TASK GROUP C (CANADIAN SECTION)
ACTIVITIES 3 AND 4

INTERNATIONAL REFERENCE GROUP
ON
GREAT LAKES
POLLUTION FROM LAND USE ACTIVITIES

POLLUTION FROM RURAL, TRANSPORTATION, EXTRACTIVE, AND UNDISTURBED LAND USES IN THE GRAND AND SAUGEEN WATERSHEDS

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3.0 DISCLAIMER

The study discussed in this document was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group, an organization of the International Joint Commission, established under the Canada-US Great Lakes Water Quality Agreement of 1972. Funding was provided through the Ontario Ministry of the Environment. Findings and conclusions are those of the author and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

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8.0 SUMMARY

The effects of land drainage from rural land use, transportation corridors, extractive operations and undisturbed (under perennial vegetative cover) areas on the receiving water quality in the Grand River and Saugeen River pilot watersheds (Ontario) were investigated as part of the Task C activities under the Pollution from Land Use Reference Group (PLUARG) of the International Joint Commission. Water-quality and water-quantity data were collected during 1975 and 1976 from: eight rural watersheds; upstream and downstream of a major highway corridor, a sand and gravel pit, a limestone quarry and; from two relatively undisturbed (wooded/idle) land areas in the Grand River and Saugeen River pilot watersheds. Based on the analysis of the data over a two-year period (1975-1976), the major sources of pollutants from these different land uses have been tentatively identified as follows:

Rural Land Uses	-	sediment, phosphorus, nitrogen
Transportation	-	lead, chloride
Extractive Operations	-	insignificant
Undisturbed (wooded/idle)	-	insignificant

Intensive agricultural activity, poor soil conservation practices and inadequate livestock management were observed to contribute significant loads of sediment, phosphorus and nitrogen from rural land-use areas. In addition, streambank erosion was observed as one of the major factors contributing sediment in two of the rural watersheds (the Nith River tributary in the Grand River pilot watershed and the South Saugeen tributary in the Saugeen River pilot watershed.

Atrazine was the only herbicide frequently found in the rural tributary waters. At present there are no known deleterious effects of atrazine on water quality. Residues of DDT and dieldrin pesticides from past uses were found in about 10% of the water samples from the rural tributaries studied. The industrial chemicals, PCBs, were also found in the rural tributary waters and their source is attributed to atmospheric fallout.

Rural land use does not appear to be a source of metals (lead, copper, zinc) pollution to receiving waters.

The major source of chlorides from transportation corridors was observed to arise from road maintenance operations using deicing salt during the winter period. The emissions from automobiles appear to be the source of lead accumulation downwind of the highway which was studied. The lead is eventually transferred to the receiving stream in association with the sediment, during surface runoff.

The extractive operations in the Grand River pilot watershed that were monitored under the PLUARG studies had associated settling ponds and these operations did not seem to affect the

water quality of the receiving stream.

The effect of pollutant runoff on receiving stream water quality was considered insignificant from undisturbed land uses comprised of wooded/idle or perennial vegetative cover.

Unit-area loads were used to rank land uses requiring control measures. Rural runoff was found to be as large a contributor of sediment and nutrients as urban runoff. High unit-area loads of sediment and total phosphorus accompanied by low soluble nutrient inputs appear to be indicative of streambank erosion. Agricultural activities tend to produce high inputs for all these parameters.

Monitoring data suggest that the bulk of the river loads (up to 80%) are transported during February, March, April and May which is normally the spring-melt or high-flow period of the year.

In terms of relative significance, rural land comprises 75% and 64% of the total drainage areas in the Grand River and Saugeen River pilot watersheds, respectively, but contributes up to 84% and 90% of the sediment load and 84% and 69% of the phosphorus load measured at the mouths of these pilot watersheds. Nitrogen yields from rural-land runoff were estimated to be almost directly proportional to the areal extent of rural land use in the pilot watersheds.

Extrapolation of the pilot-watershed information to other unmonitored parts of the Great Lakes basin is possible providing the watershed characteristics are similar. Although "average", unit-area load values were used for predicting loads in the subwatershed studies, comparison with the monitored loads were similar (less than 20% difference) in the majority of the estimates. Differences in the estimated and monitored loads were principally attributed to the varying intensity of land use amongst the subwatersheds.

9.0 INTRODUCTION

The Pollution from Land Use Activities Reference Group (PLUARG) was established by the International Joint Commission (IJC) as a result of the Great Lakes Water Quality Agreement of April 15, 1972. The Reference Group was requested to conduct studies on the impact of land-use activities and practices on the water quality of the Great Lakes basin and to recommend remedial measures for maintaining or improving Great Lakes water quality.

The PLUARG program consisted of four major tasks as outlined in the Reference Group's February 1974 Detailed Study Plan.

"Task A is devoted to the collection and assessment of management and research information and, in its later stages to the critical analysis of implications of potential recommendations. Task B is first the preparation of a land-use inventory, largely from existing data, and, second, the analysis of trends in land-use patterns and practices. Task C is the detailed survey of selected watersheds to determine the sources of pollutants, their relative significance and the assessment of the degree of transmission of pollutants to boundary waters. Task D is devoted to obtaining supplementary information on the inputs of materials to the boundary waters, their effect on water quality and their significance in these waters in the future and under alternative management schemes."

As part of the Task C program, several pilot watersheds were chosen in the United States and Canada for intensive study, to cover a wide variety of potential sources of pollution to the boundary waters of the Great Lakes. Based on the climate, geology, soils and land uses, the Grand River and Saugeen River basins were chosen as pilot watersheds for intensive study under the Task C program in Canada (Figure 1). The land uses not adequately represented in the pilot watersheds were incorporated into the PLUARG program as subwatershed studies conducted in different parts of the Great Lakes basin.

9.1 STUDY OBJECTIVES

This report deals with the impact of rural land use on stream water quality and is one of four technical reports prepared by the Ontario Ministry of the Environment, based on the results of Canadian Task C pilot-watershed studies. Rural land use occupies a large portion (30%) of the Great Lakes basin. The term "rural land use", in this report, refers to and includes crop land, barnyard areas, rural roads, dwellings and other associated rural activities. Extractive, transportation and undisturbed land-use categories have also been included with the rural land uses described herein.

9.2 STUDY APPROACH

Monitoring networks were established in the Grand River and Saugeen River basins for the purpose of collecting quality and quantity data to derive pollutant loading estimates from various land uses

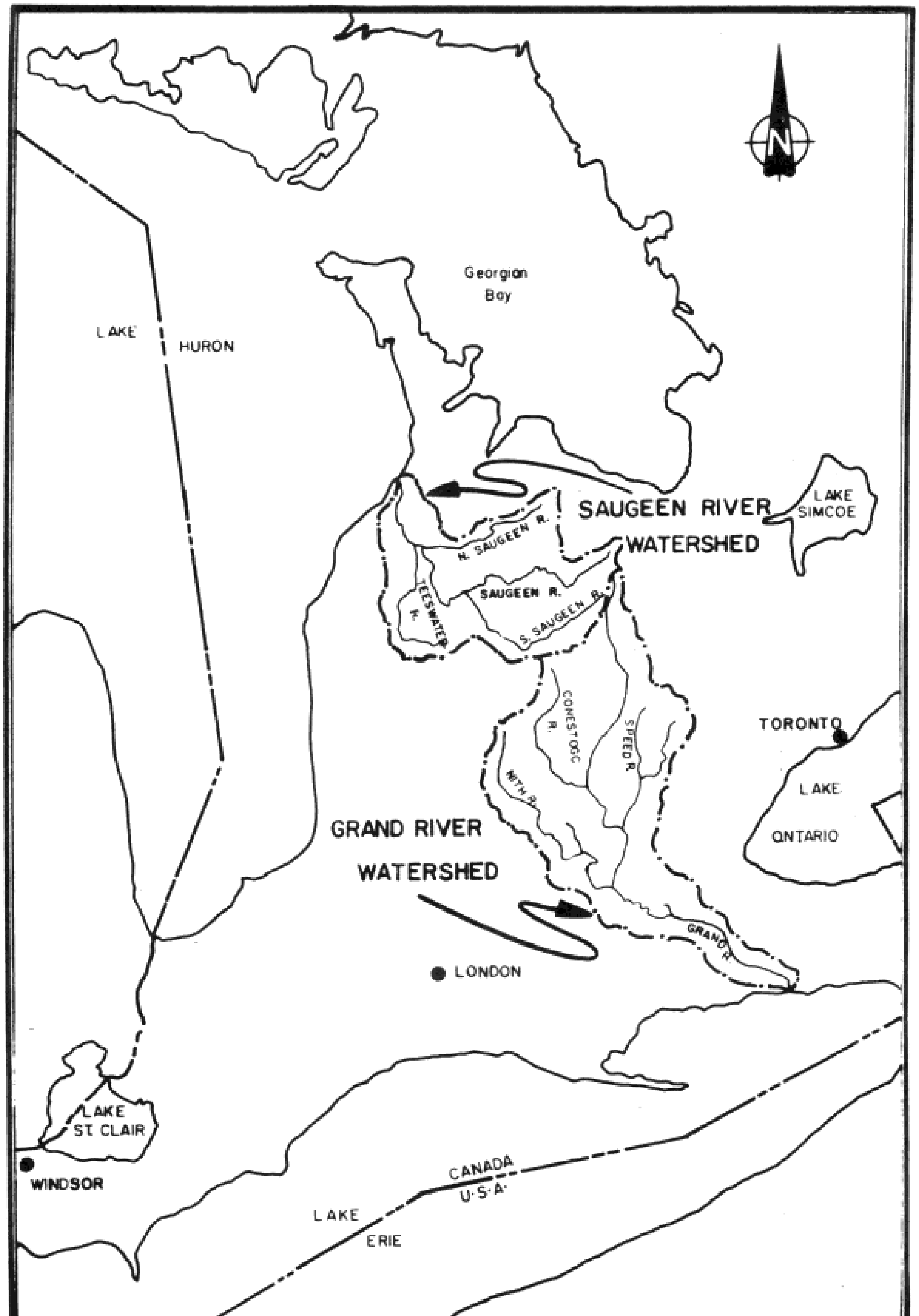

Figure I : LOCATION OF CANADIAN TASK C PILOT WATERSHEDS

Scale : 0 50 100 Kilometres

in each watershed. Monitoring stations were established upstream and downstream of selected land uses, at the outlets of subwatersheds with relatively homogeneous land uses, at downstream main-stem localities and at the mouths of the pilot watersheds, to collect water-quality data as part of a mass-balance approach to answer the PLUARG reference:

"1) Are the boundary waters of the Great Lakes system being polluted by land drainage from agriculture, forestry, urban and industrial development, recreational and park development, utility and transportation systems, and natural sources?

2) If the answer to the foregoing question is in the affirmative, to what extent, by what causes, and in what localities is the pollution taking place?

3) If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would in its judgement be most practicable, and what would be the probable cost thereof?"

Specific land uses were identified in the PLUARG Detailed Study Plan (Feb. 1974) for investigation under Activities 1,2,3 and 4 of Task C as follows:

<u>Activity 1</u> - Agricultural land use,

<u>Activity 2</u> - Forested watersheds,

<u>Activity 3</u> - Urban land development use, transportation and utility systems, sanitary landfills, processed organic waste disposal, waste-water lagoons and irrigation systems, landfills, extractive industries, private waste disposal, recreational land use,

<u>Activity 4</u> - Extensive surveillance network, intensive studies program.

Some of the land-use studies noted above were conducted outside of the pilot watersheds and the information thus generated was extended to the pilot watersheds on the basis of unit-area loads and land-use inventories. Land-use inventories of the pilot watersheds were assembled for extrapolation purposes using the Canada Land Inventory (CLI) system, which is based on census (enumeration) data from 1968 to 1974.

In order to answer the PLUARG reference, the causes, sources and extent of pollutant contributions were identified in the Grand River and Saugeen River pilot watersheds. A simple mass-balance approach was utilized by assigning unit-area loads from the PLUARG monitoring data to the land-use inventory compiled for each basin. This approach assumed that the long-term delivery of material is essentially unity and therefore implies that all land-use activities regardless of their distance from the receiving waters will have an impact upon the boundary waters of the Great Lakes. The relative significance of the sources in the basin were identified by attributing portions of the monitored loads at the mouths of the pilot watersheds to the various land uses in the basin. Information on overland and in-stream transport processes were generally lacking and only general observations from the pilot-watershed studies can be applied to other parts of the Great Lakes basin where similar conditions exist.

Possibilities for pollutant control from various land uses and practices were tabulated by the Task A studies under PLUARG and the technical feasibility of these measures were assessed, where applicable, using information from the Task C studies.

9.3 DESCRIPTION OF STUDY AREAS

The Grand River and the Saugeen River pilot watersheds are located in the southwestern part of Ontario and the rivers drain to lakes Erie and Huron, respectively (Figure 1). The two rivers share common headwater areas in the upland area south of Georgian Bay. The Grand River is the largest river basin in southern Ontario, draining an area of approximately 667,200 hectares. The drainage area of the Saugeen River basin is about 397,900 hectares. Agriculture is the major land use comprising 75% of the area in the Grand River watershed and 62% in the Saugeen River basin.

9.3.1 RURAL LAND USE AREAS

The surveillance network stations (figures 2 and 3), which were established under the water-quality monitoring framework (Activity 4) of the Canadian Task C study, were designated with the letters "GR" in the Grand River basin (i.e. GR-1) and "SR" in the Saugeen River basin (i.e. SR-1). Many of these stations drained predominantly rural areas in the Grand River and Saugeen River basins and the data from these stations were used to assess the impact of rural runoff on receiving-stream water quality.

Similarly, upstream monitoring sites of other land-use studies (i.e. urban, designated as UL) were also used where applicable. The stations with "AG" designations refer to the Agricultural Watershed Studies under Activity I of the Task C study, which was undertaken as a cooperative program amongst the Canada Department of Agriculture, the Ontario Ministry of Agriculture and Food and the Ontario Ministry of the Environment. Eleven small agricultural watersheds in Ontario were selected to be representative of major agricultural regions in the Canadian Great Lakes Basin. Only two of these small watershed, were situated in the pilot watersheds, one each in the Grand River and Saugeen River pilot watersheds.

The tributaries which drain predominantly agricultural areas in the Grand River basin are the Nith and Conestogo rivers, Canagagigue, Horner and Mackenzie creeks (Figure 4). Western sections of the mid-basin in the vicinity of the Nith River and the Conestogo River systems are subject to more intensive cultivation than other parts of the basin. The rural population is approximately 79,000 out of a total basin population of 514,000.

