	L 10.0	37.6	426.0	.2	21.1	.5	212.0
WI1A	14.9	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	.4	C 0.0	.7	C 0.0
WI3A	13.4	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	.3	C 0.0	1.1	C 0.0
NI2A	7.7	L 10.0	76.6	L 10.0	64.6	514.0	.2	L 10.0	.5	477.0
NI2B	7.8	L 10.0	75.7	L 10.0	55.1	442.0	.2	L 10.0	.5	456.0
WR4A	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	.3	C 0.0	C 0.0	C 0.0
WI1B	19.0	L 10.0	168.0	L 10.0	200.0	3110.0	.4	38.3	.3	3690.0
WI3B	17.6	L 10.0	198.0	42.3	1430.0	692.0	.2	447.0	.1	996.0
NI1A	C 0.0	L 10.0	186.0	L 10.0	1060.0	411.0	C 0.0	543.0	C 0.0	1680.0
NI1B	C 0.0	L 10.0	217.0	46.3	698.0	397.0	C 0.0	533.0	C 0.0	1670.0
FI1N	2.9	.9	48.0	3.0	21.0	640.0	.1	C 18.0	.2	370.0
WI1N	10.2	3.9	700.0	9.5	150.0	4100.0	L .1	120.0	.2	1600.0
WR4N	4.7	2.4	35.0	4.5	31.0	740.0	L .1	18.0	.3	230.0
NI1N	7.1	.6	60.0	5.5	130.0	450.0	L .1	45.0	.6	240.0
NI3N	7.0	1.1	84.0	4.5	110.0	630.0	L .1	14.0	.8	430.0
NR4N	3.9	1.4	41.0	2.0	25.0	250.0	L .1	8.5	.1	270.0
NI2N	5.5	.9	210.0	3.0	32.0	550.0	C 0.0	13.0	.4	340.0
WI3N	8.6	6.5	69.0	16.0	990.0	820.0	C 0.0	320.0	.5	360.0
WI1E	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	.8	C 0.0	C 0.0	C 0.0
WI1F	C 0.0	L 10.0	194.0	L 10.0	239.0	2593.0	C 0.0	94.0	C 0.0	2403.0
NI1F	C 0.0	L 10.0	225.0	37.0	670.0	315.0	C 0.0	413.0	C 0.0	2479.0
WI3E	C 0.0	L 10.0	150.0	26.0	1566.0	572.0	.2	503.0	C 0.0	650.0
NI1E	C 0.0	L 10.0	285.0	33.0	1525.0	359.0	C 0.0	898.0	C 0.0	2390.0
NI2E	C 0.0	L 10.0	131.0	L 10.0	62.0	456.0	.3	39.0	C 0.0	473.0
NI3A	C 0.0	L 10.0	140.0	22.0	105.0	920.0	.2	31.0	C 0.0	671.0
NR4B	11.0	L 10.0	69.0	L 10.0	36.0	429.0	.1	49.0	.2	409.0
NI3B	C 0.0	L 10.0	118.0	10.0	90.0	721.0	.2	L 30.0	C 0.0	585.0
FI1F	C 0.0	L 10.0	145.0	L 10.0	85.0	1191.0	C 0.0	60.0	C 0.0	643.0
NI2F	8.7	L 10.0	108.0	L 10.0	48.0	527.0	C 0.0	L 30.0	.4	412.0
NI3E	8.7	L 10.0	137.0	L 10.0	101.0	963.0	.1	56.0	.5	591.0
NR4E	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	.1	C 0.0	C 0.0	C 0.0
NR4F	C 0.0	L 10.0	173.0	14.0	126.0	821.0	C 0.0	55.0	C 0.0	433.0
NI3F	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	C 0.0	.1	C 0.0	C 0.0	C 0.0
FI10	5.4	2.4	120.0	4.4	40.0	2500.0	C 0.0	66.0	.2	550.0
WI30	7.5	2.1	133.0	16.0	1200.0	940.0	C 0.0	420.0	.2	290.0
WI10	44.9	3.3	470.0	11.0	190.0	3000.0	C 0.0	100.0	.5	2900.0
WR40	3.4	2.9	43.0	3.5	26.0	760.0	C 0.0	22.0	.2	360.0
NI20	5.9	1.6	76.0	2.2	35.0	1500.0	C 0.0	14.0	.3	410.0
NI30	C 0.0	3.8	120.0	7.0	72.0	1200.0	C 0.0	25.0	C 0.0	410.0
NR40	4.1	1.3	69.0	21.0	29.0	910.0	C 0.0	20.0	C 0.0	310.0