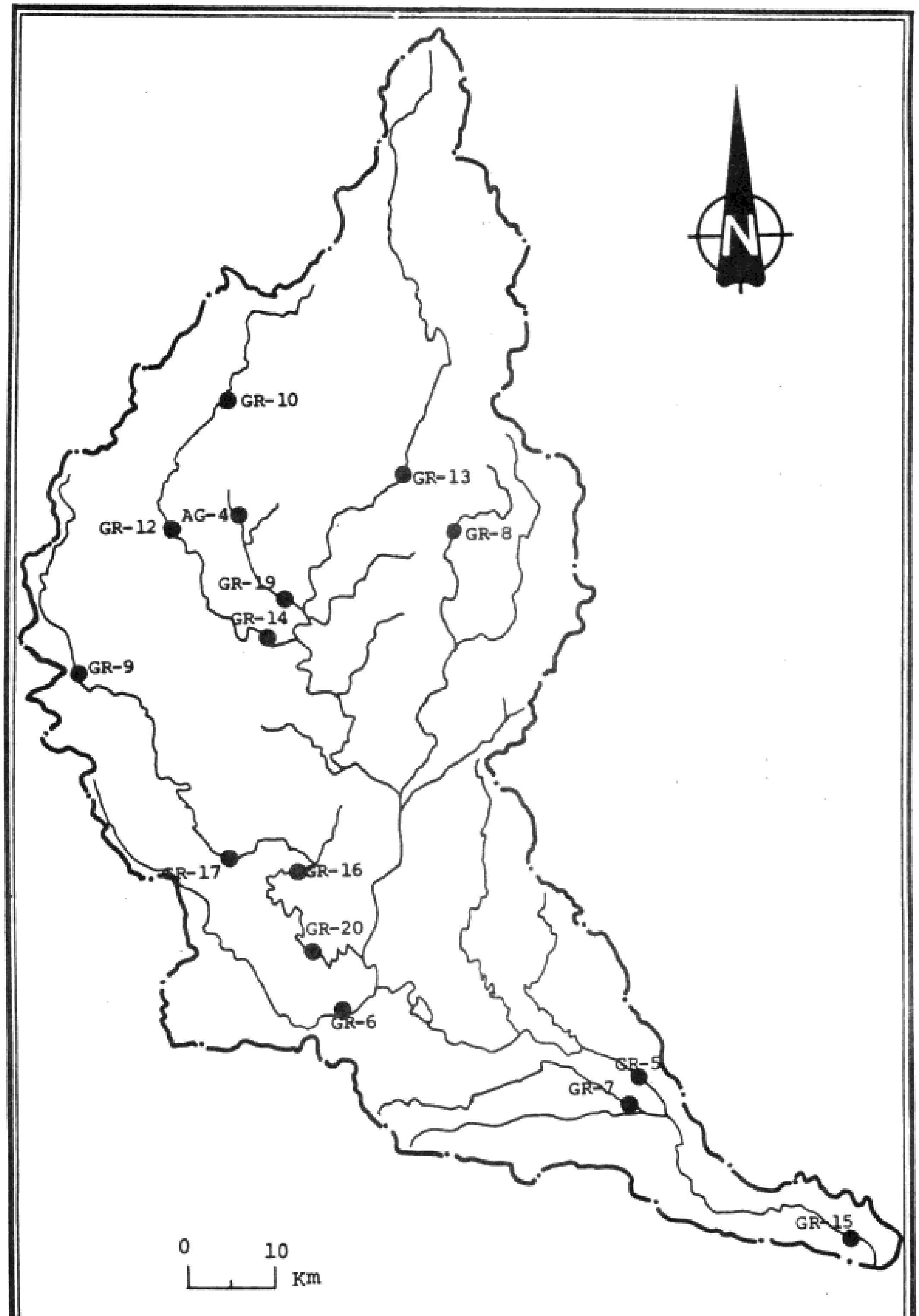

FIGURE 2: STREAM WATER-QUALITY MONITORING NETWORK, GRAND RIVER BASIN

LEGEND +
GR : Activity 4, monitoring sites
AG : Activity 1, monitoring sites

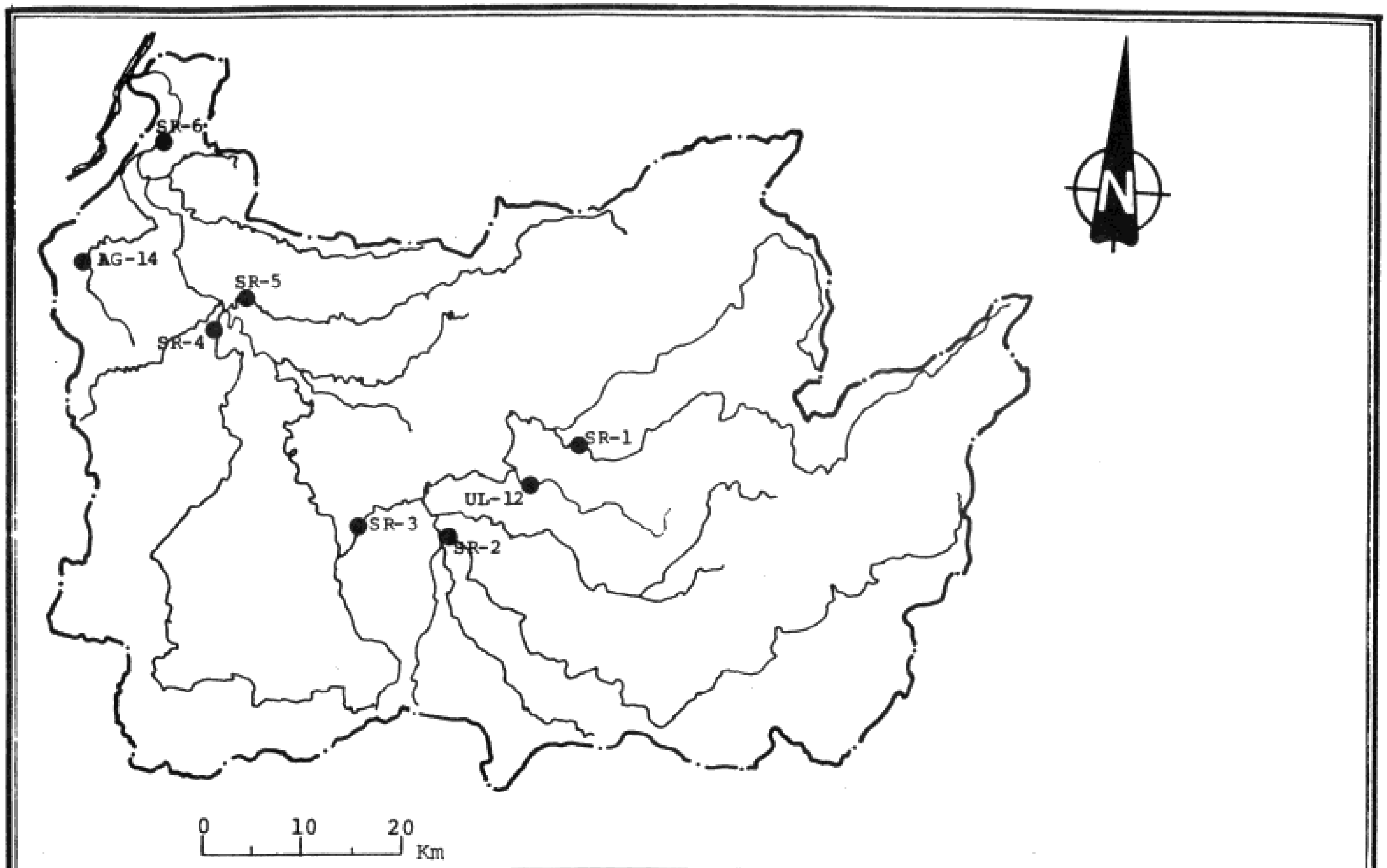

FIGURE 3: STREAM WATER-QUALITY MONITORING NETWORK, SAUGEEN RIVER BASIN

LEGEND: GR : Activity 4, monitoring sites
AG : Activity 1, monitoring sites
UL : Activity 3, monitoring sites (urban)

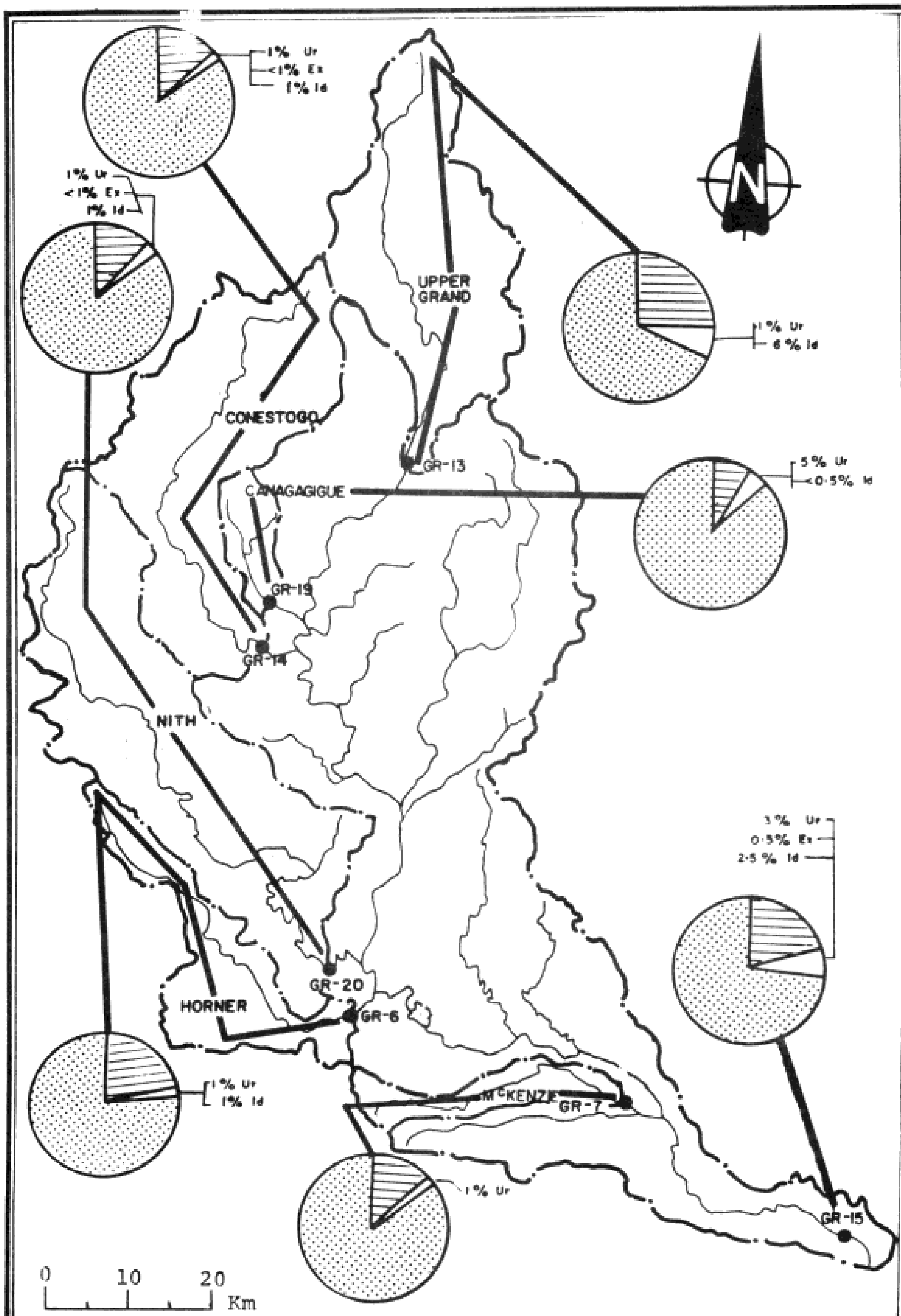

FIGURE 4: LAND-USE PERCENTAGES, GRAND RIVER BASIN

LEGEND :
AGRICULTURE [dotted] : WOODED [hatched] :
Ur-URBAN, Ex-EXTRACTIVE, Id-IDLE [blank]

Intensive livestock and poultry operations and a wide variety of props are also present in the Saugeen River basin. The South Saugeen River, Teeswater River and Little Mill Creek in the Saugeen River basin (Figure 5) drain predominantly agricultural areas. Urban development is restricted to a handful of small urban centres whose population is generally less than 5,000 each. The entire population of the Saugeen River basin is about 57,280 of which approximately 50% or 28,880 are concentrated in urban areas.

Land-use distribution in the rural tributary catchments of the two pilot watersheds are presented in Table 1.

9.3.2 TRANSPORTATION

A study area was selected to monitor highway maintenance operations and their effect on receiving-stream water quality. This study area of approximately 100 hectares is located adjacent to Cedar Creek, a tributary to the Nith River (Figure 6) in the Grand River pilot watershed. The study area drains a 1.4 km-stretch of four-lane highway (401) in the middle portion of the basin. The upstream (TU-3) and downstream (TU-4) stations, are shown in Figure 6 along with the land-use distribution at these sites.

9.3.3 EXTRACTIVE INDUSTRIES

Two study areas, at Aberfoyle and Glenchristie, in the Grand River pilot watershed were selected to determine the effect of land-based extractive operations on water quality. The gently-rolling landscape of a 250-hectare sand and gravel operation (7% of drainage area) is drained by Aberfoyle Creek, also known as Galt Creek. The upstream sampling stations (EX-1, EX-3) and the downstream station (EX-2) are shown in Figure 7. The second study area covers about 500 hectares (8.7%) of the drainage area and consists of a limestone quarry and a lime plant. The upstream and downstream station locations (EX-4 and EX-5) on the Speed River and their land-use distributions are also shown in Figure 7.

9.3.4 WOODED AND IDLE (UNDISTURBED LAND-USE AREAS)

Relatively undisturbed areas under perennial vegetation (wood lots, unimproved pasture, swamps, etc.) have been categorized as wooded and idle land use in this report. Approximately 19% of the Grand River and 33% of the Saugeen River pilot watersheds can be categorized as wooded or idle lands. Based on the data collected from the Canada Land Use Inventory, aerial photography and topographic maps, stations GR-8 (Grand River) and UL-12 (Saugeen River) drain areas of about 70% in perennial vegetation (Table 2). Both these subwatersheds, drained by stations GR-8 and UL-12, are situated in the headwater areas of the two pilot watersheds and were used to represent wooded/idle land-use study areas.

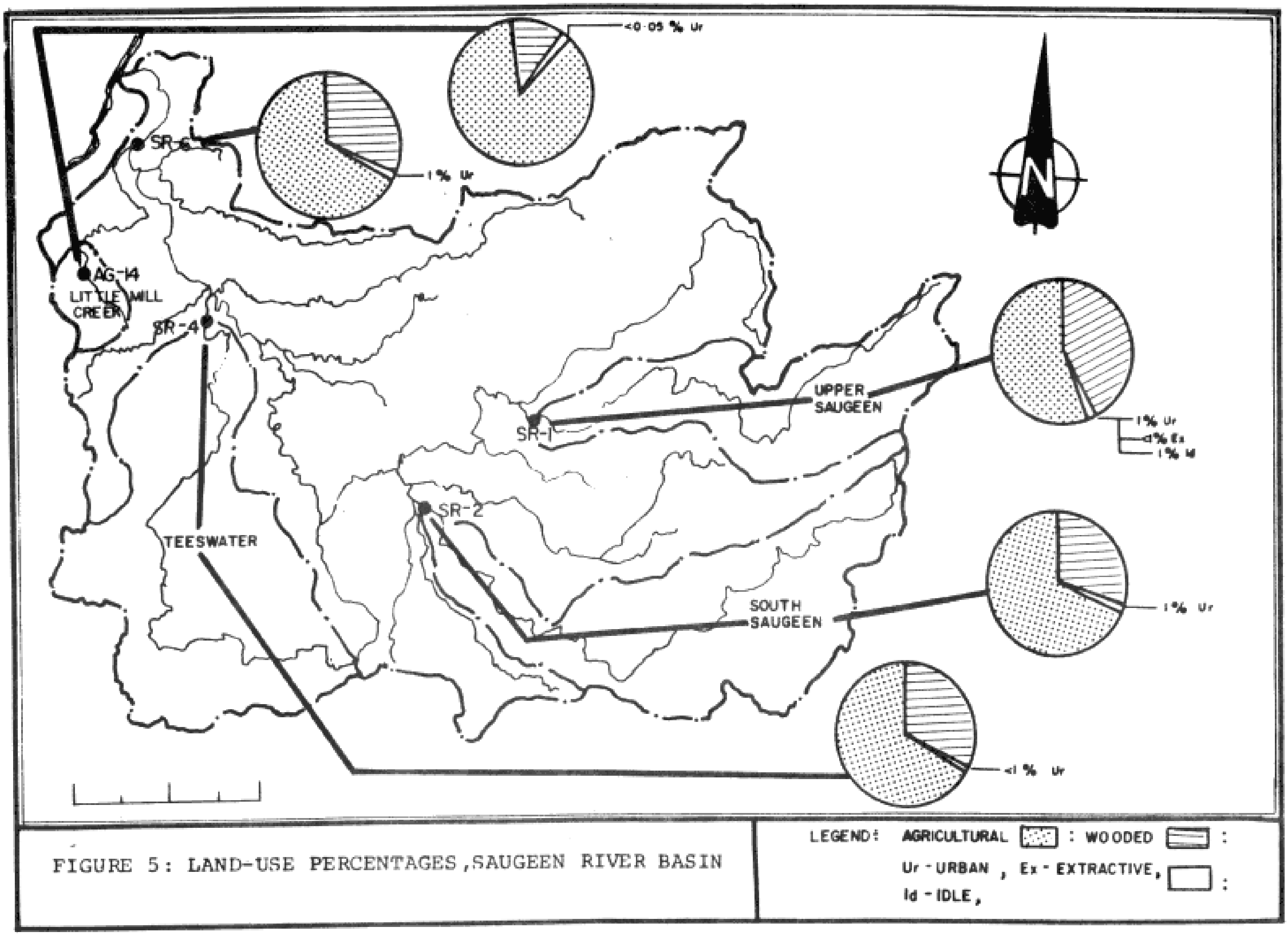

FIGURE 5: LAND-USE PERCENTAGES, SAUGEEN RIVER BASIN

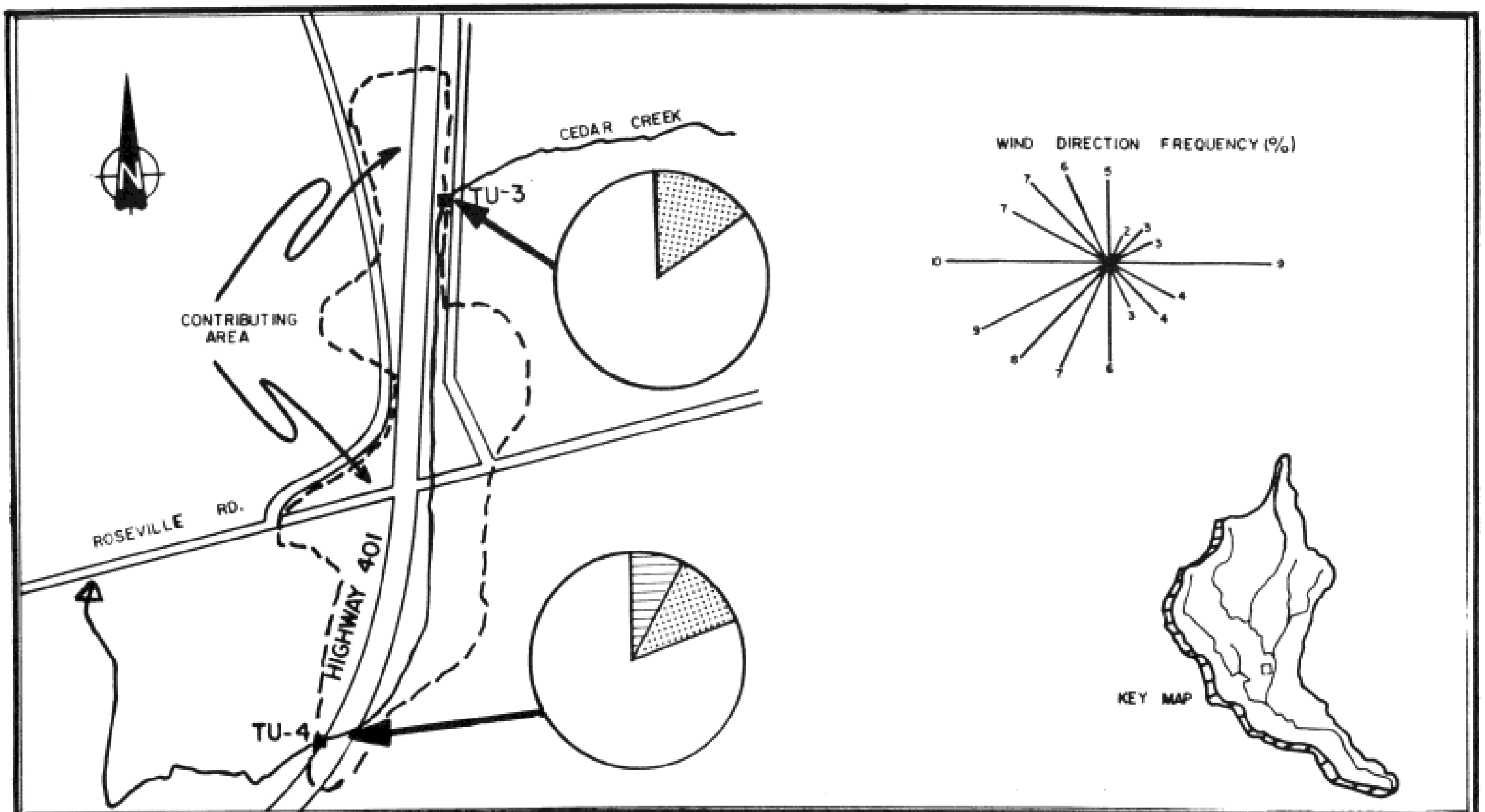

Figure 6 : LOCATION OF TRANSPORTATION SITES

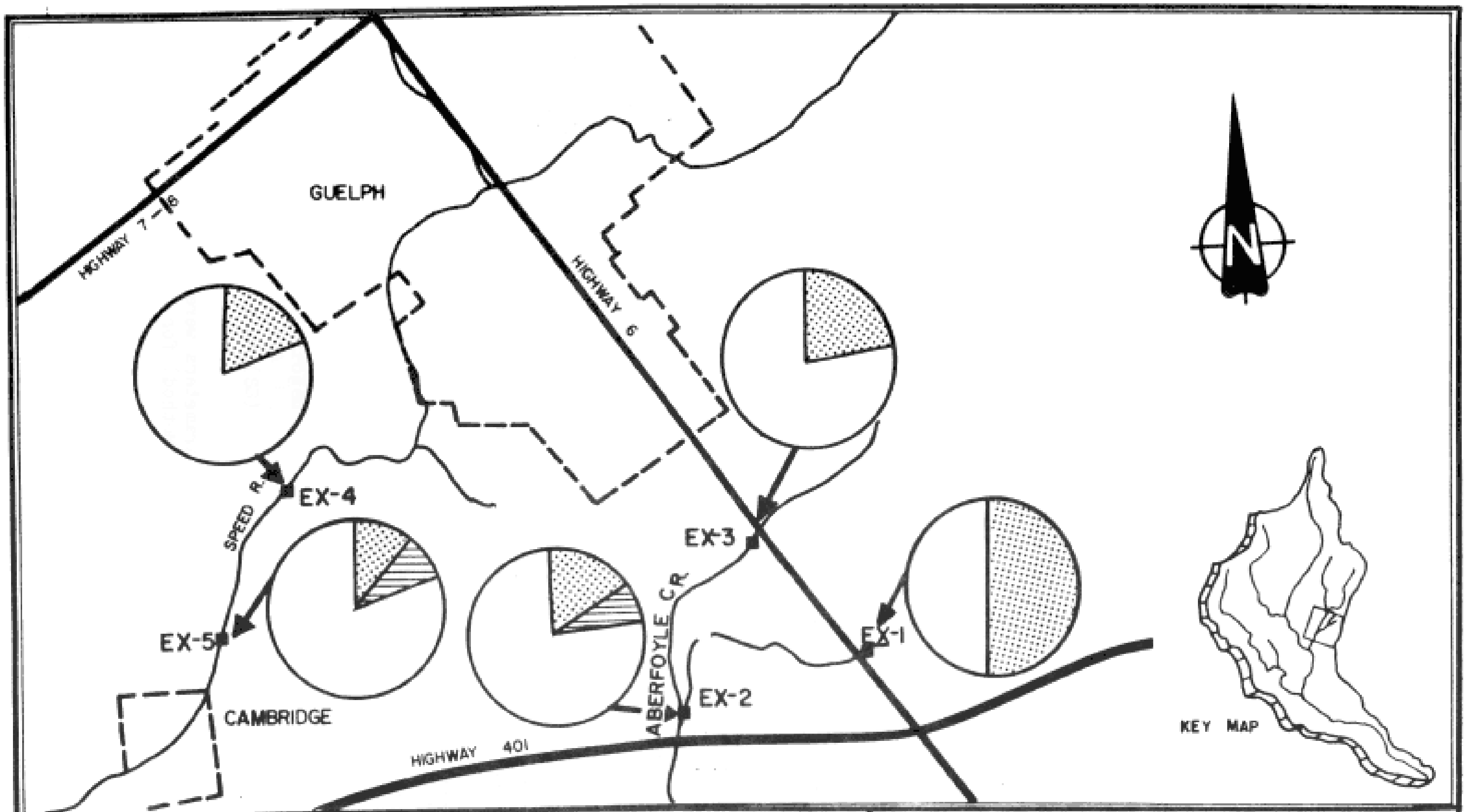

Figure 7 : LOCATION OF EXTRACTIVE SITES

9.4 METHODS

Details of water-quantity measurement, water quality and sediment collection are described in the MOE-PLUARG technical report on methodology (Onn, in preparation). Surface-water samples for water-quality analyses were collected by manual and automatic sampling methods. Continuous flow records obtained from streamflow gauging stations and in conjunction with concentration data were used to calculate loading estimates.

9.4.1 CONCENTRATIONS

The parameter concentrations are presented as flow-weighted mean concentrations over a two-year period, i.e. from January 1975 to Dec. 1976. Flow-weighted concentrations are more representative than the arithmetic means for parameters that are flow related (i.e. vary with flow) such as sediment and phosphorus. Flow-weighted mean concentrations were computed by the following method:

$$\text{Flow-Weighted Mean Concentration} = \frac{\text{Total Load}}{\text{Total Flow}}$$

9.4.2 LOAD ESTIMATES

In order to evaluate the significance of pollution from land drainage, the water-quality and quantity data generated at the sampling sites were translated into quantitative estimates of pollutant mass transport (i.e. loadings = concentration x flow). Various methods were used to derive loads and these are described below.

9.4.2.1 IJC Recommended Method

As suggested in the IJC-PLUARG, Quality Control Handbook for Pilot Watershed Studies (March 1977 Revision), a stratified, random-sampling model employing a ratio estimator was adopted as a suitable method of load calculation. This method provides estimates of both mean and variance and was recommended in order to make broad comparisons across the entire Great Lakes basin. Loads were estimated for all stations using the IJC recommended method.

A simplified scheme involving the subdivision of concentration records according to an arbitrary classification of high and low flows was applied wherever possible. Based on duration analysis of mean daily-flow records, high flows were assumed to be those equalled or exceeded 15% of the time. In many instances the loading estimates appeared biased towards the high-flow data (i.e. loads are overestimated) as a result of the event-sampling nature of the program.

9.4.2.2 Unit-Area Load Estimates

The unit-area loads for different parameters were calculated by dividing the loading estimates (IJC Method) for each station by the station drainage area. Subsequently, only data from homogeneous land uses were used to estimate the load contribution from unmonitored subwatersheds comprised of different land-use categories.

Drainage basins with a single or dominant land use (greater than 70% of the drainage area) in the two pilot watersheds were considered to be homogeneous land-use areas. Twelve stations (GR-6, GR-7, GR-9, GR-10, GR-12, GR-14, GR-19, GR-20, TU-3, TU-4, AG-4 and EX-3, Figure 2) in the Grand River basin having more than 80% of their drainage area in agricultural land use were used to derive an average unit-area load estimate for rural land use. Data from these stations represent a wide range of agricultural activities (from low to high intensity).

Similarly, the loads from two, predominantly wooded areas, with more than 70% of their drainage area in perennial cover (stations GR-8 and UI-12, figures 2 and 3), were used to estimate unit-area loads for the wooded and idle (undisturbed) land-use category.

The monitoring data collected from the transportation and extractive study-area sites (TU-3, 4; EX-1, 2, 3, 4 and 5) were influenced by runoff from agricultural land which comprises the bulk of the land (more than 70%) in the respective drainage areas (figures 6 and 7). As a result, the unit-area load estimates for transportation and extractive land uses from these monitoring data are not considered to be entirely representative for these land uses.

9.4.3. PREDICTED LOADS

The land-use distribution, physiography and tributary monitoring network were used to divide the Grand River and Saugeen River basins into eight and six subwatersheds, respectively. Pollutant loads from the many diffuse sources in each subwatershed were "estimated" using the most reasonable unit-area load values derived from single or dominant land-use studies (Section 9.4.2.2). All the inputs, including the point sources and monitored upstream loads, were added to the total "estimated" diffuse-source loads for the subwatershed and compared with the monitored load at the outlet of the subwatershed, for each of the key parameters considered. These "estimated" loads are referred to as "predicted loads" hereafter.

9.5 PARAMETERS

The parameters identified by the PLUARG for intensive study in the pilot watersheds were as follows:

- Total Phosphorus (TP)
- Filtered Reactive Phosphorus (FRP)
- Filtered (Nitrite + Nitrate)-Nitrogen F(NO_2 + NO3)
- Total Kjeldahl Nitrogen (TKN)
- Total Nitrogen (TN)
- Suspended Sediment (SS)
- Lead (Pb)
- Copper (Cu)
- Zinc (Zn)
- Chloride (Cl)
- Polychlorinated biphenyls (PCBs)
- Pesticides

These parameters were considered important because of their impact on water quality i.e. eutrophication, health hazards and aesthetics.

Although not discussed in this report, additional information is available on the major chemical cations and anions, phenols, carbon, mercury, chromium, arsenic, nickel, cadmium and cobalt. These data are on file with the Ontario Ministry of the Environment.

10.0 TABULATED RESULTS OF DATA COLLECTION

10.1 LAND USES

The land uses and their percentages of the total drainage area in the tributaries that were designated as rural land-use studies are shown in Table 1. Table 2 presents the land-use data for the undisturbed (wooded/idle) study areas in the pilot watersheds. These land-use data were used in conjunction with the unit-area loads to provide loading estimates for the rural tributaries.

TABLE 1. LAND-USE AREAS IN RURAL TRIBUTARIES

STATION	TOTAL AREA (ha)*	URBAN AREA (ha)	WOODED AREA (ha)	TOTAL AGRIC (ha)	AGRICULTURE AREA CROP (ha)	PASTURE (ha)	OTHER (ha)
Grand River							
GR-13	79512	795	24649	54068	22263	25364	6441
		1%	31%	68%	41%	47%	12%
GR-19	12217	611	1099	10507	5779	3993	735
		5%	9%	86%	55%	38%	7%
GR-14	77459	775	10844	65840	31526	26646	7668
		1%	14%	85%	48%	40%	12%
GR-20	102144	1021	14301	86822	46858	26480	13484
		1%	14%	85%	54%	30%	16%
GR-6	38438	384	8457	29597	20372	7649	1576
		1%	22%	77%	69%	26%	5%
GR-7	17125	171	2741	14213	8100	2963	3151
		1%	16%	83%	57%	21%	22%
GR-15	667091	20012	126749	520330	255848	171007	93475
		3%	19%	78%	49%	33%	18%
Saugeen River							
SR-1	39005	390	16383	22232	5656	10960	5617
		1%	42%	57%	26%	49%	25%
SR-2	61497	615	19064	41818	17096	20540	4182
		1%	31%	68%	41%	49%	10%
SR-4	66503	665	21281	44557	16759	24739	3059
		1%	32%	67%	38%	55%	7%
AG-14	4380	22	574	3784	817	2520	447
		.5%	13%	86.4%	22%	66%	12%
SR-6	397197	3972	131075	262150	89022	128376	44752
		1%	33%	66%	34%	49%	17%

* hectares

TABLE 2. LAND-USE AREAS IN UNDISTURBED (WOODED/IDLE) DRAINAGE SITES

Station	TOTAL AREA (ha)	URBAN AREA (ha)	EXTRACTIVE (ha)	CROP LAND (ha)	PERENNIAL COVER		LENGTH OF RIVER BANK WOODED (km)
					WOODED (ha)	IDLE (ha)	
Grand River							
GR-8	6,200	25	-	1897	2034	2232	28.8 (67.5%)*
Percent of basin area		1	-	31	33	36	
Saugeen River							
UL-12	10,800	43	86	2430	4536	3672	52 (86.4%)*
Percent of basin area		1	1	23	42	34	

* Percent of river bank that is wooded.
(ha) hectares

10.2 POLLUTANT CONCENTRATIONS IN TRIBUTARIES DRAINING DIFFERENT LAND-USE AREAS

The concentration data were used to rank the pollutant contribution from different rural land uses in the pilot watersheds.

Flow-weighted mean concentrations of suspended sediment, total phosphorus, total nitrogen, filtered reactive phosphorus, (nitrite + nitrate) - nitrogen and Kjeldahl nitrogen, for the combined 1975 and 1976 period, in the rural tributaries of the Grand River and Saugeen River pilot watersheds are presented in figures 8, 9 and 10. The flow-weighted mean concentrations of copper, lead and zinc are presented in Table 3. The mean concentrations of DDT, dieldrin and atrazene + de-ethylated atrazine are summarized in Table 4 along with the total number of samples and percentages of samples below the laboratory detection limit. Similar information on PCBs and Mirex are presented in Table 5. Flow-weighted mean concentrations, mean annual loads and unit-area loads of water-quality parameters in the transportation, extractive and wooded/idle land-use areas are presented in tables 6, 7 and 8, respectively. Comparisons of lead concentrations in the soils, sediment, bed material and receiving waters at the transportation study sites are shown in Figure 11.