HEAVY METALS WATER (MG/L) *HG IN UG/L*

	AS	CD	CU	CO	CR	PB	HG	NI	SE	ZN
FI1A	.0006	L .0100	.0350	L .0100	L .0100	L .0100	6.4000	.0200	.0019	.0460
FI1B	.0004	L .0100	L .0100	L .0100	L .0100	L .0100	6.0000	L .0100	.0007	.0110
WI1A	.0011	L .0100	L .0100	.0100	L .0100	L .0100	4.7000	L .0100	.0002	.0300
WI3A	.0008	L .0100	.0110	.0100	L .0100	L .0100	4.7000	L .0100	.0004	.0460
FI1D	.0003	L .0100	.0100	L .0100	L .0100	L .0100	C0.0000	.0100	.0006	.0100
WI3C	L .0300	L .0100	.0200	L .0200	L .0100	.0700	7.1000	L .0300	.0300	.1100
WI3D	.0017	L .0010	.0060	L .0100	C0.0000	.0030	C0.0000	.0320	.0008	.1800
WR4A	.0010	L .0010	.0130	L .0100	C0.0000	.0020	7.4000	.0130	.0005	.0670
WR4B	.0009	L .0010	.0060	L .0100	C0.0000	L .0010	7.6000	.0040	.0011	.0240
NI2A	.0014	L .0010	.0240	L .0100	C0.0000	.0020	7.4000	.0040	.0018	.0020
NI2B	.0011	L .0010	.0080	L .0100	C0.0000	L .0010	7.2000	.0020	.0003	.0010
NI2C	L .0300	L .0100	.0500	L .0200	L .0100	.0600	7.2000	L .0300	L .0300	.0200
NI2D	.0012	L .0010	.0130	L .0100	C0.0000	L .0010	C0.0000	.0050	.0004	.0020
WI1B	.0005	L .0010	.0070	L .0100	C0.0000	L .0010	7.1000	.0070	L .0001	.3500
NR4C	.0010	.0003	.0090	L .0010	L .0010	.0040	7.7000	.0020	L .0010	.0100
NI3C	.0010	L .0002	.0090	.0010	.0020	.0160	6.7000	.0040	L .0010	.0170
NI1A	.0010	L .0010	.0050	.0020	.0010	.0030	8.2000	.0160	.0005	.0570
NI1B	.0008	L .0010	.0180	L .0010	L .0010	L .0010	8.0000	.0200	.0006	.1100
WI1D	.0008	L .0010	.0120	L .0010	L .0010	.0050	C0.0000	.0050	.0005	.1590
FI1C	L .0300	L .0100	L .0100	L .0400	L .0100	L .0600	8.5000	L .0300	L .0300	.0300
WI1C	L .0300	L .0100	L .0100	L .0400	L .0100	L .0600	7.7000	L .0300	L .0300	.3900
WR4C	L .0300	L .0100	L .0200	L .0400	L .0100	L .0600	8.2000	L .0300	L .0300	.0100
NI1C	L .0300	L .0100	L .0200	L .0400	L .0100	L .0600	8.4000	L .0300	L .0300	.0100
FI1E	.0003	L .0010	.0220	L .0010	L .0010	.0010	7.2000	.0080	.0004	.0430
WI1E	C0.0000	L .0010	.0220	L .0010	L .0010	.0040	7.3000	.0020	C0.0000	.0050
WI1F	.0008	L .0010	.0100	L .0010	L .0010	.0170	7.3000	.0050	.0001	.3100
WI3E	.0009	L .0010	.0140	.0020	L .0010	.0040	.1000	.0100	.0001	.0490
NI1E	C0.0000	L .0010	.0180	L .0010	L .0010	.0010	7.2000	.0150	C0.0000	.1100
NI1F	C0.0000	L .0010	.0120	L .0010	L .0010	L .0010	6.5000	.0110	C0.0000	.1200
NI2E	.0010	L .0010	.0180	L .0010	L .0010	L .0010	7.5000	.0020	.0002	.0060
NI3A	.0006	L .0010	L .0010	L .0010	.0010	L .0010	7.3000	.0030	L .0001	.0030
NR4A	.0005	L .0010	.0080	L .0010	L .0010	.0020	7.2000	.0020	.0002	.0110
WR4D	.0013	L .0010	.0120	L .0010	L .0010	.0030	C0.0000	.0090	.0002	.0650
NI1D	.0006	L .0010	.0080	L .0010	L .0010	.0010	C0.0000	.0030	.0002	.0100
NI2F	.0010	L .0010	.0140	L .0010	.0020	L .0010	6.8000	.0020	.0003	.0020
NI3B	.0008	L .0010	.0050	L .0010	L .0010	.0020	1.3000	.0030	L .0001	.0070
NR4B	.0007	L .0010	.0050	L .0010	L .0010	L .0010	7.4000	.0020	.0003	.0040
FI1F	.0004	L .0010	.0090	L .0010	L .0010	.0020	6.8000	.0030	.0003	.0220
WI3B	.0013	L .0010	.0100	.0020	.0010	.0120	6.5000	.0090	.0002	.0590
WI3F	.0010	L .0010	.0060	.0010	L .0010	.0080	6.4000	.0120	.0005	.0460
WR4E	.0008	L .0010	.0100	L .0010	L .0010	.0040	7.9000	.0090	.0002	.0680
NR4D	.0005	L .0010	.0090	L .0010	L .0010	L .0010	C0.0000	.0020	L .0001	.0110
NI3D	.0008	L .0010	.0050	L .0010	L .0010	.0040	C0.0000	.0020	L .0001	.0110
WR4F	.0005	L .0010	.0020	L .0010	L .0010	.0030	.6000	.0050	L .0001	.0110
NI3E	.0012	L .0010	.0030	L .0010	.0010	.0220	1.1000	.0050	L .0001	.0050
NI3F	.0007	L .0010	.0090	L .0010	.0020	.0560	1.0000	.0040	L .0001	.0400
NR4E	.0009	L .0010	.0100	L .0010	L .0010	.0040	1.2000	.0050	L .0001	.0270
NR4F	.0007	L .0010	.0100	L .0010	L .0010	.0020	1.3000	.0040	L .0001	.0190