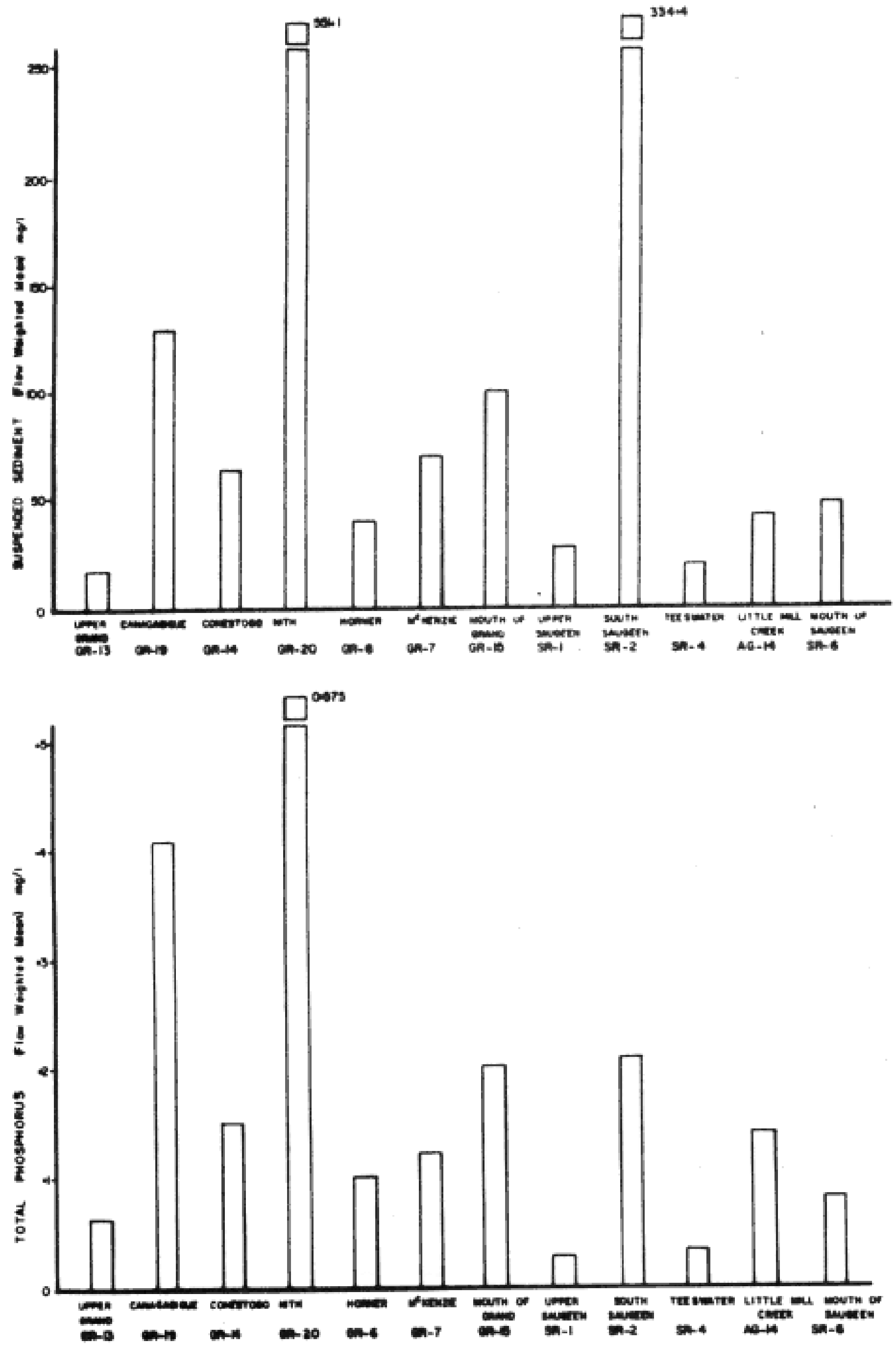

Figure 8: FLOW-WEIGHTED MEAN CONCENTRATION 1975 AND 1976 PERIOD

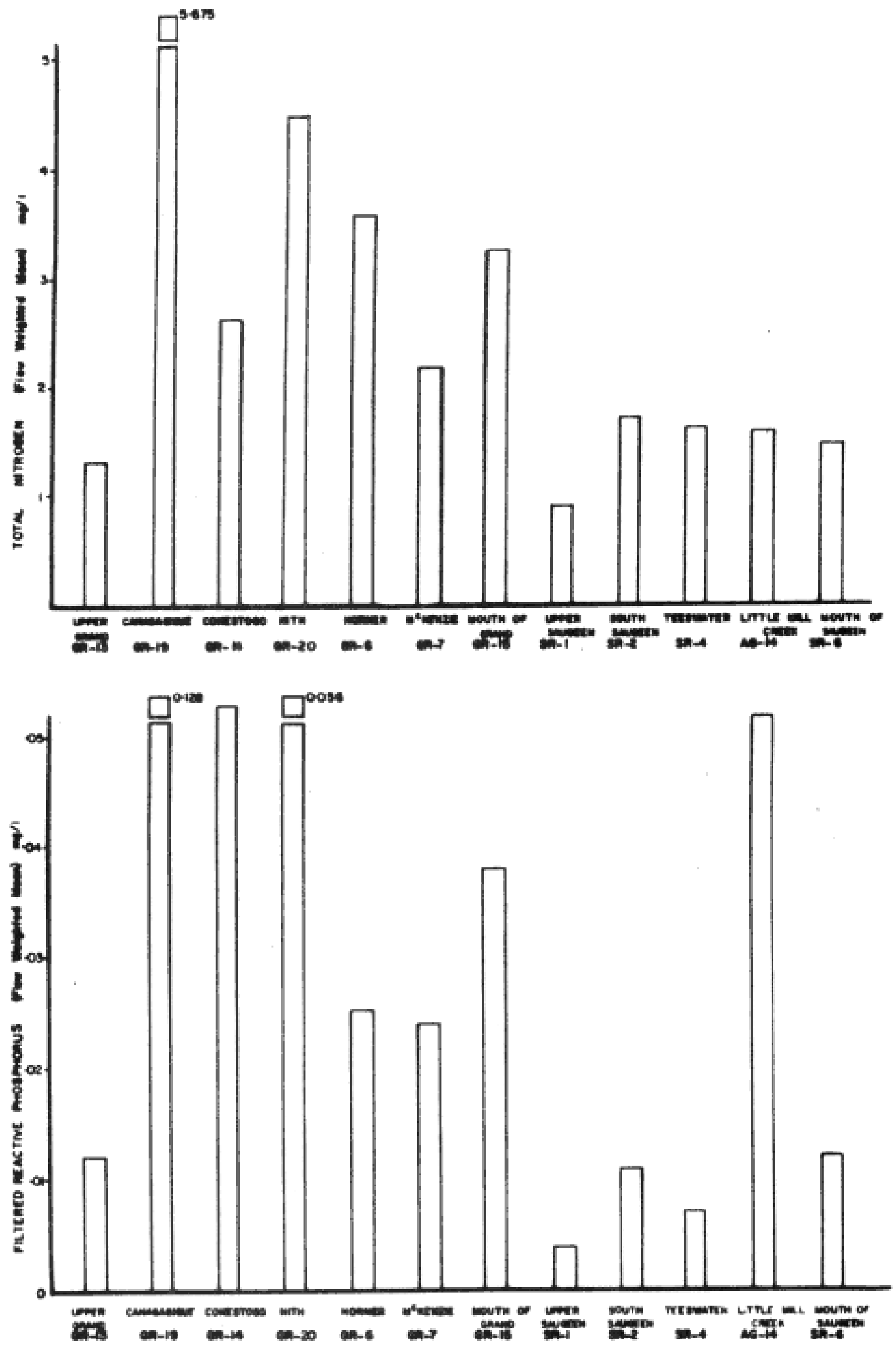

Figure 9: FLOW-WEIGHTED MEAN CONCENTRATION 1975 AND 1976 PERIOD

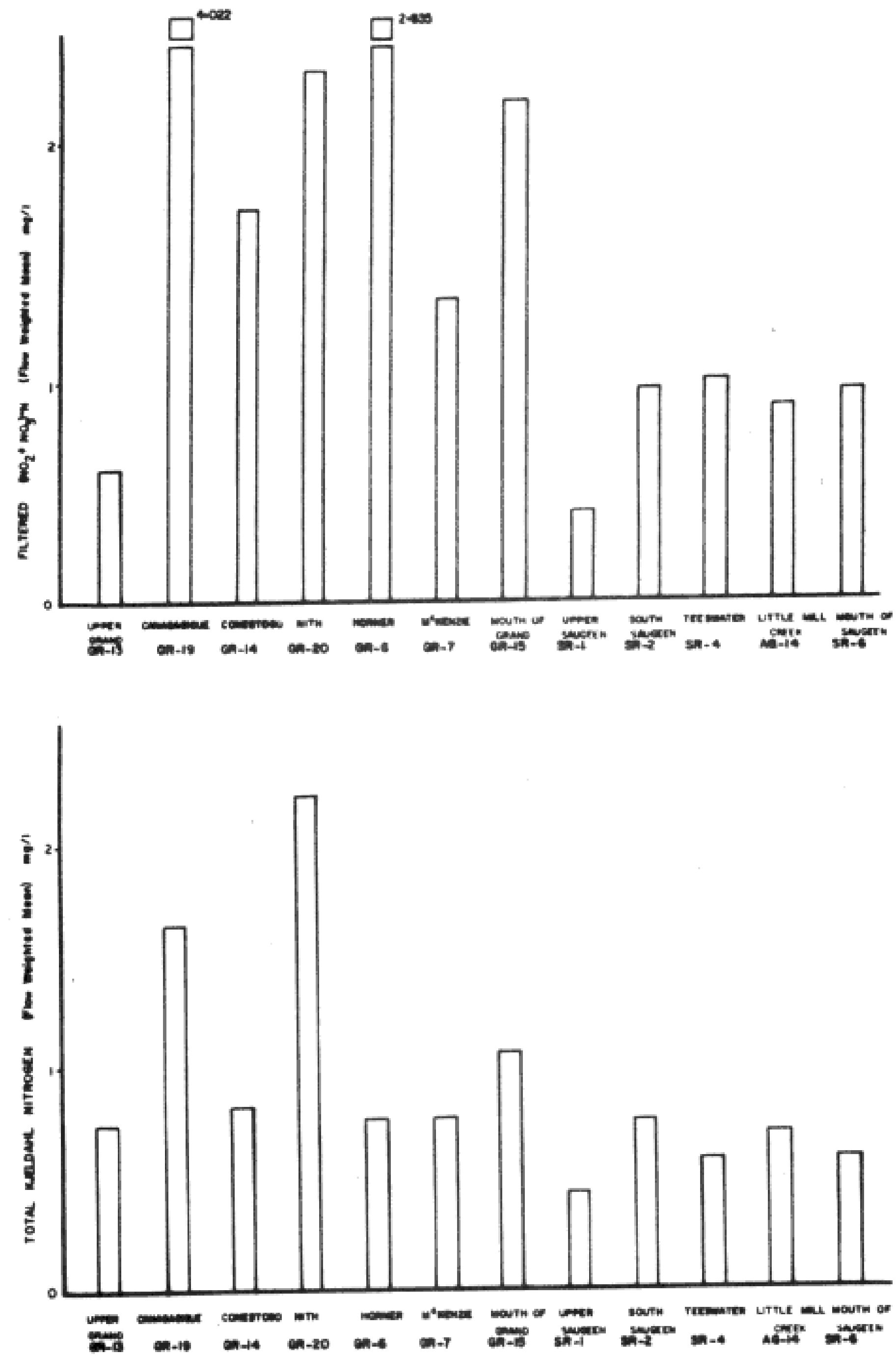

Figure 10: FLOW-WEIGHTED MEAN CONCENTRATION 1975 AND 1976 PERIOD

TABLE 3. MEAN-ANNUAL METALS CONCENTRATIONS IN RURAL TRIBUTARIES, 1975 AND 1976 PERIOD

Parameter Location	Copper*	Lead*	Zinc*
Grand River			
Upper Grand			
GR 13	.004	.004	.008
GR 19	.008	.010	.031
GR 14	.006	.004	.014
GR 20	.023	.020	.069
GR 6	.008	.010	.012
GR 7	.011	.008	.020
GR 15	.011	.005	.030
Saugeen River			
Upper Saugeen			
SR 1	.006	.005	.007
SR 2	.015	.012	.020
SR 4	.009	.005	.016
AG 14	.007	.005	.014
SR 6	.007	.003	.017
Ontario Ministry of the Environment Criteria for Public Surface Water Supplies	1 mg/L	.05 mg/L	5 mg/L

* Flow-weighted mean concentration in mg/L.

TABLE 4. PESTICIDES IN RURAL TRIBUTARIES, 1975 AND 1976 PERIOD

STATION	DDT			Dieldrin			Atrazine + De-ethylated Atrazine		
	Number Of Samples	% Non-Detected	Mean Conc'n* (µg/L)	Number Of Samples	% Non-Detected	Mean Conc'n* (µg/L)	Number Of Samples	% Non-Detected	Mean Conc'n* (µg/L)
Grand River									
GR-6	20	75.0	0.006	5	20.0	0.002	5	40.0	0.390
GR-7	20	100.0	-	5	80.0	0.002	5	80.0	0.130
GR-13	64	95.3	0.001	16	93.8	0.001	15	33.0	0.180
GR-14	48	100.0	-	12	91.7	1.0	11	0.0	0.330
GR-15	88	94.3	0.005	22	86.4	0.002	11	9.0	0.350
GR-19	56	100.0	-	114	92.9	1.0	36	2.8	0.550
GR-20	108	99.1	0.003	27	92.9	0.002	19	5.3	0.510
Saugeen River									
SR-1	16	100.0	-	4	75.0	0.002	4	75.0	0.090
SR-2	24	100.0	-	6	66.7	0.002	6	66.7	0.100
SR-4	80	100.0	-	20	95.0	0.002	19	21.0	0.118
AG-14	139	47.0	0.005	30	90.0	0.001	131	14.5	0.660
SR-6	136	98.5	0.004	34	94.1	0.001	22	63.6	0.110

* Mean Concentration Of Those Samples In Which Pesticides Were Detected

TABLE 5. PCBs AND MIREX IN RURAL TRIBUTARIES, 1975 AND 1976 PERIOD

Station	PCBs			Mirex		
	Number Of Samples	% Non-Detected	Mean Conc'n* (µg/L)	Number Of Samples	% Non-Detected	Mean Conc'n (µg/L)
Grand River						
GR-6	5	100.0	-	0	-	-
GR-7	5	100.0	-	0	-	-
GR-13	16	93.8	0.010	10	100.0	-
GR-14	12	100.0	-	6	100.0	-
GR-15	23	91.3	0.055	20	100.0	-
GR-19	114	85.7	0.020	8	100.0	-
GR-20	27	96.3	0.050	15	100.0	-
Saugeen River						
SR-1	4	100.0	-	0	-	-
SR-2	6	100.0	-	0	-	-
SR-4	20	100.0	-	15	100.0	-
AG-14	63	11.1	0.029	0	-	-
SR-6	34	100.0	-	28	100.0	-

* Mean Concentration Of Those Samples In Which PCBs Or Mirex Were Detected

TABLE 6. WATER-QUALITY DATA SUMMARY AT TRANSPORTATION SITES, GRAND RIVER BASIN, 1975 AND 1976 PERIOD

PARAMETER	TU-3			TU-4		
	FLOW WEIGHTED MEAN CONC'N (mg/L)	MEAN ANNUAL LOADS (tonnes)	UNIT AREA LOAD (kg/ha/yr)	FLOW WEIGHTED MEAN CONC'N (mg/L)	MEAN ANNUAL LOADS (tonnes)	UNIT AREA LOAD (kg/ha/yr)
Total Phosphorus	0.120	0.08	0.050	0.133	0.20	0.107
Filtered Reactive Phosphorus	0.074	0.05	0.031	0.070	0.10	0.056
Total Kjeldahl Nitrogen	1.026	0.72	0.424	0.840	1.25	0.677
Filtered (Nitrite + Nitrate) - Nitrogen	0.480	0.34	0.198	0.767	1.14	0.619
Total Nitrogen	1.506	1.06	0.622	1.607	2.39	1.296
Suspended Solids	7.142	5.04	2.948	17.714	26.26	14.279
Lead *	0.002	0.01	0.001	0.005	0.01	0.004
Zinc	0.011	0.01	0.005	0.015	0.02	0.012
Copper	0.004	0.01	0.002	0.006	0.01	0.005
Chloride	12.635	8.91	5.214	29.475	43.69	23.760

* 1976 Data Only (1975 Data Not Reported Due To Biased Analytical Technique)

TABLE 7a. WATER-QUALITY DATA SUMMARY AT ABERFOYLE EXTRACTIVE SITE, GRAND RIVER BASIN, 1975 AND 1976 PERIOD

PARAMETER	EX-1			EX-2			EX-3		
	Mean Flow Weighted Conc'n (mg/L)	Mean Annual Loads (Tonnes)	Unit Area Load (Kg/ha/yr)	Flow Weighted Mean Conc'n (mg/L)	Mean Annual Loads (Tonnes)	Unit Area Load (Kg/ha/yr)	Flow Weighted Mean Conc'n (mg/L)	Mean Annual Loads (Tonnes)	Unit Area Load (Kg/ha/yr)
Total Phosphorus	0.012	0.04	0.04	0.021	0.29	0.069	0.027	0.18	0.067
Filtered Reactive Phosphorus	0.003	0.01	0.009	0.003	0.05	0.011	0.003	0.02	0.008
Total Kjeldahl Nitrogen	0.368	1.17	1.265	0.376	5.26	1.268	0.420	2.82	1.033
Filtered (Nitrite + Nitrate) - Nitrogen	0.263	0.84	0.903	0.461	6.44	1.553	0.351	2.35	0.862
Total Nitrogen	0.631	2.01	2.168	0.837	11.70	2.821	0.771	5.17	1.896
Suspended Solids	2.785	8.88	9.577	7.907	110.42	26.647	10.830	72.63	26.630
Lead*	0.003	0.01	0.010	0.002	0.03	0.008	0.003	0.02	0.008
Zinc	0.027	0.09	0.092	0.046	0.65	0.156	0.052	0.35	0.128
Copper	0.004	0.01	0.015	0.004	0.06	0.014	0.006	0.04	0.015
Chloride	4.526	14.43	15.561	11.702	163.43	39.438	10.439	70.01	25.670

* 1976 DATA ONLY

TABLE 7b. WATER QUALITY DATA SUMMARY AT GLENCHRISTIE EXTRACTIVE SITE, GRAND RIVER BASIN, 1976 PERIOD

PARAMETER	EX-4			EX-5		
	Flow Weighted Mean Conc'n (mg/L)	Mean Annual Loads (Tonnes)	Unit Area Load (Kg/ha/yr)	Flow Weighted Mean Conc'n (mg/L)	Mean Annual Loads (Tonnes)	Unit Area Load (Kg/ha/yr)
Total Phosphorus	0.087	24.32	0.390	0.063	18.28	0.287
Filtered Reactive Phosphorus	0.026	7.29	0.117	0.017	4.78	0.075
Total Kjeldahl Nitrogen	1.020	285.24	4.570	0.950	273.75	4.296
Filtered (Nitrite + Nitrate) - Nitrogen	1.693	473.22	7.581	1.850	532.91	8.364
Total Nitrogen	2.713	758.46	12.151	2.80	806.66	12.660
Suspended Solids	15.698	4388.87	70.313	10.642	3065.56	48.115
Lead*	0.017	4.74	0.076	0.004	1.06	0.017
Zinc	0.049	13.71	0.220	0.039	11.12	0.174
Copper	0.01	2.72	0.044	0.008	2.19	0.034
Chloride	31.528	7403.96	118.618	33.473	8094.85	127.050

* 1976 DATA ONLY

TABLE 8. WATER-QUALITY DATA SUMMARY AT UNDISTURBED (WOODED/IDLE) SITES, 1975 AND 1976 PERIOD

PARAMETER	GR-8			UL-12		
	Flow Weighted Mean Conc'n (mg/L)	Mean Annual Loads (Tonnes)	Unit Area Load (Kg/ha/yr)	Flow Weighted Mean Conc'n (mg/L)	Mean Annual Loads (Tonnes)	Unit Area Load (Kg/ha/yr)
Total Phosphorus	0.020	0.51	0.081	0.023	0.91	0.086
Filtered Reactive Phosphorus	0.002	0.06	0.009	0.002	0.07	0.007
Total Kjeldahl Nitrogen	0.496	12.57	2.023	0.402	16.00	1.506
Filtered (Nitrite + Nitrate) - Nitrogen	0.862	21.87	3.519	0.854	33.98	3.398
Total Nitrogen	1.358	34.44	5.542	1.256	49.98	4.904
Suspended Solids	9.354	237.28	38.172	11.727	466.63	43.943
Lead'	0.003	0.08	0.013	0.003	0.12	0.012
Zinc	0.007	0.18	0.030	0.004	0.17	0.016
Copper	0.008	0.21	0.034	0.006	0.24	0.023
Chloride	8.209	208.24	33.501	6.959	276.89	26.075

* 1976 DATA ONLY

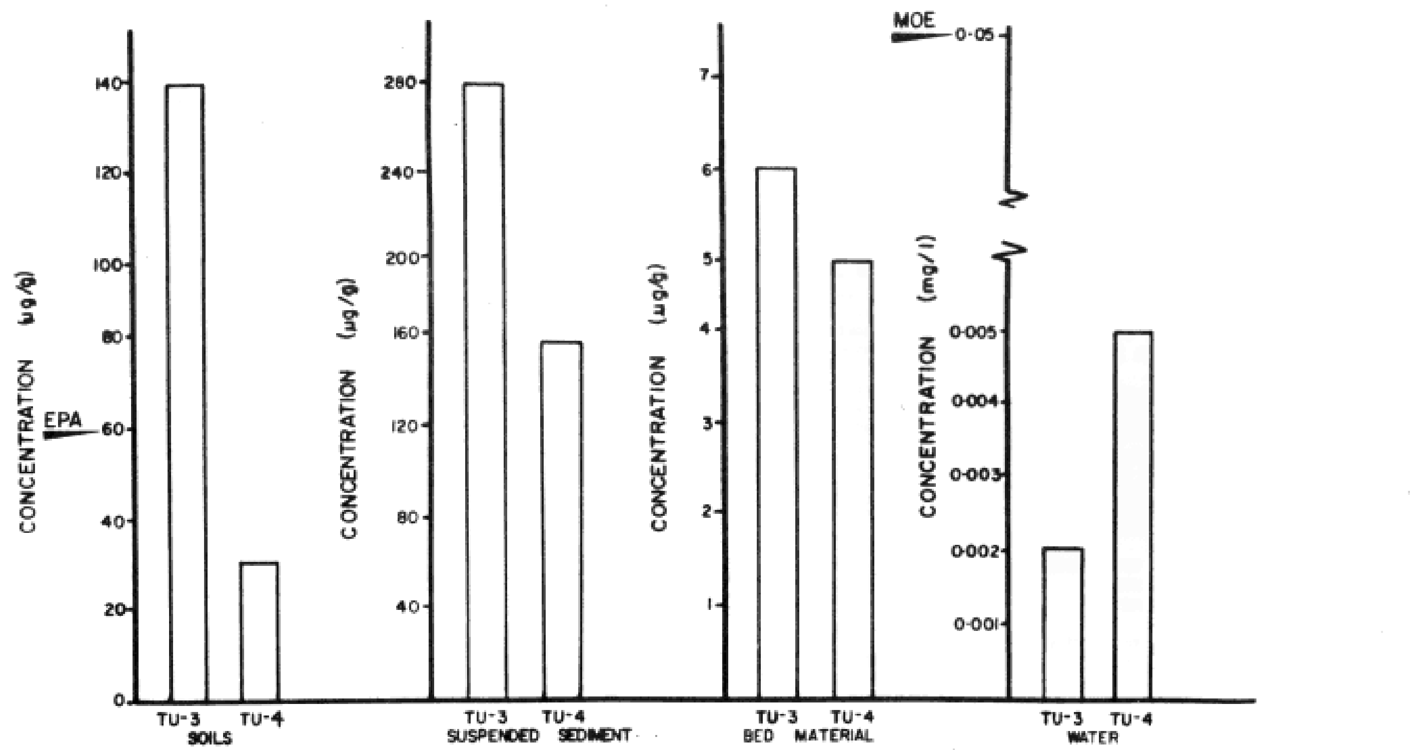

Figure 11 : LEAD DISTRIBUTION AT THE TRANSPORTATION SITES, GRAND RIVER, 1976

LEGEND:
EPA : GUIDELINE CRITERIA FOR SEDIMENT POLLUTION >60 µg/g HEAVILY POLLUTED
MOE: PUBLIC SURFACE WATER SUPPLIES CRITERIA

10.3 EXTENT OF POLLUTANT CONTRIBUTIONS AS UNIT-AREA LOADINGS FROM LAND-USE AREAS

Unit-area loadings were used in rankings of loads from different land uses. Estimates of unit-area loads for different land uses in the pilot watershed were calculated and are presented in Table 9. The ranges of unit-area loading data from rural tributaries in the pilot watersheds have been classified arbitrarily as 'high', 'medium' and 'low' as listed in Table 10. In Figure 12, the unit-area loadings from rural and wooded/idle land uses in the pilot watersheds are compared with the average unit-area loadings from the PLUARG Agricultural Watersheds Studies which was a cooperative program amongst Canada Department of Agriculture, Ontario Ministry of Agriculture and Food and the Ontario Ministry of the Environment. Eleven small agricultural watersheds in Ontario were selected to be representative of major agricultural regions in the Canadian Great Lakes Basin and a variety of detailed investigations into the relationship between agricultural land and water quality were conducted by other investigators (Coote *et al*, 1978).

TABLE 9. LAND USES AND UNIT-AREA LOAD ESTIMATES *

Land-use Category			Suspended Sediment	Total Phosphorus	Filtered Reactive Phosphorus	Total Nitrogen	Filtered (Nitrite + Nitrate)-Nitrogen	Chloride	Lead **	Zinc	Copper
			Unit-area Load (Kg/ha/yr)								
Urban	General	Mean	1.070	1.39	0.085	8.45	3.03	200	0.4	0.48	0.092
		Range	400-1.750	0.73-2.05	0.05-0.12	6.65-10.2	3.00-3.06	132-268	0.33-0.47	0.33-0.62	0.53-0.130
		Area-weighted Mean	1.380	1.63	0.107	9.48	3.05	239	0.45	0.561	0.114
Rural	General	Mean	569	0.899	0.202	11.7	7.70	47.2	0.015	0.107	0.036
		Range	2.9-2,230	0.05-2.30	0.008-0.533	0.62-23.5	0.198-16.7	5.0-124	0.004-0.037	0.005-0.28	0.002-0.093
		Area-weighted Mean	961	1.29	0.233	14.3	8.86	51.8	0.019	0.14	0.052
Wooded/idle	Perennial	Mean	40.7	0.083	0.007	5.15	3.30	29.8	0.0125	0.02	0.029
	Cover	Range	38.2-43.9	0.081-.086	0.007-0.009	4.9-5.54	3.39-3.52	26.1-33.5	0.012-0.013	0.016-0.03	0.023-0.034
		Area-weighted Mean	40.6	0.084	0.008	5.05	3.37	29.5	0.012	0.021	0.027

* Land-Use Category. URBAN GENERAL: commercial, industrial, and residential land, parking lots and all road systems in the urban area.
RURAL GENERAL: crop lands, livestock, barnyard areas, rural dwellings and roads.
WOODED/IDLE: perennial vegetative cover, woodlots, swamps and idle land (unimproved pasture).