TABLE A. Annual Toxics Loadings in Stormwater From Fort Erie

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.0192	0.0675	0.0422
Organochlorine Pesticides			
Hexachlor benzene	0.0011	0.0028	0.0019
α - BHC	0.0380	0.0527	0.0472
Lindane	0.0139	0.0196	0.0174
Heptachlor	0.0002	0.0025	0.0013
Aldrin	0.0000	0.0015	0.0007
Heptachlor epoxide	0.0017	0.0043	0.0030
γ - chlordane	0.0008	0.0045	0.0025
α - chlordane	0.0003	0.0040	0.0020
α - Endosulfan	0.0010	0.0046	0.0027
p,p' - DDE	0.0001	0.0025	0.0012
Dieldrin	0.0005	0.0041	0.0021
Endrin	0.0016	0.0084	0.0047
o,p' - DDT	0.0000	0.0015	0.0007
p,p' - TDE	0.0015	0.0031	0.0023
p,p' - DDT	0.0002	0.0017	0.0008
β - Endosulfan	0.0027	0.0046	0.0037
Mirex	0.0001	0.0016	0.0007
Methoxychlor	0.0026	0.0113	0.0067
Polyaromatic Hydrocarbons			
Indene	0.0005	0.1867	0.0841
1,2,3,4 tetrahydro-napthalene	0.0005	0.1867	0.0841
2, methylnaphthalene	0.0204	0.1799	0.0933
Quinoline	0.0025	0.1861	0.0850
1, Methylnaphthalene	0.0090	0.1847	0.0884
β - chloronaphthalene	0.0179	0.1833	0.0933
Acenaphthylene	0.0374	0.2067	0.1159
Acenaphthene	0.0085	0.1737	0.0831
Flourene	0.0010	0.1840	0.0831
Phenanthrene	0.0135	0.1943	0.0955
Flouranthene	0.0379	0.2143	0.1196
Pyrene	0.0359	0.2047	0.1141

TABLE A. Annual Toxics Loadings in Stormwater From Fort Erie

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
<u>Chlorinated Benzenes</u>			
1,3 dichlorobenzene	0.0082	0.0247	0.0162
1,4 dichlorobenzene	0.0075	0.0251	0.0159
1,2 dichlorobenzene	0.1057	0.1522	0.1339
1,3,5 trichlorobenzene	0.0011	0.0043	0.0026
1,2,4 trichlorobenzene	0.0031	0.0071	0.0051
1,2,3 trichlorobenzene	0.0003	0.0039	0.0020
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0005	0.0039	0.0021
1,2,3,4 tetrachloro-benzene	0.0001	0.0038	0.0017
pentachlorobenzene	0.0001	0.0038	0.0017
Hexachlorobenzene	0.0009	0.0033	0.0020
<u>Heavy Metals</u>			
Arsenic	2.2	3.0	2.7
Cadmium	.8	1.1	1.0
Copper	30.3	45.3	39.1
Cobalt	2.4	6.3	4.3
Chromium	.9	4.1	2.4
Lead	19.7	32.5	26.8
Mercury	16.7	23.1	20.7
Nickel	19.7	27.3	24.5
Selenium	3.1	45.3	3.9
Zinc	157.3	217.5	195.2

TABLE B. Annual Toxics Loadings in Sediment from Fort Erie

Substance	Annual Total Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.0681	0.6114	0.2633
Organochlorine Pesticides			
Hexachlor benzene	0.0004	0.0064	0.0021
α - BHC	0.0014	0.0159	0.0062
Lindane	0.0011	0.0135	0.0051
Heptachlor	0.0001	0.0048	0.0013
Aldrin	0.0000	0.0046	0.0010
Heptachlor epoxide	0.0000	0.0042	0.0009
γ - chlordane	0.0069	0.0655	0.0275
α - chlordane	0.0103	0.0960	0.0406
α - Endosulfan	0.0000	0.0054	0.0012
p,p' - DDE	0.0024	0.0224	0.0094
Dieldrin	0.0001	0.0058	0.0014
Endrin	0.0000	0.0079	0.0017
o,p' - DDT	0.0008	0.0131	0.0043
p,p' - TDE	0.0003	0.0102	0.0028
p,p' - DDT	0.0025	0.0279	0.0108
β - Endosulfan	0.0000	0.0081	0.0018
Mirex	0.0001	0.0086	0.0021
Methoxychlor	0.0000	0.0092	0.0020
Polyaromatic Hydrocarbons			
Indene	0.0000	0.0993	0.0214
1,2,3,4 tetrahydro-napthalene	0.0000	0.0993	0.0214
2, methylnaphthalene	0.0000	0.0993	0.0214
Quinoline	0.0000	0.0993	0.0214
1, Methylnaphthalene	0.0000	0.0993	0.0214
β - chloronaphthalene	0.0000	0.0993	0.0214
Acenaphthylene	0.0000	0.0993	0.0214
Acenaphthene	0.0000	0.0993	0.0214
Flourene	0.0000	0.0993	0.0214
Phenanthrene	0.0925	0.9159	0.3762
Flouranthene	0.1263	1.2194	0.5069
Pyrene	0.5367	4.9058	2.0948

TABLE B. Annual Toxics Loadings in Sediment from Fort Erie

Substance	Annual Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0009	0.1008	0.0234
1,4 dichlorobenzene	0.0097	0.1601	0.0533
1,2 dichlorobenzene	0.0544	0.5479	0.2232
1,3,5 trichlorobenzene	0.2295	2.0674	0.8894
1,2,4 trichlorobenzene	0.0026	0.0283	0.0112
1,2,3 trichlorobenzene	0.0074	0.0737	0.0302
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0005	0.0140	0.0040
1,2,3,4 tetrachloro-benzene	0.0002	0.0103	0.0026
pentachlorobenzene	0.0001	0.0099	0.0023
Hexachlorobenzene	0.0001	0.0052	0.0014
Trace Elements			
Arsenic	2.1879	19.6515	8.4645
Cadmium	0.4420	3.9700	1.7100
Copper	30.8516	277.1060	119.3580
Cobalt	2.2277	26.4204	10.0035
Chromium	67.4492	605.8220	260.9460
Lead	214.6794	1928.2290	830.5470
Mercury	0.0358	0.3593	0.1462
Nickel	30.8030	281.0760	120.1190
Selenium	0.0884	0.7940	0.3420
Zinc	184.4908	1657.0780	713.7540

TABLE C. **Annual Toxics Loadings in Stormwater from Niagara Falls**

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.0672	0.2446	0.1516
Organochlorine Pesticides			
Hexachlor benzene	0.0039	0.0101	0.0070
α - BHC	0.1332	0.1907	0.1697
Lindane	0.0486	0.0710	0.0625
Heptachlor	0.0008	0.0090	0.0045
Aldrin	0.0001	0.0055	0.0025
Heptachlor epoxide	0.0059	0.0157	0.0108
γ - chlordane	0.0027	0.0164	0.0090
α - chlordane	0.0010	0.0145	0.0071
α - Endosulfan	0.0034	0.0168	0.0097
p,p' - DDE	0.0004	0.0089	0.0042
Dieldrin	0.0016	0.0150	0.0077
Endrin	0.0055	0.0305	0.0171
o,p' - DDT	0.0001	0.0056	0.0026
p,p' - TDE	0.0054	0.0112	0.0084
p,p' - DDT	0.0006	0.0060	0.0030
β - Endosulfan	0.0094	0.0166	0.0134
Mirex	0.0002	0.0057	0.0027
Methoxychlor	0.0092	0.0408	0.0240
Polyaromatic Hydrocarbons			
Indene	0.0017	0.6765	0.3022
1,2,3,4 tetrahydro-napthalene	0.0017	0.6765	0.3022
2, methylnaphthalene	0.0716	0.6516	0.3355
Quinoline	0.0087	0.6740	0.3055
1, Methylnaphthalene	0.0314	0.6690	0.3177
β - chloronaphthalene	0.0628	0.6640	0.3355
Acenaphthylene	0.1309	0.7489	0.4166
Acenaphthene	0.0297	0.6291	0.2988
Flourene	0.0035	0.6665	0.2988
Phenanthrene	0.0471	0.7040	0.3433
Flouranthene	0.1327	0.7764	0.4299
Pyrene	0.1257	0.7414	0.4099