Unit-Area Loadings. MEAN AND RANGE are estimates based on PLUARG Task C monitoring of selected sites in the Saugeen and Grand River basins using the IJC recommended method for computing loads. Monitoring sites with more than 60% urban land were used to estimate the urban general contribution. Monitoring sites from the Grand River watershed GR-9, GR-20, TU-3, TU-4, GR-10, GR-12, GR-14, GR-19, AG-4, GR-6, GR-7 and EX-3 draining subwatersheds with about 80% agricultural land, were used to estimate the rural general contribution. Monitoring sites GR-8 (Grand River) and UL-12 (Saugeen River) draining subwatersheds with more than 70 of the river bank area in perennial cover, were used to estimate the wooded/idle contribution.

$$\text{AREA-WEIGHTED MEAN} = \frac{\text{sum of monitored loads at each site}}{\text{sum of drainage areas at each site}}$$

** 1975 LEAD DATA NOT REPORTED -

TABLE 10. EXTENT OF POLLUTANT CONTRIBUTION AS UNIT-AREA LOADINGS FROM RURAL TRIBUTARIES

RIVER REACH	(STATION)	SUSPENDED SEDIMENT	TOTAL PHOSPHORUS	FILTERED REACTIVE PHOSPHORUS	FILTERED $(NO_2 + NO_3)$ -NITROGEN
Canagagigue	(GR-19)	High	High	High	High
Nith	(GR-20)	High	High	Med.	Med.
South Saugeen	(SR-2)	High	High	Low	Low
Conestogo	(GR-14)	High	Med.	Med.	Med.
Mill Creek	(AG-14)	Med.	Med.	High	Low
Horner	(GR-6)	Med	Low	Low	Med.
McKenzie	(GR-7)	Med	Low	Low	Low
Teeswater	(SR-4)	Low	Low	Low	Med.

RANGES	SUSPENDED SEDIMENT (kg/ha/yr)	TOTAL PHOSPHORUS (kg/ha/yr)	FILTERED REACTIVE PHOSPHORUS (kg/ha/yr)	FILTERED $(NO_2 + NO_3)$-NITROGEN (kg/ha/yr)
High	>300	>1.0	>0.30	>12
Med.	150-300	0.5-1.0	0.15-0.30	6-12
Low	<150	<0.5	<0.15	<6

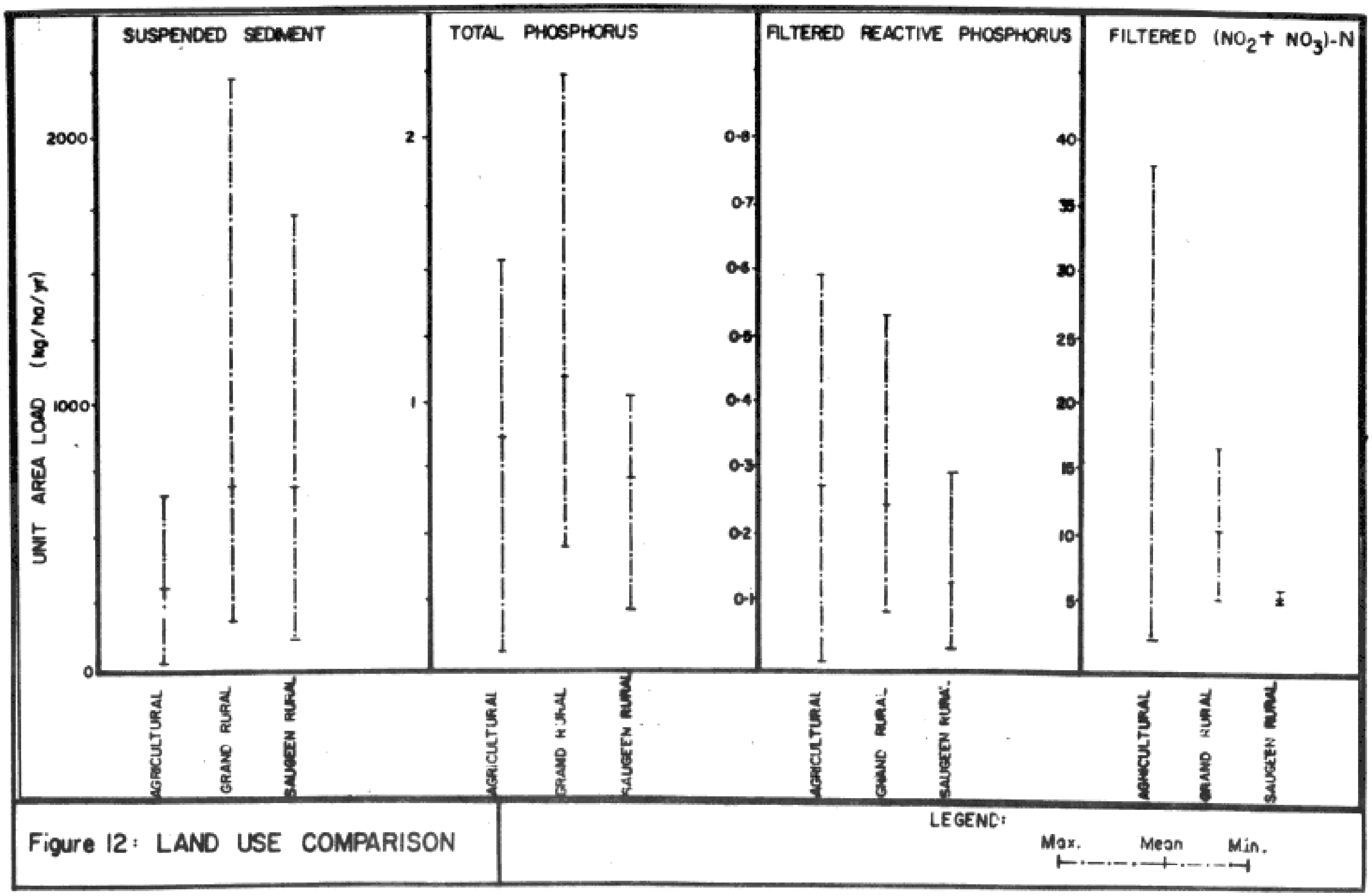

Figure 12: LAND USE COMPARISON

10.4 RELATIVE SIGNIFICANCE OF SOURCES

The mean, annual loading estimates of suspended sediment, total phosphorus, total nitrogen, filtered reactive phosphorus, Kjeldahl nitrogen and (nitrate + nitrite) - nitrogen for the rural tributaries in the pilot watersheds are presented in figures 13, 14 and 15. Based on the unit-area load data presented in Table 10 and land-use area (Table 1), estimates of predicted loads from rural, wooded/idle land-uses in the entire drainage areas of the Grand River and Saugeen River pilot watersheds were calculated as shown in Table 11. In addition, these values were expressed as a percent of a predicted total load, which includes estimates for all diffuse and point sources in the pilot watersheds to permit comparison with the monitored loads at the pilot watershed mouths.

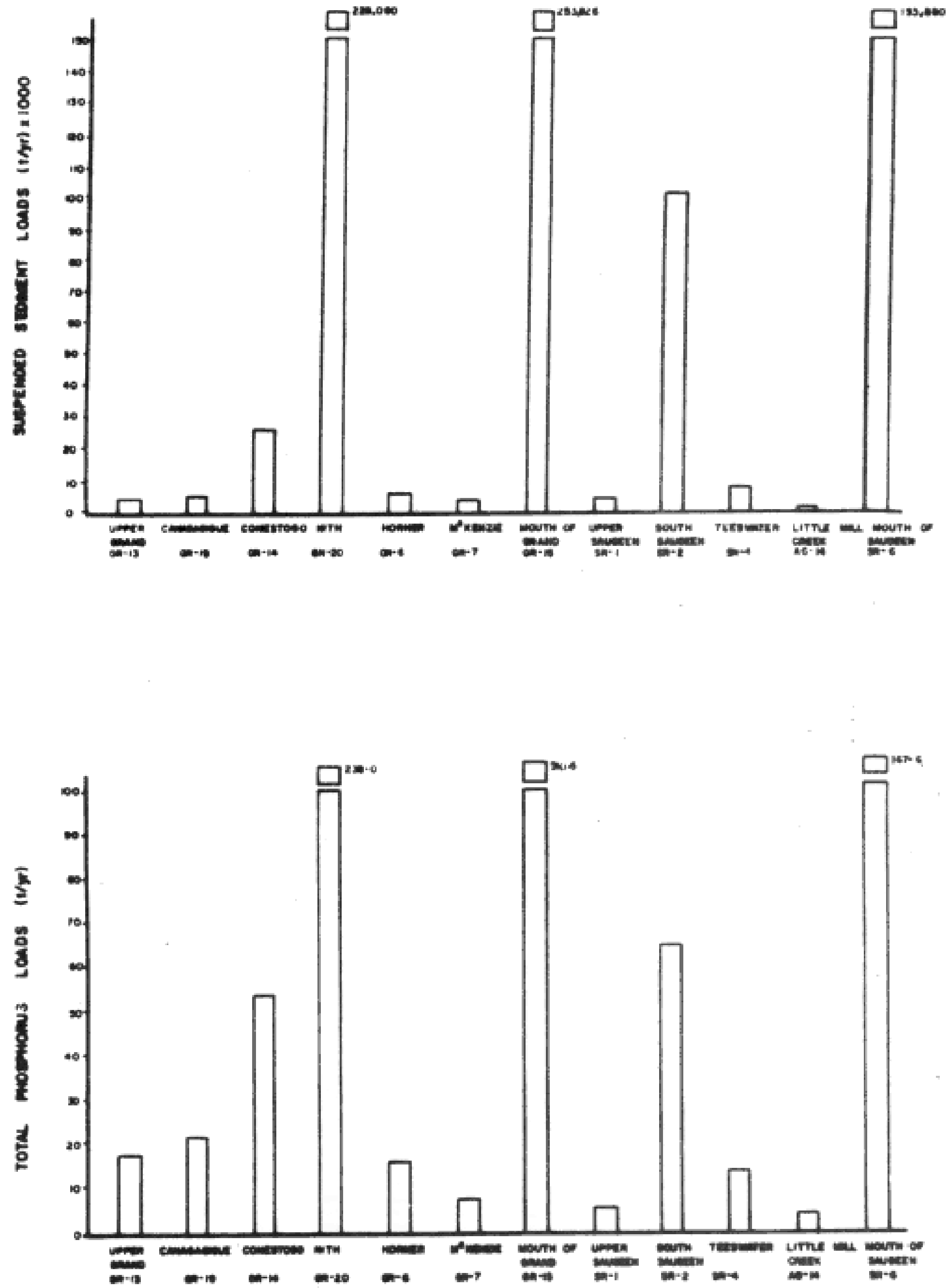

Figure 13: MEAN LOADING ESTIMATES FOR THE COMBINED 1975 AND 1976 PERIOD

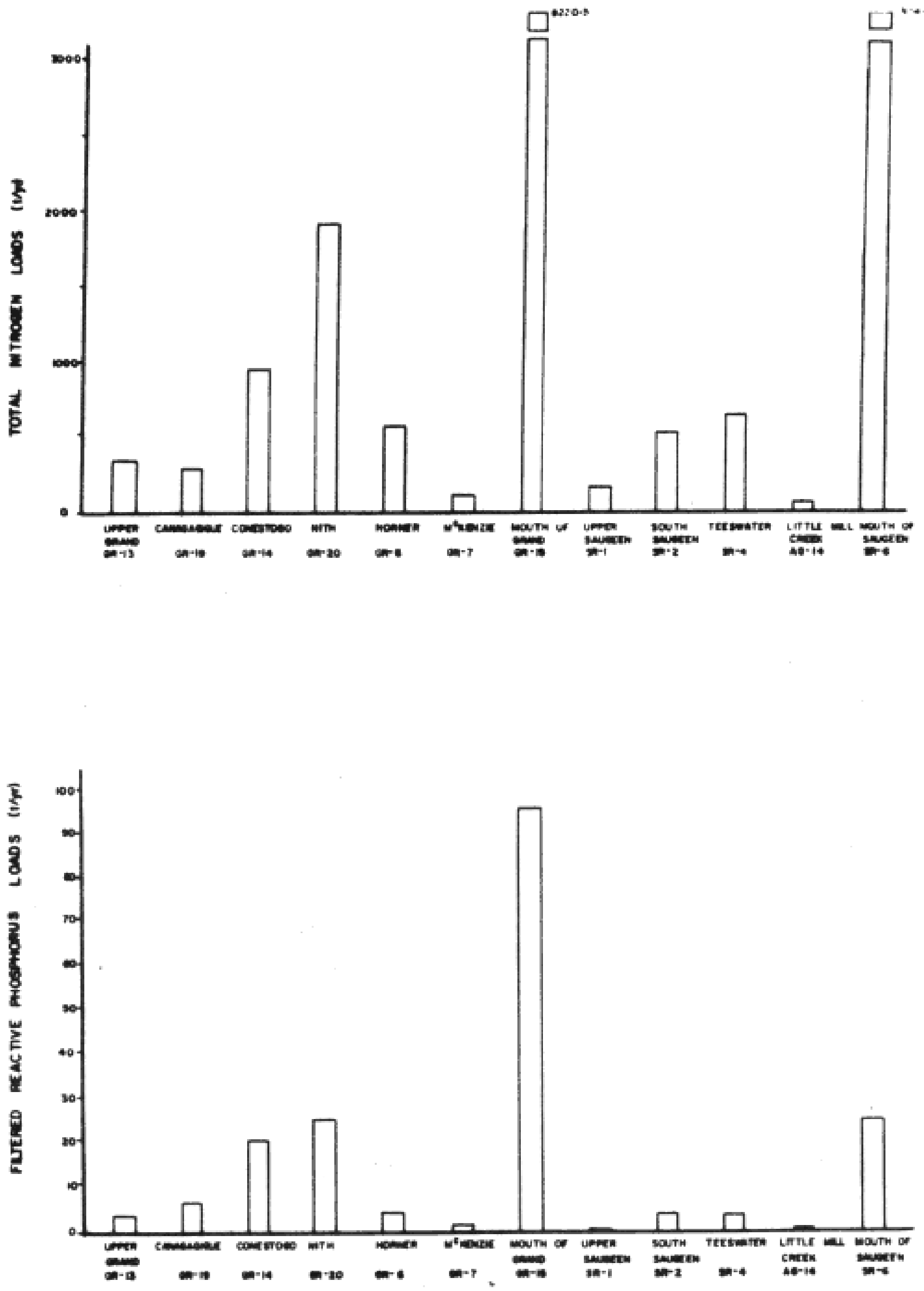

Figure 14: MEAN LOADING ESTIMATES FOR THE COMBINED 1975 AND 1976 PERIOD

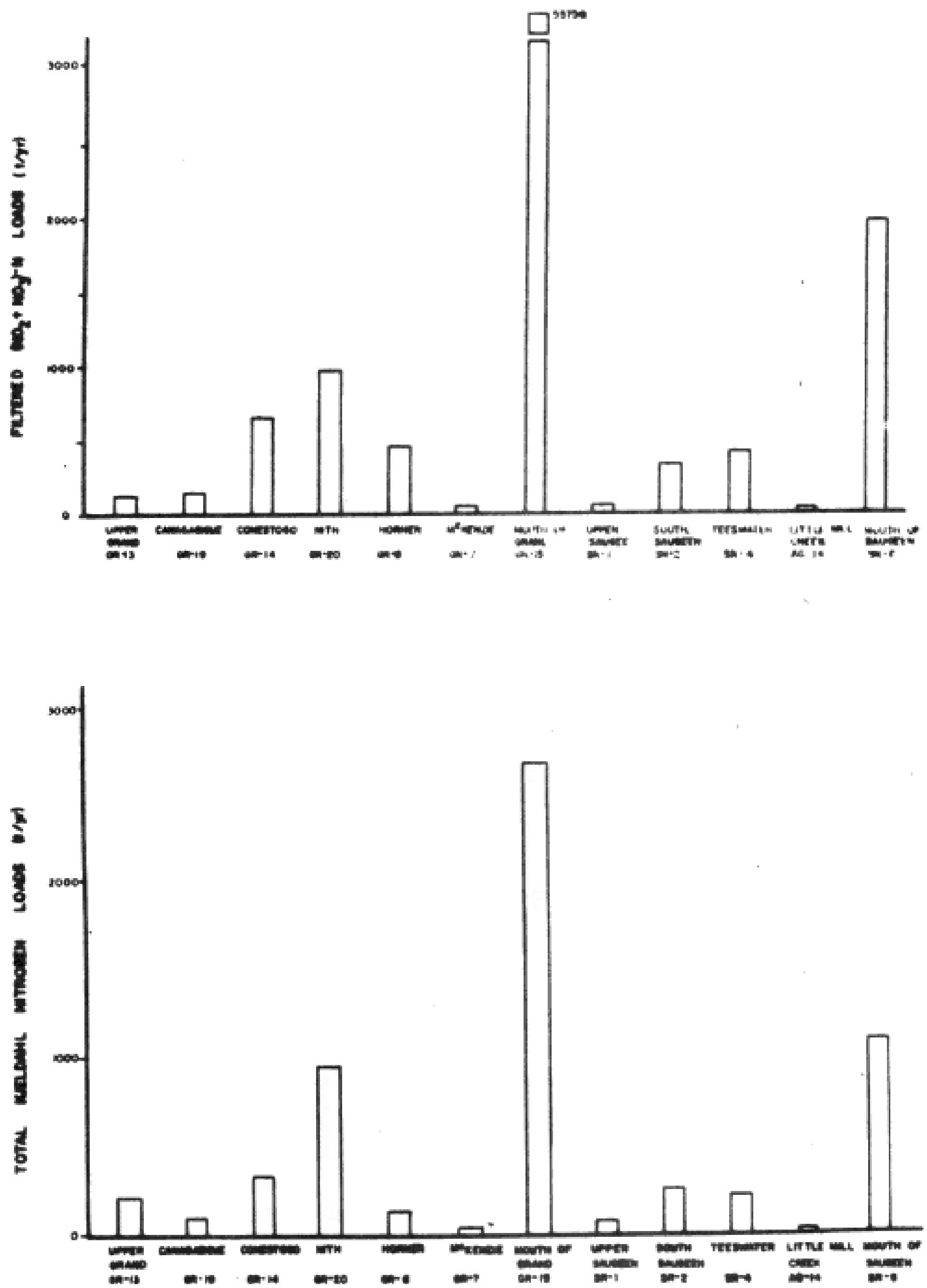

Figure 15: MEAN LOADING ESTIMATES FOR THE COMBINED 1975 AND 1976 PERIOD

TABLE 11. PREDICTED POLLUTANT LOADS FROM RURAL AND WOODED/IDLE LAND USES IN THE PILOT WATERSHEDS, 1975 AND 1976 PERIOD

Watershed (ha)	Land Use	Drainage Area (ha)	Predicted Loads (tonnes/year)					
			S.S.	T.P.	F.R.P.	T.N.	NO_2 + NO3	T.K.N.
Grand River (668,000)	Rural	521,000	286,000	452	102	5,860	4,460	1,400
	(% of Predicted Total Load)	-	83.6	64.5	48.9	67.3	78.2	46.5
	Wooded/Idle	127,000	5,200	11	0.9	654	419	235
	(% of Predicted Total Load)	-	1.5	1.5	0.4	7.5	7.4	7.8
	Predicted Total Load*	-	342,000	701	208	8,700	5,700	3,010
	Monitored Load at Outlet GR-15	-	254,000	570	93	8,220	5,580	2,640
Saugeen River (400,000)	Rural	258,000	145,000	229	52	2,970	1,960	1,010
	(% of Predicted Total Load)	-	90.3	84	69	76.7	77.0	76.2
	Wooded/Idle	131,000	7,100	13	1.2	675	432	243
	(% of Predicted Total Load)	-	4.4	4.8	1.6	17.4	17.0	18.3
	Predicted Total Load*	-	161,000	273	74.6	3,870	2,540	1.320
	Monitored Load at Outlet SR-6	-	195,000	168	26.0	3,180	1,970	1,210

SS = Suspended Sediment
TP = Total Phosphorus
FRP = Filtered Reactive Phosphorus
TN = Total Nitrogen
$NO_2 + NO_3$ = Nitrite + Nitrate - Nitrogen
TKN = Total Kjeldahl Nitrogen
* Predicted Total Load includes estimates for all diffuse and point sources in the pilot watersheds; Diffuse-source loads were derived from unit-area loads (Table 9) and land-use area (Table 1.