TABLE C. Annual Toxics Loadings in Stormwater from Niagara Falls

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0287	0.0895	0.0581
1,4 dichlorobenzene	0.0261	0.0809	0.0571
1,2 dichlorobenzene	0.3704	0.5515	0.4812
1,3,5 trichlorobenzene	0.0039	0.0156	0.0094
1,2,4 trichlorobenzene	0.0108	0.0258	0.0183
1,2,3 trichlorobenzene	0.0012	0.0141	0.0074
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0018	0.0141	0.0074
1,2,3,4 tetrachloro-benzene	0.0002	0.0137	0.0063
pentachlorobenzene	0.0002	0.0137	0.0063
Hexachlorobenzene	0.0031	0.0120	0.0073
Heavy Metals			
Arsenic	7.7	11.0	9.8
Cadmium	2.9	4.1	3.7
Copper	106.1	164.0	140.5
Cobalt	8.4	22.7	15.5
Chromium	3.1	15.0	8.7
Lead	69.0	117.8	96.3
Mercury	58.6	83.8	74.5
Nickel	69.1	98.9	88.0
Selenium	10.8	164.1	14.2
Zinc	551.0	788.1	701.4

TABLE D. Annual Toxics Loadings in Sediment from Niagara Falls

Substance	Annual Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.2563	2.3125	1.0469
Organochlorine Pesticides			
Hexachlor benzene	0.0013	0.0242	0.0082
α - BHC	0.0054	0.0600	0.0246
Lindane	0.0043	0.0512	0.0203
Heptachlor	0.0005	0.0182	0.0051
Aldrin	0.0000	0.0174	0.0039
Heptachlor epoxide	0.0000	0.0158	0.0036
γ - chlordane	0.0260	0.2476	0.1092
α - chlordane	0.0386	0.3633	0.1615
α - Endosulfan	0.0000	0.0205	0.0046
p,p' - DDE	0.0089	0.0864	0.0374
Dieldrin	0.0002	0.0220	0.0054
Endrin	0.0000	0.0300	0.0068
o,p' - DDT	0.0029	0.0494	0.0170
p,p' - TDE	0.0011	0.0385	0.0110
p,p' - DDT	0.0094	0.1054	0.0430
β - Endosulfan	0.0002	0.0305	0.0073
Mirex	0.0005	0.0324	0.0083
Methoxychlor	0.0000	0.0348	0.0079
Polyaromatic Hydrocarbons			
Indene	0.0000	0.3754	0.0850
1,2,3,4 tetrahydro-napthalene	0.0000	0.3754	0.0850
2, methylnaphthalene	0.0000	0.3754	0.0850
Quinoline	0.0000	0.3754	0.0850
1, Methylnaphthalene	0.0000	0.3754	0.0850
β - chloronaphthalene	0.0000	0.3754	0.0850
Acenaphthylene	0.0000	0.3754	0.0850
Acenaphthene	0.0000	0.3754	0.0850
Flourene	0.0000	0.3754	0.0850
Phenanthrene	0.3483	3.4644	1.4956
Flouranthene	0.4754	4.6121	2.0151
Pyrene	2.0206	18.5555	8.3276