11.0 DATA INTERPRETATION AND CONCLUSIONS

11.1 CAUSES AND SOURCES OF POLLUTANT CONTRIBUTIONS

The major sources of pollution from land uses, other than urban, in the Grand River and Saugeen River pilot watersheds have been tentatively identified as follows:

Rural Land Drainage	-	sediment, phosphorus, nitrogen
Transportation	-	lead, chloride
Extractive	-	insignificant
Undisturbed land	-	insignificant

11.1.1 RURAL LAND DRAINAGE

The major pollutants from rural land drainage were identified as sediment, phosphorus and nitrogen. Metals and only some of the pesticides in current use were detected at low levels in the receiving streams.

The term rural land use, as used herein, refers to the general rural complex which includes cropland, barnyard areas, rural roads, dwellings and associated activities. Agricultural practices and livestock operations have been identified as the major sources that generate pollutants in rural areas.

The tributaries which drain predominantly agricultural areas in the pilot watersheds are the Nith and Conestogo rivers, Canagagigue, Horner and Mackenzie creeks in the Grand River and the South Saugeen and Teeswater rivers and Little Mill Creek in the Saugeen River (figures 4 and 5). These tributaries drain more than 32% of the drainage areas in the pilot watersheds. Amongst these, the Nith River is the largest tributary, with about 85% of its drainage area under rural land use in extensive cropland and livestock operations.

11.1.1.1. Sediment

Inadequate conservation practices on croplands can increase sediment concentrations in rural runoff. Excessive tillage on agricultural land can promote soil erosion. These practices will consequently increase the amount of sediment in agricultural runoff. Excessive amounts of sediment may also cause aesthetic problems in the receiving waters and make fish spawning areas unsuitable. Sediments may also carry adsorbed nutrients (especially phosphorus) and indirectly enhance eutrophication in streams and lakes.

The highest mean concentrations of suspended sediment (551.1 mg/L and 334.4 mg/L (Figure 8) were observed in the Nith River and the South Saugeen River (Figure 1), respectively. Field reconnaissance and closer examination of the data suggest that severe streambank erosion occurred during very high flows in these tributaries and contributed significant amounts of sediment. The South Saugeen River and Little Mill Creek in the Saugeen River pilot watershed and all the rural tributaries in the Grand River pilot watershed exhibited higher concentrations of suspended sediment compared to those at stations SR-1 (Saugeen River basin) and GR-13 (Grand River basin) which are situated in the headwater areas (Figure 8). Agricultural practices are less intensive in these smaller headwater areas which is reflected in their better water quality.

11.1.1.2 Phosphorus

Phosphorus is one of the most essential nutrients to field crop growth. In addition, phosphorus is a limiting nutrient in the eutrophication process in water bodies. Phosphorus is applied to agricultural lands mostly in the form of inorganic fertilizers. Other sources of phosphorus are the application of animal manure on farmlands and naturally occurring phosphorus in the mineral soil. Phosphorus is relatively immobile in soils and its leaching to and accumulation in the ground water is minimal. Only a small percentage of the applied phosphorus is used by the standing crop and the rest is generally adsorbed to soil mineral particles. The principal medium carrying phosphorus to receiving waters is the sediment that is carried away with the surface runoff from croplands and feedlots.

Dissolved phosphorus is more readily available for biological uptake than the particulate form of phosphorus. Filtered reactive phosphorus is considered to be bio-available and its impact on aquatic systems is readily recognizable in algal-bloom production. Phosphorus fertilizers contain available forms of phosphorus which may be transported to the receiving streams during surface runoff.

Comparing all the rural areas in the two pilot watersheds, (Figure 8), the highest mean concentration of 0.575 mg/L total phosphorus was observed in the Nith River tributary. This high concentration is attributed to relatively intensive agricultural activity and heavy sediment loss in this drainage area. The other rural tributaries had mean, total-phosphorus concentrations ranging from 0.036 mg/L (Upper Saugeen River) to 0.41 mg/L (Canagagigue Creek).

The highest mean concentration of 0.128 mg/L filtered reactive phosphorus was observed in the Canagagigue Creek (GR19), tributary to the Grand River (Figure 9). The mean concentration of 0.052 mg/L of filtered reactive phosphorus observed in Little Mill Creek (AG14) was the highest from the rural tributaries in the Saugeen River pilot watershed.

Concentrations of mean total phosphorus and filtered reactive phosphorus were lower in the less intensively farmed headwater areas of the Grand River and Saugeen River pilot watersheds (GR-13 and SR-1, respectively) than in the rural tributaries. The high density of agricultural and livestock practices in the rural areas (GR-19 and AG-14) is reflected in the poorer water quality of their receiving streams.

11.1.1.3 Nitrogen

Nitrogen is also a plant nutrient. In nature, nitrogen is subjected to complex transformations such as: dissolved to particulate, organic to inorganic and vice versa, depending on various environmental factors (i.e. physical, chemical and biological). Total nitrogen is expressed as the sum of: Kjeldahl nitrogen, which is a measure of the organic form of nitrogen and free ammonia; and the soluble, inorganic form, (nitrite plus nitrate) - nitrogen. The major sources of nitrogen pollution are from animal wastes or manures (principally measured as total Kjeldahl nitrogen) and chemical fertilizers.

Comparison of the total nitrogen data from all the rural tributaries studied indicates that the highest mean concentration of 5.7 mg/L was observed in Canagagigue Creek (tributary to the Grand River, Figure 9). This stream also showed the highest (nitrite plus nitrate)-nitrogen mean concentration of 4 mg/L (Figure 10). The mean concentrations of (nitrite plus nitrate)-nitrogen in all the rural tributaries studied ranged from 1.4 mg/L to 4 mg/L in the Grand River pilot watershed and from 0.89 mg/L to 1.04 mg/L in the Saugeen River pilot watershed. These mean concentrations were well below the Ontario Ministry of the Environment's criterion of 10 mg/L of nitrate nitrogen for public surface-water supplies (MOE 1974). Comparison of the water-quality data collected in the rural tributaries showed the Canagagigue Creek (GR19, Grand River) and Little Mill Creek (AG-14, Saugeen River), which drain small but intensive agricultural catchments, to be potentially large sources of nitrogen to the receiving waters. The highest concentration (2.2 mg/L) of total Kjeldahl nitrogen was observed in the Nith River (GR 20, Figure 10) and is attributed to high-intensity agricultural and livestock practices in this tributary. The mean concentrations of total Kjeldahl nitrogen in the rural tributaries were lower than the mean concentrations of (nitrite plus nitrate)-nitrogen (Figure 10) suggesting that the nitrogen is primarily transported in the dissolved form.

11.1.1.4 Metals

The major sources of metals in the runoff from rural areas appear to be due to the natural weathering of rocks, minerals and soil. Excessive application of sewage sludge on farmlands may result in metals enrichment of the soils, and consequently, higher metals values in surface runoff to the receiving waters from these lands.

The mean concentrations of copper, lead and zinc in the rural tributaries of the Grand River and

Saugeen River pilot watersheds were well below the guideline criteria (MOE 1974) for these metals in public surface-water supplies (Table 3). These data suggest that rural land use in the two pilot watersheds is not a source of metal pollution to the boundary waters of the Great Lakes.

11.1.1.5 Pesticides, PCBs and Mirex

Insecticides and herbicides are the two main types of pesticides commonly used on farms and agricultural lands for crop protection from insects and weeds. Many pesticides are persistent (i.e. do not degrade rapidly) and may be carried to receiving waters by runoff from croplands. Pesticides may also reach streams as a result of atmospheric fallout, tile drainage and accidental spills. Analyses for 26 pesticides in water samples collected from the rural tributary studies, detected only two insecticides, DDT and dieldrin, and one herbicide, atrazine.

DDT (including DDT isomers and metabolites) was detected in 10% of the water samples. The mean concentration of DDT, using only the samples where it was detected (Table 4), was above the IJC criterion of 0.003 µg/L in Little Mill Creek (AG-14), Horner Creek (GR-6), Nith River (GR-20) and at the outlets of the Grand (GR-15) and Saugeen (SR-6) rivers. The sources of DDT in these tributaries are attributed to the past use of this persistent insecticide which was widely used prior to its restriction in 1970.

Dieldrin is another persistent insecticide and its official use in Ontario was discontinued in 1969. Dieldrin is an epoxy derivative compound of aldrin which was widely used as a pesticide before its restriction. The use of this pesticide is restricted to structural pest control by special permission of the Ministry of the Environment. Aldrin is transformed into dieldrin in nature and hence the analysis of dieldrin in water samples will indicate the presence of either of these pesticides. Dieldrin was detected in 11% of the water samples (Table 4). The mean concentrations of these samples (in which dieldrin was detected) were at or above the IJC criterion of 0.001 µg/L. The source of this insecticide is attributed to past uses of aldrin for control of soil insects in cash crop and vegetable growing areas. Two samples, one each from GR-14 and GR-19, showed dieldrin concentrations of 1 µg/L. These high values are probably due to an accidental spill or careless handling of these restricted pesticides at some upstream location at the time of sampling.

Atrazine is a herbicide used exclusively for pre-emergent weed control in corn. Atrazine and de-ethyl atrazine were found in 79% of the water samples collected from rural tributaries in the Grand River and Saugeen River pilot watersheds. The mean concentrations of those samples in which atrazine or de-ethyl atrazine were detected (Table 4) were below the IJC criterion (28 µg/L) in all of the rural tributaries. The major source of atrazine is attributed to runoff from rural areas with large acreages in corn production.

PCBs (Polychlorinated biphenyls) are persistent industrial chemicals whose present use in Ontario is restricted to closed systems. The main sources of PCBs in rural areas appear to be from atmospheric inputs (industrial emissions). Approximately 27% of the water samples collected from the rural tributary studies contained PCBs above the detection limit and the mean concentrations of the detected values (Table 5) were higher than the IJC criterion of 0.002 µg/L. PCBs were not detected in seven of the twelve rural watersheds that were studied.

Mirex is another persistent industrial chemical which has been used as a fire retardent and insecticide to control fire ants. Mirex was not detected in any of the water samples taken from the rural tributaries in the pilot watershed studies (Table 5).

11.1.2 TRANSPORTATION CORRIDORS

Provincial, county and township highways occupy approximately 2% of the land in the Grand River and Saugeen River pilot watersheds (11,300 and 6,700 hectares, respectively). The major pollutants produced as a result the maintenance of these transportation corridors are chloride and sodium from highway deicing operations. Literature studies (Ministry of the Environment, 1974) report that other pollutants such as oil, grease, pesticides and heavy metals may be produced as a result of routine maintenance operations. One study (Laxen *et al*, 1977) reported that airborne lead was accumulating in the soil downwind of major highways.

Monitoring of a small stream draining a 1.4-km stretch of 4-lane highway, averaging 18,600 cars per day, was undertaken as part of the pilot-watershed studies. The study area is drained by Cedar Creek, a tributary to the Nith River in the Grand River pilot watershed (Figure 5). Monitoring data confirm increased chloride levels as a result of deicing operations. Preliminary results from soil sampling suggest that lead has been accumulating downwind of the highway in the soil. Levels of heavy metals and pesticides were unchanged from upstream to downstream of the highway in both suspended-sediment and bed-sediment samples.

11.1.2.1 Chloride

Salt used as a deicing agent is one of the most important practices contributing to increased chloride levels in the boundary waters. Records from the Ministry of Transportation and Communications indicate that salt usage on provincial highways has doubled from 1960 to 1975. A complete inventory of salt usage as a deicing agent was solicited from the larger municipalities in Ontario and the Ministry of Transportation and Communications for the winter period of 1975-76. Based on these data, the amount of salt (41,800 tonnes of chloride) used as a deicing agent during the winter of 1975-76 in the Grand River pilot watershed accounted for approximately 50% of the chloride load that was measured at the mouth of the river in 1976. Approximately 7,100 tonnes of chloride were applied on streets, roads and highways within the Saugeen River pilot watershed and this amount accounts for approximately 45% of the chloride load measured at the watershed outlet in 1976. It is not anticipated that all of the salt spread in 1975-76 will immediately appear in the river system because of infiltration into the ground-water system and subsequent slow discharge of ground water to receiving streams.

The mean concentrations of chloride measured at the upstream (TU-3) and downstream (TU-4) sites of the stream draining the transportation corridor studied under the PLUARG program are presented in Table 6. These data indicate that chloride levels increased significantly at the downstream site, TU-4. The major source of chloride is attributed to deicing operations conducted on the 4-lane highway adjacent to the stream.

11.1.2.2 Lead

The mean concentrations of lead (Figure 11) in water samples from the highway monitoring sites on Cedar Creek (Figure 6) were found to be very low, about an order of magnitude lower than the permissible criterion recommended by the Ministry of the Environment (1974). However, the mean concentrations of lead in the suspended-sediment samples from the upstream (TU-3) and downstream (TU-4) sites were 274 µg/g and 156 µg/g, respectively. These concentrations were higher than the EPA recommended guideline criterion for heavily-polluted sediments (greater than 60 µg/g of lead). The concentration of lead in a composited soil sample (40 subsamples) from the upstream area (TU-3, Figure 11) was approximately 140 µg/g or about four times as high as the soil in the downstream area (TU-4). The high lead values in the upstream area of the highway suggest that deposition of lead from automobile emissions may be occurring in the soils upstream of the highway (downwind) as a result of the prevailing southwesterly and westerly winds in this area. Consequently, as a result of surface runoff, lead-enriched soil from the upstream area appears in the suspended sediment of Cedar Creek.

The concentrations of lead in the bed-material samples and the composite soil sample from the downstream study area (Figure 11) were significantly lower than the EPA guideline criteria for polluted sediments. These data, in conjunction with the upstream information, suggest that lead is not being accumulated in the bed material or in soils downstream of the study area.

11.1.2.3 Nutrients and other Water Quality Parameters

The concentrations of total phosphorus at both the upstream and downstream highway monitoring sites were found to be as high (Table 6) as those values found in some of the rural tributaries (Figure 8). The source of these high concentrations of phosphorus is attributed to the high density of agricultural land (81%) surrounding the study area.

The mean concentrations of nitrogen, zinc and copper were well below the MOE criteria of 10 mg/L, 5 mg/L and 1 mg/L, respectively (Table 6). Suspended-sediment concentrations (7 and 17 mg/L) from the transportation study were as low as the lowest sediment concentrations found in the pilot-watershed studies.

11.1.3 EXTRACTIVE INDUSTRIES

Sand and gravel pits and limestone quarries occupy approximately 130 hectares in the Grand River pilot watershed and about 79 hectares in the Saugeen River pilot watershed. The major pollutant from these kinds of extractive industries is the sediment generated from processing of the aggregates. Two extractive areas draining into Aberfoyle Creek and the Speed River (Figure 7) were investigated as part of the Grand River pilot watershed studies.

Mean suspended-sediment concentrations of 7.9 mg/L and 10.6 mg/L, were observed (Table 7) at the downstream stations (EX-2 and EX-5, respectively) of the two extractive study areas. The low levels of sediment (Table 7) from these extractive operations are a result of their small areal extent (<10%) in the monitored drainage areas as well as the use of treatment facilities (settling ponds) for processing the aggregates.

The sediment-associated parameters (i.e. phosphorus and metals) were also found to be at very low levels (Table 7). These results suggest that extractive industries with treatment facilities do not appear to be a significant source of pollution to the Great Lakes.

11.1.4 UNDISTURBED LAND (WOODED/IDLE)

Approximately 19% of the Grand River pilot watershed and 33% of the Saugeen River pilot watershed are wooded/idle land. Soils under perennial vegetative cover are much less prone to erosion and as a result sediment contribution from these areas is minimal. However, idle lands devoid of vegetative cover may contribute slightly higher levels of sediment to the receiving waters.

The PLUARG monitoring data indicate low concentrations of all water-quality parameters (Table 8) in the stream reaches that receive drainage from wooded/idle areas. The concentrations of pollutants and other water-quality parameters in the wooded/idle areas are considered to represent natural levels since there is no major anthropogenic influence in these areas.

11.2 EXTENT OF POLLUTANT CONTRIBUTIONS AS UNIT-AREA LOADINGS FROM LAND-USE AREAS WITHIN THE WATERSHED

The extent of pollutant contribution from a specific area is dependent on the magnitude of the input from the various land uses and practices in that area during a given period of time. This pollutant input can be reduced to a unit-area load which is the total load divided by the contributing area. If the contributing area is in a homogeneous land use, then the unit-area load will be representative of that particular land use (i.e. rural). Unit-area loads can be used to rank land uses or practices that require control measures. Prioritization of the most cost-effective, pollution control measures and their implementation can also be based on ranking of unit-area loads. Examination of the seasonal loading distribution can identify critical periods of the year during which controls should be applied (i.e. spring melt).

11.2.1 LAND-USE RANKING

Pollutant ranking of the three major land-use categories (rural, undisturbed and urban) in the pilot watersheds was based on the unit-area loads listed in Table 9.

The data from two urban land-use studies draining more than 60% urban land in the Grand River basin were included in these comparisons in order to present a complete perspective of the extent of pollutant contribution from the major land-use categories in the pilot watersheds. The data from those monitoring stations draining 80% or more of agricultural land were included in the estimates of unit-area loads as being representative of rural land uses (Table 9). Two sites, one each in the Grand River and Saugeen River pilot watersheds, draining subwatersheds with more than 70% of their respective areas in perennial vegetation (Table 2), were used to estimate the undisturbed (wooded/idle) contribution. Although studies were conducted on transportation and extractive land uses, these land uses formed less than 10% of the monitored drainage area. Consequently, overall water quality at the monitoring stations was more representative of rural and perennial vegetation (figures 6 and 7).