TABLE D. Annual Toxics Loadings in Sediment from Niagara Falls

Substance	Annual Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
<u>Chlorinated Benzenes</u>			
1,3 dichlorobenzene	0.0033	0.3804	0.0929
1,4 dichlorobenzene	0.0366	0.6056	0.2119
1,2 dichlorobenzene	0.2047	2.0722	0.8871
1,3,5 trichlorobenzene	0.8640	7.8097	3.5356
1,2,4 trichlorobenzene	0.0099	0.1072	0.0446
1,2,3 trichlorobenzene	0.0278	0.2788	0.1200
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0020	0.0531	0.0161
1,2,3,4 tetrachloro-benzene	0.0007	0.0390	0.0103
pentachlorobenzene	0.0003	0.0375	0.0091
Hexachlorobenzene	0.0005	0.0197	0.0055
<u>Trace Elements</u>			
Arsenic	8.2368	74.3292	33.6501
Cadmium	1.6640	15.0160	6.7980
Copper	116.1472	1048.1168	474.5004
Cobalt	8.3866	99.9315	39.7683
Chromium	253.9264	2291.4416	1037.3748
Lead	808.2048	7293.2712	3301.7886
Mercury	0.1348	1.3589	0.5812
Nickel	115.9642	1063.1328	477.5255
Selenium	0.3328	3.0032	1.3596
Zinc	694.5536	6267.6784	2837.4852

TABLE E. **Annual Toxics Loadings in Stormwater from Welland**

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.0325	0.1151	0.0716
Organochlorine Pesticides			
Hexachlor benzene	0.0019	0.0047	0.0033
α - BHC	0.0644	0.0897	0.0801
Lindane	0.0235	0.0334	0.0295
Heptachlor	0.0004	0.0042	0.0021
Aldrin	0.0001	0.0026	0.0012
Heptachlor epoxide	0.0029	0.0074	0.0051
γ - chlordane	0.0013	0.0077	0.0042
α - chlordane	0.0005	0.0068	0.0034
α - Endosulfan	0.0017	0.0079	0.0046
p,p' - DDE	0.0002	0.0042	0.0020
Dieldrin	0.0008	0.0070	0.0036
Endrin	0.0026	0.0144	0.0081
o,p' - DDT	0.0001	0.0026	0.0012
p,p' - TDE	0.0026	0.0053	0.0040
p,p' - DDT	0.0003	0.0028	0.0014
β - Endosulfan	0.0045	0.0078	0.0063
Mirex	0.0001	0.0027	0.0013
Methoxychlor	0.0045	0.0192	0.0113
Polyaromatic Hydrocarbons			
Indene	0.0008	0.3183	0.1427
1,2,3,4 tetrahydro-napthalene	0.0008	0.3183	0.1427
2, methylnaphthalene	0.0348	0.3066	0.1584
Quinoline	0.0041	0.3171	0.1443
1, Methylnaphthalene	0.0152	0.3148	0.1500
β - chloronaphthalene	0.0304	0.3124	0.1584
Acenaphthylene	0.0633	0.3524	0.1967
Acenaphthene	0.0143	0.2960	0.1411
Flourene	0.0017	0.3136	0.1411
Phenanthrene	0.0228	0.3312	0.1621
Flouranthene	0.0641	0.3653	0.2030
Pyrene	0.0607	0.3488	0.1936

TABLE E. Annual Toxics Loadings in Stormwater from Welland

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0139	0.0421	0.0274
1,4 dichlorobenzene	0.0126	0.0426	0.0270
1,2 dichlorobenzene	0.1790	0.2595	0.2272
1,3,5 trichlorobenzene	0.0019	0.0073	0.0044
1,2,4 trichlorobenzene	0.0052	0.0121	0.0067
1,2,3 trichlorobenzene	0.0006	0.0066	0.0033
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0009	0.0066	0.0035
1,2,3,4 tetrachloro-benzene	0.0001	0.0065	0.0030
pentachlorobenzene	0.0001	0.0065	0.0030
Hexachlorobenzene	0.0015	0.0057	0.0035
Heavy Metals			
Arsenic	3.7	5.2	4.6
Cadmium	1.4	1.9	1.7
Copper	51.3	77.2	66.3
Cobalt	4.1	10.7	7.3
Chromium	1.5	7.1	4.1
Lead	33.4	55.4	45.5
Mercury	28.3	39.4	35.2
Nickel	33.4	46.5	41.5
Selenium	5.2	77.2	6.7
Zinc	266.3	370.8	331.2