Ratios of the unit-area loads listed in Table 9 for rural, urban and undisturbed land, were computed using the smallest unit-area load as unity. These ratios are presented below:

	TP	FRP	TN	SS	Cl	Pb	Zn	Cu
Urban	17	12	1	26	6	20	25	3
Rural	10	29	2	14	1	1	5	1
Undisturbed	1	1	1	1	1	1	1	1

where:	TP	= total phosphorus;	Cl = chloride
	FRP	= filtered reactive phosphorus;	Pb = lead
	TN	= total nitrogen;	Zn = zinc
	SS	= suspended solids;	Cu = copper

The above ratios suggest that urban and rural runoff when compared with runoff from undisturbed land are the major contributors of sediment and nutrients. Rural runoff (i.e. from fertilization and manure applications), when compared to runoff from urban and undisturbed lands, contributes the largest unit-area load of filtered reactive phosphorus and total nitrogen. Contribution of metals and chlorides can be solely attributed to drainage from urban land. Although the transportation-corridor study formed less than 10% of the monitored drainage area, unit-area loads for chloride increased by a factor of four at the downstream station, suggesting that a significant input of chloride reaches the stream from the highway.

11.2.2 LAND-USE DIFFERENTIATION

The unit-area loads for sediment, total phosphorus, filtered reactive phosphorus, and (nitrite plus nitrate)-nitrogen were compared amongst the rural tributaries of the Grand River and Saugeen River pilot watersheds (Table 10). The ranges of the unit-area loads were arbitrarily divided, for comparative purposes, into high, medium and low catagories as listed at the bottom of Table 10.

Examples of intensively cultivated areas in the pilot-watershed studies are the Canagagigue (GR-19) and Nith (GR-20) river reaches (Figure 4, Table 10). Both these areas have more than 85% of their respective watersheds in agricultural activities which are predominantly devoted to cropping (55 and 54%, respectively, Table 1). These areas produced medium to high unit-area yields for the soluble nutrients (filtered reactive phosphorus and nitrite plus nitrate-nitrogen), total phosphorus and suspended sediment (Table 10). The Conestogo River (GR-14) with approximately the same agricultural activity (85%, Table 1) and less area devoted to cropping (48%), produced medium unit-area loads for the same parameters. With the exception of high, filtered-phosphorus yields, low to medium yields were obtained for the same parameters from Little Mill Creek (AG-14), which is characterized by a livestock-oriented agricultural practice (Frank and Ripley, 1977) and low cropland (22%). The other watersheds, with less area devoted to agricultural activities (67 to 83%), had yields ranging from low to medium (Table 10). Agricultural activities in these watersheds (SR-2, GR-6, GR-7 and SR-4) can also be qualitatively categorized as being less vigorous than in the Canagagigue Creek (GR-19), Nith (GR-20) and Conestogo (GR-14) rivers (Figure 4).

These data suggest that intensive agricultural practices (livestock, cropping, fertilization and/or manure application) will produce medium to high unit-area yields for sediment, total phosphorus (a sediment-associated parameter) and the soluble nutrients (filtered phosphorus and nitrite plus nitrate-nitrogen). Further investigation of the data suggests that high unit-area loads of sediment and total phosphorus accompanied by low, soluble nutrient inputs (i.e. South Saugeen River, SR-2) appear to be associated with streambank erosion and possibly soil erosion from undisturbed land.

Further comparisons were made using data from rural drainage areas of the Grand River (Grand Rural) and Saugeen River (Saugeen Rural) pilot watersheds with data from the PLUARG Agricultural Watershed Studies in southern Ontario (Figure 12). These latter studies consisted of a variety of investigations which were co-ordinated by Agriculture Canada into the relationships between agricultural land and water quality in the Great Lakes basin (Coote *et al*, 1978). Monitoring was conducted at eleven small watersheds selected to be representative of major agricultural regions in the Canadian Great Lakes basin. Two of these small watersheds, Canagagigue (AG-4) and Little Mill (AG-14) creeks were situated in the Grand River and Saugeen River pilot watersheds, respectively.

The mean, maximum and minimum values of unit-area loads presented in Figure 12 show that the rural tributaries in both the Grand River and the Saugeen River pilot watersheds contribute significantly more (approximately two times) sediment and less soluble nutrients (i.e. filtered reactive phosphorus and filtered nitrite plus nitrate-nitrogen) than the Agricultural Watershed Studies. As indicated previously, high suspended sediment and total-phosphorus yields in conjunction with low, soluble-nutrient loads are characteristic of streambank erosion rather than intensive agriculture. Comparison of the data in Figure 12 suggests that streambank erosion is more prevalent in the rural tributaries of the pilot watersheds than in the PLUARG Agricultural Watershed Studies.

11.2.3 TEMPORAL DISTRIBUTION OF POLLUTANT CONTRIBUTION

PLUARG monitoring data suggest that the bulk of the river loads are transported during the months of February, March, April and May which is normally the spring melt or high-flow period of the year. This marked seasonality of pollutant transport is illustrated in figures 16 to 19. The monthly percentages of the loads at the stations are based on daily-load estimates derived from sampling and supplemented by regression estimates where daily samples were not obtained. The values demonstrate that a significant proportion of the total load for all parameters is delivered during the spring melt.

In 1975, during the months of February, March, April and May, approximately 55% of the total annual flow occurred. During the same period, 60 to 70% of the total annual load for each parameter, except chloride, was exported at the Grand River pilot watershed outlet (GR-15, Figure 16). During the same months in 1976, 70% of the flow occurred resulting in a delivery of 75 to 85% of the total annual load for each parameter, except chloride (Figure 16).

Similar seasonal distribution during the spring melt was also observed in the Saugeen River pilot watershed during the study period. Approximately 59% of the total annual flow occurred during the months of February, March, April and May in 1975. During the same period, 60 to 73% of the total annual load for each parameter, except chloride, was exported from the watershed outlet (SR-6). The flow during the same months in 1976 was 68% of the annual flow with deliveries of 75 to 95% of the total annual loads for each parameter but chloride (Figure 17).

With relatively constant inputs, chloride, as a conservative parameter (i.e. 100% delivery), will tend to decrease in concentration as flow increases; nevertheless, a substantial proportion of the total annual load was delivered during the spring melt (an average of 55 and 57% in the Grand and Saugeen watersheds, respectively). This seasonality in loadings is a result of significant inputs of chloride from surface runoff associated with highway deicing operations in the winter period. Similar seasonal dependencies are more sharply delineated in small catchment areas (e.g. GR-20 in the Grand River, Figure 18, and SR-2 in the Saugeen River, Figure 19).

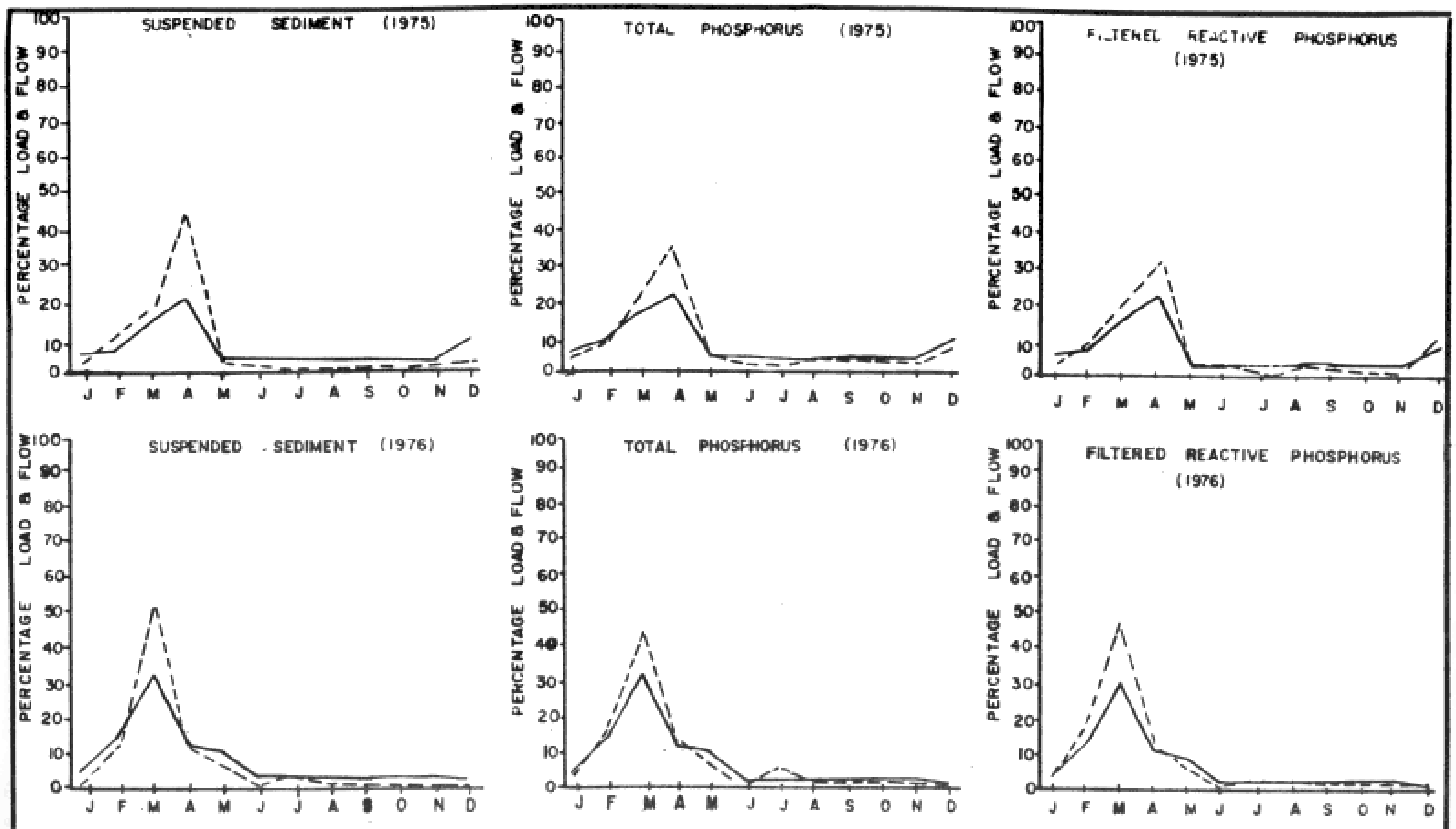

Figure 16: MONTHLY PERCENT DISTRIBUTION OF ANNUAL LOADS GRAND RIVER OUTLET (GR-15) 1975 AND 1976 PERIOD

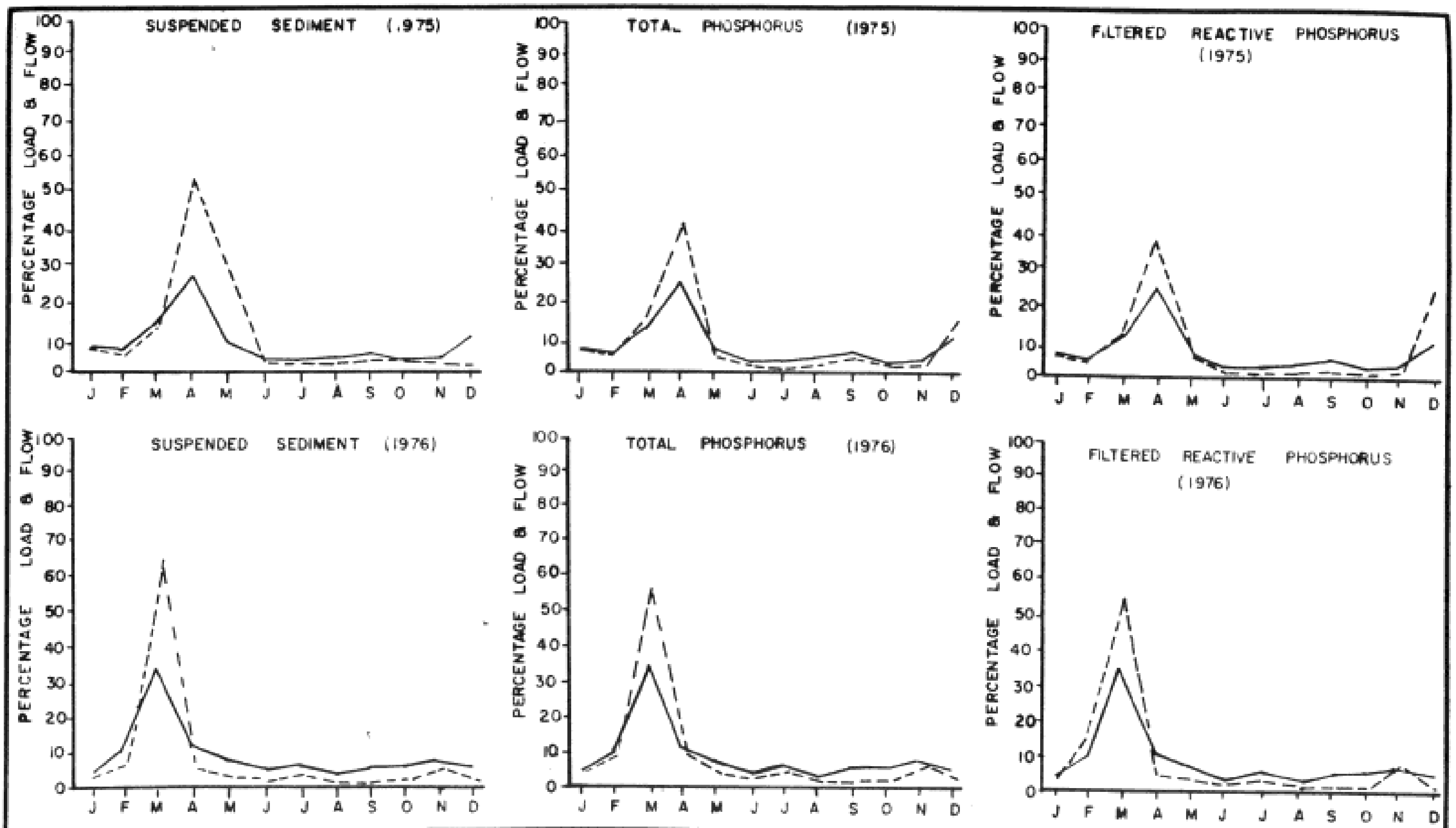

Figure 17: MONTHLY PERCENT DISTRIBUTION OF ANNUAL LOADS SAUGEEN RIVER OUTLET (SR-6) 1975 AND 1976 PERIOD

LEGEND:
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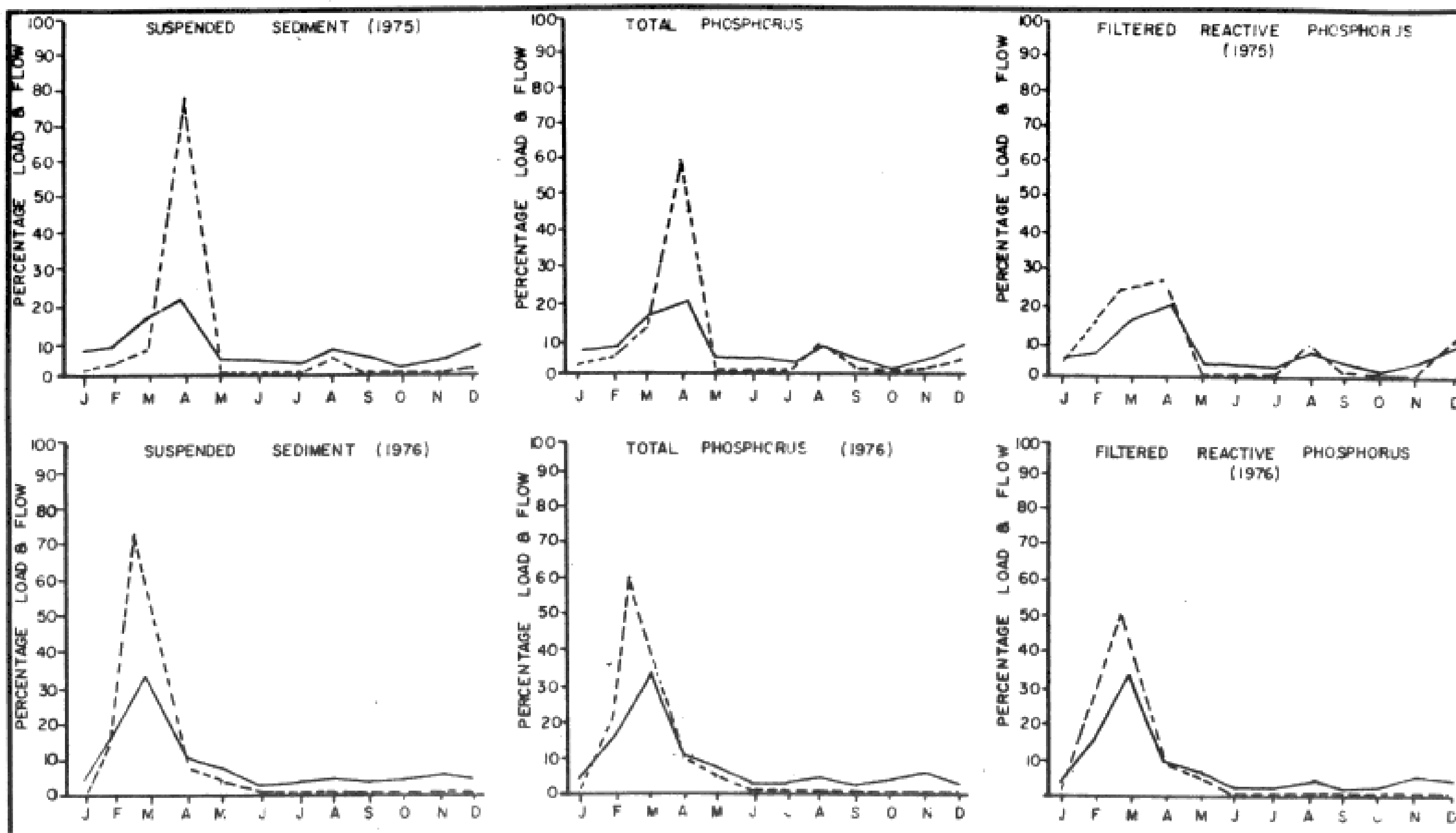

Figure 18: MONTHLY PERCENT DISTRIBUTION OF ANNUAL LOADS NITH RIVER (GR-20) 1975 AND 1976 PERIOD

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—— FLOW

The data for suspended sediment and total phosphorus (sediment associated) at site SR-2 (Figure 19), in the headwaters of the Saugeen River show more pronounced seasonal dependencies than those that appear at the outlet of the Saugeen River, SR-6 (Figure 17). In both study years, the month of highest flow (April of 1975 and March of 1976) at Site SR-2 accounts for about 40% of the total annual flow which delivers approximately 90% of the total annual sediment load and 75% to 85% of the annual phosphorus load. Severe streambank erosion occurring only during the highest flows recorded over the PLUARG study period is believed to account for those disproportionately large sediment and phosphorus loads which occur at SR-2 during March and April. The data at SR-2 are generally illustrative of conditions in which streambank erosion may play a significant role in generating sediment and other sediment-associated loads.

11.3 RELATIVE SIGNIFICANCE OF SOURCES YIELDING POLLUTANTS

In general, if the proportion of a particular land use in any watershed is large (i.e. agriculture), the contribution from that land use will be relatively large, even if the unit-area load from that land use is small. PLUARG monitoring data indicate that rural land use compared to other land uses is a significant contributor of sediment, phosphorus and nitrogen in the Grand River and Saugeen River pilot watersheds (Section 11.2). Comparisons of mean annual pollutant loads amongst the rural tributaries of the pilot watersheds suggest that the magnitude of pollutant load is influenced by the intensity and extent of the drainage area under agricultural activity.