TABLE F. Annual Toxics Loadings in Sediment from Welland

Substance	Annual Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.1214	1.0946	0.5137
Organochlorine Pesticides			
Hexachlor benzene	0.0006	0.0114	0.0040
α - BHC	0.0025	0.0284	0.0121
Lindane	0.0020	0.0242	0.0100
Heptachlor	0.0002	0.0086	0.0025
Aldrin	0.0000	0.0083	0.0019
Heptachlor epoxide	0.0000	0.0075	0.0018
γ - chlordane	0.0123	0.1172	0.0536
α - chlordane	0.0184	0.1720	0.0793
α - Endosulfan	0.0000	0.0097	0.0023
p,p' - DDE	0.0042	0.0400	0.0183
Dieldrin	0.0001	0.0104	0.0027
Endrin	0.0000	0.0142	0.0033
o,p' - DDT	0.0014	0.0234	0.0083
p,p' - TDE	0.0005	0.0182	0.0054
p,p' - DDT	0.0044	0.0499	0.0211
β - Endosulfan	0.0001	0.0145	0.0036
Mirex	0.0002	0.0153	0.0041
Methoxychlor	0.0000	0.0165	0.0039
Polyaromatic Hydrocarbons			
Indene	0.0000	0.1777	0.0417
1,2,3,4 tetrahydro-napthalene	0.0000	0.1777	0.0417
2, methylnaphthalene	0.0000	0.1777	0.0417
Quinoline	0.0000	0.1777	0.0417
1, Methylnaphthalene	0.0000	0.1777	0.0417
β - chloronaphthalene	0.0000	0.1777	0.0417
Acenaphthylene	0.0000	0.1777	0.0417
Acenaphthene	0.0000	0.1777	0.0417
Flourene	0.0000	0.1777	0.0417
Phenanthrene	0.1649	1.6399	0.7339
Flouranthene	0.2251	2.1832	0.9889
Pyrene	0.9569	8.7835	4.0866

TABLE F. Annual Toxics Loadings in Sediment from Welland

Substance	Annual Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0016	0.1801	0.0456
1,4 dichlorobenzene	0.0173	0.2867	0.1040
1,2 dichlorobenzene	0.0969	0.9809	0.4353
1,3,5 trichlorobenzene	0.4092	3.7016	1.7351
1,2,4 trichlorobenzene	0.0047	0.0508	0.0219
1,2,3 trichlorobenzene	0.0132	0.1320	0.0589
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0009	0.0251	0.0079
1,2,3,4 tetrachlorobenzene	0.0003	0.0185	0.0051
pentachlorobenzene	0.0001	0.0178	0.0044
Hexachlorobenzene	0.0002	0.0093	0.0027
Trace Elements			
Arsenic	3.9006	35.1846	16.5132
Cadmium	0.7880	7.1080	3.3360
Copper	55.0024	496.1384	232.8528
Cobalt	3.9715	47.3037	19.5156
Chromium	120.2488	1084.6808	509.0736
Lead	382.7316	3452.3556	1620.2952
Mercury	0.0638	0.6433	0.2852
Nickel	54.9157	503.2464	234.3373
Selenium	0.1576	1.4216	0.6672
Zinc	328.9112	2966.8792	1392.4464

TABLE G. Annual Toxics Loadings in Stormwater from the Study Area

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.1189	0.4272	0.2654
Organochlorine Pesticides			
Hexachlor benzene	0.0070	0.0176	0.0122
α - BHC	0.2356	0.3331	0.2970
Lindane	0.0860	0.1240	0.1095
Heptachlor	0.0014	0.0157	0.0079
Aldrin	0.0002	0.0096	0.0044
Heptachlor epoxide	0.0105	0.0274	0.0188
γ - chlordane	0.0047	0.0286	0.0157
α - chlordane	0.0018	0.0253	0.0124
α - Endosulfan	0.0060	0.0294	0.0169
p,p' - DDE	0.0007	0.0155	0.0074
Dieldrin	0.0028	0.0261	0.0135
Endrin	0.0097	0.0533	0.0299
o,p' - DDT	0.0003	0.0097	0.0045
p,p' - TDE	0.0096	0.0195	0.0147
p,p' - DDT	0.0010	0.0105	0.0053
β - Endosulfan	0.0166	0.0290	0.0234
Mirex	0.0004	0.0100	0.0047
Methoxychlor	0.0163	0.0712	0.0420
Polyaromatic Hydrocarbons			
Indene	0.0031	1.1816	0.5289
1,2,3,4 tetrahydro-napthalene	0.0031	1.1816	0.5289
2, methylnaphthalene	0.1266	1.1380	0.5873
Quinoline	0.0154	1.1772	0.5348
1, Methylnaphthalene	0.0556	1.1685	0.5561
β - chloronaphthalene	0.1111	1.1598	0.5873
Acenaphthylene	0.2315	1.3080	0.7292
Acenaphthene	0.0525	1.0987	0.5231
Flourene	0.0062	1.1641	0.5231
Phenanthrene	0.0834	1.2295	0.6009
Flouranthene	0.2346	1.3559	0.7525
Pyrene	0.2223	1.2949	0.7175

TABLE G. Annual Toxics Loadings in Stormwater from the Study Area

Substance	Annual Loadings in Stormwater (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0507	0.1564	0.1017
1,4 dichlorobenzene	0.0462	0.1588	0.1000
1,2 dichlorobenzene	0.6552	0.9633	0.8423
1,3,5 trichlorobenzene	0.0068	0.0272	0.0164
1,2,4 trichlorobenzene	0.0191	0.0450	0.0321
1,2,3 trichlorobenzene	0.0022	0.0247	0.0124
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0032	0.0246	0.0130
1,2,3,4 tetrachloro-benzene	0.0004	0.0240	0.0110
pentachlorobenzene	0.0004	0.0240	0.0110
Hexachlorobenzene	0.0055	0.0209	0.0128
Heavy Metals			
Arsenic	13.6	19.2	17.1
Cadmium	5.1	7.2	6.4
Copper	187.7	286.4	245.9
Cobalt	14.9	39.7	27.1
Chromium	5.6	26.2	15.2
Lead	122.1	205.7	168.6
Mercury	103.6	146.3	130.5
Nickel	122.3	172.7	154.0
Selenium	19.0	25.6	24.8
Zinc	974.7	1376.5	1227.8

TABLE H. Annual Toxics Loadings in Sediment from the Study Area

Substance	Annual Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
PCB's			
Total polychlorinated biphenyls	0.4456	3.7984	1.8240
Organochlorine Pesticides			
Hexachlor benzene	0.0023	0.0420	0.0143
α - BHC	0.0093	0.1043	0.0428
Lindane	0.0074	0.0890	0.0354
Heptachlor	0.0008	0.0315	0.0088
Aldrin	0.0000	0.0303	0.0069
Heptachlor epoxide	0.0000	0.0274	0.0062
γ - chlordane	0.0452	0.4303	0.1902
α - chlordane	0.0675	0.6313	0.2814
α - Endosulfan	0.0000	0.0357	0.0081
p,p' - DDE	0.0155	0.1470	0.0651
Dieldrin	0.0004	0.0383	0.0095
Endrin	0.0000	0.0522	0.0118
o,p' - DDT	0.0050	0.0850	0.0296
p,p' - TDE	0.0019	0.0670	0.0191
p,p' - DDT	0.0163	0.1831	0.0748
β - Endosulfan	0.0003	0.0531	0.0126
Mirex	0.0009	0.0562	0.0145
Methoxychlor	0.0000	0.0604	8.0137
Polyaromatic Hydrocarbons			
Indene	0.0000	0.6524	0.1481
1,2,3,4 tetrahydro-napthalene	0.0000	0.6524	0.1481
2, methylnaphthalene	0.0000	0.6524	0.1481
Quinoline	0.0000	0.6524	0.1481
1, Methylnaphthalene	0.0000	0.6524	0.1481
β - chloronaphthalene	0.0000	0.6524	0.1481
Acenaphthylene	0.0000	0.6524	0.1481
Acenaphthene	0.0000	0.6524	0.1481
Flourene	0.0000	0.6524	0.1481
Phenanthrene	0.6057	6.0203	2.6057
Flouranthene	0.8269	8.0146	3.5109
Pyrene	3.5141	32.2447	14.5089

TABLE H. Annual Toxics Loadings in Sediment from the Study Area

Substance	Annual Loadings in Sediment (kg/yr)		
	Lower Estimate	Upper Estimate	Best Estimate
Chlorinated Benzenes			
1,3 dichlorobenzene	0.0058	0.6611	0.1619
1,4 dichlorobenzene	0.0637	1.0525	0.3691
1,2 dichlorobenzene	0.3560	3.6010	1.5456
1,3,5 trichlorobenzene	1.5027	13.5887	6.1590
1,2,4 trichlorobenzene	0.0173	0.1863	0.0777
1,2,3 trichlorobenzene	0.0484	0.4845	0.2090
1,2,4,5 + 1,2,3,5 tetrachlorobenzene	0.0035	0.0922	0.0280
1,2,3,4 tetrachloro-benzene	0.0013	0.0678	0.0180
pentachlorobenzene	0.0005	0.0652	0.0158
Hexachlorobenzene	0.0009	0.0343	0.0096
Trace Elements			
Arsenic	14.3253	129.1653	58.6278
Cadmium	2.8940	26.0940	11.8440
Copper	202.0012	1821.3612	826.7112
Cobalt	14.5858	173.6556	69.2874
Chromium	441.6244	3981.9444	1807.3944
Lead	1405.6158	12673.8558	5752.6308
Mercury	0.2344	2.3615	1.0127
Nickel	201.6829	1847.4552	831.9818
Selenium	0.5788	5.2188	2.3688
Zinc	1207.9556	10891.6355	4943.6856

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