11.3.1 SEDIMENT

The mean-annual sediment discharges at the outlets of the Grand River and Saugeen River were estimated as 254,000 and 195,000 metric tonnes, respectively. The Nith and South Saugeen rivers drain approximately 15% each of the pilot watershed areas and contributed the highest, average sediment loads of 228,000 and 105,000 metric tonnes per year respectively (Figure 13). These values are approximately an order of magnitude greater than any of the other rural-tributary yields and constitute 90% and 53% of the load monitored at the mouth of the Grand and Saugeen rivers, respectively. The high sediment load in these streams is largely attributed to severe streambank erosion. The mean annual sediment loads from the other rural tributaries in the pilot watershed studies were comparable to the sediment loads from the head-water areas of the Grand (GR-13) and Saugeen (SR-1) rivers (Figure 13).

In terms of relative significance, rural land comprises only 75 and 64% of the total drainage area in the Grand River and Saugeen River pilot watersheds, respectively, but contributes up to 84% and 90% of the sediment load (Table 11) measured at the mouths of these pilot watersheds. These values were estimated using unit-area loads from Table 9 in conjunction with the rural land-use data listed in Table 1. The predicted total load (Table 11) includes estimates for all the point and diffuse sources in the pilot watersheds.

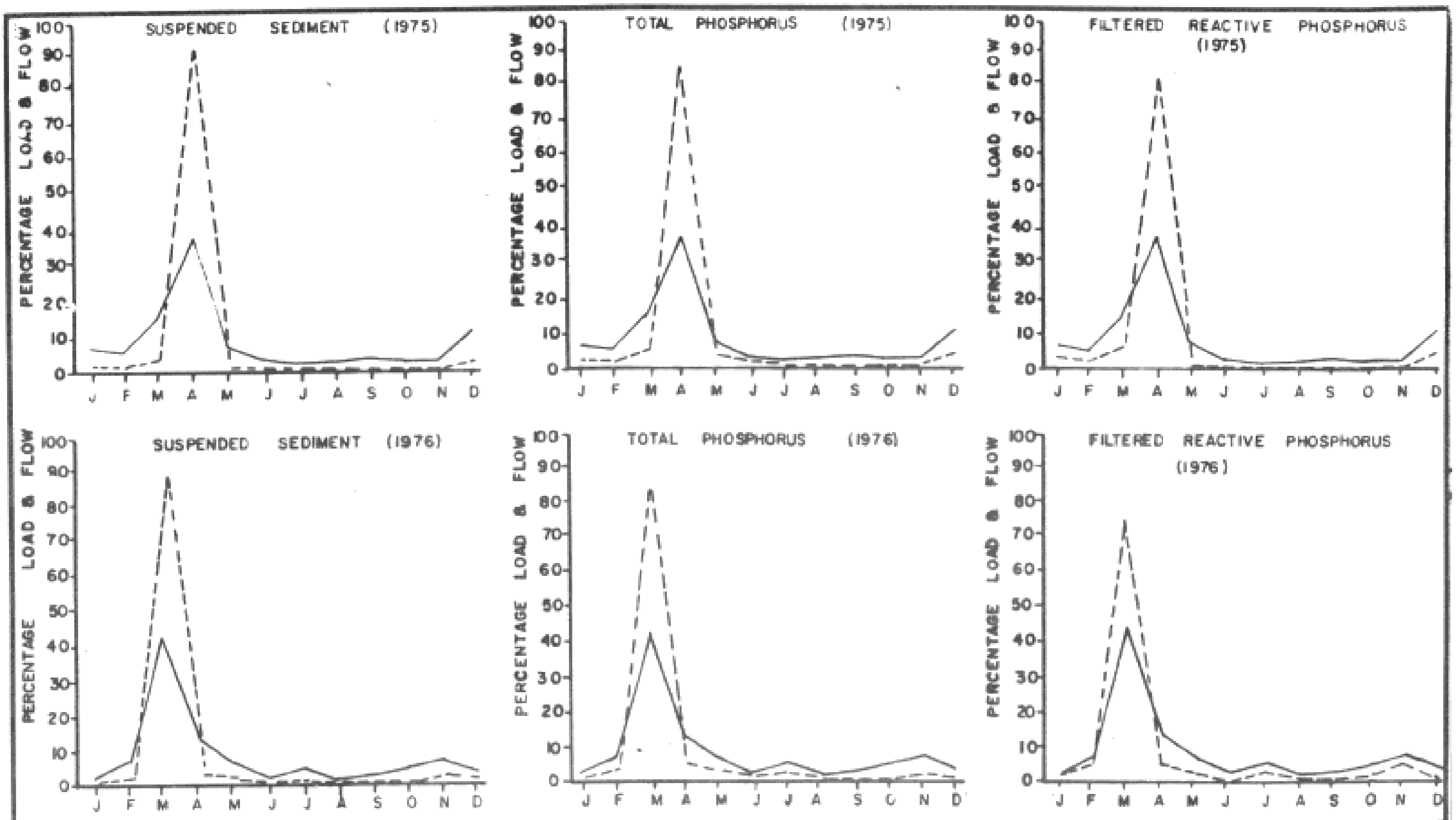


Figure 19: MONTHLY PERCENT DISTRIBUTION OF ANNUAL LOADS SOUTH SAUGEEN RIVER (SR-2) 1975 AND 1976 PERIOD

Although wooded and idle land (i.e. land in perennial vegetation) constitute a significant proportion of the drainage area in the pilot watersheds (19 and 33%, Table 1), sediment yields from this land use were minimal in relation to the total load transported to the mouths of the pilot watersheds (2 to 4% of the total load).

11.3.2 PHOSPHORUS

Contribution of total phosphorus from rural tributaries in the pilot watersheds followed similar patterns to that for the suspended sediment. Among the rural tributaries, the Nith and South Saugeen rivers contributed the highest phosphorus loads (238 and 65 metric tonnes per year, respectively) followed by the Conestogo River (54 metric tonnes per year) as shown in Figure 13.

The Nith and Conestogo rivers produce about 58% of the phosphorus load measured at the mouth of the Grand River but drain only 27% of the total drainage area. Similarly, the South Saugeen River yields about 39% of the total load at the mouth of the Saugeen River while draining only 16% of the total area. High phosphorus loads in these tributaries are attributed to the high intensity of agricultural practices and streambank erosion. The mean annual loads of total phosphorus from the other rural tributaries (Figure 13) were relatively low and comparable to the total phosphorus loads in the headwater areas (Upper Grand, GR-13 and Upper Saugeen, SR-1) which are undisturbed areas and assumed to represent natural levels. Although agricultural intensity is high in the Canagagigue, Horner, McKenzie and Little Mill creeks their small drainage areas restrict the total load generated from these watersheds.

Filtered reactive phosphorus loads from the Nith River were slightly higher than the loads from the Conestogo River. These rivers accounted for about 46% of the total filtered reactive phosphorus load at the mouth of the Grand River; however, they only drain 27% of the total Grand River drainage basin. The two rivers each contributed higher loads of filtered reactive phosphorus than any of the other rural tributaries in the Grand River and Saugeen River pilot watersheds (Figure 14). The sources of filtered reactive phosphorus in these rural tributaries are mainly attributed to fertilizer and manure application on agricultural lands.

The Nith and South Saugeen rivers which contributed the highest total phosphorus loads (Figure 13), exhibited the lowest ratios of (0.09 and 0.05) filtered reactive phosphorus to total phosphorus. This suggests that the bulk of the phosphorus is in the particulate form which is considered to originate from streambank erosion. The ratios of filtered reactive phosphorus to total phosphorus loads for Little Mill Creek, Conestogo River and Canagagigue Creek, were higher (0.38, 0.36 and 0.31, respectively), reflecting the highly intensive agricuitural operations in these catchments.

The data presented in Table 11 suggest that rural land use, which comprises 75% of the total drainage area in the Grand River pilot watershed contributes about 65% of the total phosphorus and 49% of the filtered reactive phosphorus loads at the mouth of the river. In the Saugeen River pilot watershed, rural areas constitute a lower proportion of the total drainage area, about 64%, but contribute more of the load at the mouth; about 84 and 69% of the total phosphorus and filtered reactive phosphorus loads, respectively. Wooded/idle land uses which comprise 19 and 33% of the Grand River and Saugeen River pilot watersheds respectively, contribute less than 5% of the total load at the mouth.

Discrepancies between the "predicted total load" and the "monitored load" (Table 11), by approximately a factor of 2 higher for the predicted phosphorus values, are a result of using average unit-area load values which are not totally representative of the conditions in the pilot watersheds. However, the predicted phosphorus values are considered to be sufficiently accurate for the purposes of delineating the relative significance of land-use inputs in the pilot watersheds.

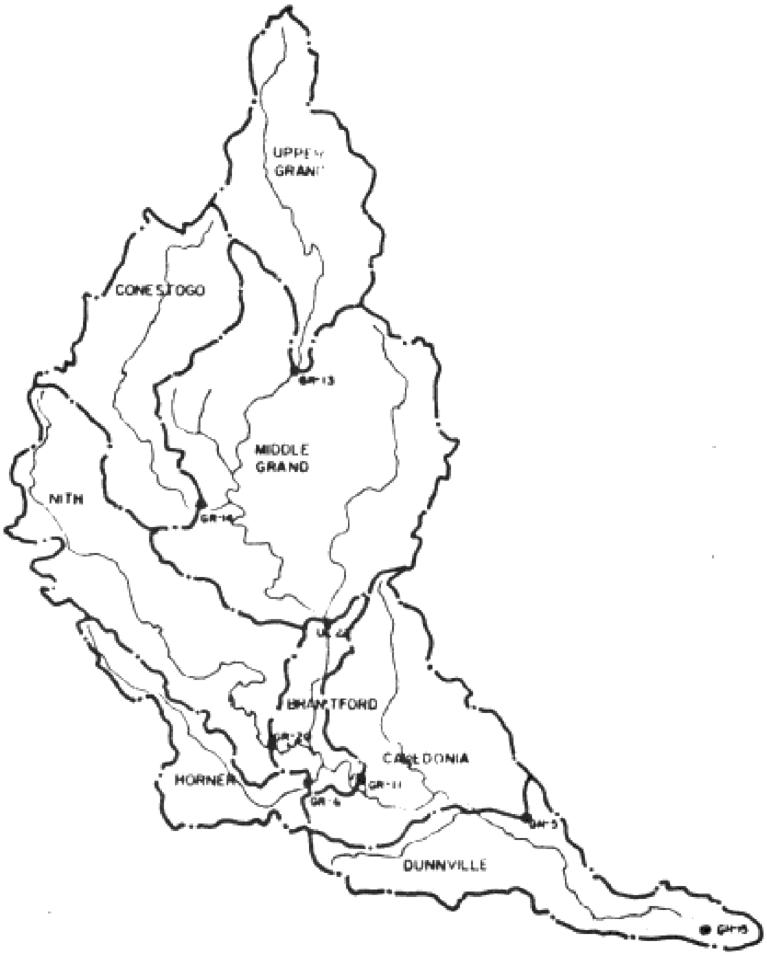
11.3.3 NITROGEN

Rural land use comprises 75 and 64% of the total area in the Grand River and Saugeen River pilot watersheds, respectively and yields 67 and 77% of the total nitrogen loads at the respective mouths (Table 11). These results suggest that total nitrogen yields from rural lands are directly proportional to their areal extent in the pilot watersheds. Wooded/idle lands constitute 19 and 33% of the total area in the pilot watersheds, respectively; however, total nitrogen yields from this land use are estimated to be approximately 8 and 17% for the respective basins.

The Nith and Conestogo rivers yielded higher loads of nitrogen than any of the other rural tributaries studied in the pilot watersheds (figures 14 and 15). The combined yield of the rivers, which drain about 27% of the Grand River watershed area, is approximately 35% of the load measured at the mouth of the pilot watershed. About 50 to 70% of the total nitrogen loads in the Nith and Conestogo rivers are comprised of (nitrite plus nitrate)-nitrogen, the soluble nitrogen form which is associated with intensive agricultural activities.

11.14 DATA TRANSFERABILITY

The unit-area loads developed in Table 9 were used to test the transferability of these data to other monitored areas within the Grand River and Saugeen River pilot watersheds. Loads for sediment, total phosphorus and (nitrite plus nitrate)-nitrogen were estimated using these unit-area loads and compared with the monitored loads at the outlets of 14 subwatersheds (figures 20 and 21). Estimates for the diffuse-source loads were calculated as the sum of the products of the unit-area load (Table 9) and the area for each land use in the subwatershed (Table 1). Point-source inputs and monitored loads from influent tributaries were added to the diffuse-source loads to obtain the "predicted load" (figures 20 and 21) from each subwatershed.



Sector	SUSPENDED SEDIMENT Monitored Load (ML) (t/yr)	Predicted Load (PL) (t/yr)	ML/PL	TOTAL PHOSPHORUS Monitored Load (ML) (t/yr)	Predicted (Load (PL) (t/yr)	ML/PL	NITRITE & NITRATE-NITROGEN Monitored Load (ML) (t/yr)	Predicted Load (PL) (t/yr)	ML/PL
Upper Grand	5470	16723	.327	20	28	.719	192	298	.644
Conestogo	31643	38203	.828	60	61	.983	668	548	1.219
Middle Grand	320984	195052	1.646	664	404	1.644	3002	2641	1.137
Nith	128235	86944	1.475	165	139	1.184	1006	834	1.206
Brantford	491567	469528	1.047	653	867	.753	4959	4808	1.031
Horner	5592	17332	.323	14	28	.519	615	527	2.395
Caledona	563120	536082	1.050	465	746	.624	5162	5558	.929
Dunnville	304092	615531	.494	606	539	1.124	6324	5679	1.113
Total Grand River	254000	342000	.745	570	701	.813	5580	5700	.979

FIGURE 20: MONITORED AND PREDICTED LOADS IN SUBWATERSHEDS, GRAND RIVER BASIN,1975 AND 1976 PERIOD

Sector	SUSPENDED SEDIMENT Monitored Load (ML) (t/yr)	SUSPENDED SEDIMENT Predicted Load (PL) (t/yr)	SUSPENDED SEDIMENT ML/PL	TOTAL PHOSPHORUS Monitored Load (ML) (t/yr)	TOTAL PHOSPHORUS Predicted (Load (PL) (t/yr)	TOTAL PHOSPHORUS ML/PL	NITRITE & NITRATE-NITROGEN Monitored Load (ML) (t/yr)	NITRITE & NITRATE-NITROGEN Predicted Load (PL) (t/yr)	NITRITE & NITRATE-NITROGEN ML/PL
Upper Saugeen	3653	13905	.263	6	25	.235	87	230	.379
South Saugeen	108089	25068	4.312	68	41	1.646	358	394	.907
Central Saugeen	38617	155670	.248	47	149	.314	983	1166	.844
Teeswater	9233	26648	.346	13	42	.310	410	415	.986
North Saugeen	4757	8854	.537	7	14	.492	89	145	.612
Lower Saugeen	113690	92013	1.235	158	137	1.156	2151	2067	1.041
Total Saugeen River	195000	161000	1.211	168	273	.586	1970	2540	.776

FIGURE 21: MONITORED AND PREDICTED LOADS IN SUBWATERSHEDS, SAUGEEN RIVER BASIN, 1975 AND 1976 PERIOD

The "predicted" loads, using <u>average</u> unit-area load values for sediment and phosphorus, were highly variable when compared with the "monitored" load from the pilot watershed studies. Significant differences (greater than 20%) were noted between the "predicted" and "monitored" loads for 21 out of 32 load estimates (figures 20 and 21). These differences are considered to be most likely due to varying intensity of land-use activities, differences in soil materials and physiography amongst the subwatersheds. For example, overestimation of sediment and phosphorus yields (i.e. predicted loads) in the Upper Grand and Horner subwatersheds (Figure 20) and four of the five subwatersheds in the Saugeen River basin (Figure 21) is probably due to low-intensity agricultural activities in these areas. Another example is the overestimation of sediment yields (i.e. predicted loads) below Brantford to the mouth of the Grand River (Dunnville subwatershed) which is related to the reduced carrying capacity of the river as a consequence of the lower hydraulic gradient in this reach of the river. Further examples are the underestimation of both sediment and phosphorus loads (¼ to ½, respectively) for the "predicted load" in the South Saugeen subwatershed (Figure 21) as a result of severe streambank erosion and low "predicted" loads in the Nith and Middle Grand subwatersheds (Figure 20) where intensive agricultural activities occur.

The "predicted" loads of (nitrite plus nitrate)-nitrogen compared more reasonably with the "monitored" loads from most of the subwatersheds (figures 20 and 21) studied in the Grand River and Saugeen River pilot watersheds. Significant differences (greater than 20%) were noted in only four out of 16 "predicted" load estimates. This is in large part due to the nitrite plus nitrate form of nitrogen showing less variability than suspended sediment and the sediment-associated parameters (i.e. more constant inputs). The largest anomaly was found in the Horner subwatershed (Figure 20) where the monitored loads were more than double the predicted loads. The reason for this anomaly may be due to the use of excessive nitrogen fertilizers and manure application and/or to defective private-waste disposal systems in this subwatershed.

In conclusion, transferability of the unit-area loads to subwatersheds draining multiple land uses within the Grand River and Saugeen River pilot watersheds shows a significant variability in many instances for sediment, phosphorus and nitrogen. However, on a pilot watershed basis (for all the land uses totalled in each pilot watershed) the use of an <u>average</u> unit-area load resulted in reasonably good agreement of the "predicted" loads with the "monitored" loads of sediment, phosphorus and nitrogen (figures 20 and 21). Based on these results, extrapolation of the unit-area loadings data to unmonitored areas outside the pilot watersheds is possible provided the watershed characteristics are similar. Other limitations on data transferability consist of a paucity of information on the in-stream transport of materials and biochemical transformations, the inherent inadequacies of the monitoring program, the different hydrologic characteristics (streamflow and precipitation) between watersheds, and the various methods of calculating loadings (Section 9.4.2).

12.0 RECOMMENDATIONS

12.1 FEASIBLE REMEDIAL MEASURES

The results presented in this report lead to the conclusions that sediment, phosphorus and nitrogen are the major inputs from rural land uses. Control measures can be applied to reduce these inputs through the implementation of better soil conservation methods (contour cropping, crop rotation, strip cropping, mulching, buffer strips, streambank stabilization, etc.) and better management of livestock operations. Timely application and incorporation of fertilizers and manures in the soil will also reduce nutrient losses to receiving waters.

Site-specific recommendations are required to control the pollutant loads from rural runoff. The rural land use considered in these studies (i.e. lumped) does not permit such extrapolation; however, a detailed catalogue of remedial measures to control non-point sources of water pollution was prepared under Task A (IJC-PLUARG 1977) and is available for site-specific implementation.

12.2 FUTURE STUDIES

Based on the PLUARG investigations, it is recommended that the following studies be undertaken in order to assist in the effective application of remedial measures:

1. Overland and in stream pollutant transport mechanism studies should be conducted to quantify assimilation characteristics of receiving waters.

2. Hydrologically active zones should be delineated to identify the areas of greatest pollutant potential to receiving streams.

3. Demonstration projects to study the effectiveness of remedial measures should be conducted before wide-spread implementation of remedial measures is recommended.

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